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Woodland transitions and rural livelihoods: an interdisciplinary case study of Wedza Mountain, Zimbabwe

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Declaration

The candidate confirms that the work submitted is her own, except where indicated otherwise. No part of this thesis has been submitted for any other degree or qualification.

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Abstract

Tropical woodlands play a key role in the livelihoods of rural communities in southern Africa, but exist in contexts of constant ecological and socioeconomic change. With research into tropical woodlands neglected compared to tropical forests, it is important to improve understanding of the consequences of tropical woodland change for rural wellbeing. The aim of this thesis is to examine the dynamic interactions between woodland change and rural livelihoods through an interdisciplinary case study of a miombo woodland landscape on and around Wedza Mountain, Zimbabwe. The thesis is organised into three parts addressing: (1) the patterns of land use intensity and provisioning ecosystem service availability around Wedza Mountain; (2) the importance of environmental resources in rural income portfolios and hazard coping strategies; and (3) the adequacy of ecosystem service literature in representing the environmental values of rural African communities.

The first part of this thesis explores patterns of land use and woodland structure on the woodland cover gradient around Wedza Mountain. In Chapter 2 I characterise land use intensity in the six study villages using a new method of calculating human appropriation of net primary productivity (HANPP) at the village scale. Use of this approach indicates that previous studies have underestimated land use intensity in African small-scale farming areas, with village-scale HANPP estimates in Wedza ranging from 48% to 113% of total potential annual NPP as compared to 18 to 38% in published studies. In Chapter 3 I combine woodland survey data with a quantitative ethnobotanical assessment of the use values of woody species and demonstrate that per-household availability of provisioning ecosystem services declines with declining relative tree cover. These findings also suggest that more deforested villages have reduced diversity of ethnospecies underlying service provision, with ramifications for service resilience and livelihood option values in response to future change.

The focus of the second part of the thesis is on the role of woodland resources in rural livelihoods. In Chapter 4 I quantify the contribution of environmental income to the total income portfolios of 91 households and show that lower village woodland cover is not associated with reduced livelihood diversity, in part because a large proportion of environmental income is derived from degraded woodland or non-woodland environments. In Chapter 5 I assess the importance of environmental resources for coping with hazard exposures, drawing on recall of past exposure responses and a survey exercise weighting the elements of coping strategy portfolios in response to varying shock scenarios. Synthesis of these data sets indicates that environmental resources represent an important safety net in coping with interacting covariate and idiosyncratic hazard exposures.

The third part of the thesis consists of critical reflection, firstly on the adequacy of current ecosystem services research in southern Africa landscapes and secondly on this specific research project. In Chapter 6 I identify the value discourses which are most dominant across 356 peer-reviewed papers adopting an ecosystem services approach to miombo landscape research, and contrast these with the environmental values of study communities in Wedza District. Through this I show that the current ecosystem service literature is failing to represent rural African social and spiritual imaginaries of landscapes, with potentially serious consequences for the efficacy and equity of landscape management interventions. In Chapter 7 I examine some of the methodological and ethical challenges encountered during this research project through a discussion of the relationships between researcher, research assistant and respondents in an interdisciplinary field research context.

Finally, in Chapter 8 I synthesise the key messages from the thesis, and conclude by discussing the implications of our findings for understanding of how future change will impact the resilience and vulnerability of savanna woodland socioecological systems.

Lay Summary

Communities in rural Africa have high dependence on resources such as firewood, medicinal plants and wild foods, and many of these resources are collected from tropical forests and woodlands. Many areas of woodland in Africa are changing because of collection of woodfuel and clearance for farming, and this has raised concerns that rural people will no longer be able to access the resources they need. The objective of this thesis is to explore how the livelihoods of local people interact with changes in woodlands in the small-scale farming communities around Wedza Mountain in central Zimbabwe. I firstly demonstrate that there is very high land use intensity in the study area, with humans appropriating more than half of all the plant biomass produced each year. Secondly, I show that villages with less woodland also have lower availability and diversity of the trees needed to provide key resources such as firewood, medicinal plants and fruits. However, I subsequently show that loss of woodland cover has had a less severe impact on local people than anticipated, as many of the resources people require can be found even in heavily disturbed woodlands or in other land cover types such as fields. I next explore the importance of natural resources such as gold and wild fruits for coping with shocks like droughts, and find that coping strategies based on natural resources are more important for poor households headed by widows and for households exposed to multiple simultaneous shocks. I finally discuss the broader set of values derived from the Wedza landscape by local people, and argue that the current failure of research literature to consider spiritual and historical landscape values is resulting in missed opportunities to engage communities in sustainable landscape management.

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1. Introduction

1.1 Setting the Scene: the forest-livelihood nexus

Recent years have seen increasing recognition of the diverse values derived from forest and woodland ecosystems by rural communities in developing countries. The 'hidden harvest' (Scoones et al., 1992; Campbell & Luckert, 2002) of resources such as firewood, construction materials and wild foods is estimated to account for over 20% of rural household incomes (Cavendish, 2000; Heubach et al., 2011; Angelsen et al., 2014) and is perceived to act as a safety net during periods of shortage (McSweeney, 2004; Fisher et al., 2010; Paumgarten & Shackleton, 2011; Kalaba et al., 2013a). Forests and woodlands also provide services of global importance, such as carbon storage and improvement of soil quality (Chazdon, 2008), and have numerous perspective-dependent social and spiritual significances (Kennedy, 1985; Bengston, 1994; Byers et al., 2001; Sheridan, 2009; Cocks et al., 2012). Equally, the livelihood decisions and local systems of resource governance in rural communities are important determinants of the extent and structure of woody vegetation, and thus of the opportunities and services available in forested tropical landscapes (Fairhead & Leach, 1998; Birch-Thomson et al., 2001; Geist & Lambin, 2002; Lestrelin & Giordano, 2006; McCusker & Carr, 2006).

With the increased research effort into forest-livelihood interactions there has come increased incidence of case studies contradicting the previously perceived 'truths' of the forest-livelihood nexus. Recent work has queried, for example, whether ecologically 'intact' forest ecosystems really have greater value in rural livelihoods or cultures than ecologically degraded systems (e.g. Ambrose-Oji, 2003; Pouliot et al., 2012), and has suggested that the characterisation of 'forest as safety net' for coping with hazards may have been overstated (Debela et al., 2012; Wunder et al., 2014; Börner et al., 2014). The question of which socioeconomic groups have high forest dependence also remains unclear: while it is widely observed that poorer households in developing countries have greater dependence on environmental resources (Cavendish, 2000; Mamo et al., 2007; Heubach et al., 2011), there is varied and contradictory evidence on how factors such as age, gender, social capital and spiritual beliefs shape patterns of environmental resource use and the values prioritised in forest management. The lack of consistent answers to these questions is indicative of the complexity of forest-agriculture socioecological systems in developing countries, where livelihood choices and environmental dependence are influenced not just by the internal characteristics of individuals, households or communities, but also by dynamic cultural, social,

political, economic and ecological contexts at multiple spatial scales (Scoones, 1998; Leach et al., 1999; Ribot & Peluso, 2003; Turner et al., 2003). Untangling the detail of forest-livelihood interactions therefore necessitates high-resolution analysis of landscape structure and livelihood strategies to be nested within understanding of these broader contexts.

The motivation to improve understanding of forest-livelihood interactions is invested with greater urgency due to the novel challenges which will be imposed on environmentally-dependent rural communities by local and global environmental change. Dominant in the literature on these challenges is climate change, which is anticipated to have particularly severe impacts in developing countries (Mertz et al., 2009). However, the prevailing high poverty and food insecurity in many forested regions (Wunder, 2001) means that climate change impacts will not be experienced in isolation, but will instead interact with existing hazards and with broader socio-political trends such as economic globalisation (O'Brien & Leichenko, 2000; Reid & Vogel, 2006; Quinn et al., 2011). It is therefore critical to improve understanding of the resilience and vulnerability of both human and ecological aspects of forest-agriculture socioecological systems under these conditions of flux and uncertainty.

Dry forests and woodlands cover an estimated 17 million km^2 in Africa (Chidumayo & Marunda, 2010) and are important multifunctional ecosystems, playing a key role in the global carbon cycle (Grace et al., 2006; Ciais et al., 2011), supporting high levels of endemic biodiversity (Bond & Parr, 2010; Timberlake et al., 2010), and contributing to the livelihoods of millions of people in both rural and urban areas (Chidumayo & Marunda, 2010; Dewees et al., 2010). These woodlands are complex and dynamic, structured by histories of disturbance (Sankaran et al., 2005; Sankaran et al., 2008) and continuing to change in response to local and global drivers (Ryan et al., 2016). With dry open-canopy woodlands neglected in the research literature in comparison to tropical closed canopy forests (Parr et al., 2014), there is a particular imperative to improve understanding of the functioning of dry woodland socioecological systems.

The aim of this thesis is to explore the dynamic interactions between miombo savanna woodlands and rural livelihoods through a case study of a woodland-agriculture matrix landscape in Zimbabwe. Drawing upon datasets including woodland surveys, household income surveys, focus groups and participant observation, I explore the interactions between woodlands and livelihoods in the study area by addressing four key themes: (1) the spatial patterns of land use intensity and provisioning ecosystem service availability in an African smallholder farming landscape; (2) the importance of woodlands in facilitating livelihood diversification and reducing inequality; (3) the use of natural resources for coping with multiple interacting hazard exposures; and (4) the broader range of environmental values

shaping rural livelihood decisions in Wedza and the representation of these values in peer-reviewed academic literature. Through this analysis I hope to gain insight into the diverse contributions of woodlands to rural livelihoods and into the vulnerability of human and ecological system components in contexts of local and global change.

In this introduction I firstly provide a background to the study site, beginning by outlining the ecological characteristics and socio-political history of woodlands in Zimbabwe before describing the study landscape of Wedza Mountain. I then introduce the conceptual frameworks important in shaping the research design and provide an overview of data collection methods, also discussing the role of positionality in shaping the research design and the ethical considerations attached to carrying out fieldwork in Zimbabwe. I conclude by outlining and providing justification for the following thesis chapters.

1.2 The 'social forest': miombo woodlands in Zimbabwe

Miombo woodlands are deciduous open-canopy savanna woodlands found across much of southern Africa (**Figure 1.1**). While all miombo is distinguished by dominance of tree species in subfamily Caesalpinioideae, miombo woodlands in the drier areas of the ecoregion in Zimbabwe, Mozambique and Malawi are distinguished by lower diversity of woody species compared to areas with higher precipitation and by dominance of *Brachystegia spiciformis, B.boehmii* and *Julbernardia globiflora* (Frost, 1996).

Miombo woodlands have been described as 'social forests' (Nhira & Fortmann, 1993; Campbell et al., 2001), reflecting their continued importance in providing firewood, construction materials, wild foods and medicinal plants to rural communities (Grundy et al., 1993; Cavendish, 2000; Kamanga et al., 2009; Kalaba et al., 2013b). A recent compilation of environmental income case studies in the ecoregion found that on average 26% of household income is derived from non-cultivated environmental resources (Ryan et al., 2016). Miombo soils are often poor quality (Campbell et al., 1996) and so miombo leaf litter is an important agricultural input (Campbell et al., 1991), while the flush of new leaves just before the rains in October/November (Ryan et al., 2017) is an important source of livestock browse in the late dry season (Gambiza et al., 2010).

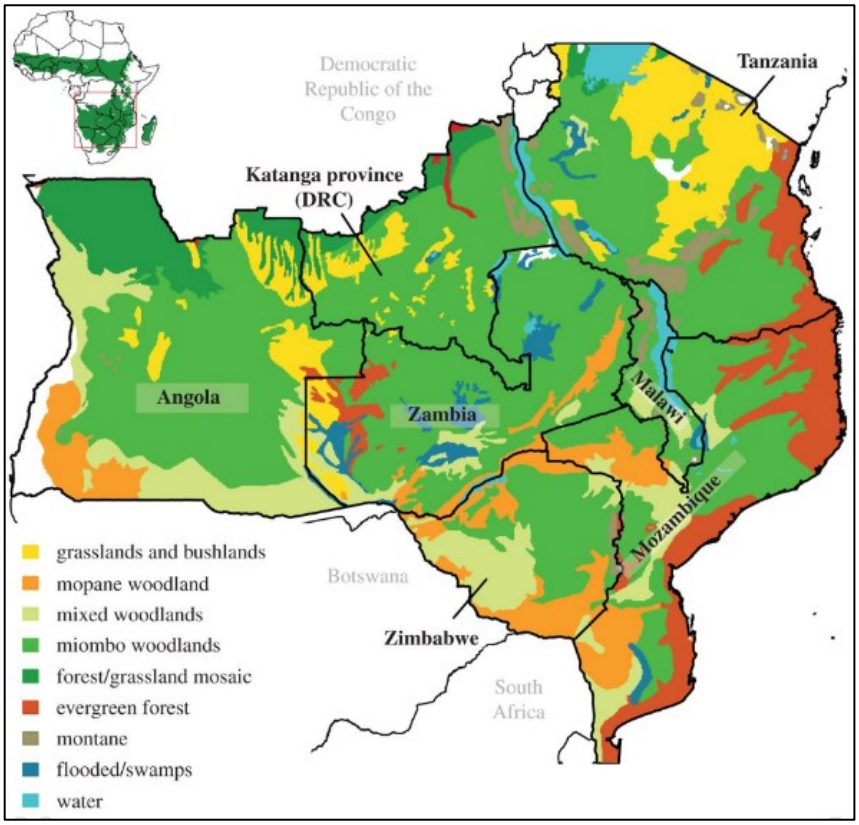

Figure 1.1 Land cover map of the miombo ecoregion of southern Africa, with example photographs of dry miombo woodland. Land cover map is derived from Ryan et al. (2016). Photographs were taken by R. Pritchard in Zimbabwe.

Deforestation and degradation of woodlands is widespread across the miombo region (McNicol et al., 2017) and is resulting in significant changes in woodland structure and composition (Banda et al., 2006; Jew et al., 2016). Clearance for agriculture and charcoal production are important proximate drivers for the region as a whole (Mwapamba, 2007; Ahrends et al., 2010; Ryan et al., 2014), but unlike in adjacent countries there is minimal charcoal production in Zimbabwe, with collection of wood for tobacco curing instead identified as a primary degradation driver (Geist, 1999; EMA, 2014).

Zimbabwe was the British colony of Southern Rhodesia from 1888 until 1965, when the Rhodesian government led by Ian Smith issued a Unilateral Declaration of Independence. The Ian Smith government intended to perpetuate white minority rule in Rhodesia, and this amongst other factors intensified the conflict between Rhodesian government forces and black nationalist groups which would become known as the Second Chimurenga (also referred to as the Rhodesian Bush War or Zimbabwe War of Liberation). This civil war concluded with the signing of the Lancaster House Agreement in 1979, the result of which was the establishment and recognition of the independent country of Zimbabwe under black majority rule. The elections which followed in 1980 were won by the Zimbabwe African National Union – Patriotic Front (ZANU-PF), and Robert Mugabe became the first prime minster. A subsequent amendment to the constitution in 1987 made Mugabe President of Zimbabwe, a role which he has retained up to the present time.

One of the greatest issues facing the newly independent Zimbabwe was the inequitable distribution of land, with ownership of high quality agricultural land concentrated amongst a minority of white commercial farmers. Land redistribution had been at the core of nationalist rhetoric during the Chimurenga, and so the immediate post-independence period saw an initial land reform process based on a 'willing buyer willing seller' model where large scale farmers were compensated for giving up their land (for contemporary discussion of this initial programme see Moyo, 1995; Kinsey, 1999). However, by the late 1990s less than half of the target number of farming households had been resettled (71,000 households as opposed to an optimistic target of 162,000 households; Kinsey, 1999), and this led in 2000 to the official adoption of the Fast Track program involving compulsory purchase of large white-owned farms. This fast-track land reform (and the associated shrinking of the agricultural sector) interacted with an increasingly fragile economic situation in Zimbabwe created through economic mismanagement, corruption, and international trade sanctions during the 1990s, the upshot being an economic crisis culminating in hyperinflation of the Zimbabwe Dollar in 2008/2009 (Scoones et al., 2010). The economic crisis, along with the increasing impact of

the HIV/AIDS epidemic, was associated with a decline in life expectancy in Zimbabwe from 65 in 1990 to 43 in 2006 (WHO, 2008).

Following disputed and sometimes violent elections in 2008, in which ZANU-PF failed to secure a clear majority for the first time since independence, an alliance was negotiated between ZANU-PF and the two branches of the Movement for Democratic Change (MDC), one headed by Morgan Tsvangirai and the other by Arthur Mutambara. Robert Mugabe remained as President, while Morgan Tsvangirai acted as Prime Minister. This coalition adopted a number of measures to stabilise the economy, most notably the replacement of the now worthless Zimbabwe dollar with the US dollar in 2009. Despite some subsequent improvement in the economy, however, unemployment remains high and the political situation uncertain. ZANU-PF regained their majority in the elections of 2013, but recent years have seen increasing media gossip over the health of Robert Mugabe (now 93 years old), as well as manoeuvring and conflict amongst potential successors. As of 2017 the country was also facing a serious cash shortage; banks were running out of US dollars, and given the recent history of currency in Zimbabwe there seemed little trust for government-printed bond notes.

This recent land reform means that small-scale farming areas in Zimbabwe can be split into three broad categories: communal areas, 'old' resettlement areas from the initial land reform programme of the 1980s and 'new' resettlement from the fast track programme in the 2000s. The focus of this thesis is on communal areas, previously termed 'native reserves' and subsequently 'tribal trust lands', which were areas designated for occupation by black farmers during the colonial period. Woodlands in communal areas are in the main common property resources and are governed by a broad and often conflicting range of rules and behavioural norms (Campbell et al., 2001). McGregor (1991) separates the institutions mediating use of communal area woodland resources into three categories: spirit mediums and land guardians, modern organisations such as Rural District Councils, and communities and individuals. The sacred values that previously shaped resource use patterns and which were enforced by traditional leadership and spirit mediums are perceived to have strongly declined through the late 1900s (McGregor, 1991; Campbell, 2001), although informal rules persist such as the taboo on cutting indigenous fruit trees (Campbell et al., 1991; Grundy et al., 1993; McGregor, 1994). Enactment of national law on use of forest resources is the responsibility of the office of the District Administrator, the Forestry Commission and the Environmental Management Agency (EMA). While grazing area woodlands in communal area villages are common property, trees growing within fields or trees which have been planted by a householder are considered the property of the individual, and so permission is required to extract resources.

Much forest policy in Zimbabwe has been informed by twin narratives, one on the role of rural communities in driving deforestation and the other on the economic value of afforestation (McGregor, 1991). Concerns regarding degradation of communal area woodlands date back to the 1920s. Mukamuri (1995, in Jagger & Luckert, 2008) suggests that degradation at that time was driven by a combination of overcrowding in Native Reserves and timber extraction by miners, whereas McGregor (1991) suggests that mining was the major driver but that deforestation was framed as a problem caused by black African populations in order to avoid upsetting the powerful mining sector. Compensating for woodland degradation by planting exotics such as *Eucalyptus* sp. had been championed in the 1950s on economic and aesthetic grounds (McGregor, 1991), but the idea was reinvigorated in the 1970s by fears over an impending global woodfuel shortage. While the woodfuel gap theory was later consummately debunked (see e.g. Dewees, 1989; Bradley & Campbell, 1998; Arnold et al., 2006), it motivated projects such as the Rural Afforestation Programme (described in Du Toit et al., 1984; Casey & Muir, 1986) which ran from 1981 to 1998 and focused on development of *Eucalyptus* woodlots to reduce pressure on indigenous woodlands. However, to date such programmes have had little success, attributed variously to poor understanding of the drivers of woodfuel shortages (Bradley & Campbell, 1998), weakness of governing institutions in communal areas (Campbell et al., 2001), and poor economic returns, particularly in the absence of government subsidy (Jagger & Luckert, 2008). This lack of success also reflects broader themes in Zimbabwean forest governance, with McGregor (1991) arguing that policy development has rarely truly engaged with the livelihood requirements of rural communities and Mapedza (2007) arguing that policy has been 'deracialised' rather than 'democratised', with post-independence governments continuing to perpetuate colonial top-down models of natural resource governance.

1.3 Case Study Landscape: Wedza Mountain, Zimbabwe

Wedza Mountain is located in the Mashonaland East province of Zimbabwe, around 150 km by road from the capital city Harare (**Figure 1.2**). The mountain was chosen as a study site because a mixture of traditional beliefs, legal restrictions on tree cutting and poor suitability for cultivation have resulted in the mountain retaining cover of high biomass miombo woodland, whereas the surrounding lowlands have been largely deforested for many years (Gumbo, 1988). Villages in Wedza Communal Area, which lies on and around the mountain, are therefore on a gradient of woodland resource availability.

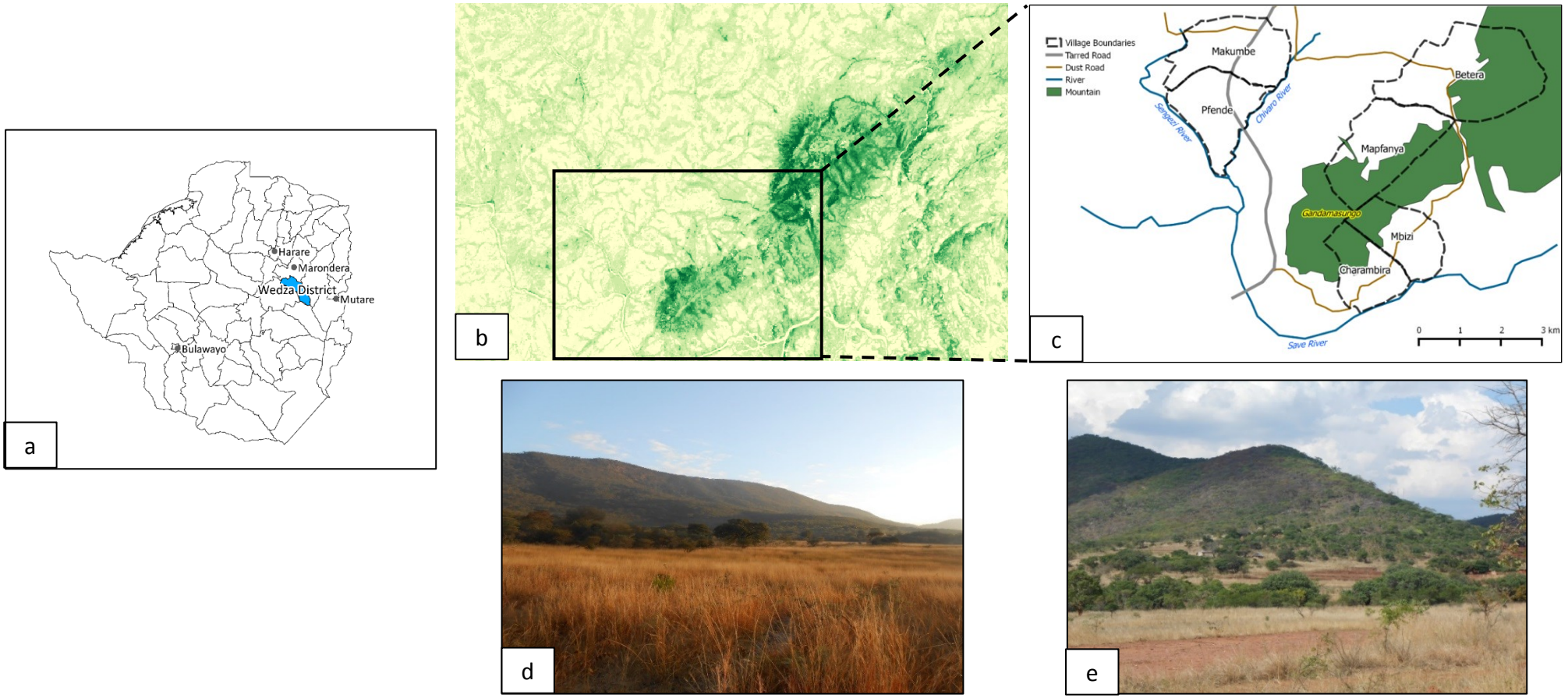

Figure 1.2 Location and characteristics of Wedza Mountain, Zimbabwe. a) shows the location of Wedza District within Zimbabwe relative to major population centres. b) shows Wedza Mountain on the land cover maps developed by Hansen et al. (2013), with the darker green indicating the higher woody biomass on the mountain. c) shows the locations of the six study villages relative to the Gandamasungo peak of Wedza Mountain. Photograph d) was taken in Charambira village and photograph e) in Betera, with both photos illustrating the higher woodland cover on Wedza Mountain in comparison to surrounding land.

Following scoping trips in October 2013 and April 2014, six study villages were chosen around Gandamasungo, the southern peak of the Wedza mountain range. The six study villages consist of three adjacent village pairs, chosen to represent a range of woodland cover and market access conditions (**Figure 1.2**). Makumbe and Pfende are in the deforested lowlands to the west of the mountain, with households either side of the tarred road that runs between Wedza and Sadza Growth Points (small towns with shops and services). The two villages are also close to the township of Garaba, which has a number of small general stores. Mapfanya and Betera are on the western edge of the mountain woodland and can be reached via a good quality dust road from Garaba, with the walk taking around 45 minutes to an hour each way. Charambira and Mbizi are on the more remote eastern side of the mountain. Vehicle access to these villages is via a poor quality dust road while foot access involves climbing over Gandamasungo, and residents are further isolated during the rains when the flooding of the Save River prevents access to the adjacent Njanja area. While all lying within 6km of Gandamasungo, these villages therefore represent a diverse range of socioecological contexts.

The majority of residents of the study villages are Shona, specifically *Zesuru* (there is continued debate over whether the Shona are a unified ethnic group, with Shona originally being a pejorative Ndebele construct that was later adopted by colonial settlers to refer to multiple distinct peoples; Bourdillon, 1987). There are a number of in-migrants from areas such as Manicaland, Mount Darwin and Buhera, predominantly women who have migrated to the area for marriage. There are also a small number of migrants from Malawi and Mozambique, most of whom came to Zimbabwe to work in the mines or commercial farms and were subsequently granted land in the communal areas.

Small-scale farming is the keystone of rural Wedza livelihoods, particularly cultivation of the maize which is used to make the ubiquitous staple carbohydrate **sadza** (a maize meal porridge). Groundnuts, roundnuts and beans are also widely grown, and most households additionally cultivate a small vegetable garden close to a water source. Cattle are the most important local livestock, used for ploughing and pulling the household **ngoro** (a small metal cart). Other livestock commonly kept by study households are goats and poultry including chickens, turkeys and guinea fowl (and a single highly obstreperous duck).

Wage labour is also important in the study area. A small number of households have regular paid employment; teachers from the local Rambanapasi and Magamba Secondary Schools live in the villages, while other residents are security guards, cleaners or domestic workers. Several residents are also skilled builders and craftsmen who take on short term contracts locally and in Harare and Marondera. For the majority of residents, however, paid

labour is in the form of **maricho** (ie piecework): weeding maize fields, building garden fences, shelling maize cobs or cutting firewood. Wages for these jobs are small, at around US$5 per day, and with cash difficult to obtain workers are often paid in maize, sweet potatoes or soap.

Environmental resources are used daily in Wedza households. Firewood is the primary fuel in almost every household, rondavel kitchen huts are capped with carefully layered cones of thatching grass, gardens are surrounded by bristling fences of thorn trees, and children gather handfuls of **tsokotsiyana** (*Rhus longipes*), **matohwe** (*Azanza garckeana*) and **matufu** (*Vangueriopsis lanciflora*) on the way to and from school. Mineral resources are also important, particularly the gold found inside Gandamasungo and panned along the Save River. Villagers remember that there was once a larger scale mining operation on the mountain run by a German company, and the rumour is that when they left they sealed the tunnel network without having removed all the gold. So far the treasure hunt for these tunnels has been unsuccessful: instead men work at the mining concessions on the mountain, either independently or employed by the concession owner, and bring back stones which the women of the household pound in search of extra points of gold.

Religion plays an important part in the social life of the villages. Older residents are more likely to align themselves with one of the 'old' Christian mission churches (Catholic, Methodist and Anglican) which have had a presence in Wedza since the colonial period and still run many of the boarding schools and medical facilities. The 'new' churches include Pentecostal, Apostolic and Seventh Day Adventist (church typology follows Bourdillon, 1987). Church affiliation can influence patterns of natural resource use, with the new churches in particular imposing taboos on consumption of certain wild foods and on use of medicinal plants. Rather than replacing traditional Shona beliefs with church teachings, most villagers follow individual blendings of Christian and Shona beliefs, with different problems considered the preserve of doctor, pastor and **n'anga** (spirit medium). An example of such a blending is illustrated by practices around marriage: many young people will have a church or civil marriage ceremony, but the marriage will be considered incomplete until the families have met to negotiate and begin payment of **lobola** (the price paid by the family of the husband to the parents of the wife).

The economic and social turbulence in Zimbabwe has also transformed lives in Wedza. Many older residents recall experiences during the Chimurenga war, when the mountain was a guerrilla base and they found themselves caught between government and nationalist forces. More recently, land reform has dramatically altered the local landscape: most of the large-scale farms between Wedza and Marondera were appropriated during fast-track land reform in the early 2000s, and at present the employment opportunities the farms

used to offer have not been replaced. Many non-farm workers such as shop and factory employees were also made unemployed during the financial crisis, in some cases returning to the rural area due to lack of livelihood opportunities in the city. Others lost all their savings during hyperinflation, and incomes such as rents and pensions continue to be unreliable. While presently comparatively peaceful, political violence and intimidation were serious issues in the mid-2000s. Incidence of HIV/AIDS and TB is high, and while NGOs provide free anti-retrovirals, their efficacy is contingent on being able to afford enough food. Coupled with the widely held perception that the first change of leadership since establishment of black majority rule is inevitably approaching, it often seems that these multiple layers of stress and uncertainty are the only constants Wedza residents can use to structure their lives.

1.4 Conceptual Approaches

1.4.1 The Ecosystem Services Framework

The initial framework influential in shaping the structure of this research was the Ecosystem Services Framework. The idea of ecosystem services, defined as 'the benefits people obtain from ecosystems' (MEA, 2005) was first raised in the 1970s (Gomez-Baggethun et al., 2010; Baveye et al., 2013), but has increased exponentially in popularity in recent years (Fisher et al., 2009) following high impact publications such as Costanza et al. (1997), Daily (1997), de Groot et al. (2002) and the Millennium Ecosystem Assessment (MEA, 2005). The utility of the ecosystem service concept is twofold: on the one hand it is a powerful metaphor expressing the values of nature to public and policymakers, while on the other it is a practical instrument used for structuring investigation into the synergies and trade-offs between different values in complex landscapes (Farber et al., 2002; Rodriguez et al., 2006; Raudsepp-Hearne et al., 2010).

The Millennium Ecosystem Assessment (2005) identified four types of ecosystem service: supporting, regulating, provisioning and cultural. While supporting and regulating services are undoubtedly important in rural Zimbabwe, the livelihoods approach adopted in this research means I focus primarily on what would be classed as provisioning and cultural services. Provisioning services are materials collected from the environment, such as food, building materials, medicinal plants and biomass fuels. Cultural ecosystem services include the spiritual, historical, aesthetic, recreational and educational values of ecosystems. Such cultural values are contingent upon stakeholder perspectives and are challenging to measure, particularly in quantitative terms, which has contributed to their current underrepresentation in ecosystem service literature (Chan et al., 2012; Daniel et al., 2012; Milcu et al., 2013; Satz

et al., 2013). Several authors have recently argued for a change in approach towards assessing the cultural and social values of ecosystems, proposing a more pluralist conceptualisation which does not reduce value to a purely monetary metric (Kenter et al., 2015; Pascual et al., 2017).

The logistical challenges of allotting value to non-marketable ecosystem functions is just one of a number of criticisms levelled at ecosystem services research (a review of critiques and counterarguments is presented in Schröter et al., 2014). Of particular relevance to this thesis are ethical questions raised over whose environmental worldviews are most prominently reflected by in ecosystem services literature (Jax et al., 2013) – the classic question of 'Whose reality counts' asked by Chambers (1997) in the context of Participatory Rural Appraisal methods – and over the negative impacts on particular social groups which can result from management interventions based on ecosystem service based conceptualisations of human-environment interactions (see e.g. Corbera et al., 2007; Beymer-Farris & Bassett, 2012). While the ecosystem services framework was influential in determining the research approaches adopted in this project, I directly address the flaws and blind spots of extant ecosystem services research in the miombo ecoregion in Chapter 6 of this thesis.

1.4.2 Livelihoods Approaches to Environmental Dependence

Livelihood approaches have commonly been used to understand patterns of resource use in developing country contexts. Scoones (1998; 5) defines a livelihood as follows:

'A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base.'

In this thesis I draw upon the Sustainable Livelihood Framework (SLF: Scoones, 1998) to examine the factors shaping rural livelihood strategies. Paralleling the environmental entitlements framing of Leach et al. (1999) and the capitals and capabilities framework developed by Bebbington (1999), the SLF is designed to structure analysis of the following question:

'*Given a particular context…what combination of livelihood resources (different types of 'capital') result in the ability to follow what combination of livelihood strategies…with what outcomes?'*

Scoones (1998; 3).

Assessments of the capitals of a household often include natural capital (natural resources such as soil, water or trees), physical capital (assets such as farm equipment of livestock), financial capital (savings and access to financial services), social capital (social resources such as social networks) and human capital (skills, knowledge and labour capability; Scoones, 1998; DFID, 1999). The ability to transform these capitals into actions or benefits is dependent on diverse environmental, economic, historical and socio-political contexts, and also on the formal and informal institutions mediating access to resources. The importance of social capital and institutional relations resonates with the work of Ribot and Peluso (2003), who characterise the ability to benefit from resources as being determined by the 'bundle of powers' held by a social unit relative to their position within overlapping 'webs' of power at local and regional scales.

While the SLF has proven valuable in motivating research, Scoones (2009) highlights a number of knowledge gaps which continue to pervade the sustainable livelihoods literature. Power relations and political factors are perceived as too often neglected, despite their critical importance in shaping livelihood strategies. Scoones (2009) also argues for increased analysis of the role of large scale factors in influencing local scale processes and of the impact of long term system dynamics on rural livelihood sustainability. With these critiques in this mind, I therefore attempt to place the microscale livelihood strategies and patterns of natural resource use documented within this thesis within these broader contexts of power and regional/local change.

1.4.3 Resilience and Vulnerability

Understanding the sustainability of a socioecological system in the context of global change depends upon understanding the vulnerability, resilience and adaptive capacity of the system as a whole and of the people and households comprising the system (Folke et al., 2002). The terms 'resilience' and 'vulnerability' are often viewed as two sides of the same coin, but have very different disciplinary histories; whereas vulnerability analysis was originally prevalent in development economics and disaster relief literature, resilience has its roots in ecology (Füssel, 2007; Miller et al., 2010). The two fields appear to be becoming increasingly integrated with respect to global environmental change (Janssen et al., 2006), but these different disciplinary backgrounds can result in varying use of terminology (Miller et al., 2010), and it is therefore important to provide clear definitions for both concepts as used in this thesis.

In discussing vulnerability I follow the definition of Turner et al. (2003: 8074):

'The degree to which a system, subsystem or system component is likely to experience harm due to a hazard, either a perturbation or stressor.'

The vulnerability framework developed by Turner et al. (2003) is similar to the vulnerability context detailed by Scoones (1998) in discussion of the SLF, and is intended for use in analysis of 'contextual' or 'start-point' vulnerability (O'Brien et al., 2007) mediated by the internal characteristics of the social unit of study, by the characteristics of a hazard exposure, and by surrounding ecological, social, political and economic contexts.

In discussing resilience I adopt the definition proposed by the Resilience Alliance (2017):

'Resilience is the capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the systems remains within the same regime, essentially maintaining its structure and function.'

1.5 Data Collection Methods

The following section provides an overview of the main data collection methods adopted in this project, with additional detail provided in the relevant chapters and in the appendices. In total the research presented in this thesis involved three main stints of fieldwork (April to September 2014, February to May 2015 and September to December 2015) with shorter follow up visits and feedback workshops in June 2016 and April/May 2017, totalling almost a year of fieldwork over the course of the PhD. The majority of this time was spent living in Makumbe Village at the home of my main research assistant, Nyaradzo Shayanewako (hereafter termed Amai Simba).

1.5.1 The importance of scale: why a case study approach?

In the earliest stages of this research it was necessary to make a decision on the scale of study. The choice faced was whether to carry out multi-location fieldwork in order to develop a comparative data set of larger scale but shallower depth, or to focus on high resolution analysis in a single site. While such a decision is in part necessarily made on a logistical basis, there

are also strong theoretical grounds for adopting a case study approach given the research themes in this thesis.

