**Appendix S1 – Expanded Manuscript**

**Introduction**

Forests and woodlands are among the most important providers of ecosystem services (the benefits provided by nature) worldwide (Millennium Ecosystem Assessment 2005; UK National Ecosystem Assessment 2011). Forest resources have long served as safety nets and supported coping strategies in periods of economic and environmental shocks and are an important part of livelihood strategies in many countries (Cavendish 2000; Fisher 2004; Shackleton & Shackleton 2004). However, environmental degradation, population increase and climate extremes have placed the resources supporting human wellbeing under pressure. Forest resource managers worldwide are now faced with the crucial challenge of providing forest products for the global population despite a reduction in the natural resource base (Peng 2000). Depletion of natural resources has led to an interest in sustainable forest management in an effort to meet the increasing demands of a growing human population whilst also maintaining socio-ecological function (see MacDicken *et al.* 2015) for a full discussion). To manage a forest sustainably requires the balancing of forest productivity, predicted through the use of forest growth models, with off-take rates, known as sustained yield management (Monserud 2003; Nasi & Frost 2009).

**Methodology**

Study area

The Southern Region ranks highest in the country in terms of population density, poverty incidence, and scarcity of forest resources (Government of Malawi 2010). The mean annual temperature is 22°C and annual rainfall, confined to the period from November to April, ranges from 600 mm to 1225 mm (Ngongondo *et al.* 2011). The elevation of the study area ranges from 625 m above sea level in the low lying areas around Lake Chilwa to 1450 m in the Zomba-Malosa Forest Reserve.

Miombo woodlands supply around 93% of Malawi's energy needs, provide timber and poles for construction and non-timber forest products (NTFPs) for food and income (Nkwanda *et al.* 2008). Rapid deforestation of around 1% per year (Government of Malawi 2010) limits the current and future ability of forests and woodlands to continue to meet the timber and NTFP needs of local people (Nkwanda *et al.* 2008). The problems associated with depletion of miombo woodland resources are further exacerbated by the low productivity of miombo woodlands, resulting in existing levels of wood demand and harvest off-take rates (~15 million m3 per year) far surpassing sustainable yield (~7-8 million m3 per year) (Government of Malawi 2001; Smith *et al.* 2015). However, information on the inventory and productivity of miombo woodlands in Malawi remains scattered and discontinuous and there is a lack of tree growth data which is required for assessing the sustainability of current tree management (Abbot *et al. 1997)*. Even less is known about tree resources outside forests, although it has long been established that NTFPs are frequently collected from non-forest areas.

Establishment of sample plots

In June and July 2013, three 20 x 20 m sample plots were established within each dominant land use (forest [predominantly miombo woodland], settlement, cropland and grassland) of the four study villages, resulting in 48 plots in total. A stratified random sampling technique was used to locate tree inventory plots within each village based on the following protocol: 1) Each village was divided into three equal sections using a village map (Fig. 2); 2) In each section of the village one plot within each land use category was randomly sampled. Where only one area of each land use was present within a section, this was selected. Where multiple areas of the same land use were present, they were assigned a number and selected using a random number generator (Fig. 2, Section 1); 3) A Google Earth image, with village boundaries added via participatory mapping, was used to estimate the length and width of the forest area (Google Inc. 2013). The position of a sample plot was determined by locating the south west corner of the forest area and generating a random number of paces to walk as a percentage of the forest area length. This was then repeated with a second random number along the width of the forest area in order to establish the south western corner of the 20 x 20 m plot (e.g. Fig. 2, Plot F1). Settlement boundaries were less defined, therefore the centre of the settlement was identified by a Village Natural Resource Management Committee (VNRMC) member. The random number generator was used to determine the number of steps to walk north and east to reach the south western corner of the 20x20 m plot. Areas classified as cropland and grassland varied in size considerably and in three (out of 24) instances a 20 x 20 m plot was not obtainable; however, all models were corrected for plot size. Grassland and cropland plots were identified by the VNRMC member who assisted with identifying perimeters from which the area was calculated.

Inventory methods

Vernacular names were translated into scientific names using a three staged methodology: 1) Initially forestry experts from the Forestry Institute of Malawi (FRIM) translated from vernacular to scientific names; 2) Any vernacular names remaining unidentified from step 1 were then researched using literature available in the archives of Kew Royal Botanical Gardens; 3) Finally, an online literature search was undertaken by entering any vernacular names remaining unidentified from step 2 (e.g. Mpindimbi) into ISI Web of Knowledge, Google Scholar, ScienceDirect and Google between 5th September 2013 - 13th February 2014.

**Discussion**

The impact of people on aboveground biomass

Dewees (1995) suggested that there has been a tendency to assume that trees located outside of forest areas within Malawi are usually left unmanaged. However, as pressure for woodfuel increases, it is predicted that there will be a subsequent increase in the management of trees and the amount of trees planted outside of forest areas to provide NTFPs and timber (de Foresta *et al.* 2013). This seems to be happening in the study area as interviews highlighted that tree planting to replenish and restock the settlement and village forest areas was occurring to meet increasing demand for wood products. Research focussing on understanding the long term household responses to woodfuel scarcity would be beneficial (Zulu 2010; Smith *et al.* 2015), as would an exploration of how demand for timber, poles and woodfuel (often expressed by different people) may interact to lead to increased tree planting.

A new modelling paradigm

The choice of modelling tool is imperative given that climate simulations for Malawi show that temperatures and wet season rainfall are likely to increase, but climate will become more variable (Government of Malawi 2010; Doherty *et al.* 2009). This may coincide with a rising human population and associated demand on natural resources, agricultural conversion and further deforestation (Government of Malawi 2010). Such changes are likely to impact on AGB growth rates and augment forest resource deficits at village and regional level.

Despite limitations highlighted in this study, forest yield and process modelsare useful initial tools for establishing a baseline growth rate in data deficient landscapes, from which to assess future sustainability. However, there is an increasing demand for forest models to develop beyond simulating tree growth rates to include evaluation of trade-offs between ecosystem services, climate and human impact (Mäkelä *et al.* 2012; Willcock *et al.* 2016a). Sustainable forest management should incorporate the maintenance of ecological functions and contributions to economic and social wellbeing. Assessment of these ecosystem service benefits are beyond the scope of this study, and to date, no comprehensive models exist that can be used to predict all the indicators of sustainable forest management simultaneously (Mäkelä *et al.* 2012). However, there is a rapidly growing literature base and ecosystem modelling tools that incorporate and evaluate interactions between humans and ecosystems across a range of scales (Vigerstol & Aukema 2011). Such multi-ecosystem service models represent the beginning of a new modelling paradigm and may be beneficial for informing the sustainable management of forests in the future (Villa *et al.* 2014). These models still need to be rigorously validated and verified against observed data before application in data deficient areas but should be considered for future assessments.

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