These grounds relate to the construction of the term 'location' or 'locality'. Vedeld et al. (2012:25) suggest that 'location' as a variable 'represents environmental, climate, agro-ecological, ethnic, socio-cultural and political conditions, involving different social institutions, values and norms that often impacts resource use patterns.' Eriksen et al. (2005: 289), in an analysis of vulnerability in Kenya and Tanzania, draw upon Massey's (1999) interpretation of a locality:

'Massey suggests that each locality, or unique set of geographical conditions of a place at a particular time, is a point of interaction between processes, both social and physical…locality is a manifestation of vulnerability at a specific point in space and time and can be understood as a product of various processes operating at various geographic levels. Processes may converge differently at different points in space or time, creating a very different manifestation of vulnerability. A locality, or snapshot of vulnerability, can be investigated with the specific aim of distinguishing processes and how they interact.'

While the case study presented in this thesis is not focused purely on vulnerability, I have already detailed how understanding livelihood strategies depends upon investigating a socioecological system (and the behaviour of people within that system) nested within broader contexts – reflecting the social and physical processes described by Eriksen et al. (2005). Given the complexity of understanding these contexts and their influences at the local scale, I believe that a single site approach with quantitative methods complemented by qualitative and ethnographic understanding gained through long, continuous residence within the study site provides the best method of gaining insight into relevant processes.

It should be acknowledged, however, that a case study approach encompassing six villages does place certain limits on the research questions which can be addressed in this thesis. A more intensively anthropological approach might have invested the available time in analysis of only one or two village communities, and the understanding gained through such an approach may have been better suited if the chosen research questions concerned information and resource flows in social networks, institutional dynamics, or intrahousehold variation in resource use and vulnerability. Conversely, research questions on how livelihoods co-vary with variation in forest type (e.g. tropical forest vs. savanna woodland) or on how national-scale social and political factors impact woodland-livelihood interactions would require a much larger village data set, such as that developed by CIFOR-PEN (Angelsen et al., 2014). In the choice of six villages within the same communal area I have chosen the point on the continuum between these two extremes best suited to answer my focal research questions. Carrying out research in six villages with varying socioecological characteristics gives some

sense of the scale of variation in livelihood strategies and thus increases confidence in the research conclusions, but working within only one communal area permits development of greater insight into the influence of broader socio-political contexts.

1.5.2 Interdisciplinary perspectives and mixed methods approaches

Much research in both ecology and the social sciences has dichotomised human societies and the 'natural world' as being separate systems, but there is growing recognition that this binary conceptualisation is insufficient to inform sustainable environmental management practice (Daily & Ehrlich, 1999; Ostrom & Cox, 2010; Pretty, 2011) and is also alien to the worldviews of many rural indigenous communities in the developing world (Berkes et al., 2000). This recognition gave rise to the idea of socioecological systems, where landscape features most commonly considered in ecological analysis such as land cover and biodiversity, and social features of landscapes such as livelihood strategies and institutions, are all considered as interacting elements within a single complex system (Berkes et al., 2000).

Examining the case study in this thesis through an interdisciplinary socioecological systems lens meant that it was appropriate to adopt a mixed methods approach. Johnson et al. (2007; 123) define mixed methods research as:

'…the type of research in which a researcher…combines qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purpose of breadth and depth of understanding and corroboration.'

Mixing of methods in this study occurred both sequentially and simultaneously (Cresswell, 2013). The sequence of data collection consisted of (1) an initial qualitative phase of contextual data gathering which informed later research questions and the design of data collection instruments; (2) a main phase of simultaneous quantitative and qualitative data collection; and (3) a final qualitative phase involving discussion of the findings from the main phase in focus groups with respondents. The main phase of data collection followed what Cresswell (2013) terms a concurrent embedded strategy, where greater weight is given to either quantitative or qualitative methods and the other approach becomes a secondary strategy 'embedded' in the first. In this case study quantitative data collection was the primary strategy, with complementary qualitative data used to improve understanding of the factors and processes producing quantitative patterns.

1.5.3 Contextual data collection: participatory mapping and transect walks

The core fieldwork for this project began with contextual data collection in May 2014. The focus of initial contextual data gathering was threefold: (1) to develop village land cover maps; (2) to gain basic understanding of local livelihood strategies; and (3) to build trust with local people.

Two participatory mapping groups were held within each of the six study communities, one with men and one with women as key livelihood activities in rural Zimbabwe are partially determined by gender (Mehretu & Mutambirwa, 1992; Mupawaenda et al., 2008). Locally available materials such as stones and maize stalks were used to create maps of key village landmarks and annotated versions of the maps subsequently transferred to paper. Mapping groups were also used to establish lists of resident households and their locations within the village. Refreshments were provided at mapping groups and all villagers were invited, providing an informal opportunity to raise questions or concerns about the research.

Four transect walks were carried out in each of the six study villages, two with men and two with women. In five of the six villages the **Sabhuku** (village head) was one of the transect walk respondents, and all other respondents were long term village residents recommended by the Sabhuku or village secretary. Transect walks lasted between 30 minutes and 2 hours dependent on respondent preference and followed a route of the respondent's choosing. Walks were GPS tracked and used to confirm village boundaries and the locations of key landmarks, and the conversations had during the walk were translated in situ and verbal notes recorded by dictaphone with reference to GPS waypoints where appropriate.

Data from mapping groups and transect walks were combined with Google Earth satellite imagery to create village land cover maps, which were checked for accuracy with focus groups of between four and six residents assembled by the Sabhuku of each village. These focus groups were also used to determine the gender of the household head and the number of adults and children resident in each household to allow stratified random sampling for the household survey.

1.5.4 Household Survey

The main household survey instrument used in this research was a disaggregated environmental income survey (Jagger et al., 2012) based on CIFOR-PEN (2008; Appendix 3).

Following a number of similar studies (e.g. Cavendish, 2000; Kamanga et al., 2009; Angelsen et al., 2014), total household income is the sum of all cash and subsistence income minus input costs except for own labour (deducting labour inputs is not seen as appropriate in areas without functioning labour markets; Campbell & Luckert, 2002). 'Environmental income' is generally perceived to refer to organic wild-sourced resources (Sjaastad et al., 2005), but particularly given the importance of gold in the study area we follow Cavendish (2000) in also including mineral resources in environmental income and disaggregating organic and non-organic environmental income during analysis.

Household lists were grouped by household head (male, widow/divorced, or female with husband working away; categories follow Cavendish, 2000) and household size (1-2, 3-5 and 6+ residents) and then a random sample selected proportionate to village size and the representation of each group within the village to give a total of 104 households. The main income survey was carried out three times to reflect seasonal variation in resource use, in June/July 2014, February/March 2015 and October/November 2015. Recall periods of one month or six months were used as appropriate for the income category, and data extrapolated to represent a full farming year from September/October 2014 to September/October 2015. Survey attrition over the data collection period resulted in a final sample size of 91 households, representing a mean sampling intensity of 52±16% of resident households in each village. The potential biases introduced by survey attrition, along with further detail of the income survey, are considered in Chapter 4.

Additional modules were added to the household survey in the second and third field seasons. The additional module in February/March 2015 looked at coping strategies in response to hazard exposures. Respondents were first asked to describe how they coped with the drought of 2002 and the combined drought and economic crisis of 2008. They were then presented with 11 potential coping strategies, derived from the literature and from discussions during the first season of fieldwork, and with three locally-relevant shock scenarios: idiosyncratic household crop failure, covariate crop failure due to drought, and long-term incapacitating illness in the household head. Respondents were then asked to weight the importance of the strategies using 20 beans, and to describe the reasoning behind the assigned scores.

An additional module in October/November 2015 was aimed at eliciting use values for woody ethnospecies found during tree surveys. Based on quantitative ethnobotany approaches developed by Phillips & Gentry (1993a;b) and used by Luoga et al. (2000) in Tanzanian miombo, respondents were asked to score ethnospecies as 0 (not useful), 1 (moderately useful) or 2 (very useful) in six provisioning ecosystem service categories:

firewood, fibre, construction poles, medicine, food and leaf litter fertiliser. The mean of all responses per ethnospecies was then used as the ethnospecies category use score and combined with woodland survey data to quantify the use value of village woody cover.

1.5.5 Woodland Survey

Woodland survey plots were established in the three land cover types with significant woody cover, namely mountain woodland, lowland woodland and agricultural land. Five plot locations in each village were randomly located in each land cover using land cover maps made in QGIS (QGIS, 2016), giving a total of 30 plots in lowland woodland and agricultural land and 20 plots in mountain woodlands (Makumbe and Pfende have no mountain woodland area). Plots were circular with a radius of 20m and were inventoried between February and April 2015, recording diameter at breast height (DBH: measured at 1.3m) and local Shona vernacular name for all stems of DBH >= 3cm. Vernacular names were translated to scientific names using Mullin (2006) and Hyde et al. (2016), and translations checked using Coates Palgrave (2002). If a Shona name did not have a previously recorded translation, or if the species was locally scarce and not familiar to research assistants, then samples were taken for identification at the National Herbarium of Zimbabwe in Harare.

1.5.6 Additional Qualitative Data

A number of qualitative data sets have also been invaluable in triangulating and complementing the structured interviews described above. Qualitative data collection was mainly carried out in focus groups, including six focus groups with long term village residents in February 2015 discussing changes in ecosystem services, 6 feedback focus groups in June 2016 and 18 feedback groups in April/May 2017. Additional key informant interviews were also carried out with Sabhukus, gold miners and traditional healers, and a further 21 semi-structured interviews were conducted with purposively sampled members of different churches to examine links between religious beliefs and environmental values (these were carried out by Amai Simba from an interview script following my return to the UK, and were translated, transcribed and discussed when I returned for the feedback visit in 2016). Additionally, the long period of time spent living with Amai Simba's home in the study village and travelling between study villages on foot or using local transport gave rise to numerous chance encounters and observations, while being personally present for all the household survey interviews rather than employing a team of enumerators resulted in a wealth of informal

data not captured during the questionnaires. The field diary used to record these observations has also been useful in improving understanding of the context of woodland-livelihood interactions in Wedza.

1.6 Positionality and Ethics

1.6.1 The academic location of the thesis

Interdisciplinary work demands a number of choices, initially in terms of the most appropriate disciplines on which to draw, and subsequently in terms of the weighting afford to the literature, methods and conventions (e.g. writing styles) associated with each thesis. The primary theoretical engagement of this thesis is with the savanna ecology and ecological economics literatures, and the decision to draw mainly upon these literatures was in large part motivated by my personal academic positioning. My undergraduate background was in the natural sciences, specifically in zoology and ecology, and so my training was based on a positivist epistemology and centred on hypothesis testing through statistical analysis of quantitative data. Despite interest in anthropological approaches to the study of human-environment interactions, my tropical fieldwork experience before starting this project all focused on biodiversity monitoring and involved only peripheral contact with local people. In the development of this research my tendency was therefore to turn to the literatures and philosophies with which I was most familiar, which is also why quantitative methods were adopted as the primary approach with qualitative methods as an embedded secondary.

However, this academic positioning has shifted over the course of the research project, almost entirely due to the long period of residence in Wedza District and the continual interactions with local people. Growing familiarity with the study area and of the finer detail of Wedza livelihoods brought with it a feeling that the approaches initially adopted might not be the most appropriate to answer some of the most interesting questions on forest-livelihood interactions in the study area. Firstly, while many papers on environmental resource use associate environmental dependence to household socioeconomic characteristics at a single time point, speaking with respondents made it clear than current livelihood strategies could not be fully understood divorced from individual and community histories. Secondly, I became increasingly aware of the importance of the 'imagined' landscapes of respondents – the Wedza landscape viewed through individual-specific historical, spiritual and social filters. These imagined landscapes seemed at least as important in shaping resource use patterns as the physical landscapes documented using ecological field techniques, but had been almost absent from the ecosystem service literature underpinning the thesis. The recognition of a need for a

greater diversity of approaches in examining interactions between people and woodlands in Wedza is reflected in the ordering of chapters in this thesis: from a purely quantitative assessment of land use intensity in Chapter 2, to the much higher qualitative data contents of Chapters 5 and 6.

1.6.2 Ethical considerations in Zimbabwean field research

As a white female student of a British university, fieldwork in rural Zimbabwe requires particular attention to research ethics, and the exact nature of the ethical dilemmas encountered evolves of the course of long residence in the field. At the beginning of the research project attention focused primarily on the power imbalances in interactions with respondents, produced by contexts past and present. White minority rule and economic control are recent memories in rural Zimbabwe, and the knowledge that simply being a white researcher in rural Africa is a circumstance created by past inequity creates a need for particular attentiveness and humility, particularly as these past contexts are reinforced by modern discrepancies in wealth and opportunity. It would be easy for these power imbalances to make respondents feel coerced to participate, and I worked hard to try and reduce the probability of this, both by providing clear project descriptions in written English and spoken Shona when beginning the household questionnaire, but also by creating informal spaces such as village tea parties where local people could comfortably raise questions. Trust building also involved a peculiar tight rope act, of maximising points of similarity while needing to avoid being patronising by appearing to be 'playing poor.' Thus while Amai Simba and I always walked or took local transport, ate local food and slept on kitchen floors when staying out in the villages, the purpose of this was not to try and replicate the lived experience of local people, but to try and avoid demonstrating obvious points of difference which would make respondents unwilling to speak to us openly about concerns.

However, while the initial phase of research involved trust building and increasing respondent confidence, the long fieldwork duration meant that my place in the community shifted from being a total outsider to becoming a partial insider – someone who was still different but known, and who was therefore expected to have a certain understanding of local behavioural norms. This brought with it new ethical considerations, mainly centred on local customs around gift exchanges. As a young person working in the community, it was viewed as appropriate at the beginning of each season to make courtesy visits to older community residents whether or not they were involved in the household questionnaire, and to bring the makings for tea to these visits. It was also seen as appropriate to make visits to say

makorokoto (congratulations) after a marriage or birth and **nematambudziko** (condolences) following a death, usually accompanied by a small gift such as a dollar of sugar or a loaf of bread. Gifts were also acceptable within the framework of the research as long as they were seen as being equitably shared: tea and refreshments were provided for all village residents at the start and end of each long fieldwork stint, so that all villagers felt involved with the research programme, and household survey respondents were given small gifts of vegetable seeds. There is a risk that giving gifts for questionnaire involvement can represent a form of coercion, but given that household surveys could take up to two hours, it was appropriate to provide some recognition of the time given up by respondents. Using seeds as gifts also followed a precedent set by previous researchers in the adjacent Sengezi resettlement area.

The working relationship with Amai Simba lies at the heart of the research, and the ethical aspects of this relationship merit specific attention. Amai Simba has been working as a research assistant since 1996 and is also a resident of Makumbe village, and her experience and local knowledge were invaluable in shaping the process and interpretation of this research. However, dependence on a research assistant as a translator in a context where I had limited command of the local language brought with it both methodological and personal challenges, particularly as living with Amai Simba and her family throughout the research placed the relationship under greater pressure. This pressure was felt most strongly during the first field season, but when looking for ways to ameliorate the conflicts we had encountered I was surprised to find very little literature on relationships with local assistants in developing country fieldwork. Later discussions with Amai Simba on these same themes developed into the analysis presented in Chapter 7 of this thesis.

Perhaps one of the greatest ethical responsibilities attached to a long term field research project is to ensure that the final work is as fair and accurate a representation of the study community as possible and that this representation is shared with the respondents. This was my purpose in carrying out two rounds of feedback workshops in Wedza to discuss results with respondents, and copies of this thesis will also make their way back to Zimbabwe, one to the Research Council and one to Amai Simba in Wedza. I hope that this project will represent the start of a continued relationship, whether academic or personal; there is distinct (and I believe justifiable) contempt in Wedza towards researchers who leave and then never look back. For now I hope that this thesis does credit to the time invested by all participants in this research.

1.7 Chapter Outlines

The remainder of this thesis consists of seven chapters in total, comprised of five research chapters, one reflective chapter considering the influence of power asymmetries and interdisciplinarity on research outcomes, and a discussion chapter synthesising key findings and discussing cross-cutting research themes.

The research chapters have been written in the format of scientific journal articles, and so while chapters have been edited to minimise repetition there is unavoidably some crossover between chapters in the detail of the methods. This is also why the research chapters adopt the journal paper convention of using 'we' rather than 'I' when discussing the research approach. A preamble is provided to each chapter explaining the contribution made by each of the authors who will be listed on the submitted journal paper.

Chapter 2: Human appropriation of net primary productivity and rural livelihoods: findings from 6 villages in Zimbabwe

Global increases in land use intensity are projected to have significant negative impacts on biodiversity and ecosystem services (Foley et al., 2005; Tscharntke et al., 2005; Flynn et al., 2009). The African continent is often portrayed as having comparatively low land use intensity and as being a hotspot of potential new agricultural land (Ramankutty et al., 2002; Deininger & Byerlee, 2011; Lambin & Meyfroidt, 2011), but there have been few high resolution studies in Africa utilising integrated socioecological indicators of land use intensity. Human appropriation of net primary productivity (HANPP) is one such socioecological indicator, but has only once been calculated at the village scale in Africa (Bartels et al., 2017). In this chapter I calculate HANPP in the six study villages using a novel approach based on woodland and household survey data and compare our findings to the results of published regional scale studies. I also explore inequalities in NPP appropriation and assess whether higher co-option by wealthier households results in elite capture of potential NPP.

Chapter 3: Could tree planting mitigate the impacts of savanna woodland degradation? Looking at the 'tyranny of trees' debate through a livelihoods lens.

It has recently been argued that there is a 'tyranny of trees' in ecological thought, with the transference of degradation narratives developed in closed-canopy tropical forests resulting in inappropriate tree-planting programmes which could jeopardise the biodiversity and functioning of grassy savannas and open-canopy woodlands (Veldman et al., 2015a; 2015b). However, to date the 'tyranny' narrative has failed to consider the role of trees in rural

livelihoods, or the diverse values and services derived from trees by rural communities. In this chapter I assess the potential for tree planting to improve livelihood opportunities in rural areas by examining the relationship between reduced tree cover and the availability of provisioning services important in rural livelihoods. Drawing on a combination of woodland survey data and local ethnobotanical knowledge I firstly assess whether decreasing miombo woodland cover is associated with reduced per-household availability of firewood, construction poles, fibre, food, medicinal plants and leaf litter fertiliser. I secondly investigate whether decreasing miombo woodland cover is associated with reduced diversity of ethnospecies underlying provisioning services, and therefore with reduced service resilience and livelihood option values in the context of global change.

Chapter 4: Woodland Cover, Environmental Income and Livelihood Diversification in rural Zimbabwe

Non-cultivated environmental resources provide important livelihood diversification opportunities in rural areas of developing countries, with environmental income accounting for on average 26% of total household income in the miombo ecoregion (Ryan et al., 2016), and concerns have been raised that the widespread deforestation and degradation observed in miombo woodlands (McNicol et al., 2017) will reduce livelihood diversity and increase intra-community inequality. However, few studies have linked patterns of environmental income derivation to the ecological characteristics of source land cover types, or attempted to place environmental income within the context of the broader socioeconomic processes co-producing change in land cover and livelihoods. The objective of Chapter 4 is therefore to assess whether variation in village woodland cover is associated with household environmental income, livelihood diversity, or intra-community income inequality. Using data from an environmentally-augmented income survey carried out in 91 households across the six study villages, I quantify the contribution of different land cover types to total environmental income and explore the roles of household socioeconomic characteristics and village socioecological context in mediating dependence on environmental resources.

Chapter 5: Natural resources as safety nets under multiple hazard exposures in rural Zimbabwe

Natural resources, particularly forest provisioning services, have often been perceived as important for coping with hazard exposures in rural areas of developing countries (Fisher et al., 2010; Paumgarten & Shackleton, 2011; Kalaba et al., 2013a), but a recent global analysis (Wunder et al., 2014) queried this characterisation of 'forest as safety net.' However, many

studies of vulnerability and coping have considered climate hazards such as drought in isolation, when coping strategy decisions are often made in response to multiple interacting hazard exposures (Reid & Vogel, 2006; Quinn et al., 2011; Eriksen & Silva, 2009). While the analysis in Chapter 4 documents the day-to-day importance of environmental income, in this chapter I draw upon recall data from past hazards and a scenario exercise compiling strategy portfolios to investigate the importance of natural resources for coping with shocks. By illustrating quantitative data sets with individual household case studies I explore whether interactions between covariate and idiosyncratic shock exposures can necessitate increased environmental dependence in the Wedza context.

Chapter 6: Blind-spots in ecosystem services literature: the neglected social values of southern African landscapes.

The ecosystem services framework provides a valuable method of structuring research into the values and services derived from complex socioecological systems, and was highly influential in the design of the research reported in the preceding chapters of this thesis. However, making informed trade-offs between services relies upon having a complete representation of the values important to all stakeholder groups, and ecosystem services research has often been criticised for failing to capture the cultural and social values of ecosystems (Chan et al., 2012; Milcu et al., 2013). In this chapter I first identify the main 'clusters' of value discourses in ecosystem services research in the miombo ecoregion, and juxtapose the predominance of these discourses with a case study of the spatial distributions of values in the Wedza landscape. Based on this comparison I discuss whether miombo ecosystem services research currently has the completeness to inform effective and equitable decision making in rural African landscapes.

Chapter 7: Ethical and practical perspectives on collaboration with local assistants in interdisciplinary field research

Research assistants play a critical role in field research projects, and yet there is minimal discussion in the literature of the impact of research assistants on research project outcomes and the interpretation of findings. Written as a collaboration with my two main field assistants, the objective of this chapter is to critically reflect upon the case study research findings presented in this thesis through a discussion of the triple relationship between researcher, research assistant and respondents. We particularly explore how the shifts in identities and relational power asymmetries necessitated by an interdisciplinary approach influence the logistical and theoretical aspects of the research process, and also consider some of the diverse

ethical considerations attached to carrying out interdisciplinary fieldwork in the developing world.

Chapter 8: Synthesis and Conclusions

In this chapter I summarise the key findings from the research chapters, before placing the findings of this PhD within the broader context of existing forest-livelihood research. I conclude by discussing the implications of my findings for understanding of the resilience and vulnerability of savanna woodland socioecological systems in the context of local and global change.

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2. Human appropriation of net primary productivity and rural livelihoods: findings from six villages in Zimbabwe

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Abstract

The African land system is undergoing rapid change, and novel approaches are needed to understand the drivers and consequences of land use intensification. Human appropriation of net primary productivity (HANPP) is a powerful indicator of land use intensity, but has rarely been calculated at high spatial resolutions. Based on data from six villages in Zimbabwe, we present a novel method of calculating HANPP at community and household scales, and explore to what extent household wealth is related to NPP appropriation. HANPP at the village scale was higher than expected from previous studies, ranging from 48% to 113% of potential NPP. Loss of NPP through land use change accounted for the greater proportion of HANPP in four of the six villages, but NPP embodied in livestock feed, firewood and construction materials also contributed significantly to total appropriation. Increasing household wealth was associated with increasing appropriation of NPP in harvested resources, but not with loss of potential NPP through land use change. Our results indicate that land use intensity is currently underestimated in smallholder farming areas of southern Africa. High-resolution HANPP calculations based on field data offer an effective new approach to improving understanding of land use intensification in complex socioecological systems.

Author Contributions

CMR initially suggested the HANPP framework. RP designed the data collection methods, with input from CMR and IG. RP collected and analysed the data, adapted the HANPP framework to the village scale, and wrote the manuscript. CMR, IG and DvdH reviewed the manuscript and suggested improvements. An edited version of this chapter has been published in *Ecological Economics.*

2.1 Introduction

Human activity is having unprecedented influence within the global land system. Over 80% of ice-free land has been altered by human impact (Sanderson et al., 2002), changing atmospheric composition, climate dynamics, nutrient cycling, biodiversity and ecosystem services (Chapin et al., 2000; Millennium Ecosystem Assessment, 2005; Foley et al., 2005). This 'human domination of the earth's ecosystems' (Vitousek et al., 1997) has led to reconceptualisation of humans as integral components and engineers of the global biosphere (Ellis & Ramankutty, 2008) and the recognition of a need for novel integrated approaches, breaking down the historic barriers between natural and social science, to better understand the drivers and consequences of land use change (Kates et al., 2001; Turner et al., 2007; Hackman et al., 2014).

Human Appropriation of Net Primary Productivity (HANPP), the proportion of annual plant biomass production co-opted by human activity, was first suggested as a measure of land use intensity by Vitousek et al. (1986). Land use intensity is a complex and multidimensional concept (Erb et al., 2013), and the advantage of HANPP compared to simpler metrics such as fertiliser inputs (Potter et al., 2010) or crop output (Monfreda et al., 2008) is that it is intrinsically socioecological, encompassing the interactions between human livelihoods and an ecological energy flux. Early studies quantified the annual extraction of NPP embodied in resources such as crops, livestock feed and timber as between 20 and 40% of annual global NPP (Vitousek et al., 1986; Rojstaczer et al., 2001; Imhoff et al., 2004), before Haberl et al. (2007) developed the HANPP concept further by expressing HANPP as a proportion of the potential NPP in a system undisturbed by human influence, thereby including resource extraction but also losses or gains in NPP caused by human land use change (such as deforestation or intensive agriculture). Using the latter approach, HANPP was calculated as 23.8% of potential global terrestrial NPP in the year 2000 (Haberl et al., 2007).

Land use intensification is a subject of particular research interest in sub-Saharan Africa for several reasons. Firstly, HANPP has increased more steeply in Africa over the last century than on any other continent (Krausmann et al., 2013), but yields of staple crops remain far below potential levels (Licker et al., 2010; Sanchez, 2010). Secondly, Africa has been identified as a hotspot of potential new agricultural land (Ramankutty et al., 2002; Deininger & Byerlee., 2011; Lambin & Meyfroidt, 2011; although see Young, 1999; Chamberlin et al., 2014), but agricultural expansion involves numerous conflicts – both social, such as poor recognition of land rights resulting in displacement of rural communities (Cotula et al., 2009), and ecological, such as the situation of much potential agricultural land in highly biodiverse

regions (Gibbs et al., 2010). Thirdly, and at a more local scale, rural subsistence livelihoods in Africa are often centred on crop production, livestock rearing, and collection of wild-sourced resources such as firewood and wild foods (Angelsen et al., 2014) and as such are directly linked and highly sensitive to changes in ecosystem properties. Whether approached from 'bottom-up' livelihoods and development perspectives or from 'top-down' global change and conservation perspectives, understanding the processes and impacts of land use intensification in sub-Saharan Africa is therefore a research priority.

To date there has been little use of HANPP as a land use intensity measure in sub-Saharan Africa. HANPP has been quantified at continental (Fetzel et al., 2016) and regional scales (Abdi et al., 2014), but most national case studies have been carried out in Europe (e.g. Schwarzlmuller, 2009; Musel, 2009; Kolheb & Krausmann, 2009) and Asia (Prasad & Badarinth, 2004; Kastner, 2009; Chen et al., 2015), with the only national HANPP case study in Africa focused on South Africa (Niedertscheider et al., 2012). One recent study (Bartels et al., 2017) adapted the HANPP framework to the village scale and calculated village-level HANPP to be between 34 and 38% of annual potential NPP in Tanzania, but without further case studies it is impossible to determine whether this is a representative example. The lack of fine scale HANPP research in Africa may be a consequence of data availability, with commonly used data sets such as FAOSTAT (FAO, 2015a) and the Global Forest Resources Assessment (FAO, 2015b) having well-recognised weaknesses in the African context (Mather, 2005; Fetzel et al., 2016). Previous studies may also have underestimated HANPP in rural Africa due to lack of recognition of the importance of wild-sourced resources such as firewood and construction material in rural livelihoods – a recent global analysis found that around 30% of household income in rural Africa is derived from such wild-sourced resources (Angelsen et al., 2014), but only a minority of HANPP studies have attempted to include domestic fuelwood consumption (Niedertscheider et al., 2012; Fetzel et al., 2016; Bartels et al., 2017), and resources such as construction poles have been largely omitted from existing analyses. Additionally, the low resolution and simplifying assumptions of published studies have potentially obscured important heterogeneity in parameters such as forest structure and population distribution. Drawing linkages between HANPP and ecosystem goods and services such as biodiversity demands a finer resolution of analysis (an approach adopted by Haberl et al., 2004).

Analysis of NPP appropriation patterns at the household scale also has the potential to improve understanding of the social and environmental consequences of changing rural livelihoods. Many studies have documented the income portfolios of rural African households (e.g. Cavendish, 2000; Mamo et al., 2007; Kamanga et al., 2009), but fewer have considered

how livelihood strategies and socio-economic characteristics influence household-scale environmental or NPP footprints. Further, past studies indicate that wealthier households have higher absolute environmental income (Cavendish, 2000; Mamo et al., 2007), partly driven by ability to obtain a higher share of the most lucrative environmental resources (Ambrose-Oji, 2003; Merode et al., 2004), but no research has assessed whether this pattern of 'elite capture' of environmental goods is replicated in NPP appropriation, or whether the greater capability of wealthy households to access resources or displace NPP demand during periods of scarcity results in exacerbation of rural NPP appropriation inequalities during land use intensification.

Reflecting the research gaps described above, the first objective of this chapter is to develop a novel method of quantifying HANPP at the community scale and to calculate HANPP in six villages in central Zimbabwe. Avoiding the inaccuracies associated with the use of national statistics, we instead base our analysis on detailed field data describing woodland structure and rural livelihoods. Our second objective is to adapt this method to the household scale, in order to assess the extent to which household wealth and income may be associated with household NPP appropriation and to discuss the potential ramifications of land use change for inequalities in NPP appropriation.

2.2 Methods

2.2.1 Field Data Collection

2.2.1.1 Study site and creation of land cover maps

This study was carried out in six villages in Wedza Communal Area, in the Mashonaland East province of Zimbabwe (a detailed study site description is provided in Chapter 1). Wedza Communal Area is an appropriate location to develop village-level HANPP quantification methods for two reasons. Firstly, the forest-agriculture matrix landscapes found in Wedza typify land cover patterns in many areas of the miombo ecoregion (Hansen et al., 2013). Secondly, the livelihoods of Wedza households are centred on subsistence agriculture but also include livestock rearing, off-farm labour, transfers, and use of a diverse range of environmental resources (details provided in Chapter 4), and similar livelihood strategies have been documented in other miombo ecoregion countries including Malawi (Fisher, 2004; Kamanga et al., 2009) and Zambia (Kalaba et al., 2013). These similarities mean that Wedza is likely to be more representative of broader land use intensity patterns, and also mean that a method developed in Wedza can be easily transferred to other case study areas in southern Africa.

Two participatory mapping groups and four transect walks were carried out in May 2014 in each of the six villages, and these resulted in identification of six locally understood land cover categories (**Table 2.1**). These locally derived mapping data were combined with Google Earth satellite imagery in QGIS (QGIS, 2016) to create village land cover maps. The extent of cover by high biomass mountain woodland was cross-checked using maps developed by Hansen et al. (2013).

Table 2.1 Overarching land cover categories derived from locally perceived land cover types in rural Zimbabwe. Mountain woodland, lowland woodland and wet grasslands are all common property resources available for use by all village residents, whereas croplands and gardens are privately managed.

Land Cover Category	Definition
Mountain woodland	Comparatively undisturbed miombo woodland found on Wedza Mountain
Lowland woodland	More disturbed lowland woodlands, found in village grazing areas and on riverbanks/kopjes. Also long-term abandoned fields with significant tree regrowth.
Wet Grasslands	Seasonally dry (locally termed **bani**) and non-seasonal (**dofonya**) wetlands
Croplands	Active and recently fallowed fields
Gardens	Small fields, usually found in wetlands or along riverbanks, used for growing vegetables.
Residual Area	Areas without vegetation cover, such as roads, household yards and borrow pits left following road construction.

Ecological survey plots were established in the three land cover categories with greatest spatial extent (mountain woodlands, lowland woodlands and croplands). Five plot locations were randomly generated in QGIS in each land cover category in each of the six villages, giving a total of 30 plots each for lowland woodlands and croplands and 20 plots for mountain woodland (the villages of Makumbe and Pfende have no mountain woodland area). Plots were inventoried between February and April 2015, using circular plots of 20m radius. In each plot, diameter at breast height (DBH: measured at 1.3 m) and local vernacular name were recorded for all stems with DBH > =3 cm. Where possible, names in the local Shona language were translated to scientific names in the field using Mullin (2006) or Hyde et al. (2016), and identification checked using Coates Palgrave (2002). Specimens of species unknown to research assistants and Shona ethnospecies without a previously recorded

scientific translation were taken for identification at the National Herbarium of Zimbabwe in Harare.

2.2.1.2 Household Survey

To understand household livelihood strategies, a household sample was selected using stratified random sampling. Household lists were generated during participatory mapping exercises, and in each village the households were randomly selected proportional to village size, selection stratified into three categories of household size (1-2 residents, 3-5 residents and 6+ residents) and three categories of household head (male-headed, widow-headed, and *de facto* female-headed with husbands working away; categories follow Cavendish, 2000) to give a total sample size of 104 households. High population mobility in Zimbabwe due to economic instability resulted in high survey attrition compared to similar studies, resulting in a final sample size of 91 households. Village size ranged from 10 to 53 permanently inhabited households (mean of 33 households) and sampling intensity ranged from 37 to 80% (mean of 52%).

The questionnaire was adapted from the CIFOR-PEN prototype questionnaire (CIFOR-PEN, 2008) and used to collect detailed data on use of wild-sourced resources (such as firewood and wild fruits) in the month preceding the questionnaire. Data were also collected on household assets and all other income sources, including crops, livestock, informal labour and remittances. The questionnaire was used three times to capture seasonal variation in livelihood strategies (June/July 2014, February/March 2015 and October/November 2015). Fuller detail on the household survey can be found in Chapter 4.

2.2.2 Quantifying HANPP

Following Haberl et al. (2007) and Haberl et al. (2014), we define HANPP as:

$$HANPP = HANPP_{luc} + HANPP_{harv}$$

Where $HANPP_{luc}$ is the loss of potential NPP due to land use change and $HANPP_{harv}$ is NPP harvested by humans. $HANPP_{harv}$ is further subdivided into used extraction (consumed by humans) and unused NPP, meaning NPP influenced by human activity but not extracted from the ecosystem such as unrecovered crop residues.

$HANPP_{luc}$ is calculated as:

$$HANPP_{luc} = NPP_{pot} - NPP_{act}$$

Where NPP_{pot} is the potential NPP in a hypothetical undisturbed system, and NPP_{act} is the actual NPP of the prevailing human-altered system. Reflecting the greater uncertainty associated with calculating below-ground NPP, we follow a number of previous studies by focusing solely on aboveground HANPP (Prasad & Badarinth, 2004; Kohlheb & Krausmann, 2009; Vačkář & Orlitova, 2010), hereafter aHANPP. All results are presented in tonnes of dry matter.

2.2.2.1 Potential aboveground NPP ($aNPP_{pot}$)

It is assumed that areas currently covered by woodland (both mountain and lowland), fields and residual area would, in the absence of human activity, be covered by undisturbed miombo woodlands. aNPP of undisturbed savanna woodland is the sum of annual woody growth, leaf production and understorey grass production. The area cover of all land cover types in each village is provided in Appendix 1 (Table A1.1).

Ten mountain woodland plots with minimal evidence of disturbance were used as proxies for undisturbed woodlands. Current plot stem biomass in undisturbed plots was determined using stem biomass allometric equations derived from similar dry miombo ecosystems (Grundy, 1995; Chidumayo, 1997; Ryan et al., 2011). Three different sets of annual woody increment estimates (Chidumayo, 1997; Frost, 1996; Flack, 2013) were used to project DBH one year in the future, and annual woody production determined by calculating plot biomass from the projected DBH values and deducting current standing biomass. Leaf production estimates were calculated using two leaf production equations (Chidumayo, 1997; Frost, 1996). The non-contiguous canopy in savanna woodlands also allows persistence of a grass understorey (Parr et al., 2014). As this was not measured directly in the field, expected annual grass production per hectare in relation to tree basal area was identified using Frost (1996; 26). Full details of all allometric equations, woody growth increments and annual grass production estimates can be found in Appendix 1 (Table A1.2).

There is comparatively little data on annual increments and leaf production in dry miombo systems, so all six possible combinations of increment and leaf production equation were calculated to give upper and lower $aNPP_{pot}$ estimates. Mean woody and leaf production in tonnes of dry matter ha^{-1} yr^{-1} were calculated for the ten reference plots to give the $aNPP_{pot}$

of undisturbed woodlands, and this was multiplied by the number of hectares of woodland, fields and residual area in each village (identified from village land cover maps) to give $aNPP_{pot}$ of undisturbed woodland per village.

All study villages also contain areas of wet grassland which would have low tree cover even in an undisturbed state, and total village $aNPP_{pot}$ is therefore the sum of woodland $aNPP_{pot}$ and grassland $aNPP_{pot}$. $aNPP_{pot}$ of wet grassland was assumed to be equal to peak annual grass biomass. Mean peak grass biomass was estimated from five studies in Zimbabwean and Zambian wet grassland (Scoones, 1991; Hoffa et al., 1999; Jeanes & Baars, 1991 *in* Scholes et al., 1996; Shea et al., 1996; Nyamadzawo et al., 2014; see Appendix 1 Table A1.3) and gave a mean value of 4.2±0.6SE t DM ha^{-1} yr^{-1}. This $aNPP_{pot}$ was multiplied by the number of hectares of wet grassland and gardens in each study village, and added to the $aNPP_{pot}$ of the woodland area to give total village $aNPP_{pot}$.

2.2.2.2 Actual aboveground NPP ($aNPP_{act}$)

The actual aboveground NPP ($aNPP_{act}$) for woodland area was calculated by applying the method described above to the ten plots in each land cover type in each pair of adjacent study villages, giving separate annual NPP estimates for mountain woodland, lowland woodland, and trees on agricultural land in each village pair. These woodland $aNPP_{act}$ values were multiplied by the area cover in hectares of the relevant land cover type in each village. Reflecting poor data availability on NPP in disturbed vs. undisturbed wet grasslands, wet grassland NPP_{act} was assumed to be the same as it would be in the altered landscape, so the same aNPP value of 4.2±0.6 t DM ha^{-1} was applied to wetland areas.

$aNPP_{act}$ of crop production was determined by calculating village production of eight key crops (maize, millet, sorghum, rice, sugar beans, cowpeas, sunflower and leafy green vegetables). Groundnuts and sweet potatoes are also grown in the study area, but were excluded from the analysis as the majority of biomass production is below-ground. Mean per capita production of each of the crops over the last three harvest seasons was calculated for study households in each village and used to scale crop production to the village level using village household composition lists. As survey households within each village represent a broad range of socioeconomic and agroecological conditions, we believe these village level production estimates to be robust. Locally reported units were converted to kilograms using USDA (1992) and adjusted to dry matter using appropriate moisture content estimates (Gebhardt & Thomas, 2002; OMAFRA, 2016). Associated crop residues and pre-harvest crop

losses were calculated from crop yield data using harvest factors from Haberl et al. (2007) (Appendix 1 Table A1.4).

Grass production in agricultural land is focused on contour ridges; raised boundaries between fields intended to prevent soil erosion which are also an important source of livestock feed (Scoones, 1995). However, reflecting the small area coverage of contour ridges (<2ha per village) and the lack of data on contour ridge NPP, contour ridge grass production was not included in the analysis.

2.2.2.3 Harvested NPP ($aHANPP_{harv}$)

Harvested aboveground NPP ($aHANPP_{harv}$) was calculated as the sum of crop production and recovered residues, material grazed by livestock, and consumption of three wild-sourced resources accounting for the highest proportion of extracted biomass (firewood, construction poles and thatching grass).

For crops, $aHANPP_{harv}$ was assumed to be equal to $aNPP_{act}$. The proportion of crop residues recovered for use was calculated using conversion factors in Haberl et al. (2007).

Size of the village livestock herd was calculated by estimating ownership of the main livestock species (cattle, goats, chickens, turkeys and guinea fowl) in the village from the household survey. The proportion of livestock feed derived from the environment (the feed gap) was calculated by estimating annual feed demand using daily food intake estimates from Haberl et al. (2007) and deducting dry matter mass of feed crops, purchased concentrate, and the proportion of crop residues used as livestock feed (estimated as 41% in sub-Saharan Africa by Haberl et al., 2007).

Annual firewood consumption was estimated from the three months incorporated in the household questionnaire, including both firewood used domestically and for commercial purposes such as beer brewing and tobacco curing. Firewood consumption was recorded in local units, and following a review of the literature (see Appendix 1 Table A1.5) and conversion to dry matter weight using moisture content estimates from Abbot & Lowore (1999; Appendix 1 Table A1.6), headloads were assigned a weight of 11 kg DM, wheelbarrows 20 kg DM, and cartloads 158 kg DM.

Volume of wood required annually for construction and maintenance of household structures (wooden huts, fences and cattle kraals) was calculated using volumes reported in Grundy et al. (1993) and converted to dry matter weight using published wood density values for the most prevalent local construction species (Goldsmith & Carter, 1981; Malimbwi et al., 1994; Abbot & Lowore, 1999; Williams et al., 2008; Chave et al., 2009). Firewood used for

brick burning to construct household structures was not included, as the lifespan of brick buildings means that firewood demand is very low when expressed on an annual basis.

Annual thatching grass consumption was estimated from the household survey. Following Grundy et al. (2000), we assume thatching grass bundles to weigh 5kg (fresh weight). Thatching grass is mainly collected in the early dry season, when grass moisture content is estimated to be 55% (Woollen et al., 2016). Consumption of firewood, construction materials and thatching grass was calculated on a mean per capita basis for study households in each village and then scaled to the non-surveyed households in the village.

A key consideration in calculating aHANPP is that estimates of $aNPP_{pot}$, $aNPP_{act}$ and $aHANPP_{harv}$ all apply to the same spatially bounded area, in this case the village. Village boundaries were determined during participatory mapping groups and confirmed during four GPS-tracked transect walks with key informants in each village. Use of village land cover maps and village household survey data meant that $aNPP_{pot}$, $aNPP_{act}$ and $aHANPP_{harv}$ embodied in crops could all be reliably calculated within village boundaries, while data collected during the household survey on the derivation location of wild-sourced resources meant that estimates of $aHANPP_{harv}$ of firewood and construction materials could be restricted to reflect only aNPP appropriated within the village area. There is however some uncertainty over the proportion of cattle graze sourced within village boundaries. Cattle are herded during the farming season from October to May and stay primarily within the village area, while following the harvest from May to July field crop residues are a main food source, giving cattle little motivation to roam. The only season when cattle roam further is the later dry season from July to September when food becomes scarcer; however, Scoones (1995) found that cattle roaming distance is related to distance to permanent water source. As all study villages have permanent water sources, and as roaming distance is limited by the return of all cattle to the homestead each night due to fears of theft or predation by hyenas, we have assumed for this analysis that all environmental livestock feed is derived from within the village area. The limitations of this assumption are considered in the discussion.

Unrecovered crop residues and pre-harvest crop losses were included in $aHANPP_{harv}$ but reported as unused extraction. Although human-caused veld fires were common in the study area, there is no accurate data available at sufficiently high resolution; we therefore follow Niedertscheider et al. (2012) in omitting biomass changes caused by human-induced fires from the analysis.

2.2.3 Household Wealth and aNPP appropriation

Twelve interviews were carried out, two in each village, to identify features that indicated whether households were very poor, less poor, or wealthy by local standards. Interview respondents were purposively sampled: one high income and one low income household identified from the household survey in each village to obtain a broad range of perspectives, and including only long-term village residents with a good knowledge of all other households in the village.

Wealth indicator interview responses were combined to give a wealth index with seven categories (**Table 2.2**). Indicators which were locally important but which were linked directly to NPP consumption such as cattle ownership were not included in the index. Surveyed households were assigned a wealth index between 0 and 7.

Table 2.2 Wealth Index comprised of locally derived wealth indicators relevant to Wedza District, Zimbabwe, compiled from twelve key informant interviews. Households were assigned a score between 0 and 1 in each indicator category, resulting in a total wealth index score of between 0 and 7.

Category	Very Poor (assigned score of 0)	Less Poor (assigned score of 0.5)	Locally wealthy (assigned score of 1)
Farming equipment	No large farming equipment	Own two or more of: plough, wheelbarrow, scotch cart	Fulfil 'less poor' criteria, and also own one or more of: harrow, cultivator, planter, tractor
Transport	No form of transport	Bicycle	Car
Household structures	No large bedroom house, only one or two roundhouse kitchens	Main house with 1-3 rooms	Main house with 4 or more rooms
Sanitation	No toilet		Toilet
Household furnishings	No expensive furnishings	Own two or more of the following: Bed (1 only), radio, chairs	Fulfil 'less poor' criteria and also own two more of: TV, beds (2 or more), generator, lounge suite
Domestic help	No domestic worker		Domestic worker employed at any time during study period
Water supply	Use shared water sources such as wells or boreholes		Private well, borehole or water pump

Linear regression was used to examine the relationship between aNPP appropriation and three different wealth measures: wealth index, household cash income (calculated from the household survey), and the median of household rank by these two measures (hereafter the combined wealth rank). Households were also split into two groups, those belonging to the three villages with highest land use intensity (Makumbe, Pfende and Mapfanya) and those with the lowest land use intensity (Betera, Charambira and Mbizi). The ratio of total aNPP appropriation by households with a combined wealth rank in the top and bottom 20% of each village set was compared to assess NPP appropriation inequality. The same method was used to calculate inequality in cash income. All analyses were carried out in Excel and R (R Core Team, 2014).

2.3 Results

2.3.1 $aNPP_{pot}$ and $aNPP_{act}$ in miombo woodland systems

$aNPP_{pot}$ calculated from undisturbed woodland reference sites ranged from 3.6±0.2 t DM ha^{-1} yr^{-1} to 6.0±0.2 t DM ha^{-1} yr^{-1+} dependent on the combination of leaf and increment equations used (**Figure 2.1**), with these aNPP estimates being within the range of published studies (Appendix 1 Table A1.7).

Annual $aNPP_{act}$ was highest in mountain woodland plots, with the six combinations of increment and leaf equations giving a mean annual aNPP of 4.7±0.4 t DM ha^{-1} yr^{-1} in the Charambira/Mbizi village pair and 3.8±0.3 t DM ha^{-1} yr^{-1} in Mapfanya/Betera (**Figure 2.2**). Increased grass production only partially compensated for loss of tree productivity in more disturbed lowland woodlands. Tree $aNPP_{act}$ in croplands was almost twice as high in Charambira/Mbizi as in the other two village pairs, but even in these villages amounted to only 0.5±0.05 t DM ha^{-1} yr^{-1}.

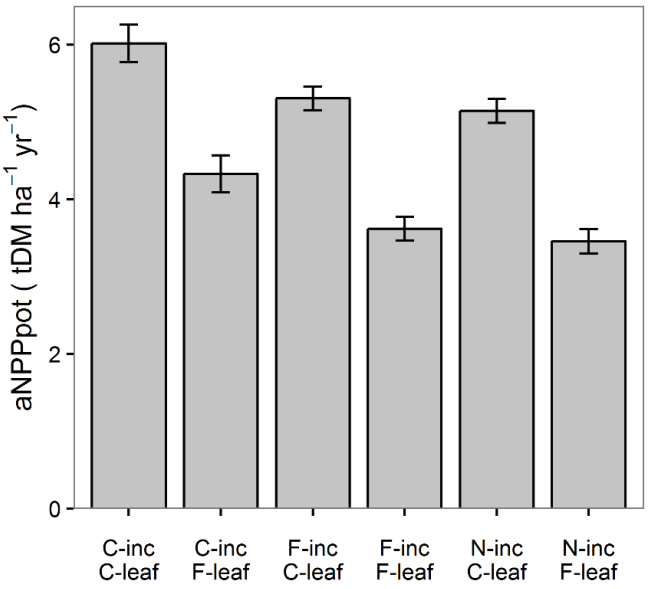

Figure 2.1 Woodland $aNPP_{pot}$ (tDM ha^{-1} yr^{-1}) calculated using all combinations of three woody increment ('inc') estimates and two annual leaf ('leaf') production allometric equations, based on data from ten comparatively undisturbed miombo plots on Wedza Mountain, central Zimbabwe. Error bars represent ± one standard error.

Abbreviations refer to equations derived from the following: C-inc = Chidumayo (1993), F-inc = Frost (1996), N-inc = Flack (2013), C-leaf = Chidumayo (1993), F-leaf = Frost (1996).

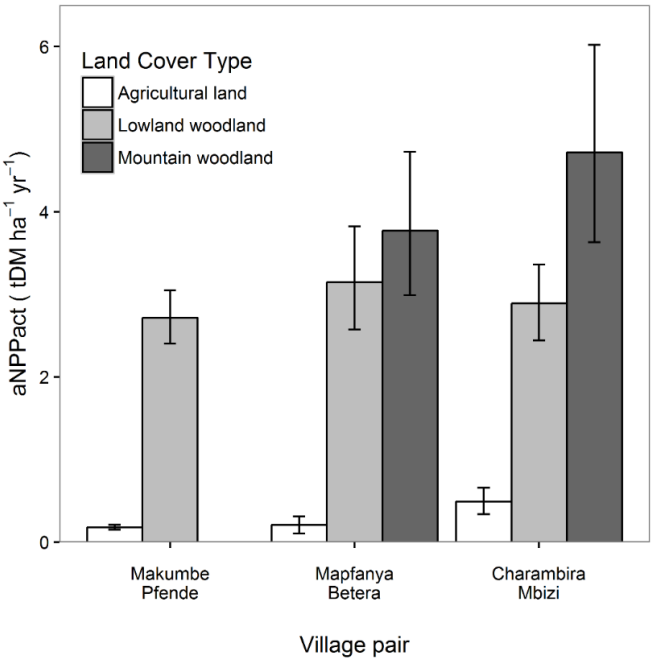

Figure 2.2 Annual NPP of tree and grass production in three different land covers in three village pairs in central Zimbabwe. Agricultural land data does not include crop production. Error bars represent range of results calculated using six different combinations of leaf production and woody increment equations.

2.3.2 aHANPP at the village scale

aHANPP ranged from 113% in Makumbe village to 48% in Charambira village (**Table 2.3**). $aHANPP_{harv}$ and $aHANPP_{luc}$ made an equal contribution to aHANPP in Mapfanya and Makumbe villages, whereas $aHANPP_{luc}$ accounted for a much higher proportion of aHANPP in the other four villages. Although different equation combinations resulted in quite high levels of variation in estimated appropriation of aNPP in tonnes of dry matter, aHANPP expressed as a percentage of $aNPP_{pot}$ was much less sensitive, with a maximum difference of 10% between upper and lower estimates. Although the choice of equation used altered the relative contributions of $aHANPP_{harv}$ and $aHANPP_{luc}$, in four of the study villages there is no overlap in the ranges of the potential percentage contributions of $aHANPP_{luc}$ and $aHANPP_{harv}$. Therefore the conclusion that $aHANPP_{luc}$ is the greater contribution to HANPP in these villages remains robust whichever equation combination is used. Compared to the findings of previous African HANPP studies (**Table 2.4**), aHANPP was substantially higher in each of the six villages.

Table 2.3 aHANPP in six villages in Wedza District, Zimbabwe, in total and disaggregated as aHANPPluc (aNPP prevented due to land use change), used $aHANPP_{harv}$ (harvested aNPP embodied in resources such as crops and firewood) and unused $aHANPP_{harv}$ (aNPP impacted by human activity but not harvested, such as unrecovered crop residues). Percentages are calculated as the proportion of $aNPP_{pot}$ (the potential NPP in a system undisturbed by human activity). Main figures are the mean of calculations using six combinations of woody increment and leaf production equations. Figures in brackets represent the range of results derived from using these six different combinations of equations.

Village	**Village Area (ha)**	**aHANPP (%)**	**aHANPP (t DM yr^{-1})**	**$aHANPP_{luc}$ (%)**	**$aHANPP_{harv}$ (used, %)**	**$aHANPP_{harv}$ (unused, %)**
Makumbe	368	113 (110 – 118)	1897 (1548 – 2294)	56 (46 – 65)	56 (43 – 68)	1.6 (1.2 – 1.9)
Pfende	323	84 (80 – 86)	1253 (915 – 1623)	59 (48 – 69)	25 (19 – 32)	0.5 (0.4 – 0.6)
Mapfanya	441	72 (68 – 78)	1461 (1125 – 1809)	35 (26 – 41)	36 (27 – 46)	0.8 (0.6 – 1.0)
Betera	636	53 (50 – 55)	1571 (1120 – 2045)	37 (30 – 42)	16 (12 – 20)	0.4 (0.3 – 0,6)
Charambira	249	48 (43 – 50)	548 (374 – 726)	31 (22 – 37)	16 (12 – 20)	0.2 (0.2 – 0.3)
Mbizi	268	58 (54 – 60)	716 (511 – 929)	39 (30 – 44)	19 (14 – 23)	0.4 (0.3 – 0.5)

Table 2.4 Previously published HANPP estimates from studies in Africa and the southern African region

Region	**HANPP estimate (%)**	**Reference**
Sub-Saharan Africa	12.4[1]	Imhoff et al. (2004)
Sub-Saharan Africa	18	Haberl et al. (2007)
South Africa	21 – 25	Niedertscheider et al. (2012)
Africa	20	Krausmann et al. (2013)
Southern Africa	23	Fetzel et al. (2016)
Ololosokwan village, Tanzania	34 - 38	Bartels et al. (2017)

[1]Imhoff et al. (2004) express HANPP as the used proportion of NPP_{act}, while all other studies define HANPP as human appropriation of NPP_{pot}.

Livestock grazing was the main contributor to $aHANPP_{harv}$, accounting for between 42 and 66% of total $aHANPP_{harv}$ (**Figure 2.3**). Collection of firewood and construction materials accounted for between 21% and 31% of $aHANPP_{harv}$, while crop production accounted for a relatively small proportion, between only 9 and 20% of $aHANPP_{harv}$.

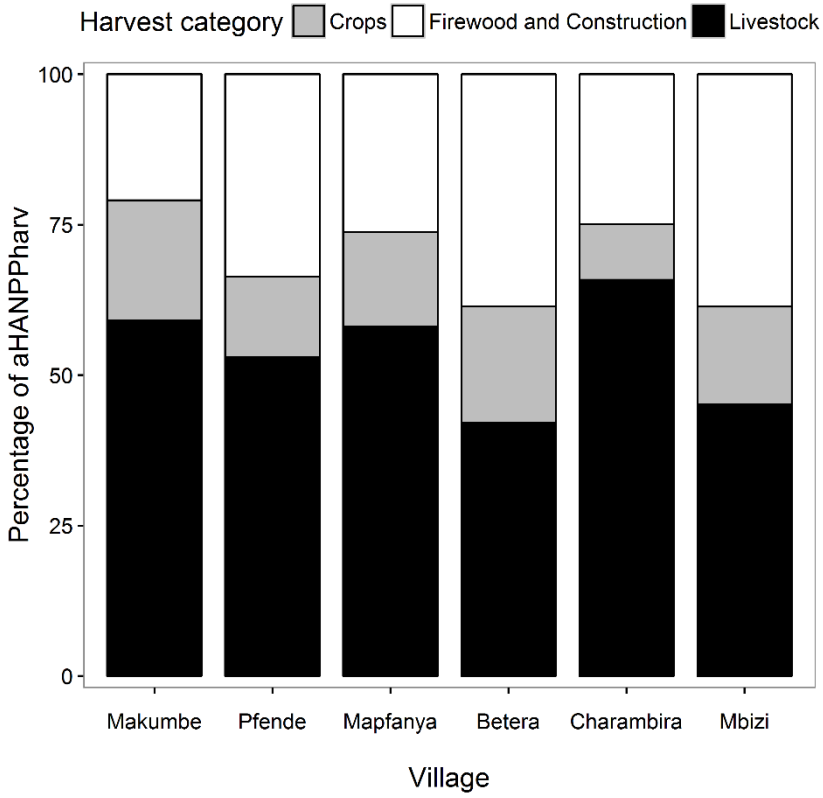

Figure 2.3 Used aHANPPharv in six villages in central Zimbabwe separated into three main harvest categories. 'Crops' includes the most important field crops in the area along with associated recovered crop residues. 'Livestock' represents grazed and browsed livestock feed. Firewood and construction encompasses all firewood, construction poles and thatching grass collected by village residents within the village area.

2.3.3 aNPP appropriation and household wealth

There were significant relationships between aNPP appropriation and household wealth index score and combined household ranking, but no correlation with log cash income per capita (**Table 2.5a**). There was no apparent relationship between household $aHANPP_{luc}$ and any wealth indicator, whereas there was a significant relationship between $aHANPP_{harv}$ and all wealth indicators. However, the low adjusted R^2 in all cases (**Table 2.5**) indicates that there are numerous factors other than wealth influencing variation in aNPP appropriation.

Table 2.5 Relationships between three indicators of household wealth and (a) total household NPP appropriation, aHANPPharv and aHANPPluc; (b) aHANPPharv disaggregated into the source categories of livestock feed, crops, and firewood/ construction material; and (c) household characteristics with potential to mediate the interaction between wealth and aHANPP. Linear regression analysis based on data from 91 households in Wedza Communal Area, Zimbabwe. Combined ranking refers to the median of household positions within the total sample when ranked by cash income and by wealth index.

	Wealth Index Score	**Log cash income per capita**	**Combined ranking**
	Adjusted R^2	Adjusted R^2	Adjusted R^2
(a)			
aHANPP (t DM)	0.21***	0.02	0.12***
$aHANPP_{luc}$ (t DM)	0.0	0.01	0.0
$aHANPP_{harv}$ (used fraction, t DM)	0.34***	0.04*	0.20***
(b)			
$aHANPP_{harv}$ (livestock feed)	0.32***	0.04*	0.21***
$aHANPP_{harv}$ (crops)	0.30***	0.03	0.15***
$aHANPP_{harv}$ (firewood/ construction)	0.0	0.0	0.0
(c)			
Agricultural efficiency (crop production t DM $field^{-1}$)	0.006	0.01	0.04*
Household field holdings	0.02	0.0	0.01
Heads of cattle	0.34***	0.04*	0.20***
Heads of poultry	0.14***	0.05*	0.15***
Heads of goats	0.05*	0.01	0.04*

Significance levels: * $p<0.05$, ** $p<0.005$, *** $p<0.001$.

When $aHANPP_{harv}$ was disaggregated by source category there was a significant positive correlation between wealth indicators and appropriation of aNPP embodied in livestock feed and crops, but no apparent relationship between any wealth indicators and appropriation of aNPP embodied in environmental resources (**Table 2.5b**). Increasing household wealth was associated with increased ownership of livestock, particularly cattle and poultry, but was not associated with increased field holdings (**Table 2.5c**).

In the higher land use intensity villages (Makumbe, Pfende and Mapfanya) the top 20% of households by combined wealth ranking appropriated on average 30.8±4.1 t DM hh^{-1} yr^{-1}, while the poorest 20% of households appropriated on average 18.4±2.9 t DM hh^{-1} yr^{-1}. In the lower land use intensity villages (Betera, Charambira and Mbizi), households in the wealthiest 20% appropriated on average 27.2±4.2 t DM hh^{-1} yr^{-1} while households in the poorest 20% appropriated 13.0±2.5 t DM hh^{-1} yr^{-1}. The ratio of total combined NPP appropriation by the richest 20% of households to that appropriated by the poorest 20% of households was 1.7 in the higher land use intensity villages and 2.1 in lower land use intensity villages, indicating slightly higher inequality in HANPP appropriation in the lower land use intensity villages.

Inequality in HANPP consumption was much lower than inequality in cash income. In the higher land use intensity villages, the ratio of cash income in the wealthiest 20% of households by combined wealth ranking compared to the poorest 20% was 23.3, with the wealthiest 20% earning US$1912.91±570 per capita yr^{-1} compared to US$82.09±13 per capita yr^{-1}. Even excluding the wealthiest household, which had cash income per capita six times that of the next wealthiest household, the ratio of cash income in the wealthiest and poorest 20% was still 15.8. In the three lower land use intensity villages the equivalent ratio was only 8.0, with the wealthiest 20% of households earning US$1079.14±249 per capita yr^{-1} compared to US$134.82 per capita yr^{-1} in the poorest 20%.

2.4 Discussion

2.4.1 aHANPP at the village scale

Our findings indicate that aHANPP quantified at the village level is much higher than would be anticipated from previous studies. aHANPP varied from 48% in Charambira up to 113% in Makumbe, whereas previous regional studies reported a range from 12.4 to 23.0% (Imhoff et al., 2004; Haberl et al., 2007; Niedertscheider et al., 2012; Krausmann et al., 2013; Fetzel et al., 2016) and the only previous village scale study estimated aHANPP as between 34 and 38% (Bartels et al., 2017). Even in the higher resolution maps developed by Haberl et al. (2007),

the majority of Zimbabwe has HANPP of between 20 and 40%, with few areas exceeding 50%.

There are several potential reasons behind the discrepancy between our results and those of published studies. Partly the high aHANPP is attributable to the choice of study site. The heterogeneity of land use in Africa is well-recognised, with some areas being underutilised while others are densely populated by smallholder farming communities (Tittonell & Giller, 2013; Chamberlin et al., 2014; Jayne et al., 2014). In Zimbabwe, these densely populated areas are a legacy of past inequity in land ownership, with many indigenous black farmers restricted to crowded Communal Areas while the best agricultural land was conserved for large commercial white farms (Palmer, 1990). While land reform has resulted in some population re-distribution (Scoones et al., 2010), the historic land ownership system still shapes the extant landscape. Although focusing on a Communal Area will undoubtedly result in higher aHANPP, there is a strong argument that, as rural populations in more marginal agricultural areas are most sensitive to environmental change (Jones & Thornton, 2009), these areas should be a priority for land use change research.

However, our higher aHANPP is also driven by a number of other factors. Firstly, use of field data rather than national statistics allowed inclusion of resources such as firewood and construction material which are only poorly recorded in national level data. Firewood, construction poles and thatching grass accounted for between 21 and 31% of total $aHANPP_{harv}$, with average per capita extraction totalling 1.1 t DM yr^{-1}, and excluding this resource flow could therefore result in significant underestimates of $aHANPP_{harv}$ particularly in rural areas of developing countries. Use of locally derived woodland survey data also meant that we could account for the contribution of woodland degradation to $aHANPP_{luc}$. The majority of published studies assume $aNPP_{pot}$ and $aNPP_{act}$ to be equal in all forest and woodland systems – and in rangeland systems in the case of Bartels et al. (2017) – but our data show human disturbance results in substantial variation in $aNPP_{act}$ over even relatively fine spatial scales. While recognising that the resource intensity of our approach would be challenging if seeking to ascertain HANPP at wider spatial scales, we suggest that detailed field data on forest and woodland structure and on rural livelihood portfolios is key to improving the accuracy of higher resolution aHANPP estimates.

The finding of extremely high aHANPP (113%) in Makumbe village has two potential explanations. The first is that the estimate includes some aNPP appropriated outside the village area due to livestock grazing. As detailed in the methods, observations of local herding patterns suggest the majority of livestock feed to be obtained within the village, but without a more detailed analysis of livestock movement patterns there is uncertainty attached to this

assumption. However, even were it very conservatively assumed that only 50% of livestock feed was obtained inside the village area, aHANPP would still be high at 91%. This leads us to suggest that the high aHANPP observed in several villages is also due to harvest of production from previous years embodied in firewood and construction poles. The high environmental pressure and unsustainable use implied by a HANPP estimate of more than 100% is supported by the levels of woodland degradation observed in the highest land use intensity villages (further details provided in Chapter 3).

2.4.2 Uncertainty in aHANPP estimates

The main source of potential error in the presented method is in the estimation of $aNPP_{pot}$ and $aNPP_{act}$ in miombo woodlands. There have been few longitudinal studies of annual production in miombo woodlands, but our estimates of annual woody $aNPP_{pot}$ of woody production lie within the range of published studies (see Appendix 1 Table A1.7). There are few published studies of annual leaf production in miombo woodland, and use of the allometric equations developed in Zambia by Chidumayo (1997) indicate much higher annual leaf production than that predicted by the Zimbabwean equations from Frost (1996). However, the mid-point of the two leaf production calculations used in this study falls within the range of published estimates.

An additional potential source of overestimation is that miombo woodland production is linked to precipitation levels (Frost, 1996), and although all allometric equations used in this study were derived from dry miombo systems, woodlands in Mozambique and Zambia typically receive higher rainfall than Zimbabwean woodlands and may have corresponding differences in growth rate and in proportional relations between DBH and leaf production. As there are no allometric equations developed within the study site, using a range of equations derived from similar systems was the only way to assess the scale of uncertainty introduced by choice of allometric. Furthermore, it could be argued that use of local reference plots may have resulted in overestimation of woodland production as some plots showed signs of minor disturbance – although given that miombo woodland evolved in a context of disturbance, either by humans or by fire and megaherbivore activity (Mapaure & Moe, 2009), the use of mildly disturbed reference plots is of less substantial concern. We also do not account for the possibility that there could have been areas which were naturally clear of vegetation even in the undisturbed landscape.

Despite these limitations, our village level HANPP estimates appear robust. The different combinations of woody increment and leaf production equations resulted in varying

estimates of woodland production in tonnes of dry matter, and altered the relative contributions of $aHANPP_{harv}$ and $aHANPP_{luc}$ to total aHANPP, but in no village did the final HANPP percentage estimate have a range of more than 10 percentage points with all equation combinations. This indicates that aHANPP has low sensitivity to equation choice and allows a high level of confidence in the results.

An additional critique of our methods might relate to our focus on aboveground NPP. Miombo woodland soils are an important carbon store (Walker & Desanker, 2004) and changes in belowground production could significantly impact $HANPP_{luc}$, while inclusion of key local crops with primarily belowground production such as groundnuts and sweet potatoes could alter both NPP_{act} and $HANPP_{harv}$. A valuable development on the present study would therefore be to explore methods of integrating belowground production into HANPP estimates.

2.4.3 aNPP appropriation and household wealth

Household wealth index score was positively associated with aNPP embodied in harvested resources, partially supporting the idea that elite capture of aNPP occurs in rural Zimbabwean communities. Our data do not allow us to isolate the reasons behind the link between household wealth and crop harvests. Wealth may be a direct driver of high crop harvests, reflecting the ability of wealthier households to afford inputs such as synthetic fertiliser and paid labour (Zingore et al., 2007), or alternatively both wealth and crop harvest may co-vary with another factor such as soil fertility in household fields. Higher extraction of livestock fodder by wealthier households reflects the significant correlation of wealth with number of cattle owned. Cattle are an important multifunctional asset in many areas of Africa, used for ploughing fields and pulling carts (and thereby helping perpetuate wealth accumulation), producing manure for fertiliser (improving soil quality of private fields), and acting as a status indicator and savings bank (Dercon, 1998; Hoddinott, 2006).

The lack of a clear link between household wealth and $aHANPP_{luc}$ is interesting. A global study found that national $HANPP_{luc}$ decreases with increasing development, as increasing agricultural yield compensates for loss of NPP_{pot} in undisturbed ecosystems (Krausmann et al., 2013). However, although wealthier households in Wedza obtained higher overall crop production, this appears to be due to increased area cultivated as there was no significant relationship between household wealth and yield. Further, while cropland area cultivated each year by the household may increase with wealth, there was no significant relationship between wealth and the total cropland area owned, suggesting that land ownership in the communal area is also linked to a diversity of other factors such as length of time resident

in the community, gender of the household head, and number of times the land has been divided amongst family members. These longer terms factors are important as the lowlands around Wedza Mountain have been largely deforested for over 30 years (Gumbo, 1988). Our data also only permitted calculation of $aHANPP_{luc}$ on household field holdings, and identifying methods of quantifying household contributions to $aHANPP_{luc}$ beyond the boundaries of household property (for example due to woodland degradation through firewood collection) should be a priority for future studies, particularly in areas such as southern Africa where there is high dependence on common property resources.

Also somewhat surprising is the finding that inequality of aNPP appropriation is slightly higher in the combined households from the three lower land use intensity villages than in the three highest land use intensity villages. However, one limit of applying the HANPP paradigm at a small scale is that it only records NPP appropriated within the village area. At the national scale, wealth is associated with an ability to displace demand for natural resources (Krausmann et al., 2009; Weinzettel et al., 2013). Without more detailed household consumption data we cannot calculate the quantity of displaced HANPP, but there is evidence that households in the highest land use intensity villages do displace a portion of their NPP appropriation: 15 out of 36 households in Makumbe and Pfende reported collecting or purchasing firewood outside their home village, as opposed to only one household in total out of the other four study villages. Obtaining firewood outside the study area in many cases requires either a cash payment or the possession of assets such as wooden cart and cattle, both of which are linked to household wealth. A further interesting development on the current analysis would be to determine whether inclusion of NPP embodied in resources obtained outside the study area alters the NPP appropriation inequality findings of the current study.

2.5 Conclusions

This study deploys a new approach to the assessment of HANPP at the household and village level, yielding new evidence in the study of socio-ecological interdependences and resource inequalities in small scale African farming systems. The findings from this study suggest that the low resolution of previous HANPP studies has resulted in a substantial underestimation of the intensity of land use in smallholder farming areas in southern Africa, masking the ramifications of land use intensification for rural livelihoods and the conservation of biodiversity and natural capital.

Our findings indicate that high-resolution calculations of HANPP based on field data can make a valuable contribution to understanding of patterns of land use intensity, improving

the accuracy of HANPP estimates by facilitating inclusion of resources omitted from many studies such as construction materials, and also allowing finer-scale analysis of human impacts on ecosystems such as woodland degradation which may not be apparent from broader scale data sets. We suggest that such high resolution approaches mapping HANPP over larger areas can make a valuable contribution to identification of 'hotspots' of environmental pressure, and that linking HANPP patterns at community and household scales to characteristics of local livelihoods may assist anticipation of environmental externalities associated with livelihood change.

2.6 Chapter 2 References

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3. Could tree planting mitigate the impacts of savanna woodland degradation? Looking at the 'tyranny of trees' debate through a livelihoods lens.

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Abstract

Concerns have recently been raised that a 'tyranny of trees' in ecological thought is motivating ecologically inappropriate efforts to increase tree cover which could jeopardise the biodiversity and functioning of tropical savanna ecosystems. However, levels of woody cover in savannas are highly variable, and woody resources are also critical in the livelihoods of environmentally dependent rural communities. In this chapter we assess whether tree planting could be beneficial to livelihoods in the miombo savanna woodlands of southern Africa by exploring links between woodland cover and provisioning service availability in six villages in central Zimbabwe. By integrating woodland survey data with local ethnobotanical knowledge we demonstrate that loss of woodland area and degradation of remnant woodland patches results in declines in per household availability of all studied services. We also show that the diversity of ethnospecies underlying services decreases with increasing land use intensity, implying decreased service resilience in deforested landscapes. We suggest that tree planting in savanna systems with high natural woody cover has potential to compensate the impacts of savanna woodland degradation and increase the resilience of woodland resource provision. However, we also qualify that tree planting should be carefully targeted at high land use intensity areas to safeguard against negative impacts on indigenous biodiversity, and that any afforestation programme will require sensitivity to local institutional tenure regimes controlling resource use from planted trees.

Author Contributions

RP developed the research questions and data collection methods with input from CMR and IG. RP collected and analysed the data and wrote the manuscript. CMR and IG provided comments and improvements on the manuscript. An edited version of this chapter is intended for submission to *World Development* in combination with Chapter 4.

3.1 Introduction

Recent years have seen increasing debate over the importance of tree cover in savanna woodland landscapes. Global imperatives to mitigate climate change and counter land degradation have motivated programmes such as the Bonn Challenge, which seeks to improve landscape multifunctionality through increased tree cover (Bonn Challenge, 2017). However, it has been argued that this emphasis on afforestation is symptomatic of a 'tyranny of trees' in ecological thought (Veldman et al., 2015a; 2015b), with poor understanding of grassy biome ecology compared to tropical forests (Parr et al., 2014) and the transference of degradation narratives developed in closed-canopy systems (Veldman, 2016) resulting in tree planting which could actually negatively impact savanna biodiversity and functioning. The miombo ecoregion, comprising the open-canopy savanna woodlands which cover much of southern Africa, is one such area which has been identified as suitable for 'forest restoration' by some authors (WRI, 2014) but as threatened by afforestation by others (Veldman et al., 2015b).

Assessing the appropriateness of tree planting in savanna systems is complicated by two factors. Firstly, 'natural' cover of woody biomass in savannas is highly variable, influenced by regional patterns of precipitation and soil and by local disturbances from fire and megaherbivores (Bucini & Hanan, 2007; Sankaran et al., 2005; Sankaran et al., 2008; Staver et al., 2011). Secondly – and little mentioned in existing 'tyranny of trees' literature – savanna resources play a critical role in the livelihoods of environmentally dependent rural communities. 100 million people are estimated to depend on miombo woodlands (Dewees et al., 2010), with environmental resources such as firewood accounting for on average 26% of rural household incomes (Ryan et al., 2016). Any analysis of 'optimal' landscape structure therefore needs to take into account not just the ecological features of the landscape, but also the ethnobotanical knowledge and resource use patterns of rural communities.

Research elucidating links between tree cover and livelihoods is particularly timely in savanna woodlands because rising demand for resources is resulting in widespread changes in savanna woodland structure (Banda et al., 2006; Ahrends et al., 2010; Jew et al., 2016). Evidence for the impacts of miombo woodland structural change on provisioning services is mixed: selectively logged construction species have been observed as most vulnerable to increased extractive pressure (Campbell et al., 1991; Vermeulen, 1996; Brown et al., 2013; Woollen et al., 2016), while firewood provision is maintained through coppice regrowth (Syampungani et al., 2017) and important fruit trees are actively protected (Campbell, 1987; Wilson, 1989; Grundy et al., 1993; McGregor, 1994), but there has been less analysis of widely-used services such as medicinal plants or biomass fertilisers. Additionally, many

existing studies rely upon free-listing or open-ended survey questions to identify useful species, which given the heterogeneity of ethnobotanical knowledge (Kristensen & Lykke, 2003) risks identifying only the most abundant or 'ideal' species in each use category. This shallow depth of ethnobotanical detail also limits the opportunity to assess changes in service quality, such as the number of conditions with local medicinal plant remedies or the availability of important famine foods. Further, afforestation and woodland cover change are landscape level processes, and yet there are few comparative assessments (although see du Toit et al., 1984; Woollen et al., 2016) of how differences in woody cover at the landscape level impact the provisioning services available to rural households.

Our objective here is to explore links between woody cover and provisioning ecosystem services on a land cover gradient in central Zimbabwe. We firstly use participatory mapping and woodland surveys to characterise village landscapes, both in terms of the spatial extent of different land cover types and of the composition of woody species within those land cover types. We then integrate ecological and ethnobotanical data sets to identify useful species and assess variation in the availability and distribution of provisioning services within and between village landscapes. We finally use this analysis to inform discussion of the appropriateness of tree planting in miombo woodland landscapes.

3.2 Methods

3.2.1 Characterising woodland cover around Wedza Mountain

Data collection for this chapter initially focused on characterising the extent and structure of woodland cover on Wedza Mountain and in the surrounding communal area. Wedza Communal Area is an appropriate location for studying links between woody cover and provisioning ecosystem service availability because both local environmental narratives and published literature (e.g. Gumbo, 1988) indicate the area to have experienced significant declines in woody cover since the mid-20th century. Rural communities in Zimbabwe have also been documented to have a high depth of ethnobotanical knowledge (e.g. Gelfand, 1985; Woittiez et al., 2013), and it is important to integrate these systems of traditional ecological knowledge into analyses of land cover change.

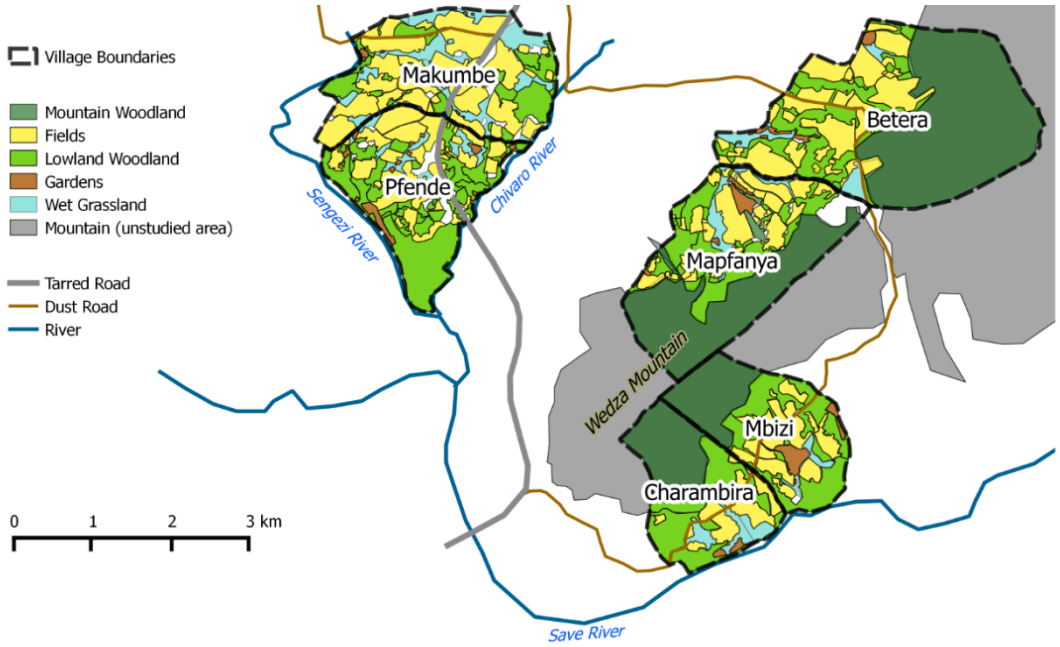

Figure 3.1 Land cover maps of the six study villages on and around Wedza Mountain, created by combining participatory mapping data with Google Earth Imagery in QGIS (QGIS, 2016).

The composition and abundance of woody plants was assessed using sample plots. Sampling strategy was informed by the land cover maps described in Chapter 2 (**Figure 3.1**). Five plot locations were randomly generated in QGIS in each village in each of the three land cover types with greatest spatial extent (mountain woodland, lowland woodland and agricultural land). Survey plots were circular with a radius of 20m. Diameter at Breast Height (DBH: measured at 1.3 m) and local vernacular (Shona) name were recorded for all stems with a DBH >= 3 cm. Local vernacular names were converted to scientific names using Mullin (2006) and Hyde et al. (2016) and identification confirmed using Coates Palgrave (2002). Samples of species which could not be identified in the field were taken to the National Herbarium of Zimbabwe in Harare.

DBH data were converted to biomass estimates using three allometric equations derived from similar dry miombo systems (Grundy, 1995; Chidumayo, 1997; Ryan et al., 2011). Stems which branched below 1.3m were treated as separate trees. Variation in species composition was analysed through clustering analysis and Shannon Index of Diversity using the Vegan package in R (Oksanen, 2013) and using the Importance Value (Kalaba et al, 2013; Jew et al., 2016; additional detail provided in Appendix 2).

3.2.2 Quantifying availability of provisioning ecosystem services

An on-going environmental income survey based on CIFOR-PEN (2008; described in Chapter 4) indicated that six of the most important provisioning services in the study area were firewood, construction materials, fibres, wild food, medicinal plants and leaf litter fertiliser. Given our emphasis on the importance of trees in landscapes we focus our analysis only on the contribution of woody species to provisioning services.

Tree uses were determined using techniques from quantitative ethnobotany (Phillips & Gentry 1993a; b) and closely followed those used by Luoga et al. (2000) in Tanzanian miombo. 87 woody ethnospecies were identified from woodland survey data, the term 'ethnospecies' referring to locally recognised 'folk' species rather than scientific species. The full list was split into eight subsets of between 9 and 12 ethnospecies, and the subsets were randomly assigned as a questionnaire module to an eighth of the 91 households involved in the environmental income survey. Four key informants identified as particularly knowledgeable during earlier household surveys answered questions about half the full ethnospecies list, and two local traditional healers discussed the full list of 87 ethnospecies.

Questions on tree uses were targeted at the member of the household identified by the family as having the best ethnobotanical knowledge. Following Kristensen and Lykke (2003), respondents were first asked if they recognised the name of the tree. If they confirmed recognition, they were then asked whether the tree was useful as firewood, construction, fibre, food, medicine or fertiliser. Trees were assigned a score of 0 (not useful), 1 (moderately useful) or 2 (very useful; following Luoga et al., 2000). Non-recognition of vernacular names was higher than anticipated, believed to be because the resident self-identifying as the most knowledgeable was often the oldest woman of the household who had migrated for marriage from a region with different Shona dialect. A follow-up visit, carrying samples of ethnospecies not recognised by name, was therefore made to each study household in order to confirm that lack of response was genuinely due to lack of familiarity with the ethnospecies rather than use of a different ethnospecies name. In total the tree use survey resulted in a mean of 14±0.3 (SE) responses per ethnospecies. Only seven ethnospecies received less than ten responses, and these were comparatively locally scarce species, accounting for only 1.4% of all measured stems. The mean of all responses for each ethnospecies was calculated to give a 'usefulness' score of between 0 and 2 for each service.

Village provisioning service availability was calculated by combining data on woodland composition with spatial extent of each land cover type in the village, using metrics appropriate to each service:

1) *Firewood* was calculated as dry matter biomass of ethnospecies scoring >= 1, indicating that the majority of respondents consider the species at least moderately useful.
2) *Construction poles* was calculated as number of stems of ethnospecies scoring >=1 for construction with DBH of >=6 cm, based on measurements of poles used by rural households in Grundy et al. (1993).
3) *Fibre* was calculated as the number of stems of ethnospecies scoring >=1 with DBH <= 6.1 cm, as fibre is preferentially removed from small stems and 90% of stems observed stripped of fibre in woodland surveys were below the 6.1 cm threshold.
4) *Food* was calculated as the number of stems of ethnospecies scoring >= 1. Quality of food availability was assessed by determining diversity of fruiting species and seasonal coverage of fruit availability (identified using fruiting dates in Coates Palgrave, 2002).
5) *Medicinal plants* were calculated as number of stems scoring >= 1. Quality of medicinal plant availability was determined by coding qualitative responses to identify the number of conditions treated and the number of potential remedies available for each type of condition. We report all locally perceived uses, making no judgement on the pharmaceutical validity of local knowledge.
6) *Leaf litter fertiliser* was calculated by estimating annual leaf production from all stems scoring >=1 using allometric equations from Chidumayo (1997). As miombo woodlands are deciduous, annual leaf production was assumed to be equal to annual litter production.

3.3 Results

3.3.1 Village Land Cover Characterisation

Relative village woodland cover ranged from 19.4% in Makumbe to 70.1% in Charambira (**Table 3.1**). Biomass was higher in mountain woodland at 44±4 t DM ha^{-1} than in lowland woodland at 15±2 t DM ha^{-1}, and was lowest in agricultural land at 5±1 t DM ha^{-1}. There was no significant difference in stem density between mountain woodland and lowland woodland (ANOVA and Tukey HSD; $p>0.05$) but there were differences in stem size distributions, with lowland woodland more heavily dominated by smaller stems. Fuller details of variation in woodland structure disaggregated by study village can be found in Appendix 2.

Table 3.1 Relative contribution of three major land cover types to total village area in six villages around Wedza Mountain, Zimbabwe. Relative cover percentages do not equal 100 as several land cover types (e.g. wet grassland) are not listed.

Village	No. of inhabited households	Total area (ha)	Relative Cover (%)			
			Mountain Woodland	Lowland Woodland	Total woodland	Agricultural land
Makumbe	57	368.4	0	19.4	19.4	54.0
Pfende	31	322.7	0	48.2	48.2	33.2
Mapfanya	38	441.3	45.6	22.7	68.3	20.3
Betera	43	635.6	53.2	16.2	68.5	25.7
Charambira	10	248.9	33.0	37.1	70.1	18.1
Mbizi	20	267.9	28.4	37.0	65.4	24.8

Clustering analysis revealed no major variations in species composition, and using the Importance Value Index to analyse pooled plot data indicated *Brachystegia spiciformis* to be the most important species in both mountain and lowland woodland. *B. boehmii, J. globiflora, Uapaca kirkiana* and *Faurea* species also scored highly in mountain woodlands, whereas *Burkea africana* and *Combretum* species were more important in lowland woodland. The most important species in agricultural land were thorn trees such as *Acacia nilotica* and *Dichrostachys cinerea*, and edible fruit trees including *Lannea discolor*, *Mangifera indica* and *Strychnos* species. There was no significant difference in Shannon index of diversity between mountain and lowland woodlands, but diversity was significantly lower in agricultural land (Tukey HSD: $P<0.001$).

3.3.2 High Use Value Ethnospecies

Firewood and construction poles were the most 'generalist' provisioning services, with 69 ethnospecies being scored as at least moderately useful in both of these categories. **Mugodo** (*Combretum* sp.), **musasa** (*B. spiciformis*) and **munondo** (*J .globiflora*) were the highest scoring firewood species, while **muunga mutema** (*A.nilotica*), **mususu** (*Terminalia sericea* and *T. stenostachya*), **mugodo** and **mupangara** (*D. cinerea*) scored highest for construction. Leaf litter fertiliser was also a generalist service, with 52 species considered useful. The highest scoring fertiliser species were **mupfuti** (*B. boehmii*), **munondo** and **mutondochuro** (*Schotia brachypetala*).

The other three studied services depended upon more specific sets of ethnospecies. 26 ethnospecies scored as useful for food, including indigenous fruit trees such as **muzhanje** (*U. kirkiana*) and **mutsubvu** (*Vitex payos*), and planted and naturalised non-indigenous species

such as guava (*Psidium guajava*) and mango (*Mangifera indica*). Fibre was derived from only three species, the miombo dominants **mupfuti, musasa** and **munondo**. 14 ethnospecies scored as useful for medicine, the highest ranking being **mufufu** (*Securidaca longipedunculata*), **muhacha** (*Parinari curatellifolia*) and **mutarara** (*Gardenia* sp.). However, it should be noted that medicinal plant knowledge was highly heterogeneous, and that all but one ethnospecies was attributed a medicinal use by at least one respondent.

The highest scoring ethnospecies overall were **mupfuti, mutsubvu, munondo, mubhuku** (*Piliostigma thonningii*) and **muhacha.** The full scored list of ethnospecies with additional qualitative information can be found in Appendix 2 (Table A2.5).

3.3.3 Within-village distribution of provisioning services

Availability of firewood, construction poles and leaf litter was consistently higher in mountain woodland than lowland woodland across all mountain-adjacent villages, while availability of medicinal plants was higher in the more disturbed lowland woodlands (**Figure 3.2**). Pooling plot data from all villages, firewood biomass was 42±4 t DM ha^{-1} in mountain woodland, 13±1 t DM ha^{-1} in lowland woodlands and 3.4±0.8 t DM ha^{-1} in agricultural land. The number of construction pole stems with DBH >= 6 cm varied from 861±68 stems ha^{-1} in mountain woodland to 382±36 stems ha^{-1} in lowland woodland and 44±11 stems ha^{-1} in agricultural land. Leaf litter production was 2.6±0.2 t DM ha^{-1} in mountain woodland, 1.3±0.1 t DM ha^{-1} in lowland woodland and 0.1±0.02 t DM ha^{-1} in agricultural land.

Stem density of the highest scoring medicinal ethnospecies ranged from 100±19 stems ha^{-1} in lowland woodland to 88±17 stems ha^{-1} in mountain woodland and 11±3 stems ha^{-1} in agricultural land. Recognising the greater variation in levels of medicinal plant knowledge amongst respondents and therefore the overall lower scores in the medicine category compared to other services, the analysis was also performed with all stems scoring >=0.5 and the same pattern observed of higher medicinal stem density in lowland woodlands.

When data were pooled from all villages, fruit tree abundance was higher in mountain woodland (395±45 stems ha^{-1}) than in lowland woodland (249±37 stems ha^{-1}), and mean number of stems suitable for fibre was 737±110 stems ha^{-1} in lowland woodland and 566±105 stems ha^{-1} in mountain woodland. However, unlike in the case of the other services the same pattern was not consistently observed across all study villages (**Figure 3.2**).

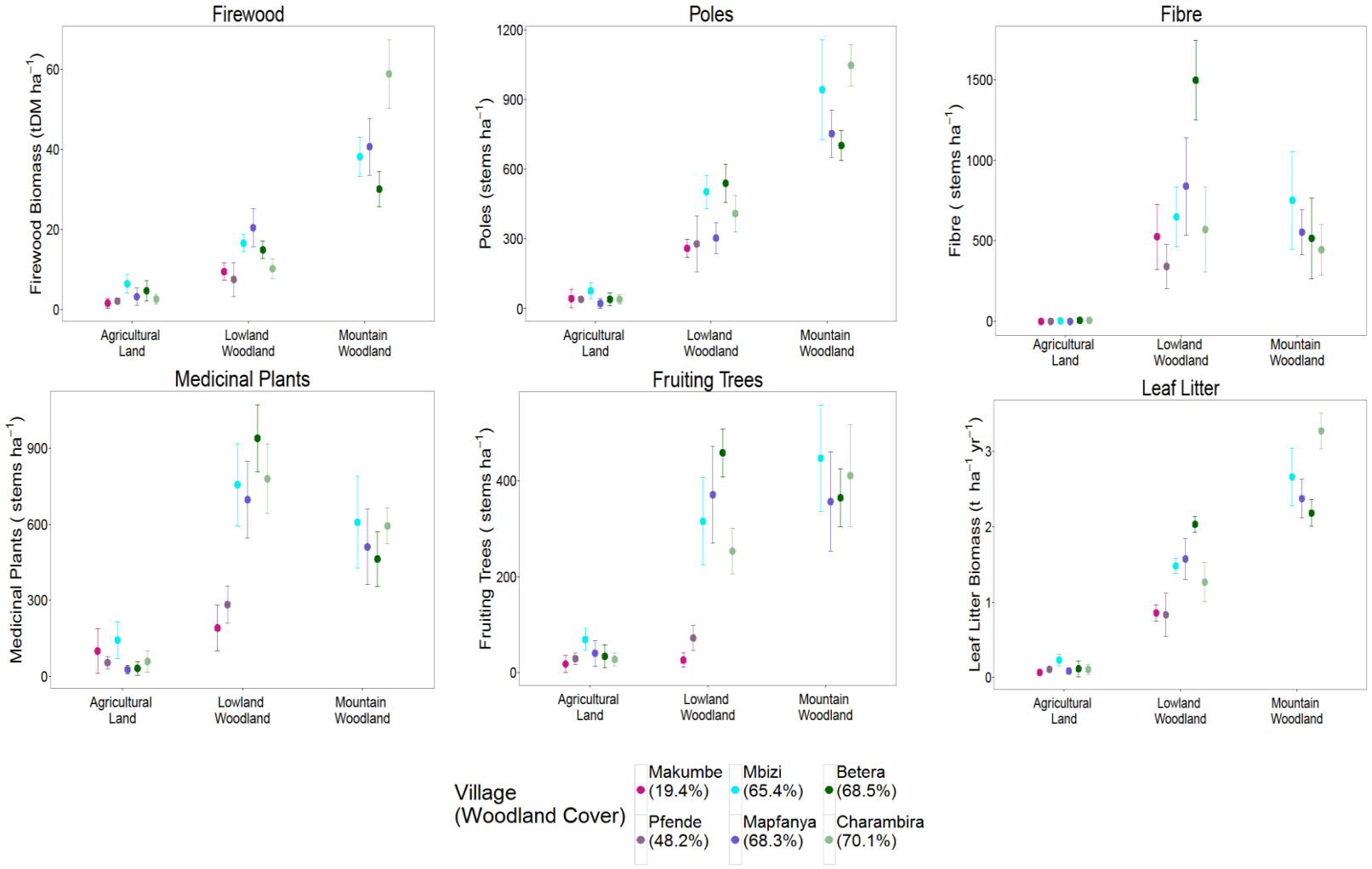

Figure 3.2 Availability of provisioning services divided by land cover type in six villages on a woodland cover gradient around Wedza Mountain, Zimbabwe. Useful species includes all species scoring >= 1 in a tree use score survey except in the case of medicinal plants, where availability includes all ethnospecies scoring >0.5 in reflection of the greater heterogeneity in medicinal plant knowledge. Error bars represent ± one standard error.

3.3.4 Between-village variation in provisioning service availability and quality

Per-hectare availability of provisioning services in all use categories was lower in Makumbe and Pfende, which have the lowest relative tree cover, and this pattern persists even when comparing only lowland woodland in the six villages (**Figure 3.2**). Declines in per-hectare availability were particularly pronounced for medicinal plant stems and fruiting stems.

All six provisioning services decreased with decreasing relative woody cover on a per household basis (**Figure 3.3**). The steepest decline in availability was in standing stock of biomass suitable for firewood, which fell from 589.1 t DM hh^{-1} in the village with highest relative tree cover to 17.4 t DM hh^{-1} in the village with lowest relative tree cover. Number of fruit tree stems per household also decreased steeply, from 5831 stems hh^{-1} in the village with highest relative tree cover to 93 stems hh^{-1} in the village with lowest relative tree cover.

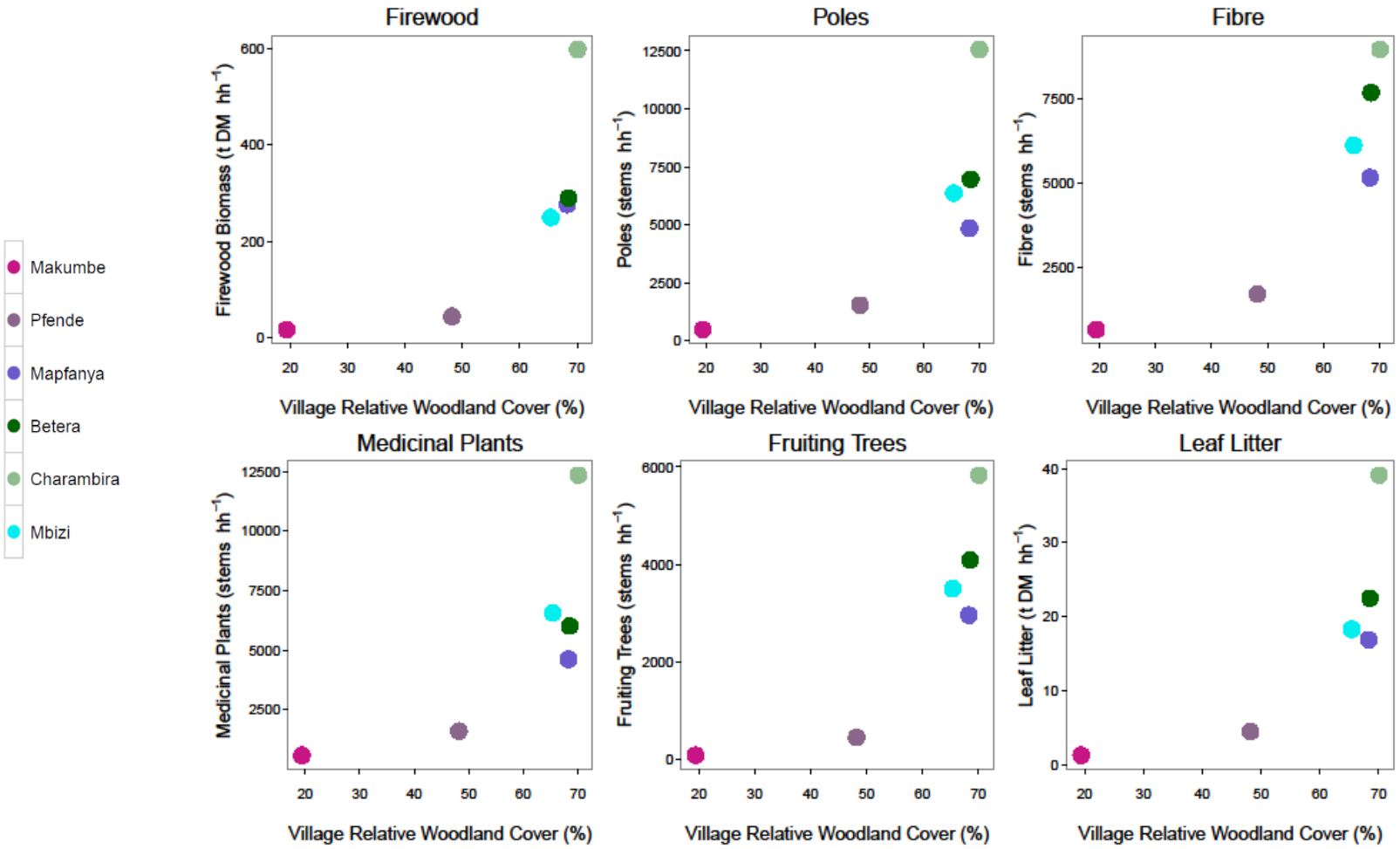

Figure 3.3 Per household availability of six provisioning ecosystem services in six villages on a woodland cover gradient around Wedza Mountain, Zimbabwe, relative to percent of village area covered by miombo woodland.

The diversity of ethnospecies underlying all studied services decreased with decreasing village woody cover. For fruiting ethnospecies, diversity was significantly lower in the two villages with lowest relative tree cover than in all mountain adjacent villages except Betera. This difference in diversity was apparent for fruiting ethnospecies throughout the year, including during the 'hungry season' of shortage before the harvest (**Figure 3.4**).

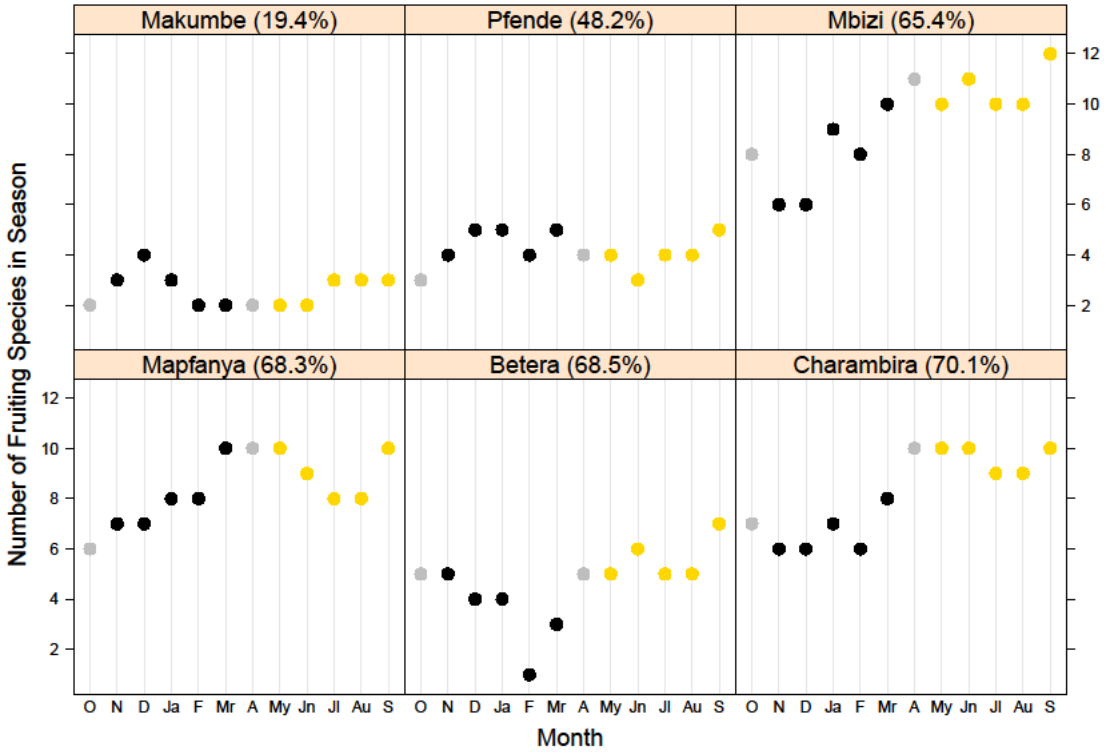

Figure 3.4 Number of woody species producing edible fruit in each month in six study villages around Wedza Mountain, Zimbabwe. Percentages in parentheses refer to relative village woodland cover. Black points indicate that the month falls within the 'hungry season', referring to the period of the year before the harvest when household food stocks from the previous harvest are running low. Hoddinott (2006) suggests that the peak of the hungry season is in February/March, but this depends on location and rainfall. In a good year, households in Wedza can avoid running out of food by harvesting early maize and green maize from riverside plots from December/January onwards, whereas in the year following a poor harvest household food stocks can run short as early as October.

Reduced diversity of ethnospecies underlying services is also pertinent to the availability of medicinal plants. Coding of qualitative data revealed that local woody ethnospecies were perceived as being useful in treating 30 types of condition. The number of conditions which could be treated by an ethnospecies found in the village area decreased from 100% in the village with highest relative woodland cover to 73% in the village with lowest woodland cover (**Figure 3.5**). For those conditions with locally available remedies, the mean number of woody ethnospecies cited as a treatment for each condition also declined with relative woody cover, from 7.9±1.4 in the village with highest woodland cover to 2.7±0.5 in the village with lowest woodland cover (**Figure 3.5**).

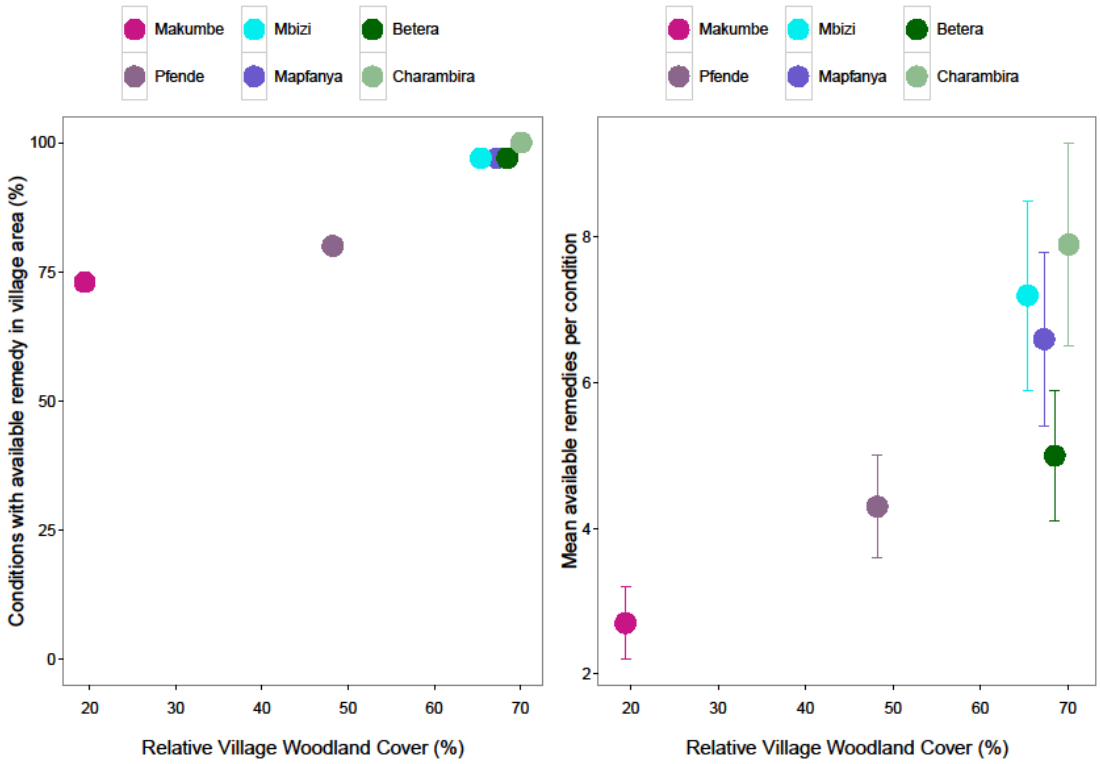

Figure 3.5 Quality of medicinal plant availability in six villages on a land cover gradient around Wedza Mountain. Left is the number of categories of condition which have a remedy from a woody medicinal ethnospecies available within the village area. Right shows the mean number of woody plant remedies available for each category of condition relative to total village woodland cover.

3.4 Discussion

Our findings indicate that loss of woody cover significantly reduces the availability of provisioning ecosystem services to rural communities in savanna woodland landscapes.

All six studied services decreased on a per household basis with declining woodland cover. While this is in part due to loss of woodland extent, the lower per hectare abundance of useful stems in woodland in villages with lower woody cover likely also reflects the higher use pressure on these remnant patches. Higher intensity of human disturbance is associated with loss of biomass in savanna woodlands (Shackleton et al., 1994; Vermeulen, 1996; Chidumayo, 2002; Kiruki et al., 2017) and with increased dominance of smaller stems (Mwase et al., 2007; Jew et al., 2016; Syampungani et al., 2016), which we suggest explains why services directly linked to biomass (firewood and leaf litter) and density of large stems (construction poles) had highest availability in the less disturbed mountain woodland, whereas services derived from smaller stems (fibre) showed less clear patterns in availability.

Our findings also raise concerns regarding the quality and resilience of services in deforested landscapes. Although the high Importance Value of species such as *Mangifera indica, Strychnos cocculoides* and *Lannea discolor* in agricultural land supports the observations of previous authors that large fruit trees are protected (Campbell, 1987; Wilson, 1989; Grundy et al., 1993; McGregor, 1994), these taboos on fruit tree cutting were insufficient to avoid an overall decline in the number of fruit trees per household with decreasing woody cover. These declines in abundance were accompanied by declines in diversity, with 7 fruiting ethnospecies recorded in the village with lowest woody cover as opposed to 19 in the village with highest woody cover. Similar declines in diversity were observed in medicinal plants, with the villages with lowest and highest woody cover having respectively 3 and 8 potential remedies occurring within the village area for each type of condition. While perhaps not directly impacting livelihoods at present, our concerns relate particularly to the loss of 'option values' implied by this loss of diversity. The environmental dependence of rural livelihoods is temporally variable: for example, wild fruits become more important to rural Zimbabwean livelihoods following poor harvests (Woittiez et al., 2013), while numerous local and global factors influence the viability of woodland product markets and their accessibility to different socioeconomic groups (Belcher & Schreckenberg, 2007; Shackleton et al., 2011; Zulu & Richardson, 2013). In light of the uncertainty attached to the impacts of interacting global change drivers such as climate change, invasive species and economic globalisation (Ryan et al., 2016), we suggest that the consequences of ecological diversity loss for the safety nets and livelihood opportunities underlying socioecological resilience require further scrutiny.

A potential critique of our analysis is our focus on resources derived only from woody plants. Four of the six studied services (firewood, construction, fibre and leaf litter) can only be obtained from woody species. In terms of food, we argue that fruit trees have particular local importance: 99% of households reported having eaten wild fruits in the household survey as opposed to 69% reporting collecting wild vegetables, and while 24 fruit tree species were represented in the household survey, almost 80% of wild vegetable consumption was comprised of the three ethnospecies **nyevhe** (*Cleome gynandra*), **mowa** (*Amaranthus* sp.) and **derere** (*Corchorus* sp.), all of which are generally collected on the margins of household maize fields. In the case of medicinal plants, however, a broad range of herbaceous plants including *Solanum incanum, Kalanchoe lanceolate* and *Mondia whytei* were observed to be widely collected in the study area. While our results provide initial insight, it would thus be valuable to extend the analysis of medicinal plants to a wider range of growth forms.

A second potential critique is that abundance of useful species is not automatically a predictor of consumption, with use of environmental resources mediated by a wide range of access restrictions, institutions and cultural norms (Rochleau & Edmunds, 1997; Ribot & Peluso, 2003; Luoga et al., 2005; Zulu, 2008). Recognising this as a limitation of our analysis, we explore spatial and temporal heterogeneity in resource use and socioeconomic influences on environmental dependence in Chapter 4 of this thesis.

We earlier detailed the two prevailing schools of thought on tree planting in savannas: the forest restoration perspective, which suggests tree planting to be critical in enhancing landscape multifunctionality, and the 'tyranny of trees' critique, which argues that tree planting is driven by a fundamental misunderstanding of grassy biome ecology (Veldman et al., 2015a; b). Our analysis leads us to adopt an intermediate position between these two perspectives. We concur that transference of degradation narratives from tropical forests to savanna systems is unwise and unhelpful, and that greater research effort is required into tropical grassy systems, but we also argue that any discussion of functioning or ecosystem services in complex agrarian savanna landscapes is incomplete if focus falls on biodiversity and carbon to the exclusion of rural livelihoods. From our comparative analysis of six village landscapes we draw the following three conclusions: (1) that woody species are a key component of detailed systems of local ethnobotanical knowledge and play a critical role in rural livelihoods in Zimbabwe; (2) that human disturbance is resulting in both deforestation and degradation of miombo savanna woodlands and resulting in levels of woody cover below the extent which would prevail in lower use intensity systems; and (3) that this deforestation and degradation results in declines in provisioning service availability and may thus reduce

the wellbeing and resilience of rural households. From these conclusions we infer that tree planting has potential to buffer provisioning service declines in open canopy woodlands.

However, we qualify this inference with a number of ecological and social caveats. Firstly, we recognise that conclusions drawn from miombo woodland landscapes may not be appropriate at the more grass-dominated end of the savanna spectrum, just as we would hesitate to transfer conclusions drawn from communities with livelihoods based on settled agriculture to those savanna areas where pastoralism is the prevailing livelihood strategy. This leads to our second caveat, that the appropriateness of tree planting depends upon being selective in terms of location and species, targeting tree planting at high use intensity areas experiencing woodland degradation and choosing species 'optimal' relative to both ecological function (e.g. carbon storage) and to local ethnobotanical values. Thirdly, afforestation projects in agrarian landscapes would require sensitivity to local tenure regimes. While indigenous woodlands are considered common property in Zimbabwe, planted trees are privately owned, and access to resources from these trees is dependent on social and kin networks. Given the widely discussed issues of elite capture in the context of REDD+ (Reducing Emissions from Deforestation and Degradation; Sandbrook et al., 2010; Larson et al., 2013), care will be needed that afforestation does not transform woodlands from ecologically degraded but common property to ecologically valuable but privatised resources.

3.5 Conclusions

Woodland cover loss and degradation can severely reduce the availability of provisioning ecosystem services to environmentally dependent rural households in southern Africa. When taking the livelihood value of woodlands into consideration, tree planting has the potential to improve landscape multifunctionality by increasing provisioning service availability, and could also enhance provisioning service resilience by increasing the diversity of species underlying services. However, such afforestation programmes require careful location-specific planning sensitive to existing vegetation patterns and to local ethnobotanical knowledge and tree tenure regimes.

3.6 Chapter 3 References

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4. Woodland cover, environmental income and livelihood diversity around Wedza Mountain, Zimbabwe

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Abstract

Increasing recognition of the importance of 'wild' environmental resources to rural household incomes in developing countries has raised concerns that vegetation cover change will reduce income diversification opportunities, particularly for poorer households. However, few studies have linked environmental income to the ecological characteristics of source land covers, and there have also been few environmental income studies considering the broader socio-economic processes co-producing change in land cover and livelihoods. In this chapter we explore links between woodland cover and livelihoods using household income data from 91 households in 6 villages on the woodland cover gradient around Wedza Mountain, Zimbabwe. Income from organic environmental resources accounted for on average 31% of total household income, with the relative contribution of environmental resources highest in asset-poor households. Tree-dominated land cover types accounted for 67% of reported environmental income, but much of this income was derived from lower biomass grazing areas rather than high biomass mountain woodland. There was no apparent link between village woodland cover, livelihood diversity, or intra-community income inequality. We conclude that rural livelihoods in Wedza have to date been resilient even to relatively high losses of woodland cover, because many resources can be derived from remnant woodland and non-woodland land, and because woodland loss has historically been associated with increased availability of alternative livelihood diversification opportunities.

Author Contributions

RP developed the research questions and data collection methods with input from CMR and IG. RP and NS collected the data. RP analysed the data and wrote the manuscript, with comments and improvements from CMR and DvdH. An edited version of this paper is intended for submission to *World Development* in combination with Chapter 3.

4.1 Introduction

Over the last two decades there has been growing recognition of the contribution made by non-cultivated environmental resources to the livelihood strategies of rural households in developing countries (Byron & Arnold, 1999; Sunderlin et al., 2005; Wahlen, 2017). Over 2.7 billion people worldwide are estimated to depend on woodfuel for the majority of their energy needs (Bonjour et al., 2013), with other important wild-sourced resources including construction materials, livestock feed and medicinal plants (Cavendish, 2000; Angelsen et al., 2014). The consumption of wild foods also enhances the diversity of rural diets in developing countries with high levels of food insecurity (Grivetti & Ogle, 2000; Golden et al., 2011; Ickowitz et al., 2014; Powell et al., 2015; Rowland et al., 2017). With widespread changes occurring in the spatial and ecological structure of vegetation cover in developing countries (Hansen et al., 2013), it is important to improve understanding of how land cover change will impact the provisioning ecosystem services relied upon by rural households.

Calculation of 'environmental income' has gained prominence as a method of quantifying the importance of environmental resources in rural livelihood strategies. First popularised by Cavendish (2000), who found non-cultivated environmental resources to account for 37% of household income in rural Zimbabwe, this approach has since been applied in numerous case studies in Africa (Ambrose-Oji, 2003; Fisher, 2004; Mamo et al., 2007; Babulo et al., 2008; Kamanga et al., 2009; Heubach et al., 2011; Pouliot et al., 2012; Kalaba et al., 2013; Dokken & Angelsen, 2015), Asia (McElwee, 2008; Rayamajhi et al., 2012; Hogarth et al., 2013; Chhetri et al., 2015; Jiao et al., 2015; Abdullah et al., 2016) and Central/South America (Uberhuaga et al., 2012; Cordova et al., 2013; Zenteno et al., 2013; Cotta, 2015). A meta-analysis of case studies found that forest environmental income accounted for on average 22% of household income (Vedeld et al., 2007), while a more recent global analysis found a mean relative contribution of 28% (Angelsen et al., 2014).

Environmental resources are also important for enhancing the diversity of income sources available to rural households. Diversified livelihoods are the norm in rural areas of developing countries (Ellis, 2000), with diversification of income sources representing a pre-emptive adaptive strategy which aids income and consumption smoothing in regions characterised by high uncertainty and frequent hazard exposures (Dercon, 2002; Delacote, 2007; Debela et al., 2012). Livelihood diversity has often been observed to be higher among wealthier households (Dercon & Krishnan, 1996; Abdulai & Crole-Rees, 2001; Block & Webb, 2001), reflecting their greater command of the capitals and powers required to access more varied livelihood options (Scoones, 1998; Bebbington, 1999; Ribot & Peluso, 2003). In

contrast, dependence on environmental resources has often been observed to be higher amongst poorer households (Cavendish, 2000; Fisher, 2004; Mamo et al., 2007; although see Ambrose-Oji, 2003), as the lack of input costs other than own labour makes environmental resource collection a diversification opportunity available even for very poor households (Tesfaye et al., 2011). The higher dependence of poorer households on environmental resources also means that inclusion of environmental income has been found to reduce estimated intra-community income inequality (Kamanga et al., 2009; Heubach et al., 2011; Kalaba et al., 2013). It is therefore possible that reduced availability of provisioning ecosystem services due to land use change could reduce livelihood diversity, particularly for poorer households, and thus increase intra-community income inequality.

However, understanding of links between land use change, provisioning ecosystem service availability and household income portfolios is currently restricted by two main factors. Firstly, much environmental income literature is currently focused on forest ecosystems, either explicitly considering only forest-derived resources (e.g. Rowland et al., 2017), or conflating 'forest income' with 'environmental income' and thus implicitly assuming all environmental resources to be forest derived (e.g. Jumbe et al., 2008; Kalaba et al., 2013). This forest focus arises from deeply entrenched narratives on the respective values of forest vs. non-forest land covers in western environmental philosophy (reviewed in Dove, 2004) and aligns conveniently with landscape management objectives centred on carbon and biodiversity conservation (although see Veldman et al., 2015a), but results in research approaches poorly equipped to understand patterns of resource collection in complex agriculture-forest matrices (Dawson & Martin, 2015; Zähringer et al., 2017). The problem of assuming the primacy of forest is well illustrated by case studies of wild food collection, which demonstrate that many foodstuffs are derived from agricultural or other non-forest land cover types (McGregor, 1994; High & Shackleton, 2000; Powell et al., 2015; Broegaard et al., 2017). Studies including a broader range of environmental services and values have also highlighted the importance of non-forest land covers in livelihoods (e.g. Ambrose-Oji, 2003; Sinare et al., 2016). Dawson and Martin (2015) found in a study in Rwanda that almost all native forest provisioning services could be substituted by species found in other land cover types, and Pouliot et al. (2012) suggest that greater reliance on non-forest land in Ghana and Burkina Faso was due to the stricter institutional barriers controlling use of 'intact' forest resources. Lack of understanding of resource collection patterns can result in serious misjudgement of management interventions; McElwee (2009), for example, documented how privatisation and reforestation of perceived 'degraded' land in Vietnam has resulted in loss of access to provisioning ecosystem services among poorer households. Inferring the livelihood impacts

of land cover change, and planning interventions which will alter woody cover, therefore requires more detailed knowledge of which land cover types underpin environmental income provision.

A second issue in current literature is that environmental income has rarely been studied in the context of the broader social processes co-producing changes in land cover and in the livelihood opportunities available to rural households. Many studies, most recently Hermanns-Neumann et al. (2016), have documented the proximate roles of drivers such as population density in reducing woody cover and provisioning ecosystem service availability, but it has been argued that an overt focus on the local obscures the fact that population growth, migration and forest use are all themselves products of larger-scale socioeconomic trends (Lambin et al., 2001; Geist & Lambin, 2002; Turner et al., 2007; McCusker & Carr, 2006). The outcomes of changes in these large scale economic and political environments for local scale land cover and livelihoods are mediated by local socioecological and institutional contexts (Leach & Fairhead, 2000; Vongvisouk et al., 2014), and are also not homogeneous across all social units within a locality; resources have different values to different actors (Dawson & Martin, 2015), and the ability of households to benefit from changing livelihood opportunities is dictated by household capitals relative to local behavioural norms (Barrett et al., 2001; McCusker & Carr, 2006; McElwee, 2009). Whether reduced provisioning service availability impacts income diversity is therefore contingent both on household characteristics and on the detail of the larger-scale drivers resulting in land cover change.

The question of links between land cover change and livelihoods is particularly relevant in the context of the miombo woodlands of southern Africa. This is in part due to the widely recognised importance of environmental resources to rural livelihoods in the miombo ecoregion (Chidumayo & Gumbo, 2010; Dewees et al., 2010), with a recent review finding that on average 26% of household income is derived from environmental resources (Ryan et al., 2016). Further motivation for study is derived from the widespread deforestation and woodland degradation currently occurring across the ecoregion (McNicol et al., 2017), with local and global change drivers including woodfuel harvesting, clearance for agriculture, climate change, and socio-political changes in tenure and governance (Ryan et al., 2014; Ryan et al., 2016). Additionally, while tree planting programmes have long been a feature in southern African environmental management (see du Toit et al., 1984; McGregor, 1991; Jagger & Luckert, 2008 for discussion of rural afforestation in Zimbabwe), concerns have recently been raised that poor understanding of tropical savanna ecology (especially compared to tropical forests) is motivating inappropriate afforestation projects which will degrade the values and services available in savanna landscapes (Veldman et al., 2015a; b). For all the

reasons given above it is important to improve understanding of patterns of resource collection in miombo landscapes, and of whether variation in tree cover is associated with variation in livelihood strategies.

In Chapter 3 it was demonstrated that lower woodland extent and biomass is associated with substantially lower per-household availability of key provisioning ecosystem services around Wedza Mountain. However, availability of resources provides only a partial story, with resource use also determined by numerous formal and informal institutional constraints and behavioural norms (Leach et al., 1999; Ribot & Peluso, 2003). The objective of this chapter is thus to explore whether lower availability of tree-derived provisioning ecosystem services is associated with changes in household income portfolios. We structure this analysis by addressing three questions:

- How important are environmental resources to rural household incomes?
- Which land cover types are important in the provision of environmental income?
- Is variation in village-level woodland cover associated with variation in livelihood diversity or intra-community income inequality?

4.2 Conceptual Background: Key definitions and livelihoods approaches

Environmental income is most often defined as all income from non-cultivated wild resources, thus including non-cultivated resources from agricultural land such as edible weedy plants, but excluding incomes such as those from plantation forestry (Sjaastad et al., 2005). One issue with this prevalent definition is that rural households in Zimbabwe also utilise numerous inorganic environmental resources such as sands and gravels for building, soils for plastering and painting, and precious metals such as gold (Cavendish, 2000). We therefore account for all natural resources including minerals under environmental income, but disaggregate the 'organic' and 'inorganic' components. We avoid all mention of 'forest income' and 'non-forest income' as being too vague and instead base our analysis on a more detailed local land cover typology.

Household income in this study refers to total income, the definition used in the majority of environmental income studies (see e.g. Cavendish, 2000; Mamo et al., 2007; Kamanga et al., 2009; Heubach et al., 2011; Angelsen et al., 2014). 'Total income' includes all cash and subsistence income from agricultural products, livestock, employment, transfers and environmental resources, minus the value of inputs such as fertiliser and feed, and is seen

as a more appropriate metric than cash income because a large proportion of income in southern African communities is derived from own-produced or own-collected resources (Cavendish, 2000). Also in common with previous studies, the value of own labour is not deducted from net income, as it is not possible to establish appropriate shadow prices for labour in areas without functioning labour markets (Campbell & Luckert, 2002).

The value of expressing income from environmental resources in monetary terms is that it permits direct comparison between environmental income and other elements of household livelihood strategies. A flaw in this method is that household income is highly variable in rural Africa, with income fluctuations meaning that many households experience periods of transitory poverty (Baulch & Hoddinott, 2000). This will also be reflected in variations in the ***environmental dependence*** of rural households, commonly defined as the proportion of net annual household income derived from environmental resources (Mamo et al., 2007; Kamanga et al., 2009). In the absence of long-term panel data, we believe that a single year study of environmental income still represents the best method of analysing linkages between landscape structure and livelihood strategies, but also address the implications of a single year timeframe for our findings in the discussion.

Dawson and Martin (2015) argue for the importance of disaggregating analyses of environmental resource use and land cover change to individual or household scales in order to assess differential value perceptions and therefore differential vulnerabilities. To address how household characteristics influence livelihood strategies we draw mainly upon the Sustainable Livelihoods Framework (SLF; 1998). The SLF visualises livelihood strategies as being shaped by household and individual capital holdings, including natural capitals such as woodland, but suggests that the ability to translate capitals into actions or benefits is determined by broader socio-economic and institutional contexts. Ribot and Peluso (2003) extend this theory by arguing that resource access is mediated by the 'bundle of powers' afforded to a social unit by its position within multiple overlapping networks of power. We therefore consider differences in capitals and powers when interpreting observed variation in patterns of environmental dependence and environmental resource use.

4.3 Methods

4.3.1 Case Study Landscape: Woodland cover and environmental resource use around Wedza Mountain

This analysis was carried out using household data from the six study villages in Wedza Communal Area. As demonstrated in Chapter 3, the six villages lie on a woodland cover

gradient, with relative woodland cover varying from 19% in Makumbe to 70% in Charambira. Low woodland cover is associated with concomitant declines in availability of key provisioning services underpinned by woody species. However, villages do not differ solely in terms of woody cover. There is also variation in market access, with villages adjacent to the tarred road having comparatively easy access to Garaba Township and Wedza Growth Point, whereas villages on the eastern side of the mountain are more remote from local markets. Villages additionally vary in terms of access to wetland resources, with Mapfanya and Betera containing only small streams and wells as opposed to significant water courses, and in terms of mineral resources, with Mapfanya and Mbizi the only villages home to residents with claims to gold mining rights on Wedza Mountain. While all lying within 6km of the Gandamasungo peak of the Wedza Mountain range, the villages thus represent a variety of socioecological contexts.

Rural Zimbabwe is an appropriate location for the study of links between land cover and environmental income due to the high environmental dependence of rural households. Numerous studies have documented the importance of wild-sourced construction materials, fuels and wild foods in Zimbabwean rural household economics (McGregor, 1991; 1994; Grundy et al., 1993; Campbell et al., 1997; Cavendish, 2000; among others). The importance of environmental resource use in Wedza District is also well-established, with Kinsey et al. (1998; working in Sengezi resettlement area adjacent to the location of the present study) and Woittiez et al. (2013; working in Dendenyore and Ushe wards of Wedza District) both chronicling the importance of environmental resources for subsistence consumption and seasonal gap-filling.

The primary data collection instrument used in this study was a disaggregated household income questionnaire survey based on CIFOR-PEN (2008; Appendix 3) and carried out three times between June 2014 and November 2015. Initial contextual data collection began in May 2014, when two participatory mapping groups and four walked transects were carried out in each village to develop a land cover typology (**Table 4.1**) which was combined with Google Earth satellite imagery in QGIS (QGIS, 2016) to create village land cover maps. Participatory mapping groups were also used to establish the number and location of village households. Village maps were subsequently checked for accuracy with focus groups of four purposively sampled key informants in each village. These focus groups were also used to establish the gender and name of the household head in each study household, the number of adults and children in the household, and whether householders were permanent residents in the study village (a number of households live in the city and keep the rural home only as a contingency).

Table 4.1 Land cover typology of Wedza Mountain and surrounding landscape, created based on participatory mapping and transect walks with local respondents. Note that this typology is more detailed than that provided in Chapter 2: while it was not logistically possible to establish vegetation survey plots or separate NPP estimates for all the land cover types listed here, it was possible to more precisely determine the source locations of environmental resources.

Land Cover Category	Definition
Mountain woodland	Comparatively undisturbed high biomass miombo woodland found on Wedza Mountain
Lowland woodland	More disturbed lowland woodlands, found in village grazing areas and on riverbanks/kopjes. Also long-term abandoned fields with significant tree regrowth.
Kopjes/Termitaria	Small rocky hills (kopjes or **zvikomo**) and large termitaria which often retain vegetation cover even when surrounding areas have been deforested.
Riparian Woodland	Remnant woodland on river and streambanks.
Wet Grasslands	Seasonally dry (locally termed **bani**) and non-seasonal (**dofonya**) wetlands
Streams and rivers	
Fields and gardens	Active/recently fallow fields and vegetable gardens
Residual Area	Areas without vegetation cover, such as roads, household yards and borrow pits left following road construction.

100 households were initially selected for inclusion in the study using stratified random sampling. Household lists were stratified by household size (1-2 residents, 3-5 residents and 6+ residents) and gender of household head (male-headed, headed by widow or divorcee, or *de facto* female headed with husband working outside the study area for more than six months of the year: categories follow Cavendish, 2000). Households were randomly selected from the stratified lists in proportion to village size and to the representation of each group within the village. Following discussion of household samples with village heads, a further 4 households were purposively added to represent livelihood strategies or wealth groups which were perceived as missing within the random sample. Survey attrition over the rounds of the questionnaire was higher than expected from previous studies, suggested by local residents to reflect high population mobility due to Zimbabwe's economic situation, with the initial 104 households reduced to a final sample of 91 households across the six villages. The extent to which survey attrition may have influenced the findings of this study is considered in the discussion. Village size ranged from 10 to 53 permanently inhabited households (mean of 33 households) and final sampling intensity ranged from 37 to 80% (mean of 52%).

The working definition of 'household' used in this study was of a group of people living under the same roof and pooling resources, following CIFOR-PEN (2007). In the majority of cases such units were easy to identify, the only exception being the four polygamous unions in the random sample. While CIFOR-PEN (2007) separates polygamous unions into multiple households if the different wives maintain separate houses, in the present case it was decided to consider polygamous unions as single households. In two cases, the two wives had adjacent kitchen huts but commonly chose to share the same kitchen, while in the other two cases there was greater distance between the houses, but in all four polygamous households agricultural land and vegetable gardens were shared and there were high levels of income and labour pooling. We therefore argue that considering elements of the polygamous union in isolation would have misrepresented the capitals available to each sub-household and thus would have limited understanding of the factors influencing livelihood decision making.

Rounds of the questionnaire survey were carried out in June/July 2014, February/March 2015 and October/November 2015 and recorded income from environmental resources (both organic and inorganic), agriculture (field crops, garden crops, livestock and livestock products), employment (skilled employment, unskilled employment and piecework) and transfers (remittances, pensions, rental incomes and government support). Recall periods were six months for 'lumpy' incomes such as livestock, remittances and field crops, and one month for smaller items such as garden vegetables and environmental income. Reported incomes were combined to represent a full year from September/October 2014 to September/October 2015. Fuller details of all income categories and recall periods are provided in Appendix 3.

Appointments were made with households in advance, and the survey carried out with the available adult most knowledgeable about household incomes. In the majority of cases this was the oldest woman in the household, as men are more likely to be engaged with off-farm work. Surveys lasted between 45 minutes and 2 hours. If the initial respondent was unsure of income in any category then a follow-up appointment was made to speak to another member of the household. Respondents were thanked for their time with a small gift of food or vegetable seeds, value totalling US$1.50. Providing gifts of seeds necessarily followed a precedent set by researchers who had previously worked in the study area, but packets were small enough not to significantly skew income from garden crops.

Valuation methods for resources were based on Cavendish (2000), Cavendish (2002), Heubach et al. (2011) and Wunder et al. (2011). Where possible, the prices used were 'revealed' by transactions reported during the household survey or observed while resident in the study area. For those resources without active local markets, respondents were asked to

estimate willingness to pay (WTP) for the resource, or in the case of materials such as gravel their willingness to pay for the labour involved in resource collection (following Heubach et al., 2011). Respondents gave WTP either in cash terms, or using a commonly bartered substitute with a well-recognised local price such as buckets of maize or bars of soap. In many cases WTP estimates clustered around a mean point, suggesting a consistent locally perceived monetary value despite no active market (Cavendish, 2002). Where WTP estimates did not coalesce in this way, prices were imputed from similar resources: for example, widely differing estimates were given for the value of fruits such as **matufu** (*Vangueriopsis lanciflora*) and **matohwe** (*Azanza garckeana*), and so prices was instead inferred from locally traded wild fruits such as guava (*Psidium guajava*), **mazhanje** (*Uapaca kirkiana*) and **tsubvu** (*Vitex payos*).

Households were asked to describe where they had obtained all resources. All household surveys were carried out by N.Shayanewako, a permanent resident of Makumbe village, and R. Pritchard, who lived with N.Shayanewako throughout the data collection period. This meant that both researchers involved in data collection had a good understanding of village layout, and any unfamiliar locations could be triangulated relative to well-known village landmarks. Locations within villages were then attributed to land cover types using village land cover maps. The only resources which could not be reliably attributed to a source land cover type were those collected by household members other than the main respondent when travelling between the village and another location, particularly the children of the household collecting wild fruits when herding cattle or going to school.

In order to understand how household capitals influence livelihood strategies, data were also collected during the household survey on the gender and age of all household residents, as well as on household assets and structures identified as important during twelve key informant interviews discussing local wealth indicators. Resource demands are not equal for all household residents, and so we follow Cavendish (2000) in expressing all income per adult equivalent unit (aeu), where the first adult is assigned a score of 1, all additional household residents of 15 and over a score of 0.5 and all residents of 14 and under a score of 0.3 (the modified OECD equivalence scale first suggested by Hargenaars et al., 1994). Household members were counted as residents if they lived in the household for more than 6 months of the year. The dependency ratio was also calculated for each household, meaning the number of residents in the household =<14 and =>66 years old relative to adults of working age. Households were further assigned a wealth index score using the wealth index detailed in Chapter 2.

4.3.2 Data Analysis

In order to assess links between wealth and environmental dependence, households were grouped into terciles across the full sample of 91 households and within each village. Nielsen et al. (2012) and Dokken and Angelsen (2015) point out that grouping households by income can reveal very different patterns to when households are grouped by asset wealth, the latter being indicative of longer term prosperity and generally having lower inter-annual variation. We therefore compare results when constructing terciles by annual income, and when terciles are constructed using household wealth index scores.

Relationships between household income/livelihood diversification and household socioeconomic characteristics were analysed using multiple regression. Significant outliers were identified by calculating Cook's Distance, resulting in exclusion of between one and three households from each regression analysis. Following Ellis (2000) and Tesfaye et al. (2011), the diversity of income sources and of environmental income sources was calculated using the inverse Simpson index of diversity, also termed the inverse Herfindahl-Hirschman index. Following numerous studies of income inequality (e.g. Kamanga et al., 2009; Kalaba et al., 2013), the Gini coefficient was used to assess income inequality with and without the inclusion of environmental income. All analyses were carried out in Excel and R (R Core Team, 2014).

Woodland cover and provisioning ecosystem service availability are embodied in the use of village as an independent variable in regression models. However, as discussed by Vedeld et al. (2012), 'village location' is a compound nominal variable also encompassing variations in market, ago-ecological, climatic and institutional conditions. In the discussion we consider how these other facets of village location may mediate the relationship between woodland cover and livelihoods.

4.4 Results

4.4.1 Household Characteristics

There were few apparent differences in the mean values of socioeconomic characteristics between household populations in the six study villages. The mean age of household heads within the sample was 58±3 (± indicates one standard error throughout this results section). Household head mean age was lowest in Mapfanya (48±4) and Mbizi (48±5) and highest in Makumbe (62±3), but these differences in age were not significant between villages (ANOVA and Tukey HSD: $p>0.05$). Mean number of individuals per household across the full 91

households was 4.7±0.3, equating to 2.4±0.1 adult equivalent units (aeu), and mean dependency ratio was 1.4±0.1. 53 households (58% of the whole sample) were headed by men, 31 (34%) headed by widowed or divorced women, and 7 (8%) by women with husbands working away from the rural areas for more than 6 months of the year.

Of the 13 households which did not complete the three rounds of the questionnaire, 4 were from Makumbe, 4 from Pfende, 3 from Mapfanya, 1 from Betera and 1 from Charambira. The mean age of households in this group was 51±8, so only slightly different to the mean of the total sample, but the group had higher representation of older household heads than would be anticipated from the total sample, with five household heads over 76 years of age either passing away or becoming too unwell to continue in the survey. Also overrepresented in the 13 households were households headed by a woman with a husband working away from home: these represented 10% of the initial 104 households, but accounted for a third of the households not completing all three survey rounds. The mean household size was 3.4±0.6, smaller than in the total sample, reflecting that several non-completing respondents were older widowed residents who lived alone or with just one grandchild. The extent to which the characteristics of the households not completing the questionnaire may have influenced our findings is considered in the discussion.

4.4.2 Absolute and Relative Environmental Income

Income from organic environmental resources contributed the greatest proportion of household income portfolios, accounting for on average 31±2% of total net income. Garden crops, livestock and remittances were also important, each accounting for on average over 10% of total income. Field crop income accounted for on average only 3.1±0.9% of total income.

When comparing mean income portfolios for the six study villages, organic environmental income was the highest ranked income source in all villages (**Table 4.2; Table 4.3**). Remittances and garden crops also ranked highly in all villages, and livestock made a high relative contribution in all villages except Makumbe. Conversely, skilled employment and pensions were highly ranked contributors only in Makumbe. Inorganic environmental income contributed a high proportion of total income portfolios in Mapfanya and Mbizi, the two villages with access claims to gold mining concessions.

When wealth terciles were defined using annual income, absolute income from environmental resources was higher in the high income and middle income households, but dependence on organic environmental income was higher in middle and low income

households (**Figure 4.1**). The high income tercile also had markedly higher absolute income from pensions, remittances, business and skilled labour. Low income households derived a higher average proportion of income from remittances, while middle income households derived a higher average proportion from gardening.

In contrast, when wealth terciles were defined using wealth index scores, both absolute organic environmental income and the relative contribution of environmental income were highest for the poorest households. Income from inorganic environmental resources was also higher amongst the poorest households. Absolute income from livestock was highest in the intermediate wealth group, while dependence upon remittances was highest in the high wealth group. Businesses, skilled labour and rent still generated much higher income for the wealthiest tercile.

Table 4.2 Mean absolute income (US$ aeu^{-1} yr^{-1}) from all income source categories around Wedza Mountain, for the full sample of 91 households and disaggregated by study village. ± represents one standard error.

	Makumbe (n=22)	***Makumbe (excluding outlier)****	**Pfende (n=14)**	**Mbizi (n=13)**	***Mbizi (excluding outlier)****	**Mapfanya (n=14)**	**Betera (n=20)**	**Charambira (n=8)**	**All (n=91)**
Village Woodland Cover	19.4%	*19.4%*	48.2%	65.4%	*65.4%*	68.3%	68.5%	70.1%	
Environmental									
Environmental resources (organic)	289±52	*294±54*	333±74	735±248	*497±74*	276±48	380±49	358±48	384±43
Environmental resources (inorganic)	20±6	*21±6*	24±7	239±103	*248±112*	135±60	27±7	25±12	72±19
Agriculture and Livestock									
Field Crops	72±21	*69±23*	38±24	9±44	*8±48*	62±42	58±11	11±26	48±11
Garden Crops	120±23	*123±25*	127±46	169±79	*200±79*	178±89	162±53	111±42	146±23
Livestock and livestock products	86±36	*70±34*	237±127	306±186	*298±202*	209±39	98±25	271±123	178±37
Business and Employment									
Business	447±424	*23±18*	15±6	79±62	*85±66*	64±51	7±4	0.4±0.4	133±103
Skilled Employment	213±156	*223±163*	80±58	51±39	*56±42*	0.5±0.5	114±81	0	96.±43
Unskilled Employment	70±46	*74±48*	39±26	14±11	*12±12*	22±12	55±38	17±16	42±14
Piecework	5±3	*5±3*	22±8	16±6	*15±6*	8±3.	6±5	97±51	18±5
Transfers									
Remittances	362±362	*263±50*	146±43	258±84	*277±88*	106±30	205±50	251±77	230±33
Pensions	94±46	*99±48*	30±30	0	*0*	0.8±0.8	25±25	0	33±14
Rental Income	197±113	*172±116*	24±17	46±46	*50±50*	95±95	172±121	0	110±42
Government/NGO	18±5	*19±5*	38±17	39±8	*38±9*	10±4	6±2	36±6	22±3
Total	**1995±582**	**1454±229**	**1151±226**	**1962±336**	**1784±310**	**1166±171**	**1315±161**	**1178±143**	**1511±161**

*One household in Makumbe has a highly specialised business focused livelihood strategy which results in earnings seven times those of the next wealthiest household, while one household in Mbizi has environmental income three times that of any other household. Inclusion of these households within villages significantly skews income estimates in the relevant categories, and so results for these villages are presented both with and without outlier households.

Table 4.3 Mean relative income contribution (% of total net household income) from all income source categories around Wedza Mountain, for the full sample of 91 households and disaggregated by study village. ± represents one standard error.

	Makumbe (n=22)	***Makumbe (excluding outlier)***	**Pfende (n=14)**	**Mbizi (n=13)**	***Mbizi (excluding outlier)***	**Mapfanya (n=14)**	**Betera (n=20)**	**Charambira (n=8)**	**All (n=91)**
Village Woody Cover	19.4%	*19.4%*	48.2%	65.4%	*65.4%*	68.3%	68.5%	70.1%	
Environmental									
Environmental resources (organic)	25±4	*26±4*	33±5	38±7	*34±6*	28±5	34±4	32±4	31±2
Environmental resources (inorganic)	2.2±0.7	*2.3±0.8*	2.8±0.7	15±6	*16±7*	10±4	2.8±0.6	2±1	6±1
Agriculture and Livestock									
Field Crops	4±1	*4±1*	2±4	0±3	*0±3*	4±3	6±2	0.8±2.2	3.1±0.9
Garden Crops	10±2	*11±2*	8±2	9±2	*11±2*	14±5	11±3	9±3	10±1
Livestock and livestock products	6±3	*7±3*	16±4	11±5	*11±6*	20±3	9±2	19±7	12±2
Business and Employment									
Business	5±3	*2±1*	1.1±0.4	3±2	*3±2*	4±3	0.5±0.3	0±0	2.5±0.9
Skilled Employment	7±5	*7±5*	3±2	2±1	*2±1*	0±0	6±4	0±0	4±2
Unskilled Employment	8±5	*9±5*	4±3	0.5±0.4	*0.4±0.4*	3±1	4±3	2±1	4±1
Piecework	0.7±0.4	*0.8±0.4*	1.9±0.5	1.2±0.4	*1.2±0.4*	1.0±0.4	0.7±0.5	12±7	2.0±0.7
Transfers									
Remittances	20±4	*20±3*	17±4	18±5	*17±5*	11±3	18±4	20±5	17±2
Pensions	6±4	*7±4*	3±3	0	*0*	0.2±0.2	1±1	0±0	2±1
Rental Income	5±3	*5±3*	6±5	1±1	*1±1*	4±4	7±5	0±0	5±2
Government/NGO	1.8±0.6	*1.9±0.6*	3±1	2.5±0.6	*2.6±0.6*	1.1±0.5	0.5±0.2	3.4±0.8	1.9±0.3

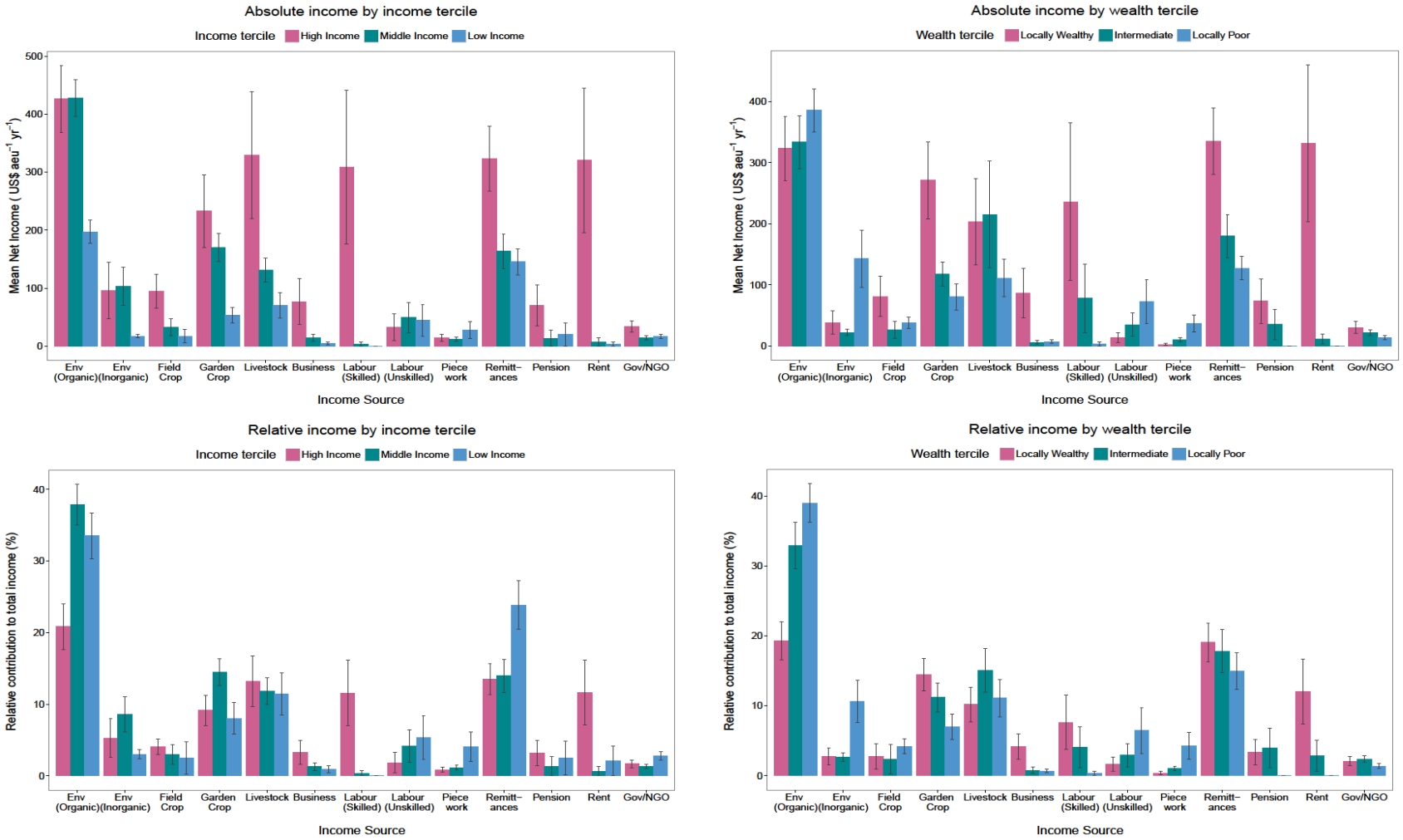

Figure 4.1 Annual absolute income (US$ aeu^{-1} yr^{-1}) and relative income contribution from each income category for terciles constructed using (left) total annual income and (right) household wealth index score. Two households with highly specialised livelihood strategies are excluded from these figures. Error bars represent ± one standard error.

Multiple regression analysis indicated that there was a significant positive relationship between total annual income and wealth index score (ANOVA: $p<0.0001$) and a significant negative relationship between total annual income and household size in capita (ANOVA: $p=0.004$), but there was no significant relationship between total income and the age or gender of the household head (ANOVA: $p>0.05$). Absolute organic environmental income was significantly associated only with the age of the household head, with older households having lower absolute organic environmental income (ANOVA: $p=0.02$). Relative share of organic environmental income in total income was significantly negatively associated with both increasing total income (ANOVA: $p<0.001$) and increasing wealth index score (ANOVA: $p=0.02$). There was no significant association between village and variation in total income, environmental income or environmental dependence. It should be noted that in no case did the adjusted R^2 of the model exceed 0.31, indicating numerous other factors influencing household income and environmental dependence not captured in the present analysis.

4.4.3 Land cover derivation of environmental income

Firewood accounted for on average 38±2% of total organic environmental income across all 91 households, equivalent to a mean value of US$104±6 aeu^{-1} yr^{-1}. Thatching grass was also important in all villages, accounting for on average 10±1% of organic environmental income. Mean collected value of the majority of resources showed no consistent relationship with village woodland cover. The only exception was wild fruits, with mean values of US$22 and US$23 aeu^{-1} yr^{-1} reported in the two villages with lowest woody cover as opposed to means of between $40 and $80 aeu^{-1} yr^{-1} in the four villages with higher woody cover.

Environmental income was derived from a broad range of land cover types (**Figure 4.2**). Tree-dominated land cover types including mountain woodland, lowland woodland, kopjes/termitaria and riparian woodland were the most important environmental income source, between them accounting for 67% of all reported organic environmental income. High biomass mountain woodland was the dominant source of environmental income in two of the mountain-adjacent villages, but in no village did the proportion of income derived from high biomass mountain woodland exceed 40%. A substantial proportion of environmental income was derived from fields, while rivers and streams were particularly important in Mbizi village.

The majority of income from firewood, poles, fibres and natural fertilisers was derived from land cover types dominated by woody species (**Figure 4.3**), whereas thatching grass and wild vegetables were almost entirely derived from fields. Lowland woodlands were the most

important source of wild fruits, with significant proportions also derived from fields and kopjes.

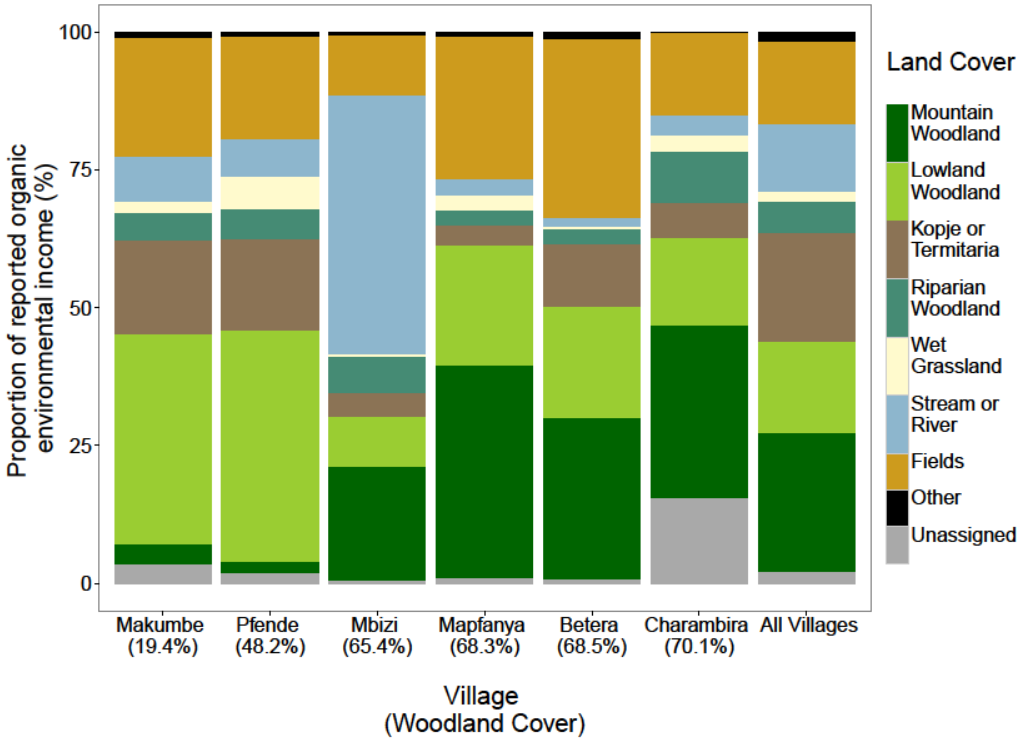

Figure 4.2 Proportion of organic environmental income derived from each land cover type, both within villages and for the full sample of 91 households. The high contribution of streams/rivers in Mbizi is partly attributable to a single household with very high dependence on hunting and fishing in wetlands.

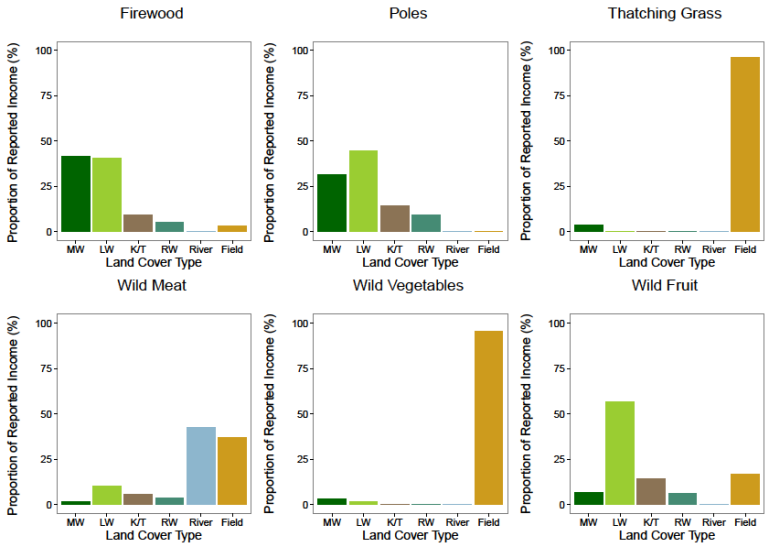

Figure 4.3 Proportion of reported organic environmental income in selected provisioning ecosystem service categories derived from each of six land cover types. Land cover types: MW=Mountain Woodland, LW=Lowland Woodland, K/T=Kopje/Termitaria, RW=Riparian Woodland. Figure excludes one household who derived more income from wild meat than the other 90 households combined, the majority of this income coming from streams and rivers.

4.4.4 Livelihood diversity and income inequality

There was a positive and significant relationship between diversity of income sources (calculated using the inverse Simpson index) and household wealth index score (ANOVA: $p<0.001$), but no significant relationship between livelihood diversity and any other variable ($p>0.05$; adjusted $R^2=0.13$). The diversity of organic environmental income sources was negatively associated with increasing household wealth index (ANOVA: $p=0.02$) and positively associated with increasing household size (ANOVA: $p=0.02$). There was no significant difference in total livelihood diversity or in the diversity of environmental income sources between villages. There were also no consistent associations between village woodland cover and livelihood diversity in the lowest wealth or income terciles.

The Gini co-efficient of income inequality was 0.39 for the whole sample, ranging from 0.18 in Charambira to 0.5 in Makumbe (**Figure 4.4**). While inequality initially appears substantially higher in the village with lowest woodland cover, exclusion of the single outlier household with income seven times that of any other household in the sample meant that the Gini coefficient for Makumbe fell to 0.36. Exclusion of environmental income increased the Gini co-efficient for the full sample to 0.47, and also resulted in increased income inequality in all study villages (**Figure 4.4**).

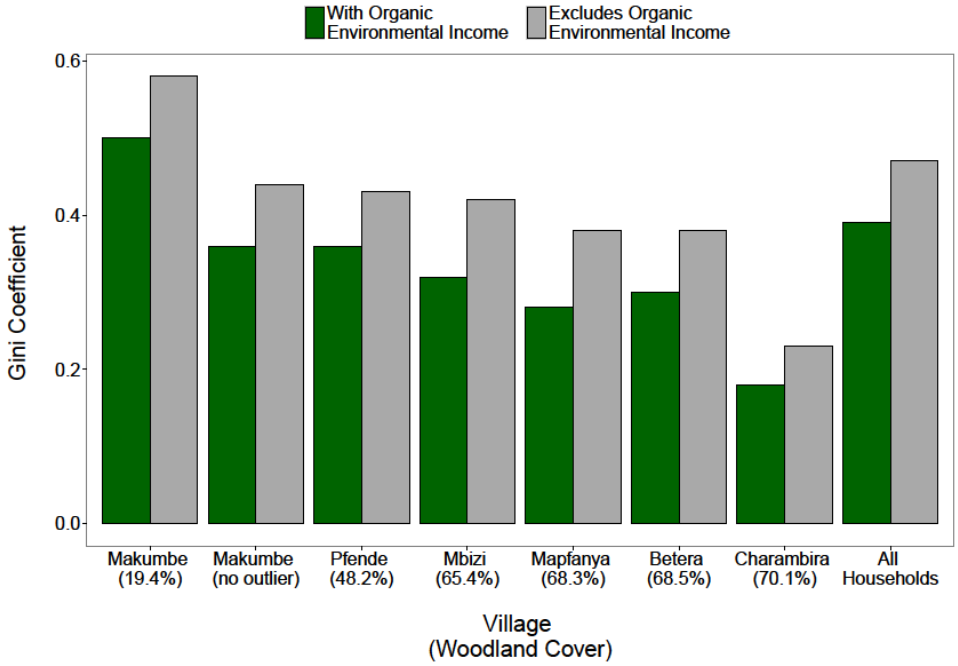

Figure 4.4 Gini Coefficients of income inequality both including and excluding income from organic environmental resources. 'Outlier' in Makumbe refers to a single household with annual income 7 times higher than the next wealthiest household; omission of this household results in there being no statistical association between village woodland cover and village Gini coefficient (linear regression: $p>0.05$).

The Gini co-efficient of organic environmental income was higher in the two villages with the lowest woodland cover than in three of the mountain villages, at 0.40 in Makumbe and 0.42 in Pfende as opposed to 0.32 in Betera and Mapfanya and 0.19 in Charambira. The Gini coefficient for environmental income was initially 0.45 in Mbizi, but this is in large part due to a single household almost entirely dependent on environmental resource income: exclusion of this household resulted in a drop in the Gini coefficient to 0.26.

4.5 Discussion

4.5.1 How important is organic environmental income?

Income from organic environmental resources was the most important income source across the 91 study households, accounting for on average 31% of total household income. This is higher than the average of 26% in a compilation of studies from the miombo ecoregion (Ryan et al., 2016), but is comparable to the average of 30.1% from the African case studies reported in Angelsen et al. (2014). In contrast, income from agriculture was much lower than in the majority of published studies, with combined income from field and garden crops accounting for only 13% of income as opposed to between 28% (Kamanga et al. 2009) and 33% (Fisher et al., 2004) in Malawi, 40% in Ethiopia (Mamo et al., 2007), 44% in Benin (Heubach et al., 2011), and an average of 32% in the African case studies covered in Angelsen et al. (2014). This lower contribution of agriculture is in part due to differences in accounting methodologies, with inputs such as manure accounted for under 'livestock' in the current study, but is also because this study was carried out in a drought year. The implications of carrying out the study in a drought year are considered under 'Study Limitations.'

Unlike a number of previous studies of environmental income (e.g. Cavendish, 2000; Mamo et al., 2007; Heubach et al., 2011), we do not find environmental dependence to be highest amongst the poorest income tercile. Dependence on environmental income was instead highest in the middle income tercile, the same pattern as observed by Kamanga et al. (2009) in Malawi and Ambrose-Oji (2003) in Cameroon. However, when wealth terciles were constructed using wealth index scores (indicative of longer term prosperity and asset wealth), both absolute and relative environmental income were highest in the poorest wealth tercile. This aligns with the findings of Fisher (2004) in Malawi, Nielsen et al. (2012) in DRC and Dokken and Angelsen (2015) in Tanzania, all of who found low asset wealth to be associated with high environmental dependence. The finding in the present study that wealth index is also positively associated with increased livelihood diversity supports the argument that environmental resources offer opportunities for households lacking the capitals to diversify

more widely (although we cannot rule out the converse, that more diverse livelihoods result in higher income and therefore accumulation of greater asset wealth).

The lower absolute environmental income of households with older heads may reflect the lower labour capability of older residents, as suggested by Cavendish (2000), or may be because older household heads were less likely to be in the lowest wealth tercile, suggesting greater access to alternative livelihood options. Interestingly, unlike in previous studies (Babulo et al., 2008; e.g. Kamanga et al., 2009; Nielsen et al., 2012) we did not find environmental dependence to vary significantly between male-headed and female-headed households. Environmental dependence was marginally lower in *de facto* female-headed households, which we suggest to be because women in such households are often the sole caregiver for young children and so have limited labour capability (and in at least one case because the husband had asked the wife not to engage in certain work perceived as 'demeaning' while he was absent). In contrast, many widows were observed carrying out tasks typically described locally as 'male' work such as collecting poles and fencing gardens, suggesting gender roles in the study area to be mutable dependent on necessity. Perhaps in reflection of the high unemployment in Zimbabwe, many widow-headed households also still contained grown-up sons. This provides another avenue maintaining access to livelihood opportunities open primarily to men, such as working in the gold mine.

4.5.2 Is high biomass miombo woodland the most important source of environmental income?

Our results match those of Angelsen et al. (2014) in finding that tree-dominated land cover types account for the majority of environmental income. However, while 67% of total income is derived from tree-dominated land cover types, a large proportion of this income is from low biomass lowland woodland, from kopjes and termitaria and from riparian woodland strips. Significant income, particularly from wild foods, is also derived from fields and from rivers and streams. These observations lead us to draw two main conclusions: (1) that conflation of 'forest income' with 'environmental income' seriously misrepresents patterns of landscape use in forest-agriculture mosaics and (2) that rural livelihoods in Zimbabwe may be more resilient to loss of woodland cover than would be anticipated from land cover data alone.

We suggest two reasons behind these observed resource collection patterns. Firstly, some of these patterns are driven by the distributions of relevant species. Thatching grass, for example, is found mainly on contour ridges (raised ridges used to present soil erosion), while the majority of wild vegetable consumption is comprised of species found on agricultural field

margins. Secondly, we observe two kinds of collection patterns, one in which the resources are the primary objective of the journey, and the other where resources were collected incidentally in the course of other work. Firewood, for example, was generally a primary trip-objective and was one of the only resources which residents of lowland villages would travel to the mountain to collect, whereas fruit was often picked by children while going to school or herding cattle and so was usually derived from lowland woodlands or fields.

One thing not observed in the present study was higher dependence on non-woodland land cover types amongst poorer households. Pouliot et al. (2012) argued that lower use of high biomass forest than non-forest land was driven by the institutional barriers restricting resource collection. However, while collection of fresh wood from Wedza Mountain is technically illegal, and Wedza Mountain is also a sacred site in local tradition with associated behavioural taboos, none of these 'on paper' institutional barriers appeared to restrict resource collection. We suggest that this reflects the particular institutional context of Wedza Communal Area. While some taboos such as not cutting fruit trees are widely observed, village heads report having little ability to enforce customary rules, while village residents said they would not risk confronting someone they observed harvesting illegally. The Environmental Management Agency are responsible for enforcing laws on use of common property resources, but have few staff operating over a large area: the only fines observed levied during the study period were on houses immediately next to the tarred road, and on tobacco farmers who could not prove sustainable harvest of tobacco curing wood. Lack of enforcement therefore means that formal penalties are less of a barrier than labour capacity or lack of assets such as carts needed for wood collection. It is possible that respondents were underreporting illegal activity, as encountered by Ambrose-Oji (2003) and Dokken and Angelsen (2015). However, the authors of these two studies were working in circumstances of on-going resource conflict related to conservation areas and timber production, and such conflicts are less common in the Wedza area. Given the long period of time invested in trust-building in the current study and based on triangulation with observations of behaviour while resident in the study area, we believe the majority of respondents to have answered honestly (to the extent that several respondents provided detailed, unprompted descriptions of how they went about avoiding penalties for cutting fresh firewood).

4.5.3 Is lower woodland cover associated with lower livelihood diversity and higher income inequality?

Livelihood diversity and diversity of environmental income were linked only to household wealth index score, with livelihood diversity increasing with increasing wealth and diversity of environmental income sources decreasing with increasing wealth. Livelihood diversity did not vary significantly with variation in village woodland cover.

The lack of link between village woodland cover and livelihood diversity is partly because (as previously discussed) the majority of resources can be derived from low biomass woodland systems or non-woodland land cover types. However, we suggest that the lack of difference is also linked to other variations between villages, particularly in terms of access to markets and infrastructure. Households in Makumbe and Pfende have easier access to the markets at Garaba and Wedza Growth Point than the other four villages due to their proximity to the tarred road, and all villages on the western side of the mountain are within easy reach of the secondary school at Rambanpasi whereas students from Charambira and Mbizi have to climb over Gandamasungo each day. The greater connectivity of Makumbe and Pfende results in access to novel diversification opportunities not available in the other study villages, and goes some way to explaining why the number of households deriving income from formal labour, pensions and rents is higher in the two lowland villages than in the other four villages. This leads us to suggest that the historic co-production of change in both market access and woodland cover has meant that reduced woodland cover did not result in reduced diversity of livelihoods.

Access to markets is also an important consideration in terms of understanding the higher inequality in environmental income in the two lowland villages. The upper limit of organic environmental income was higher in Makumbe and Pfende than in all other villages except Mbizi, while the lower limit was lower than in all villages except Mapfanya. From looking at the characteristics of households at the extremes of these income distributions, we suggest two potential explanations. The first is that some of the wealthier households at the lower end of the environmental income distribution in lowland villages reported purchasing firewood, rather than collecting their own, arguing that obtaining sufficient high quality firewood in deforested villages was not a productive activity for them given the time investment required. The upper extreme of the income distribution in lowland villages is mainly occupied by households who had engaged in tobacco farming, and who had collected fuelwood for tobacco curing. Tobacco is seen as the only reliable cash crop within Wedza, but successful tobacco growing requires high levels of inputs such as pesticides and fertiliser, good

farming knowledge, and the ability to transport the tobacco to the auction floors. While a number of households in the other four villages attempted to grow small portions of tobacco, low input availability and lack of expertise meant that these households almost universally made a significant loss, or abandoned the crop before collecting wood for curing.

4.5.4 Study Limitations

There are a number of limitations which should be considered in interpreting our findings, some of which are specific to this study and others common in existing environmental income literature. The first relates to the biases introduced by the 13 households which did not complete the three rounds of the questionnaire. The loss of households with older heads may have resulted in underestimation of the influence of household head age on environmental resource use, as many of these respondents had very low labour capability. The disproportionate loss of *de facto* female-headed households meant that the final sample size for this group was only 7 households, and with only one or two such households in each village it was not possible to assess whether *de facto* female-headed households were differentially impacted by land cover change.

A second issue is with the use of income as a metric to represent the value of environmental resources in rural livelihoods. While facilitating comparison between environmental income and other elements of livelihood strategies, income is a one dimensional measure which cannot reflect other linkages between resource use and multidimensional well-being. For example, the lower consumption of wild fruits in the two villages with lower forest cover suggests that dietary diversity could potentially be more responsive to woodland cover change than income. Further, income does not reflect the time invested in resource collection. A greater number of householders in Makumbe village travelled outside the village to collect woodfuel, either to adjacent villages or to the mountain, and this longer collection time imposes opportunity costs as time cannot be productively used on other tasks (Cooke et al., 2008). Future analysis would therefore benefit from using additional metrics to complement measurement of income.

A third critique relates to the temporal and spatial scales of the study. The study was carried out in a drought year, and this may explain why observed income from field crops was much lower than that observed in other studies. However, recall data of the years preceding the questionnaire survey indicate mean household maize production to be only 16*50kg sacks even in the good harvest seasons of 2013 and 2014, equivalent to a value of around US$330 hh^{-1}, and given the input intensity of maize production this would still equate to comparatively

little profit. During feedback workshops held in April 2017, respondents acknowledged that field crop farming was rarely a profitable exercise, suggesting that the focus on farming was instead partially culturally motivated (someone who fails to farm will lose the respect of their peers) and partially because farming is the only truly reliable way to obtain food for at least part of the year. The study was also carried out over a relatively small spatial scale, with study villages being a maximum of 10km apart. This meant that while villages varied in terms of woodland cover, households were able to obtain resources from adjacent villages where they often had kin connections who enabled resource access. A valuable advancement on the present study would therefore be to increase the temporal and spatial scales of analysis.

4.6 Conclusions

The results presented in this chapter indicate that the livelihoods of rural communities have been more resilient to past land cover change than might be anticipated from land cover data alone, demonstrating the importance of including both availability and use of resources in analyses of land cover change and livelihoods. It is also apparent that the conflation of 'forest income' and 'environmental income' is not supported in miombo-agriculture mosaic landscapes, and that livelihood value is not necessarily aligned with other landscape values such as carbon storage.

It might appear that the results in this chapter negate those of the previous chapter, where we argued that tree planting would have positive consequences for rural livelihoods. However, in interpreting the arguments presented in both of these chapters there are some important points to take into account. Firstly, in the present chapter it was shown that two thirds of organic environmental income was derived from land covers dominated by woody species, even if much of this income was derived from low biomass woodland, showing that woody species do play a key role in rural livelihoods. Secondly, the lower fruit consumption in lowland villages is a cause for concern, and as the majority of planted trees in Zimbabwean smallholder farming areas are fruit trees (Wilson 1989), tree planting may be able to ameliorate some of the loss in dietary diversity which may be associated with reduced tree diversity. Thirdly – and perhaps most importantly – the livelihoods documented in the present study are the product of a very different Zimbabwe to the one observed today. While extant patterns of livelihoods and land cover are the result of the gradual co-evolution of local and regional socioeconomic change, the employment opportunities taken by older householders and now paying off in pensions and rents may not be available to households currently in the early stages of their life cycles. While we can conclude that woodland cover change up to the present

time has not negatively impacted the livelihood diversity of households in Wedza District, the dramatic alteration in socioeconomic context means that past patterns may not be predictive of the trajectory of future change. We therefore suggest that enhancing the diversity of available livelihood opportunities, including through well-planned tree planting programmes, could still have value in enhancing the resilience of livelihoods in Wedza.

4.7 Chapter 4 References

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5. Natural resources as safety nets under multiple interacting hazard exposures in Zimbabwe

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Abstract

Climate change is anticipated to have particularly severe impacts in rural Africa, but predicting which communities and households will be most vulnerable to these impacts is complicated by the interactions between climate change and existing hazards such as HIV/AIDS. The consumption and sale of natural resources has often been cited as important in coping with climatic hazard exposures, but recent evidence has queried this idea of 'forest as safety net.' In this chapter we draw upon recall from past hazard exposures and on hazard scenario discussions to examine 1) whether natural resources are important to coping strategies in Wedza District and 2) the extent to which exposure to multiple interacting hazards increases reliance on natural resource based coping strategies. We find that prevalence of natural resource based coping strategies was higher during the combined drought and economic crisis exposure of 2008 than during the drought exposure of 2002, reflecting the lesser availability of alternative coping strategies in 2008. Clustering analysis of scenario responses suggests that the importance of natural resource based coping strategies is higher for asset poor and female headed households, and for households with younger household heads. Case studies of individual households support the argument that interactions between large-scale covariate and small-scale idiosyncratic shocks can increase reliance on natural resource based coping strategies, but this increased reliance is heavily contingent on the capitals and powers of the individual households and on the precise characteristics of the hazard exposures. We conclude that reduced access to natural resources, particularly through changes in governance, could substantially increase the vulnerability of poorer households to climate hazards.

Author Contributions

RP developed the research questions and data collection methods with input from CMR and IG. RP and NS collected the data. RP analysed the data and wrote the manuscript, with comments and improvements from CMR and DvdH. An edited version of this paper is intended for submission to *Global Environmental Change*.

5.1 Introduction

Anthropogenic climate change is anticipated to have particularly serious consequences for rural communities in Africa, with the existing vulnerability context of weak institutions and food insecurity magnifying the impacts of increased extreme weather events, high rainfall variability, and novel pests and pathogens (Fauchereau et al., 2003; Field & Barros, 2014). Developing adaptive capacity and effective disaster response strategies will rely upon understanding the factors influencing heterogeneity in vulnerability to climate change related hazards within and between communities.

However, an increasing number of authors are arguing that the focus on climate change alone provides only a blinkered representation of vulnerability in complex socioecological systems (O'Brien & Leichenko, 2000; Turner et al., 2003; Eakin & Luers, 2006; Reid & Vogel, 2006; Ziervogel & Taylor, 2008; Eriksen & Silva, 2009; O'Brien et al., 2009; Quinn et al., 2011; Nyantakyi-Frimpong & Bezner-Kerr, 2015; Bennett et al., 2016). Coupled human-environment systems in rural Africa are characterised by high uncertainty (Scoones, 2004), with livelihood decisions made in the context of interacting and dynamic exposures to economic, socio-political, climatic and ecological hazards. Understanding vulnerability thus requires understanding of how interacting hazard exposures, and the multi-scalar socioecological and institutional contexts in which these interactions occur, impact the coping strategies available to (and preferred by) rural households.

One coping strategy often considered important to rural African households is the consumption or sale of 'wild' natural resources. A number of case studies have argued for the importance of provisioning ecosystem services from forest or rangeland commons for coping with hazard exposures (e.g. Fisher et al., 2010; Paumgarten & Shackleton, 2011; Kalaba et al., 2013; Shackleton, 2017), but a recent global analysis (Wunder et al., 2014) suggested that this characterisation of 'forest as safety net' may have been overstated (a conclusion supported in case studies by Zinyama, 1990 and Debela et al., 2012). Given these contradictions in the literature, and in light of the changing availability (Hansen et al., 2013; Rudel, 2013) and governance of natural resources in sub-Saharan Africa (Ribot, 2003; Ribot & Larson, 2013), there is a need for more detailed investigation into the factors promoting or necessitating the use of natural resources in coping strategies in the context of multiple interacting stressors.

In Chapter 4 we detailed the importance of environmental resources to the 'day-to-day' livelihood strategies of rural households in the six study villages in rural Zimbabwe. Our objective in this chapter is now to explore whether natural resources are also important for coping strategies following hazard exposures. We firstly outline the conceptual background of

the topic and summarise present understanding of coping strategy choices in rural Africa, before detailing the vulnerability context of the study landscape and describing the quantitative and qualitative methods used to gain insight into coping strategy choice. We then present our results, drawing upon recall of previous hazard exposures and discussion of hypothetical shock scenarios. Finally we discuss the implications of our findings for understanding of the vulnerability of rural households in the context of future socioecological change.

5.2 Conceptual Background

The term ***vulnerability*** has numerous potential interpretations reflecting diffuse multidisciplinary origins (for conceptual histories see Adger, 2006; Füssel, 2007; O'Brien et al., 2007). We base our analysis on the framework developed by Turner et al. (2003), who define vulnerability as 'the degree to which a system, subsystem, or system component is likely to experience harm due to a hazard, either a perturbation or a stressor.' The advantage of this framework is that it structures investigation of 'contextual' or 'start-point' vulnerability, defined by O'Brien et al. (2007: 76) as follows:

'Contextual vulnerability…is based on a processual and multidimensional view of climate-society interactions. Both climate variability and change are considered to occur in the context of political, institutional, economic and social structures and changes, which interact dynamically with contextual conditions associated with a particular 'exposure unit.' Outcome vulnerability separates humans from nature, whereas contextual vulnerability includes nature as part of a broader social context.'

Such an 'integrated' framing of vulnerability (Füssel, 2007) is appropriate given that we approach our study landscape from a socioecological systems perspective, rejecting the delineation of separate social and natural systems in favour of 'the integrated concept of humans-in-nature' (Berkes et al., 2000; 4). Few analyses of vulnerability have explicitly considered links between human and ecological system components (Bennett et al., 2016; McDowell et al., 2016), a surprising omission given the dependence of rural livelihoods in developing countries on natural resources (Cavendish, 2000; Mamo et al., 2007; Kamanga et al., 2009; Angelsen et al., 2014) and the role of human activity in shaping extant landscape structure (see e.g. Fairhead & Leach, 1996; Hansen et al., 2013).

While households in uncertain environments often exhibit pre-emptive livelihood adaptations such as income diversification in anticipation of probable hazard exposures (Kinsey et al., 1998; Ellis, 2000), our primary focus in this study is on the reactive coping strategies adopted during and immediately following exposure. Bennett et al. (2016) define

coping strategies as 'short-term reactive or unplanned responses to moderate the impacts of, or sensitivity to, exposures.' Households rarely adopt a single coping strategy, instead being observe to compile portfolios of concurrent strategies (Béné et al., 2016), to use a primary specialist strategy complemented by less preferred but diverse secondary strategies (Eriksen et al., 2005), or to temporally sequence strategies as each preferred strategy becomes exhausted (Corbett, 1988). Coping strategies also vary with characteristics of the hazard exposure, for example the severity and duration of the exposure, and also whether the exposure is covariate (impacting all households within a village or region) or idiosyncratic (impacting only single households or individuals: terms follow Baulch & Hoddinott, 2000; Dercon, 2002). It is particularly critical to understand the factors motivating coping strategy selection because these strategies can at times be maladaptive, resulting in negative impacts on vulnerability and wellbeing in the longer term (Zimmerman & Carter, 2003; Bennett et al., 2016).

The use of a *livelihoods approach* to the study of vulnerability links back to the classic work of Sen (1981) on the politics of famines, which links in turn to the Sustainable Livelihoods Framework (SLF: Scoones, 1998) and to associated work on environmental entitlements (Leach et al., 1999) and theories of access (Ribot & Peluso, 2003). While the latter two frameworks are focused primarily on access to natural resources whereas the SLF considers livelihoods in totality, a commonality across the frameworks is that household livelihood options are predicated not just on household 'endowments' or 'capitals' but also on the ability to translate these capitals to actions or benefits relative to dynamic social, economic, institutional, political and ecological contexts at multiple spatial scales. Understanding coping strategy choice at the household level therefore necessitates nesting analysis of household characteristics and behaviours within these broader contexts (Turner et al., 2003; Ohja et al., 2016) and considering the relational distributions of power constraining livelihood decisions (Pelling and High, 2005; Reid & Vogel, 2006; Ziervogel & Taylor, 2008; Vervisch et al., 2013).

The majority of published studies on environmental coping strategies focus specifically on provisioning ecosystem services or non-timber forest products (e.g. McSweeney, 2004; Paumgarten & Shackleton, 2011). However, in the present case it is also important to consider the role of mineral resources such as gold in household coping strategies. The importance of small-scale mining to national accounts and rural livelihoods in sub-Saharan Africa is well-documented (Hilson, 2000; 2009), but few authors have discussed gold mining as a coping strategy. Given that gold mining and panning are common livelihood activities in the area of the study, it was necessary to include mineral resources in the analysis in order to understanding coping strategy choice.

As the apparent vulnerability of a social unit depends upon the scale of study, our choice to focus on village- and household-level case studies also requires justification. The importance of high-resolution vulnerability analysis is well-documented, with numerous studies observing inter-village (Eriksen et al., 2005; Traeurup & Mertz, 2011) and intra-village (McSweeney, 2005; Brouwer & Nhassengo, 2006; Antwi-Agyei et al., 2013) variation in vulnerability and coping strategies. In common with a number of previous authors (e.g. Eriksen et al., 2005; Willbanks, 2015), we believe that a community case study approach provides the greatest depth of understanding of past and present contexts and of the influence of these contexts on coping strategy choice.

5.3 Coping Strategies in Sub-Saharan Africa

In this section we provide a brief overview of current understanding on coping strategy options in rural Africa communities, including asset smoothing and consumption smoothing, social networks and migration, labour reallocation, and use of natural resources.

5.3.1 Consumption smoothing vs. asset smoothing

Sales of household assets, particularly livestock, have long been perceived as important for coping with shocks in Africa, the logic being that households build up asset stocks in good periods which can then be drawn down following exposures in order to smooth consumption (Dercon, 2002). However, while livestock sales have been observed as a component of household strategies following both idiosyncratic and covariate exposures (Sauerborn et al., 1996; Kinsey et al., 1998; Paumgarten & Shackleton, 2011; Hänke & Barkmann, 2017), selling livestock is not a strategy observed consistently across all households and often compensates for only a small proportion of income loss following exposures (Fafchamps et al., 1998).

A potential explanation behind these observations is that livestock are a multifunctional asset, with cattle in particular important in smallholder farming systems. Falling below a certain threshold, in this case the one or two cattle needed for ploughing, would have long-term livelihood impacts, as cattle are a ‘lumpy’ asset and poor households would struggle to raise capital to buy replacements (Dercon, 2002). The existence of this poverty trap may encourage poorer households to reduce consumption in order to smooth assets rather than the converse observed in wealthier households (Zimmerman & Carter, 2003; Carter et al., 2007), and this hypothesis is supported by observations that wealthier households were more likely to sell cattle in Ethiopia (Little et al., 2006) and Zimbabwe (Hoddinott, 2006).

The logic of smoothing assets for poorer households is compounded by the lower market prices commanded by assets during covariate exposures (Dercon, 2002).

Reducing consumption as a coping strategy has been widely observed following both covariate and idiosyncratic shocks (Kinsey et al., 1998; Paumgarten & Shackleton, 2011; Akrofi et al., 2012; Börner et al., 2015; Béné et al., 2016; Akampumuza & Matsuda, 2017) and often involves reduction in food consumption such as reducing meals and portion sizes (Maxwell, 1996). However, Quinn et al. (2011) point out that labour is often the primary asset of poorer households, and reduced consumption could thus potentially exacerbate future vulnerability.

5.3.2 Social networks and migration

Social network-based strategies include the informal networks of exchange within village communities and the exchanges of transfers and remittances over broader spatial scales. Both networks are often closely aligned with kin networks and have been observed to be important in coping strategies (Valentine, 1993; Rosenzweig, 1998; Dercon, 2002; Dekker, 2004; McSweeney, 2005; Paumgarten & Shackleton, 2011; Quinn et al., 2011; Wunder et al., 2014; Akampumuza & Matsuda, 2017; although see Kinsey et al., 1998; Yilma et al., 2014).

'Social capital' is one of the capitals identified in the Sustainable Livelihoods Framework (Scoones, 1998) and theories of social capital (reviewed in Pelling & High, 2005) have been used to explore the functions of social networks as coping strategies. 'Bonding' social capital refers to the close ties between family and close friends, while 'bridging' social capital refers to the weaker relationships beyond this close inner circle. 'Linking' social capital is a subtype of bridging social capital referring to vertical links across power differentials, for example with authority figures (Woolcock & Narayan, 2000; Cleaver, 2005; Vervisch et al., 2013). It has been argued that bonding social capital provides a safety net during periods of hardship, while bridging and linking social capital are important for accessing new livelihood opportunities and obtaining aid from institutions during crises (Carter & Maluccio, 2003; Cleaver, 2005; Quinn et al., 2011).

However, numerous authors have critiqued the idea of high social capital unfailingly providing protection against exposures (Portes & Landolt, 1996; Portes, 2000; Titeca & Vervisch, 2008; among others). Firstly, while local social networks can insure against idiosyncratic exposures (Dercon, 2002; Wunder et al., 2014), these networks become saturated and break down during prolonged common exposures (MacClean, 2011; Vervisch et al., 2013). Further, even if poor households have significant bonding social capital, this is unlikely

to provide access to shared resources as kin may be equally poor. To quote Portes and Landolt (2000: 546):

'Social capital…consists of the ability to marshal resources through social networks, not the resources themselves. When the latter are poor and scarce, the goal achievement capacity of a collectivity is restricted, no matter how strong its internal bonds.'

Secondly, several authors have highlighted how linking social capital to 'unresponsive' authorities and the power differential between rich and poor households can lead to damaging exploitative relationships between rich and poor actors which increase the long term vulnerability of poor households (Fafchamps, 1992; Morduch, 1999; Little et al., 2006; Jaspars & Maxwell, 2009; Vervisch et al., 2013). The lower assets holdings of poorer households also mean that they engage in social networks on unequal terms (Cleaver, 2005) and are thus more vulnerable to exclusion when benefits are distributed through communities (Conning & Kevane, 2002).

Social networks are also important in understanding patterns of migration in rural Africa. It has been argued by some that climate change will result in hundreds of millions of 'environmental refugees' (Myers, 2002) being displaced internally or migrating internationally, but others argue that such alarmist predictions fail to reflect the numerous social and political factors shaping the validity of migration as an adaptive or coping strategy (arguments reviewed in Tacoli, 2009). Case studies in rural Africa have shown that, far from being a novel environmentally-derived phenomenon, migration has long played a part in diversified rural livelihoods (Bourdillon, 1987), with the probability, distance and duration of migration are all affected by cultural norms around age and gender (Findley, 1994; Berhanu & White, 2000; Henry et al., 2004; Gray & Mueller, 2012). The lack of a previously established social network, and the loss of the safety net provided by having local bonding social capital, are important constraints on the decision to migrate (Banerjee & Newman, 1998; Quinn et al., 2011).

5.3.3 Labour reallocation and natural resource use

Off-farm labour plays an important role in diversified rural livelihoods in southern Africa (Reardon, 1997; Angelsen et al., 2014). In accordance with this, further diversification and increased dependence on off-farm labour are commonly observed coping strategies for idiosyncratic (Sauerborn et al., 1996; Porter, 2012) and covariate exposures (Kinsey et al., 1998; Börner et al., 2015). However, the ability to diversify is related to numerous factors

including wealth (Dercon, 2002; Debela et al., 2012), education (Börner et al., 2015) and gender (Eriksen & Silva, 2009).

Collection of natural resources for consumption and sale represents a specific form of labour reallocation. Use of natural resources in coping strategies has been widely documented in sub-Saharan Africa (Kinsey et al., 1998; Eriksen et al., 2005; Eriksen & Silva, 2009; Fisher et al., 2010; Nkem et al., 2010; Paumgarten & Shackleton, 2011; Kalaba et al., 2013; Woittiez et al., 2013), Central and South America (Pattanayak & Sills, 2001; McSweeney, 2004; 2005; Takasaki et al., 2004) and Asia (Volker & Waibel, 2010; Liswanti et al., 2011). Commonly used strategies in Africa include charcoal production (Eriksen & Silva, 2009; Kalaba et al., 2013) and consumption of wild foods, particularly wild fruits (Kinsey et al., 1998; Eriksen et al., 2005; Paumgarten & Shackleton, 2011). Natural resources are often derived from village commons, and the low input requirements of resource collection mean that the strategy is available even to poor households with few assets beyond labour capability (McSweeney, 2004; Shackleton & Campbell, 2007; Fisher et al., 2010). Poorer households have also been suggested to be more risk-averse than wealthier households, as the failure of a risk to pay off could result in total destitution (Dercon, 2002; Wood, 2003), and while many natural resources offer low returns relative to labour input, some argue that they also have lower associated risk than strategies such as migration (McSweeney, 2004; Delacote, 2007).

However, the recent global analysis by Wunder et al. (2014) found the prevalence and importance of natural resource use as a coping strategy to be much lower than anticipated. The authors suggest this may be indicative of a skew in case study literature towards forest adjacent communities (Wunder et al., 2014), and case study evidence does suggest that proximity to forest is an important factor in determining prevalence of natural resource based coping strategies (Takasaki et al., 2004; Eriksen & Silva, 2009). Generation of cash income from natural resources is also limited by power asymmetries in resource commodity chains, with rural producers vulnerable to exploitation from buyers and middlemen (Eriksen & Silva, 2009; Nkem et al., 2010). Further, collection of resources from common property systems is mediated by numerous formal and informal institutions, and changes in the nature or enforcement of resource access rules can significantly influence the use of natural resource based coping strategies (see e.g. McSweeney, 2005). Rather than simply documenting natural resource use, it is therefore necessary to examine natural resource-based coping strategies relative to the broader vulnerability context of communities and households.

In light of this debate, the objective of this chapter is therefore to address two main questions: (1) are natural resources important to coping strategies in Wedza District; and (2)

to what extent does exposure to multiple interacting hazards increase use of natural resource based coping strategies?

5.4 Methods

5.4.1 Case study landscape: Hazard exposures around Wedza Mountain, Zimbabwe

The six study villages in Wedza District present an intriguing case study for the investigation of household coping strategies. Additional to the villages encompassing a range of woodland cover and market access conditions, the vulnerability context of rural livelihoods in Wedza District has changed dramatically in recent years, mirroring the socio-political upheaval in Zimbabwe as a whole. The Zimbabwean economy declined steeply during the 2000s, coinciding with a period of fast-track land reform aimed at remedying inequities in land ownership remaining from the colonial era. Much of the region around Wedza Communal Area and north to the town of Marondera comprised large white-owned commercial farms, and the appropriation of these farms in combination with the overall economic downturn resulted in increasing unemployment in the region. The declining economy also weakened the Zimbabwean dollar, culminating in a period of hyperinflation during which many Wedza residents lost their savings and which coincided with the aftermath of a severe drought in the 2007-2008 farming season. While the economy has since stabilised, with the US dollar adopted to replace the collapsed Zim dollar, cash shortages continue to be common and unemployment levels high.

Households in Wedza are exposed to numerous other hazards within this evolving economic context (**Table 5.1**). The onset of rainfall is locally perceived as becoming increasingly variable, and recent years have seen significant crop losses to both drought and localised flooding. Additional covariate hazards include loss of access to natural resources, volatility in commodity markets, and failures in local and national infrastructure such as roads and mobile networks. Prevalence of HIV and TB is high, with associated high incidence of idiosyncratic household health shocks, while road accidents are a common cause of death or incapacitatio. Wedza has also experienced politically motivated violence, particularly around the 2008 election. Responses to any new exposure therefore need to be understood against this multi-layered, multi-scalar context of existing hazards.

Table 5.1 Hazard exposures observed to be experienced by residents of households in the six study villages in Wedza District. This table was compiled based on field notes made while in the study area, and so should not be considered a complete typology. Future work would benefit from use of participatory rural appraisal methods (Chambers, 1997) to develop a fuller compendium of hazard types and their locally perceived severity.

Hazard	Household/Individual-level exposure types	Covariate/Idiosyncratic
Environmental/Ecological Hazards		
Drought	Crop losses, water shortages, livestock mortality	Covariate
Flooding	Crop losses, livestock mortality, damage to property	Covariate
Veld fires	Crop losses, damage to property	Idiosyncratic
Pests/Pathogens	Loss of crops/livestock	Covariate (e.g. locusts, grain borer) or idiosyncratic (e.g. hyenas, baboons)
Deforestation	Reduced availability of resources such as firewood and wild foods	Covariate
Pollution	Lack of safe drinking water	Covariate
Economic Hazards		
Economic downturn	Unemployment, reduced remittance income	Covariate
Currency devaluation	Inability to purchase food or farming inputs, loss of savings and pensions	Covariate
Volatility in commodity prices (e.g. tobacco)	Loss of income	Covariate
Failures of power and communication networks	Loss of business opportunities and remittances	Covariate
Health-related Hazards		
Chronic illness (e.g. HIV/AIDS, TB)	Reduced labour availability, long-term medical expenses	Idiosyncratic
Acute illness or accident	Reduced labour availability, emergency medical expenses	Idiosyncratic
Death of household resident	Funeral costs, reduced labour availability, loss of household assets	Idiosyncratic
Death of non-resident relation	Loss of remittance income	Idiosyncratic
Social and political		
Changes in resource governance	Reduced access to resources, loss of cash income sources	Common
Politically-motivated violence*	Damage to person or property	Idiosyncratic
Theft	Loss of assets	Idiosyncratic
Familial Conflict**	Loss of support network, loss of property, discord or violence	Idiosyncratic

*There were no incidences of politically motivated violence recorded during the study period, but several respondents cited political attacks associated with the 2008 election as a factor in livelihood strategy decision making.
**Familial conflict refers both to conflict between members of the broader kin network within a village and to intrahousehold conflicts, particularly between married couples.

5.4.2 Data Collection and Analysis

The majority of analysis in this paper is based on two primary data sets: recall of responses to two past drought events, and a survey exercise weighting potential coping strategies in response to different shock scenarios.

Questions on coping strategies were appended as a module in the February/March 2015 round of the household questionnaire described in Chapter 4. The February/March survey round included 96 households, with survey households having been selected using random sampling stratified by household size and gender of household head. Questions on coping strategies were initially trialled in two households outside the main sample, but early in the full survey it became apparent that there were some inconsistencies in scenario presentations. Scenario descriptions were therefore adjusted based on respondent feedback and responses from the first 11 households excluded from quantitative analysis. This gave a total sample of 85 households, accounting for 43% of inhabited households across the six study villages. Survey appointments were made in advance and the survey carried out with the person present who had the best knowledge of the household. While in some cases this was the male household head or both the husband and wife in the household, men are more likely to be involved in off-farm labour, cattle herding or other work which takes them away from the household during the day, and the majority of surveys were therefore carried out with the highest-ranking woman in the household.

We firstly asked open-ended questions on responses to two hazard exposure events, the drought of 2002 and the combined drought and economic crisis of 2008. Respondents were asked to describe their experiences during the drought and the strategies they used, and responses were subsequently coded into coping strategy categories. Given the unstructured nature of the interview questions, these strategies should be seen as reflecting only the strategies perceived by respondents as the most important, rather than reflecting the full portfolio of coping strategies.

In the second part of the module, respondents were asked to consider three hazard exposure scenarios:

- ***Idiosyncratic crop failure***: Most of your crops are destroyed by pests like wild pigs or bushbuck, but other people in the village are not affected.
- ***Covariate crop failure resulting from drought***: There is a drought that impacts crop harvests in all of Zimbabwe, and all households including yours are struggling to harvest enough.

- ***Idiosyncratic illness***: The main income earner in the household becomes incapacitated with a serious illness and is unable to work for several months.

For each hazard exposure scenario they were presented with eleven potential coping strategies:

- Sell cattle
- Sell other assets, including small livestock
- Depend on local networks of friends and relatives
- Depend on transfers and remittances from friends and family living elsewhere
- Depend on assistance from church or society
- Depend on aid from government or NGOs
- Piecework for other households in the local area (**maricho**)
- Migrate for work (one household member)
- Migrate for work (whole household)
- Reduce consumption
- Collect natural resources for consumption or sale

Both hazard scenarios and potential coping strategies were identified through review of locally relevant literature and through key informant interviews and informal discussions with village residents during the first round of fieldwork from April to September 2014.

Respondents were given 20 beans and asked to distribute them across the eleven potential coping strategies proportional to the perceived importance of that strategy in each shock scenario. Beans could be placed on as many or as few strategies as the respondent wished. Once the respondent was happy with the distribution they were asked follow up questions to establish the reasoning behind the number of beans in each category. The exercise was facilitated in the local Shona language by an experienced local research assistant who also translated respondent explanations in situ, and the notes taken on the translations provide additional qualitative detail on the motivations behind respondent choices.

Given that Béné et al. (2016) and Eriksen et al. (2005) found households to adopt strategy portfolios rather than single strategies, scenario responses were analysed using clustering analysis to assess whether certain coping strategy sets were likely to co-occur. ANOVA and chi-squared tests were used to analyse whether households in each cluster differed in terms of household size, gender of household head, age of household head, and household wealth index score (details of how these socioeconomic characteristics were ascertained are provided in Chapters 2 and 4). All analyses were carried out in Excel and R (R Core Team, 2014).

The quantitative data presented here are also complemented by further qualitative data, particularly in the form of sketches of individual households used to illustrate quantitative patterns. These case studies were developed both from information gained during household surveys, and through numerous informal interactions and conversations recorded in field notes. All respondents are anonymised. Respectful Shona custom is to refer to adults as Amai (mother) or Baba (father) followed by the name of their first child; older residents are addressed using Mbuya (grandmother) or Sekuru (grandfather). We therefore use these titles when introducing case studies to represent the gender and approximate age of the respondent.

5.5 Results and Discussion

5.5.1 Responses to past hazard exposures: the droughts of 2002 and 2008

The droughts of 2002 and 2008 exposed the residents of Wedza District to very different sets of hazards. While crop failure was not absolutely universal in either event, in both years the majority of households fell well short of the maize yields required to be self-sufficient for the full year. The major difference cited by respondents between the two years was that in 2002 groceries could still be purchased in local shops, whereas by mid to late 2008 the economic crisis and spiralling inflation meant they were faced with empty shelves and an almost worthless currency.

The switch in vulnerability context from the single covariate hazard exposure of 2002 (drought only) to the multiple covariate hazard exposures of 2008 (drought AND economic crisis) is reflected in the primary coping strategies recalled by respondents (**Figure 5.1**). Most notable are the differences in formal wage labour, mentioned as a coping strategy by 11% of households for 2002 but only 1% for 2008, and government/NGO assistance, mentioned by 23% of households for 2002 but only 11% for 2008. Conversely, respondents identifying wild food consumption as a primary strategy increased from 12% for 2002 to 28% for 2008. The implication of these findings is that increasing unemployment and lack of welfare support (exacerbated by a government ban on foreign NGO activity for much of 2008; Moszynski, 2008; Zimbabwe Independent, 2008) resulted in increased reliance on woodland resources and particularly on consumption of **hacha** fruit (*Parinari curatellifolia*).

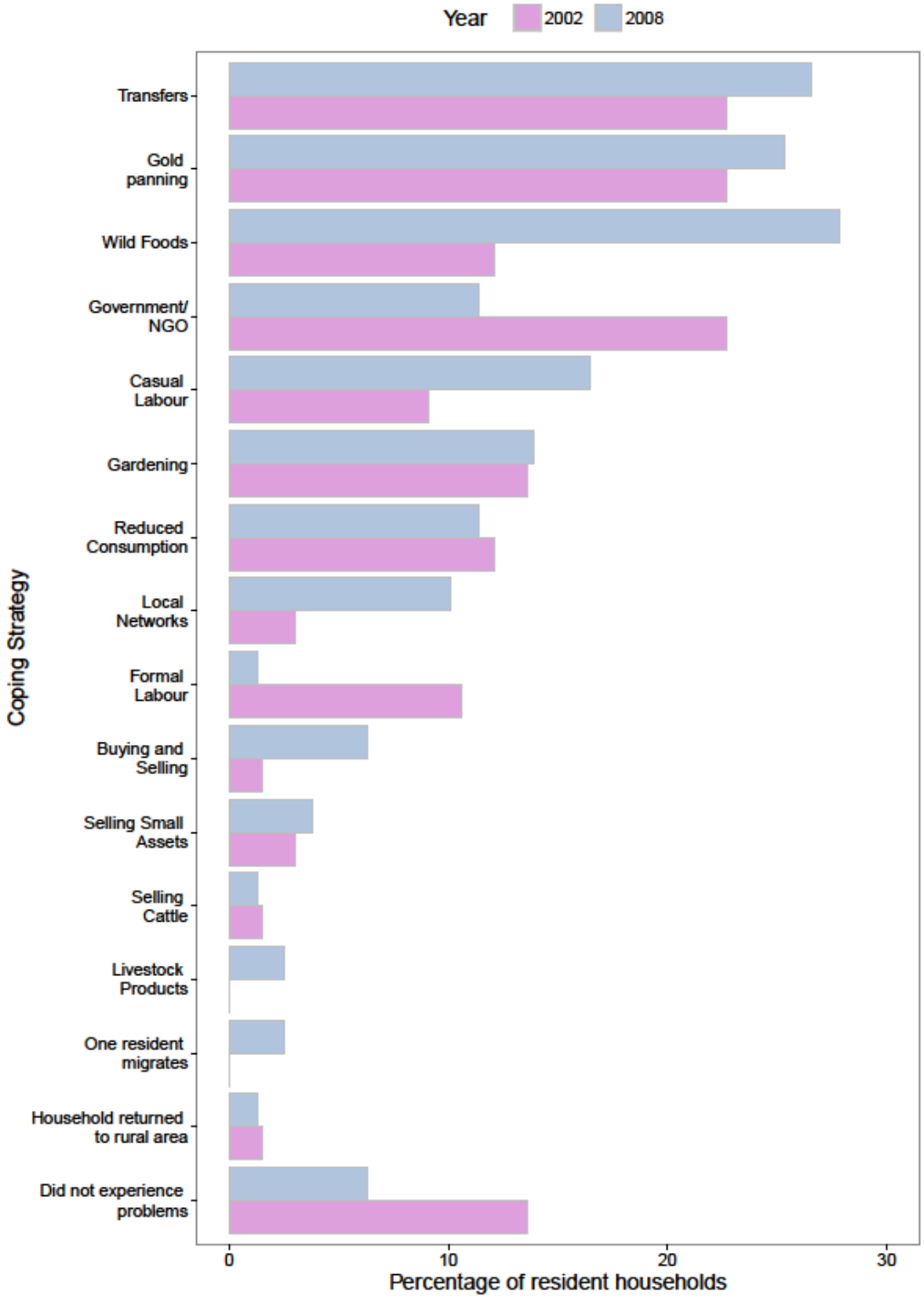

Figure 5.1 Primary coping strategies recalled by households (n=85) in Wedza Communal Area for the drought exposure event of 2002 and the drought/economic crisis exposure of 2008.

Additional insight can be gained by examining the households naming wild foods as a primary strategy in 2008, but not in 2002. Of 15 households resident in the study area in both years and reporting wild food consumption only in 2008, five had depended upon relatives in formal employment in 2002 who have since retired or been made redundant, three were supported by food-for-work aid schemes in 2002, three had previously engaged in gold panning, two achieved good harvests, one depended on casual labour, and one on savings. The switch from this variety of strategies to dependence on wild foods supports the argument that it was the interaction between multiple covariate stressors which necessitated increased dependence on natural resources.

Dependence on natural resources was also at times a consequence of the interaction between covariate hazards and idiosyncratic hazard exposures, as shown by the case study of Amai P:

Case Study: Interaction between multiple covariate hazards and an idiosyncratic mortality shock

In 2008 Amai P was in her mid-30s and living with her husband and six children in Wedza Communal Area. Her husband had been a combatant in the Chimurenga war, and with his work and his war veteran's pension they had built a comfortable home. In 2002 they had assets to sell, and so were not badly impacted by the drought. However, Baba P suffered from TB, and needed medicine and a good diet to prevent sickness. In 2008 the cash crisis meant that he could no longer withdraw his pension from the bank to obtain the food he needed. He travelled up to Marondera, leaving Amai P behind in Wedza, and spent several months in town trying to get his pension, but at the end of these few months he became seriously ill and passed away in hospital shortly afterwards. Amai P was left caring alone for several young children, and turned to eating wild fruits and growing vegetables in the garden which she could exchange for maize meal. The pension was only reinstated several years later with help from her late husband's relatives, on the understanding that she would ask them for no further assistance with future problems.

A number of the findings shown in Figure 5.1 also merit discussion due to differences with published literature, specifically the importance of local social networks and casual labour. Previous studies have indicated that local social networks become saturated during hazard exposures (Vervisch et al., 2013), but in Wedza local networks were mentioned by a greater number of respondents for the multiple covariate shock of 2008 than for the single covariate shock of 2002. However, while some respondents gave examples of important

bonding social capital, such as older residents relying upon local kin, in the majority of cases the local connections cited involved linking capital with village leadership and local government officials, or bridging capital with shop owners and 'stuff people' (wealthy, well-connected women who were able to source and sell groceries). Opportunities for casual labour in 2008 were concentrated around the remaining commercial farms and the few wealthy households who had managed to harvest: work included weeding crops, herding goats or cutting firewood in exchange for wheat or maize meal. Very few households reported depending on asset sales as a coping strategy. One respondent described how, at the peak of the food shortage in 2008, a cow (current value around $380) would be exchanged for four 50kg bags of maize meal (total current value $60), making exchanging livestock an act of desperation.

Given the importance of gold in the local village economy and the comparative reliability of the market, it is perhaps surprising that the prevalence of gold panning as a primary strategy increased only slightly from 2002 to 2008. This is in part driven by a dispute over the mining concession on the western side of the mountain, with a single owner claiming an area which had previously been believed to belong to a whole village. Disputes over gold mining claims and exploitative behaviour by concession owners are common on the western side of the mountain – one concession owner recently insisted that women panning in the concession area pay her half of all the gold found, despite her only input cost being a small quantity of mercury each month. On the eastern side of the mountain, however, gold provided a lifeline in 2008, being listed as a part of the primary coping strategy in 12 of the 22 respondent households. One respondent described the villages during 2008 as being like Mbare, the famously hectic township to the south of Harare, with vendors bringing groceries and maize in exchange for gold. Some respondents in Mbizi and Charambira even suggested that 2008 was easier than 2002, because in 2002 they had to walk for several hours to get to a shop and required a cash income source, whereas in 2008 the industry came to them and the remoteness of the villages was no longer an issue.

5.5.2 Coping strategy choices in hazard exposure scenarios

Four of the proposed coping strategies ranked highly among respondents for all three hazard scenarios: sales of small assets, transfers, natural resource use and reduced consumption were all included in strategy portfolios by more than 60 of the 85 households in response to each hazard type (**Figure 5.2a**). Discussion of asset sales mainly included selling small livestock, and many respondents also suggested they would focus more on growing garden vegetables

for consumption and sale. The main natural resource-based strategies were gold panning, eating wild fruits (particularly **hacha** *Parinari curatellifolia* and **mazhanje** *Uapaca kirkiana*), and cutting firewood and thatching grass for sale. Reduced consumption strategies were mainly focused on food – using smaller pots and having tea without bread at breakfast – but also included cutting expenditure on clothes, 'luxury' foods like sugar, and airtime (credit) for phones.

Selection of other strategies for inclusion in portfolios varied with shock type. Casual labour was chosen by fewer respondents for the covariate shock scenario, as it was argued that there would be fewer labour opportunities during a large-scale crisis. Local networks were also chosen by fewer respondents for the covariate crisis scenario, with respondents detailing long running jealousies and feuds between households, describing suspicions of witchcraft, and saying that in visiting your friends you could only 'carry your stomach' – meaning that while customary politeness means you might be invited to partake in a meal, you would leave the household otherwise empty handed. Assistance from the church was selected by few households in the crop failure scenarios, but was perceived as very important during periods of illness. Respondents suggested that the church expected a person to work while they were able and so wouldn't help following crop failure, but that if a person became ill and unable to work then they would gather for prayers and to provide useful items such as clothes and soap.

Support from government or NGOs was chosen by the greatest number of households for the covariate shock scenario. However, while more than 60 households included government support as a strategy in this scenario, the mean score assigned to the strategy across all households was only 1.5±0.2, much lower than the mean score assigned to transfers, asset sales or natural resources for the same scenario (**Figure 5.2b**). This score reflects the perceived unreliability of aid interventions, stemming from the 2008 drought when aid did not arrive until December and starvation was already at crisis levels. The low scores also reflect the perception of local people that there is too much corruption and cronyism in customary leadership and government agencies to rely upon receipt of aid. The **sabhukus** in all the villages live in close proximity to networks of blood relations, and those outside these networks argued that resources have a tendency to remain within the network rather than being targeted at those most in need. The failure of resources to disperse through the community is also linked to perceptions of poor households amongst wealthier residents: in a number of eye-opening interviews while developing an index to assess household wealth (see Chapter 2 for details), several wealthier residents argued that poor households were 'uncivilised', 'lazy', 'untidy' and 'disorganised', with the intimation that giving poor households resources would result in no benefit.

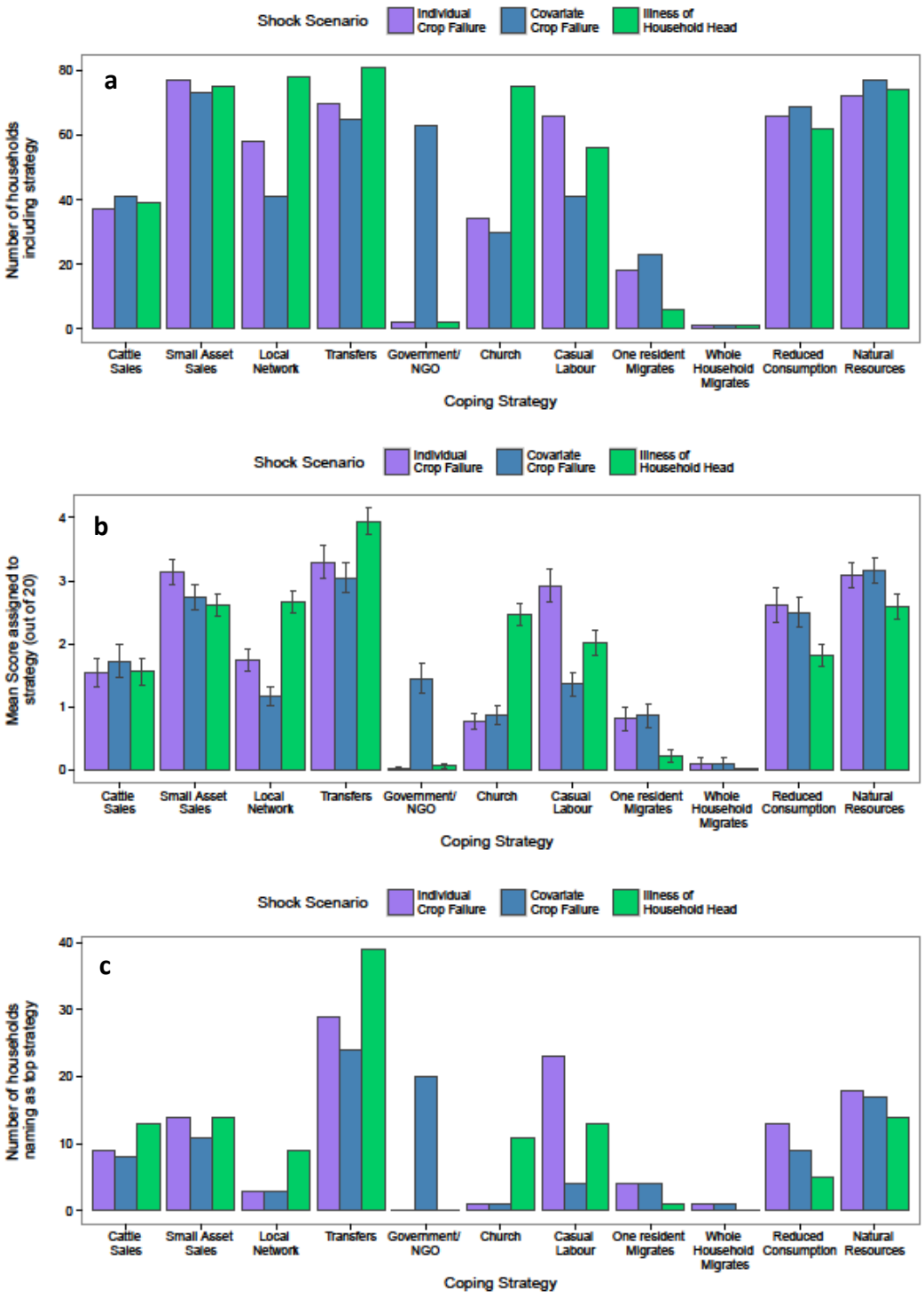

Figure 5.2 Predicted coping strategies in response to three hazard scenarios in households (n=85) around Wedza Mountain, Zimbabwe. a) shows the number of households including each strategy within the predicted portfolio in response to each hazard scenario. b) shows the mean weight out of 20 assigned to each strategy option. c) shows the number of households choosing a strategy as the top-ranked or joint top-ranked strategy in response to each scenario. Error bars in b) represent ± 1 standard error.

The implications of corruption, hostile kin networks, and negative perceptions of poorer households – and the way in which these factors can increase reliance on natural resources as a coping strategy – is demonstrated by the example of Amai M.

Case Study: Exclusionary networks and reallocation of labour

Amai M was born in the eastern mountains of Zimbabwe, but came to Wedza for marriage over 40 years ago. Since her husband passed away she has remained in the village, living with one of her grandchildren in a homestead with a two roomed main house, a small kitchen, and a half-finished pit latrine. The toilet was never finished because her husband's relatives took the cement to build her husband's grave – they promised to replace it, but never did. Her husband's relatives have also taken the lobola payment (the price paid by the husband's family to the parents of the wife) from her daughter's marriage. She has never received any of the fertiliser given to the village annually by the government before the farming season, and does not believe she would receive aid during a crisis. In both 2002 and 2008 she was dependent on hacha fruit to survive. Her livelihood strategy is focused on working for others and mowing thatching grass, being paid in maize and sometimes in cash so that she can cover school fees. Others in the village sneer at her and suggest she must be prostituting herself to get income, but following the poor harvest in 2015 she was one of the few households who had amassed enough maize to get through the year. Such a strategy does however increase her vulnerability in other ways. Thirty bundles of thatching grass were stolen from her by an adjacent landowner in the resettlement area and she had no option except to start again, and she doubts that her patron households could offer enough work in a major crisis. In case of illness, her lack of support networks would mean her only strategies would be to sell her chickens and to make sweeping brooms from grass, which she could send her grandchild to Wedza Growth Point to sell.

Eriksen et al. (2005) suggest that households adopt a specialised primary strategy supported by more diverse by less preferred secondary strategies. In the present case study transfers were the highest or equal highest weighted strategy in the most households across all scenarios (**Figure 5.2c**). Casual labour scored highly in the idiosyncratic crop failure scenario, as respondents anticipated that labour opportunities would be available and that they would still have labour capability, unlike in the illness scenario. However, selection of casual labour as a strategy was often accompanied by caveats. The lack of a fully functioning labour market in the area meant that wealthier households could get away with paying labourers very little

(recompenses of between $3 and $5 per day of work were commonplace), and time spent working in the fields of another household was time which could not be spent on the worker's own fields, potentially increasing vulnerability in the longer term.

Migration of the whole household was selected by only two households out of the 85. Urban to rural migration was a strategy adopted during the economic crisis – three households in the sample returned to the rural areas in the mid-2000s following loss of employment, as farming was the only livelihood option remaining. Respondents offered two perspectives on reasons not to move. The first focused on property in the rural area – rural homesteads often develop in a modular fashion, with kitchens, rooms and bathrooms added over periods of years as cash becomes available, and moving away from such an investment was unconscionable, particularly for long-time resident families who also cared for the burial sites of relatives near their homesteads. The second argument focused on the risks of moving away, particularly to a place with no pre-established social network. These risks were at the forefront of respondents' minds during the scenario exercise because of the co-occurrence of this research with two additional hazards: a failure in the mobile phone network, and an outbreak of violence targeted at Zimbabweans living in South Africa.

The importance of having networks in the destination area is illustrated by the households which left Wedza during the study, the majority of whom were either women with husbands working in the city, or older residents going to stay with their children in town. Similarly, the two households who suggested they would move in the scenario exercise were a woman with a husband in South Africa, and an unmarried Sekuru who wanted to go to his brother in town. In contrast, the households which had only recently become established in the study area had often been motivated to leave their homes by idiosyncratic social hazard exposures, as shown by the example of Mbuya B.

Case Study: The widow evicted by her sisters-in-law

Mbuya B moved to Wedza District in 2008 from the Mount Darwin area of Zimbabwe. She had been living with her father, who was a schoolteacher in Mount Darwin and was able to offer her land and protection following the death of her husband. However, by the time her father passed away in 2007 his sons were grown up and married, and her sisters-in-law argued that she should leave the house so that the sons could take over the land. She moved to the Wedza area in the peak of the financial crisis, and for the next few years shared a homestead consisting of two small huts with her son and grandchild. The village had given her only a 'widow's portion' of land, with a small plot for growing maize, and with no cattle or any relatives to help with labour she struggles to cultivate and often loses crops to baboons from

the mountain. Her main coping strategies in scenario exercises were dependence on her children, working for others and cutting down on consumption, but she fears for the future: her son was recently made unemployed and the land she lives on belongs to him, which means she may soon be evicted once again.

The importance of idiosyncratic shocks as a motivation for the migration of whole families is supported by many other respondents in the scenario exercise who suggested that bad feeling and witchcraft within kin networks would be the only reason they would consider leaving their home area. It should however be noted that any study of migration centred in a rural area suffers from a missing fraction problem, particularly in Wedza where some wealthier or better connected families had already decided to move away from the study area.

5.5.3 Co-occurrence of strategies in scenario portfolios

Clustering analysis of scenario responses revealed four clusters of households for the idiosyncratic and covariate crop failure scenarios and three clusters of households in the illness scenario (**Figure 5.3**).

The four clusters of households for the idiosyncratic crop failure scenario were (1) households assigning high value to **natural resources and labour**, with sale of small assets and reduced consumption also featuring highly; (2) households scoring **cattle sales** highly, with transfers from kin the second highest scoring strategy; (3) households scoring **kin transfers** highest, with natural resources and small asset sales as secondary strategies; and (4) households reporting **reduced consumption** as the most important strategy. Gender of household head was significantly related to household cluster (χ^2 test, $p=0.03$), with only two female-headed households in the cattle sales cluster as opposed to 16 male-headed households. Wealthier households were also significantly more likely to be in the cattle sales cluster than in the natural resource/labour or kin transfers clusters (ANOVA: $p=0.0005$), and the mean age of household heads in the cattle sales cluster was significantly higher than in other categories (ANOVA: $p=0.0002$), at 67±3 years as opposed to 54±3 in the kin transfers cluster and 48±2 in the natural resources/labour cluster. The frequency of cluster occurrence did not differ significantly between villages (χ^2 test, $p>0.05$). These findings suggest that asset accumulation associated with age and wealth reduces the probability that households will revert to natural resources following hazard exposures.

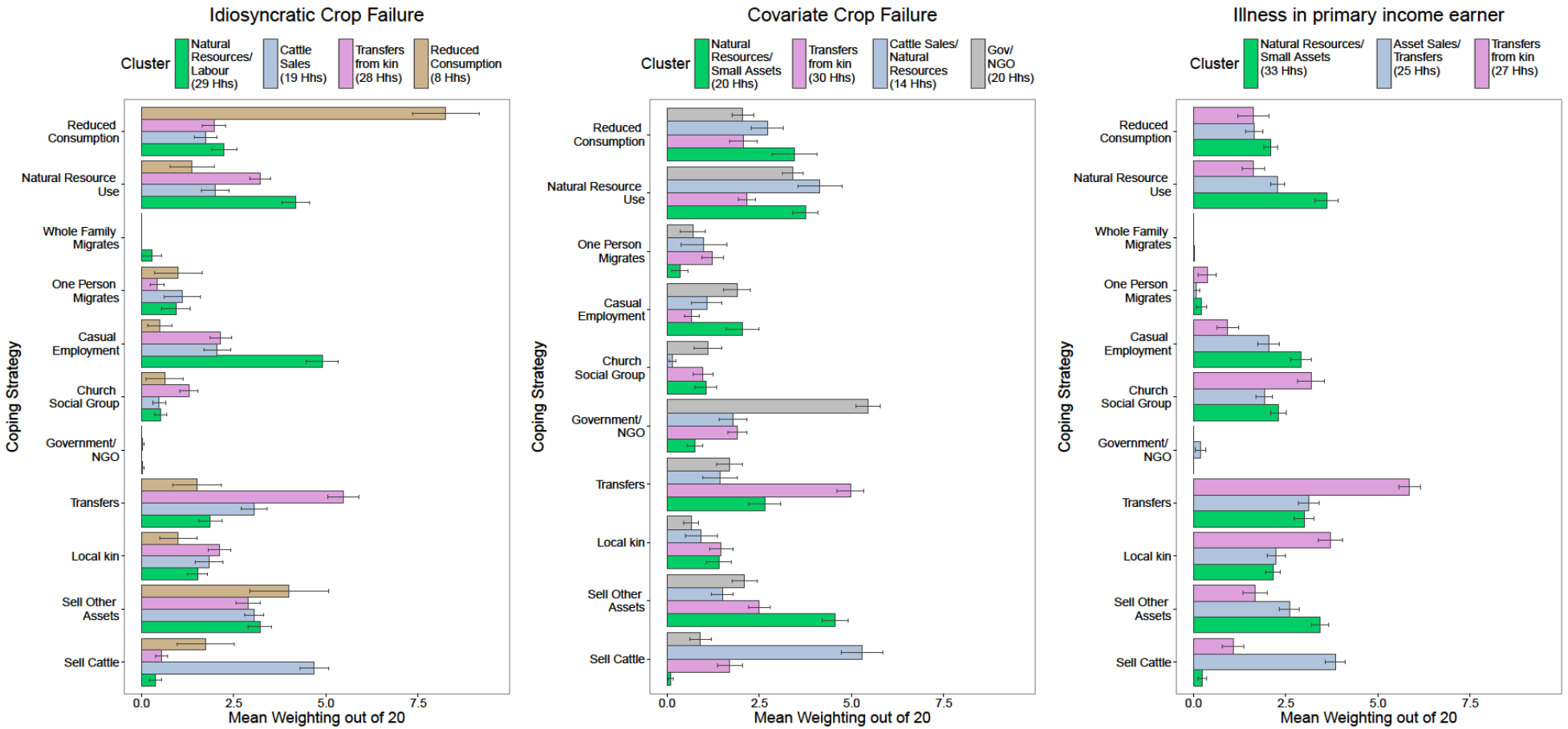

Figure 5.3 Mean score assigned to each strategy by households within each coping strategy cluster in response to three potential hazard exposure scenarios. Number of households = 84 in both crop failure scenarios and 85 in the illness scenario (one household gave incomplete responses to the crop failure scenarios and so was excluded from the analysis). Note that while the Jacqard's coefficient of similarity was more than 0.60 for all clusters in the idiosyncratic crop failure and illness scenarios, this coefficient was between 0.30 and 0.50 for clusters in the covariate crop failure scenario, indicating high within-cluster variation in strategy choice.

The reduced consumption cluster merits additional attention as households within this cluster did not differ significantly in terms of demographic or economic characteristics from other clusters. Here we take as case studies the two households who assigned the highest score to reduced consumption, Amai E and Mbuya G:

Case Study: The woman 'married' to a tokoloshi

Amai E is a single woman in her mid-40s. For a woman to never have been married at that age is unusual in Zimbabwe, and seems particularly strange given that Amai E lives in one of the best homesteads in her village, with high quality farmland and an irrigated garden. Her father was a good farmer and a very wealthy man, and her siblings now work in well-paying jobs in the city. The local rumour, however, is that her father's wealth was obtained by pledging Amai E to a tokoloshi, a spirit which ensures prosperity but which becomes malignant if not appeased (the reason that Amai E's siblings rarely return to the rural area). For this reason Amai E will never marry or have children, and it also means that she is ostracised by the networks of the village, in part due to fears of witchcraft and in part due to jealousy of the comparative wealth of the household. She is already provided for by her siblings in return for caring for the homestead, and so were the crops to fail her main option would be to cut back consumption and make do with what her family send.

Case Study: The landlord without tenants

Mbuya G is a widow in her early 70s. She returned to the village several years ago to care for her brother, but he has since passed away. Because she married away from the village and was not resident for many years, she lacks local social networks beyond being very active in an apostolic church congregation. Her daughters are all unemployed and unable to provide support in the form of remittances, and she suffers with high blood pressure and mobility problems which limit her ability to carry out physical work. The majority of her income was until recently derived from a rental property in Harare, but the poor economic situation and cash crisis mean that she is no longer able to get tenants. The consequence of these numerous overlapping exposures is that she perceives reducing consumption to be her only remaining coping strategy.

The four clusters of households in response to the covariate crop failure scenario were (1) households giving high weighting to **natural resources, small asset sales and reduced consumption**; (2) households giving high weight to **transfers from kin**; (3) households giving high weight to **cattle sales and natural resources**; and (4) households giving high weight to **government support**. Female-headed households were more likely to be in the natural resources/small asset sales and the kin transfers clusters, whereas the government/NGO cluster contained the greatest number of male headed households (16 male-headed as opposed to 3 female-headed). The heads of households in the kin transfers cluster were significantly older than in the natural resources/small assets or government supports clusters (ANOVA and Tukey HSD: $p<0.05$). Households in the natural resources/small asset sales cluster were significantly less wealthy than those in other clusters (ANOVA: $p<0.05$). Prevalence of clusters did not differ significantly between villages.

The combination of natural resources and asset sales in cluster 3 is interesting given the previously documented relationship in both this chapter and chapter 4 between low asset wealth and high environmental dependence. However, the reasoning provided by several households in this cluster referenced the importance of sequencing of coping strategies, as discussed by Corbett (1988). Respondents suggested that natural resources would be the initial strategy, with the hope that alternative options (such as support from government) might present themselves over time, but should these alternative options not materialise then they would adopt the last resort of selling cattle.

The three clusters in response to the illness of primary income earner scenario were (1) dependence on **natural resources and sales of small assets**, with reduced consumption and labour also high scoring; (2) households assigning high scores **to asset sales (including cattle) and kin transfers**; and (3) households assigning high scores to support from **transfers and local kin**, but not to asset sales. There was lower representation of female-headed households in the asset sales/kin transfers category, although this difference was not significant (χ^2 test, $p=0.07$). Heads of households in the natural resources/small assets cluster were significantly younger than those in other clusters (Tukey HSD: $p<0.05$). Households in the transfers and local kin cluster were significantly wealthier than those in the natural resources/small assets cluster (Tukey HSD: $p=0.04$).

It might be anticipated that the same households would fall within clusters prioritising similar strategies independent of exposure type, but instead we observe substantial intra-household variation in strategy choice dependent on the hazard exposure. One example of a household moving between clusters is Baba C:

Case study: The man who pays maintenance in cane rats

Baba C is in his early 40s and lives in a mountain-adjacent village with his wife and one young child. His current wife is his fourth; he was previously in a polygamous union with three wives, but all have since left him. He is obliged to pay maintenance for the children from this union, but with no cash income he draws instead on skills in hunting, catching ***nungu*** *(porcupine) and* ***tsenzi*** *(cane rats) from the Sabi River. He has high local bonding capital, with his widowed mother particularly important; the land that he farms and the cattle he uses to plough both belong to her, and he would rely upon her and his brothers following idiosyncratic crop failure or a health shock. In a covariate shock, however, he knows that she would not have anything to share, and so he would rely upon natural resources. He suggests that he can obtain and sell natural resources locally and that the police rarely catch him, and that the labour input for natural resources matches the benefit, whereas in* ***maricho*** *you work very hard in exchange for very little. Although he is not happy with his life, he would not migrate away from his current home. With no education, no skills beyond hunting, and no networks abroad, he argues that he would be equally as destitute in South Africa or Botswana as he is in Wedza.*

5.6 Conclusions

The evidence presented in this chapter suggests (1) that natural resources are important for coping with hazard exposures in rural Zimbabwe and (2) that simultaneous exposure to multiple hazards can increase the probability of relying on natural resources, but that this is strongly dependent on the capitals and powers available to each household.

Natural resources were used in coping strategies by households with a broad range of demographic and socioeconomic characteristics, but appeared to be of particular importance to asset-poor households with younger household heads. Such households are less likely to have accumulated the assets required to access alternative coping strategies, and are also less likely to be able to call on assistance from children or local kin. Natural resources appeared to be more important in the multiple covariate shock situation of 2008, while the case studies demonstrate that in some cases the interaction between covariate and idiosyncratic shocks can also necessitate increased natural resource dependence.

However, a critique commonly made by respondents is that environmental resources represent only an imperfect safety net. Sales of firewood and thatching grass were suggested by some as strategies, but the markets for these products are unpredictable. Wild fruits are reliable within their season, but can be used only for subsistence consumption rather than provision of cash income, while gold mining has reliable markets but leaves small scale miners

vulnerable to the power imbalances between concession owners and concession workers. While the advantage of natural resource collection is that it is limited only by labour capability, the case of the gold concessions shows that the power differential between resource owners and resource harvesters can increase vulnerability through the entrenchment of exploitative institutions.

The importance of relational power imbalances such as those described above is also demonstrated in the importance of social networks in determining coping strategy choice. Holdings of physical capital were undoubtedly important in this case study, particularly ownership of cattle, but in many of the case studies outlined above coping strategies were predicated almost entirely on network access (or lack thereof). Our findings suggest that access to networks in Wedza is heavily mediated by gender, and it is notable that households headed by widows were much less likely to be in the cluster affording high weight to government support than households headed by men. All customary leaders in the study area are men, and so male household heads have a higher probability of linking capital to institutions than female-headed households.

The differences between our results and the findings of Wunder et al. (2014) may be attributable to two factors. The first is that in this case study natural resources were more likely to be important when households were exposed to multiple severe interacting hazards. Given that Wunder et al. (2014) recorded hazard exposures experienced by study households over the course of only a year, there is a chance that they did not capture hazard exposures of sufficient severity to necessitate use of natural resources. The second is that the natural resource based coping strategies in this case study were highly location dependent, with all reported natural resources derived from within the 5km radius surrounding the village. Were suitable resources not available in the immediate area, there is a high chance that we would have observed different patterns of coping strategy choice (as discussed in Eriksen & Silva, 2009).

This dependence on local context raises the question of how land cover change will impact the coping strategies available to rural households. In this case study coping strategies would not inevitably be negatively impacted by overall loss of woodland cover, as respondents often highlighted dependence on specific fruit trees, and as long as these individual trees were maintained the coping strategy would remain viable. Instead we argue that the greatest threat to natural resource based coping strategies lies in changes in governance, and in the ability of more powerful actors within communities to restrict access to resources. We therefore conclude that maintenance of access to common property resources, particularly for

households which are poor, female-headed or lacking in social capital, is critical to ameliorating vulnerability to climate hazards in rural Zimbabwean communities.

5.7 Chapter 5 References

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6. Blind spots in ecosystem services literature: the neglected social values of southern African landscapes

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Abstract

Ecosystem services have gained prominence in recent years as a way of conceptualising and accounting for humanity's dependence on nature, but there has also been extensive theoretical criticism of both ethical and methodological issues in the design and application of this concept, especially with regards to what is or is not measured. However, few studies have actually used empirical case study data to explore how blind spots in the ecosystem services literature could impact the success and equity of land management. In this chapter we critically evaluate the fitness of current ecosystem services research in the miombo woodlands of southern Africa for informing conservation action outside protected areas. We firstly carry out a review of 356 peer-reviewed papers from the miombo ecoregion and identify six discourse clusters on landscape value, listed from high to low occurrence: extractive values, ecological integrity, justice and equity, regulatory function, socioecological resilience, and symbolic values. We then counterpoint these prevailing academic discourses with a detailed case study of values in a woodland-agricultural landscape in central Zimbabwe, identifying the range and spatial distributions of different values and their perceived importance amongst local respondents. High ecological value was spatially associated with high regulatory function and high symbolic value but only poorly with extractive use value, suggesting that symbolic and regulatory values may provide a valuable basis for engagement with rural communities. This contrasts with the prevailing emphasis in the literature: regulatory functions were considered in only 27% of reviewed papers and symbolic values in only 12%, compared to the 59% which considered extractive use value. We conclude that blind spots in present ecosystem service research are resulting in missed opportunities for conservation dialogues, and that neglect of social values risks perpetuating the disempowerment of rural African communities.

Author Contributions

The research questions and methods for this chapter were developed by RP, with input from CMR and IG. RP wrote the manuscript, with comments and improvements from DvdH and CMR. An edited version of this chapter is intended for submission to *Geoforum.*

6.1 Introduction

The popularity of the ecosystem services approach has increased exponentially in recent years (Fisher et al., 2009). Although initially mooted in the 1970s (Gomez-Baggethun et al., 2010; Baveye et al., 2013), the conceptualisation of the value of nature as the benefits and services provided by ecosystems to human populations has risen in prominence following publications such as Costanza et al. (1997), Daily (1997) and the Millennium Ecosystem Assessment (2005). Proponents of the ecosystem services approach argue for its utility as a method of identifying complementarities and conflicts between different services, and of facilitating the negotiation of trade-offs between these different value types in complex multifunctional landscapes (Rodriguez et al, 2006; Bennett et al., 2009; Raudsepp-Hearne et al., 2010). Others have highlighted the value of ecosystem services as a metaphor illustrating the value of nature to non-academic audiences (Costanza et al., 2014), and the potential for ecosystem services to act as a boundary object fostering co-operation between diverse academic and non-academic actors in addressing the 'wicked problems' of environmental management (Reyers et al., 2010; Abson et al., 2014; Davies et al., 2015).

However, the rising popularity of the ecosystem services approach has also triggered rising criticism (reviewed in detail by Schröter et al., 2014). A first critique points out the overrepresentation in ecosystem service literature of values which can be easily quantified, and particularly which can be valued in monetary terms (Gomez-Baggethun et al., 2010; Gomez-Baggethun & Ruiz-Perez, 2011), with the resulting neglect of cultural and social values (Chan et al., 2012; Daniel et al., 2012; Milcu et al., 2013; Satz et al., 2013) leading to calls for more plural approaches to valuation (Kenter et al., 2015; Pascual et al., 2017). Other authors have queried the place of intrinsic values within such a utilitarian framing of human-nature relationships (McCauley, 2006; Wallace, 2007), a debate mirroring that between the 'new' and 'old' schools of conservation science (Kareiva et al., 2007; Kareiva & Marvier, 2012; Soulé, 2013; Miller et al., 2014), and have cast doubt on whether it is possible to meaningfully compare services which cannot be valued in the same terms (Spash, 2008). Further criticism argues for greater scrutiny of the power asymmetries characterising ecosystem services research, both in terms of the normative concepts informing the development of the framework, and of the justice and equity of environmental research and management interventions drawing upon ecosystem service concepts (Kosoy & Corbera, 2010; Fairhead et al., 2012; Jax et al., 2013; Sikor, 2013). The ethics and methodologies of ecosystem services therefore continue to be highly contested. However, despite this intense academic debate, few studies have drawn on empirical data to critically assess how flaws in

present ecosystem service research could impact the outcome of environmental management in a real world, developing country context.

The miombo-mopane woodlands of southern Africa have been identified as a priority 'wilderness area' for biodiversity conservation (Mittermeier et al., 2003). Protected Areas have historically formed the cornerstone of conservation practice within the region, but there is increasing recognition that effective long-term conservation will require engagement with landscapes outside Protected Areas (Vandermeer & Perfecto, 2007; Gardner et al., 2007). Any conservation management intervention, however, must deal with the spatial and social complexity of African agrarian landscapes. Such complexity is partly ecological; woodland patches of varying structure are only one component in a matrix of fields, wetlands, grasslands and homesteads. Interacting with this land cover complexity are the diverse livelihoods of rural populations, which are directly linked to the land system through high dependence on environmental resources such as firewood and on small-scale agriculture (Cavendish, 2000; Kamanga et al., 2009) and through the 'profoundly ecological' (Schoffeleers, 1978 in Byers et al., 2001) nature of traditional African belief systems. Further dimensions of complexity are added by the conflicted histories of much of the region, with many communities having experienced civil unrest or having been displaced from hereditary lands by drivers such as large infrastructure projects (Cliggett et al., 2007), protected area creation (Neumann, 1998) or competition for natural resources (Spiegel, 2015). Equitable management therefore demands firstly understanding of the values and services derived from all parts of the landscape by stakeholder groups, and secondly the negotiation of trade-offs in a way sensitive to the local power asymmetries which privilege certain voices. This is one of the kinds of tasks for which the ecosystem services framework was purportedly developed.

Our objective in this chapter is to critically assess the adequacy of ecosystem services research in the miombo ecoregion for informing sustainable landscape management. To make this assessment we adopt a twofold approach, by (a) carrying out a semi-systematic review of miombo ecosystem services literature to identify dominant discourse 'clusters' on the key values of miombo landscapes and (b) using a detailed, mixed methods case study of a cultural landscape in rural Zimbabwe to explore the spatial distribution and locally perceived importance of the values emphasised in the literature. By so doing we seek to demonstrate that blind spots in present ecosystem service research are resulting in missed opportunities for conservation dialogues, and that neglect of social and spiritual values risks perpetuating the disempowerment of rural African communities.

6.2 Methods

6.2.1 Literature Review: Miombo value discourses in ecosystem services literature

A semi-systematic literature review was carried out to identify papers expressing an explicit or implicit position on the values to consider in managing savanna woodland landscapes. 314 papers were identified by searching in Google Scholar and Web of Knowledge for the following terms:

"Use Value" OR "Option Value" OR "Intrinsic Value" OR "Existence Value" OR Service OR Benefit OR Importance OR Provisioning OR Supporting Or Regulating OR Cultural
AND Miombo OR Woodland OR Landscape
AND Angola OR Malawi OR Mozambique OR Tanzania OR Zambia OR Zimbabwe

These search terms were informed by the Ecosystem Services Framework but also by the Total Economic Value Framework (discussed by Plottu & Plottu, 2007), the combination of the two enabling inclusion of a broader spectrum of literature associated with 'ecological economics' approaches to landscape values.

A search was then made of all papers citing or cited by the initial 314, and the paper set was then condensed to include only peer reviewed papers published since 2005 (the publication year of the MEA, arguably representing the point at which ecosystem services became a dominant paradigm). An additional search was made of the 25 journals which had contributed the most papers. The majority of collected studies focused on miombo landscapes, but literature was also included from other tree-dominated systems within the six countries of the miombo ecoregion, such as montane and mangrove forests in Tanzania and mopane woodlands in Mozambique.

The final literature review consisted of 356 papers, of which 177 made specific use of ecosystem services language (one or more of 'ecosystem services', 'environmental services' or 'landscape services'). Given the scale of the ecosystem service literature, we do not pretend to have captured every relevant paper. However, we believe that we have amassed a cross-section of sufficient depth and breadth to investigate the prevailing discourses.

An initial review of papers led to identification of six 'clusters' of discourses on values in miombo woodland landscapes. All papers were then read in full and coded by their alignment with these different discourse clusters. Papers were counted as aligning with a discourse if a significant part of the discursive or analytical space was focused on that topic – papers which made single sentence references to, for example, biodiversity, functioning,

resilience or justice but which did not engage critically with these themes were not counted as being aligned with that discourse. The majority of papers were coded as aligning with multiple discourses, as equal focus was placed on multiple value themes (the full coded list of papers can be found in Appendix 4).

6.2.2 Case Study: Landscape values around Wedza Mountain, Mashonaland East, Zimbabwe

The case study presented in this chapter was motivated by the diversity and complexity of environmental values described by local people in the six study villages around Wedza Mountain, and by a growing concern while resident in the study area that these values were not being adequately captured in the present literature. The majority of residents in Wedza are *Zesuru* Shona, with some in-migrants from other Shona-speaking areas of Zimbabwe and a smaller number from Malawi and Mozambique. Many residents combine elements of traditional Shona belief systems with the teachings of 'old' mission churches (Catholic, Methodist and Anglican) and 'new' churches (Seventh Day Adventist, Pentecostal and Apostolic; typology follows Bourdillon, 1987). The ways in which Wedza residents perceive the landscape, and the influence of this perception on patterns of natural resource use, is therefore strongly influenced by individual spiritual beliefs and by the livelihood strategies and priorities of rural households.

This case study draws upon the data sets previously described in this thesis, specifically on the structure and composition of woodland in the study area (described in Chapter 3), the importance of different land cover types in environmental income provision (Chapter 4) and the role of natural resources in coping with shocks (Chapter 5). Further qualitative data in this paper is derived from 22 semi-structured interviews with adherents of different churches (purposively sampled from amongst questionnaire survey respondents) carried out, translated and transcribed by a local research assistant, from six focus groups with older village residents carried out in February 2015, and from eighteen results feedback workshops carried out in April/May 2017. Additional information is derived from participant observation and from field notes on numerous informal conversations had during almost a year of residence in the study area. All respondents are anonymised, with the respectful Shona titles Sabhuku (village head), Sekuru (grandfather), Mbuya (grandmother), Amai (mother) and Baba (father) used instead to indicate the gender and approximate age of respondents.

6.3 Results

6.3.1 Miombo value discourses in ecosystem services literature

Six 'clusters' of discourses were identified in the miombo ecosystem services literature (**Table 6.1**): ecological integrity, regulatory function, extractive uses, socioecological resilience, justice and equity, and symbolic values. The most common discourse cluster was that on extractive values of landscapes, which were a focus of analysis in 209 of the collated papers (59% of the full paper set; **Figure 6.1**. Sub-themes in this cluster included the importance of environmental income in household livelihood portfolios (e.g. Kamanga et al., 2007; Njana et al., 2013; Kalaba et al., 2013), the importance of small scale agriculture and particularly agroforestry (e.g. Sileshi et al., 2007; Quinion et al., 2010) and the impacts of large scale agribusiness, including plantations (Bleyer et al., 2016; Olwig et al., 2017) and biofuels (German et al., 2011; Thondhlana, 2015). The second most common discourse was that on ecological integrity, represented in 41% of papers and focusing on the value of biodiversity (e.g. Burgess et al., 2006; Jew et al., 2015) and on the consequences of fragmentation for biodiversity (Hall et al., 2014). The relationship between biodiversity and ecosystem services is highly complex (Mace et al., 2012), but characteristic of this discourse cluster was that biodiversity and 'intact' woodlands were considered to have value in their own right, rather than due to being a factor underpinning other services.

Discourses centred on justice and equity and on regulatory function received intermediate attention. Justice and equity discourses were represented in 36% of papers, with the greater part of this literature focused on equity issues in present governance such as benefit sharing (e.g. Topp-Jorgensen et al., 2005; Nielsen & Treue, 2012; German et al., 2014). Also within this discourse were considerations of the varying 'environmentalisms' in the miombo region (Brockington, 2006), the socio-political dynamics which legitimise different landscape knowledges (Scheba & Mustalahti, 2015; Koch, 2016), and analysis of how constructions of landscapes as spaces of resistance shapes environmental values (Beymer-Farris & Bassett, 2012; Bluwstein & Lund, 2016; Chirozva et al., 2017). Regulatory functions were addressed in 27% of papers, highlighting the role of landscape structure in influencing carbon storage (Williams et al., 2008; Woollen et al., 2012; Willcock et al., 2016), nutrient cycling (Mujuru et al., 2014; Guedes et al., 2016) and hydrological cycling (Enfors & Gordon, 2007).

Table 6.1 Prevailing discourse clusters in ecosystem services related literature on the priority values in miombo woodland landscapes, identified through review of 356 peer-reviewed papers.

Discourse Cluster	Sub-Themes	Example publications	Most Common Journals
Ecological Integrity	Biodiversity conservation	Burgess et al. (2006); Jew et al. (2015; 2016)	Forest Ecology and Management (10 papers); International Forestry Review (10 papers); African Journal of Ecology (10 papers)
	Intactness and fragmentation of woodlands	Hall et al. (2014); Ojoyi et al. (2015)	
Regulatory functions	Carbon cycling and storage	Williams et al. (2008); WIllcock et al. (2016)	Ecology and Society (7 papers); Forest Ecology and Management (7 papers); Forest Policy and Economics (5 papers)
	Nutrient cycling and soil fertility	Mujuru et al. (2014) Ojoyi et al. (2017)	
	Water cycling	Enfors & Gordon (2007)	
	Erosion prevention	Winowiecki et al. (2016)	
Extractive Values	Small- and large-scale agriculture, including agroforestry	Quinion et al. (2010); Olwig et al. (2017)	International Forestry Review (15 papers); Ecological Economics (11 papers); Forest Policy and Economics (10 papers); Forests, Trees and Livelihoods (10 papers)
	Environmental resources in rural livelihoods	Kamanga et al. (2007); Kalaba et al. (2013)	
	Poverty reduction and food security	Powell et al. (2011); Bandyopadhyay et al. (2011)	
Socio-ecological resilience	Regeneration of disturbed woodlands	McNicol et al. (2015); Syampungani et al. (2016)	Agroforestry systems; Environment, Development and Sustainability; Environmental Science and Policy; Forest Ecology and Management: Philosophical Transactions of the Royal Society B; World Development (all contributing 3 papers)
	Household shock-coping strategies	Eriksen et al. (2005) ; Fisher et al. (2010)	
	Climate change adaptation	Girvetz et al. (2017); Mubaya & Mafongoya (2016)	
Justice and Equity	Landscapes as spaces of resistance	Haller et al. (2008); Bluwstein & Lund (2016)	World Development (9 papers); International Forestry Review (8 papers); Forest Policy and Economics (8 papers)
	Environmental justice in landscape governance	Beymer-Farris & Bassett (2012); Nielsen & Treue (2012)	
Symbolism and spiritualism	Religious and spiritual values	Sheridan (2009)	Ecology and Society (4 papers); Journal of Eastern African Studies (3 papers); Journal of Historical Geography (3 papers)
	Sense of place and belonging	Ekblom et al. (2017); Fontein (2011)	
	Wilderness imaginaries of African landscapes	Hughes (2006)	

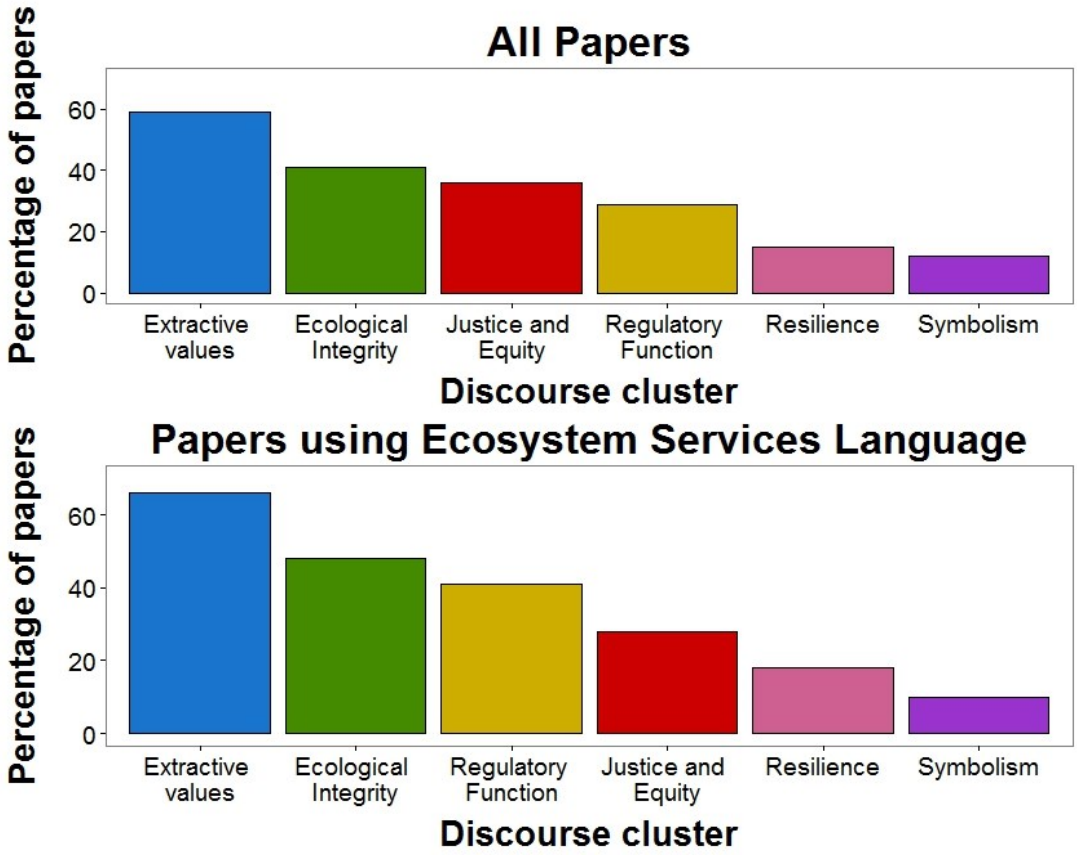

Figure 6.1 The alignment of surveyed peer-reviewed literature with six discourse clusters (a) in full literature review (n=356) and (b) within papers explicitly using ecosystem services language such as 'ecosystem services', 'environmental services' or 'landscape services (n=177).

The two discourse clusters represented in the least number of papers were socio-ecological resilience (15% of papers) and landscape symbolism (12% of papers). Resilience sub-themes focused on the regeneration potential of woodlands following disturbance (McNicol et al., 2015; Syampungani et al., 2016) and on household shock coping strategies, particularly those dependent on environmental resources (Eriksen et al., 2005; Fisher et al., 2010), these microscale sub-themes nested within broader issues of climate change adaptation (Mubaya & Mafongoya, 2016; Girvetz et al., 2017) and HIV/AIDS impacts (Timko, 2013). Landscape symbolism discourses include studies of the different imaginaries of southern African landscapes, both western wilderness imaginaries (Hughes, 2006) and the imaginaries resulting from traditional African belief systems (Sheridan, 2009). Symbolic values also include the heritage values of ancestral landscapes, and the role of locations such as burial sites in fostering senses of place and belonging (McGregor, 2005; Fontein, 2011; Ekblom et al., 2017).

In the subset of 177 papers making unequivocal use of ecosystem services language, the most common alignment was again with the extractive values discourse (66% of papers; **Figure 6.1**), and the second most common with the ecological integrity discourse (48% of papers). The proportion of papers considering regulatory functions of landscapes increased to 41%, whereas the proportion considering issues of equity and justice decreased to 28%. The proportion of papers considering issues of resilience and symbolism remained approximately the same, at 18% and 10% of papers respectively.

Our analysis therefore suggests that the dominant conversations in current miombo ecosystem services literature focus on extractive value and ecological integrity, with comparatively little detailed analysis of socioecological resilience or symbolic landscape values.

6.3.2 Landscape values around Wedza Mountain, Zimbabwe

6.3.2.1 Ecological Integrity

The sub-themes on ecological integrity identified in the literature review focused on biodiversity and intactness, with intactness being assessed through indicators such as habitat contiguousness and woody biomass. In the case study area, tree species composition and diversity (analysed through clustering analysis and the Shannon diversity index) did not differ significantly between mountain woodland and more heavily disturbed lowland woodland, perhaps because much of the remaining woodland in lowland villages is on kopjes, riparian areas and termitaria, which are suggested to act as islands and corridors of diversity in savanna matrices (Joseph et al., 2011). In terms of intactness, however, mountain woodland clearly has higher ecological value, being the only unbroken stretch of woodland in the study area (**Figure 6.2a**) and having a mean biomass of 44.2 t DM ha^{-1}, compared to only 15.1 t DM ha^{-1} in lowland woodlands (**Figure 6.2b**).Although not quantified in this study, discussions with local residents on hunting and crop raiding indicate that the mountain woodland supports substantial mammal diversity not found in the lowlands, including baboons, hyena, bushbaby, monkeys and pangolin. From an ecological integrity perspective, therefore, the mountain woodland would be considered to have the greatest value.

6.3.2.2 Regulatory function

Literature sub-themes on regulatory functions focused on carbon storage, nutrient cycling, soil protection and hydrological cycling. In the case study landscape, the mountain woodland has

the highest value in terms of carbon storage, storing on average 20.8 t C ha^{-1} (these data refer only to aboveground carbon stored in trees, even though significant carbon can also be stored in miombo soils; Ryan et al., 2011).

However, while carbon storage may have high policy relevance, local communities identified different priority regulating services. First amongst these was nutrient cycling. Poor soil fertility is one of the major constraints on achieving food security in southern Africa (Sanchez, 2002), and 63% of households in the income questionnaire reported using environmentally derived fertilisers such as leaf litter and termitaria soil to ameliorate poor soil quality.

Respondents also highlighted the regulatory role of trees in bringing rain – a function attributed to forests in many African traditional ecological systems (Fairhead & Leach, 1996; Sheridan, 2009; Zulu, 2013). Specific trees were also identified as important in regulating lightning. Fear of lightning is common in the study area, and protective measures include preserving large trees such as **muonde** (*Ficus* sp.) near households and holding apostolic church congregations close to **mukonde** (*Euphorbia ingens*). Local knowledge systems therefore recognise a wide range of regulatory functions of natural systems, even if the importance allotted to particular functions differs from that in academic discourse.

6.3.2.3 Extractive uses and socioecological resilience

Extractive uses were important in rural livelihoods, with on average 31% of net household income derived from environmental resources such as firewood, 12 % from livestock and livestock products, 10% from garden horticulture crops, and 3% from field crops such as maize. Both mountain and lowland woodlands (including woodland on kopjes, termitaria, and riparian areas) had high extractive use value in terms of environmental income (**Figures 6.2c and 6.2d**). Resources such as firewood, construction poles and leaf litter were predominantly derived from woodland systems, whereas thorn tree fencing and wild-sourced foods were mainly obtained from wetlands and agricultural land.

Environmental resources were also perceived as being important for coping with shocks, with respondents focusing on particular locations in the landscape (**Figure 6.2e**) such as small-scale mining concessions on Wedza Mountain and specific **muhacha** (*Parinari curatellifolia*) trees which were important food sources during the 2008 drought and economic crisis. Further important shock coping mechanisms were growth of horticulture crops, and sales of small livestock such as goats and chickens.

6.3.2.4 Justice and equity

One literature review sub-theme on justice and equity highlights the importance of past conflict in shaping present values. The environmental values of older Wedza residents were influenced by the second *Chimurenga* (Rhodesian Bush War), when Wedza Mountain was a site of conflict. One elder recalled living near the mountain during that time:

'You couldn't let cattle escape up the mountain, because if the comrades [guerrilla forces] caught you they would think you were a government spy, and if the government soldiers caught you they would think you were helping the comrades.'

Sekuru M, village history interview, April 2014

More recent conflict also structures approaches to the land. The Wedza area includes many previously white-owned commercial farms, most of which were appropriated during fast-track land reform in the 2000s. The recentness of the white landowners' departure creates a palpable awareness of absence; their economic and social power left an indelible stamp on Wedza landscapes and livelihoods, but there is also a space where the people themselves used to be. It might be anticipated that residents of Wedza Communal area would celebrate the redistribution of land, but responses are more ambivalent. There is an awareness that colonial-style land designations place residents in a precarious position – Wedza Mountain is a reserved area, meaning that villages could be relocated if the area were designated a game reserve or in order to extract minerals from the mountain, and examples such as the displacement of communities from Marange diamond fields loom large in local consciousness. On the other hand, white-owned farms and businesses were a major source of employment, and the vacuum left by the loss of opportunity is sorely felt (particularly by those who took pride in professional employment and see farming as a step back, and by migrants who find themselves adrift in villages where they have no ancestral links).

The second sub-theme considers equity in present governance. Strong and equitable social networks were viewed by focus groups as a defining characteristic of a good home area; but despite the perceived importance of co-operation and equity, respondents reported that the current economic situation was causing a breakdown of trust within communities. This may have been at the forefront of respondents' minds due to events just before the 2017 workshops (a theft from a mining company and an attack on a woman walking through the nearby resettlement area), but appears to stretch more widely than a few isolated incidents. Respondents railed against the endemic corruption of national and local institutions, particularly in the context of the distribution of aid following bad harvests:

'The government take their share, at Wedza they take their share, the Sabhuku takes his share, and you end up left with just a bucket [of maize]… if they want taxes they go door to door, if they want money for independence [celebrations] they go door to door, but they never go door to door with aid.'

Baba P, feedback workshop, April 2017

We have not attempted to express values of justice and equity in spatial terms; certain locations may have particular historic associations, but more appropriate would be to map the dynamics of power in the social and institutional networks influencing resource use patterns. However, the vehemence with which respondents discussed themes of trust and justice suggests that any attempt to interpret present environmental values without attention to historic context or local political economy is fated to result in only incomplete understanding.

6.3.2.5 Symbolic Values

Traditional beliefs have been suggested to have significant impacts on Zimbabwean landscape structure, for example through protection of sacred groves. (Byers et al., 2001). However, respondents suggest that the increasing dominance of Christian beliefs is weakening traditional institutions. Respondents identified a dichotomy between 'traditional' and 'modern', often with the inference that modernity was better than tradition – one Sabhuku spoke proudly about running a 'modern' village with no space for beliefs such as witchcraft. A n'anga (traditional healer and spirit medium) observed how the rainmaking ceremony had declined in importance during her lifetime:

'We used to brew beer and leave it under the tree for seven days, it was sacred and everyone left, you just had a temporary shelter. Now they brew beer at the village head's…You need to give everything to the ancestors to show love and respect for them, but it's difficult to stop people taking when it's in someone's homestead.'

Mbuya N, household survey, October 2015

A superficial reading would suggest that traditional beliefs are disappearing. However, participant observation revealed a more complex story. Respondents pointed out river pools and described relatives who had been kidnapped by *njuzu* (water spirits; **Figure 6.2f**), while others reported encounters with guardian snakes at springs after they had broken local taboos, for example by attempting to collect water in a fire-blackened pot. Multiple households were reported to have *tokoloshi*, spirits which initially bring luck but which if not appeased will start to bring misfortune and even death. We therefore suggest that, while traditional practice may

not be perpetuated at the more 'formal' institutional level, rural residents have vivid landscape imaginaries drawing upon diverse blends of 'traditional' and 'modern' symbolism.

Wedza Mountain presents an interesting case study in this regard. The area surrounding the mountain has been inhabited for many centuries (Mackenzie, 1975), and despite contentions by local people that the sacred values of the mountain are no longer respected, informal codes of conduct still persist. Thus when three young men were killed in a mine shaft collapse in 2012, one local narrative was that this was due to the boys smoking dagga and playing radios on the mountain, behaviours disrespectful to the ancestors. The mountain also illustrates the perceived importance amongst some families of burial sites (Fontein, 2011). One family, experiencing hardship at home, drove to Wedza Mountain from Johannesburg in order to honour an ancestor believed to be buried in a mountainside cave.

These blends of church and tradition result in significant conflict, both within and between people. An example of an internal contradiction is the use of medicinal plants by Pentecostal churchgoers. Medicinal plants are banned by several churches, and yet respondents reported using them 'mischievously', or justified use of medicines like mango leaves as being 'modern' medicines because they were derived from 'modern' trees. Conflicts between people can be resource based, such as not respecting traditional taboos on fruit tree cutting, or impact social relationships – one apostolic churchgoer refused to attend village functions including traditional practices, and was subsequently excluded by the traditionalist village head from receiving donor aid. These rural landscapes imaginaries therefore vary considerably, both between people and over time, and represent fertile ground for a study – a year of fieldwork illuminated only a small proportion of their complexity.

6.3.2.6 Synergies in value distributions

Figures 6.2a to 6.2f show the spatial distributions of a number of values around Wedza Mountain. There are substantial spatial overlaps between ecological integrity and regulating function (**Figure 6.2b**). Carbon storage is directly associated with biomass, but (although not mapped) respondents also argued for the value of mountain woodland for nutrient cycling, bringing rain and reducing soil erosion. Although our data do not permit us to map every site of symbolic importance within the Wedza landscape (**Figure 6.3f**), the cultural significance of the mountain, perceived importance of pools and springs, and the common use of kopjes and termitaria as burial sites also suggests that there are spatial linkages between symbolic values and ecological integrity.

We also observe some interesting differences in the spatial distribution of value, most notably between ecological integrity and extractive use value. Although there initially appear to be spatial overlaps between total extractive value and ecological integrity in some villages (**Figure 6.2c**), this is largely because many households in these villages depend on small-scale gold mines on the mountain. When considering only those non-cultivated environmental resources directly dependent on the ecosystem (i.e. excluding crops and mineral resources), there is little spatial relationship between biomass and use value (**Figure 6.2d**). Even in villages with access to high biomass mountain woodland, many households preferentially collect resources from lower biomass lowland woodland, suggesting that the resources necessary for livelihoods can be derived even from systems which are heavily degraded in ecological terms (see Chapter 4 for details).

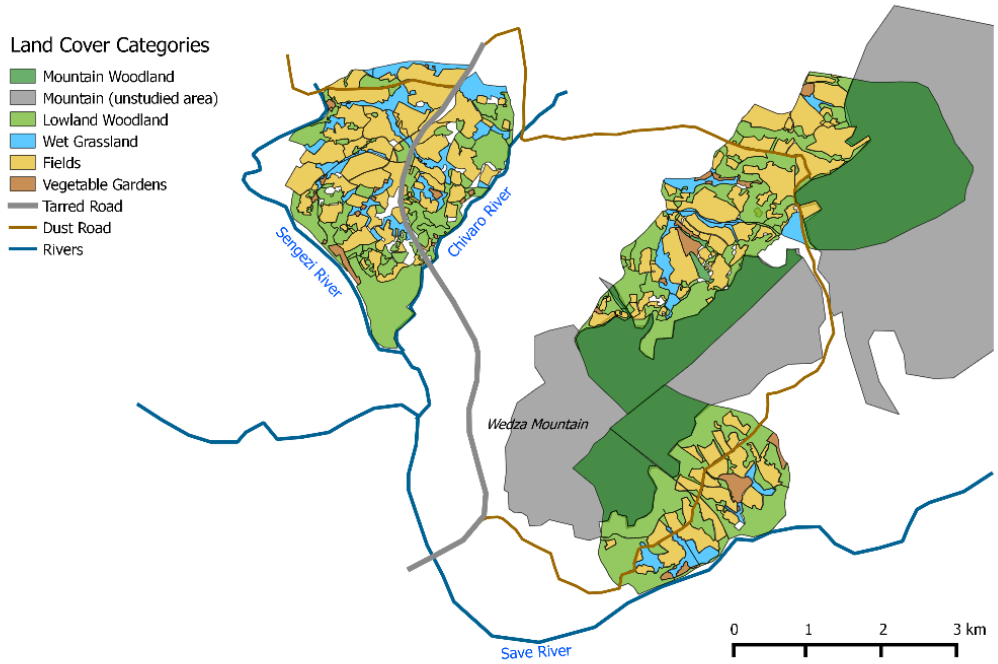

Figure 6.2a Land cover map of three pairs of adjacent study villages on and around Wedza Mountain, Mashonaland East, Zimbabwe. White areas indicate villages not included in the study.

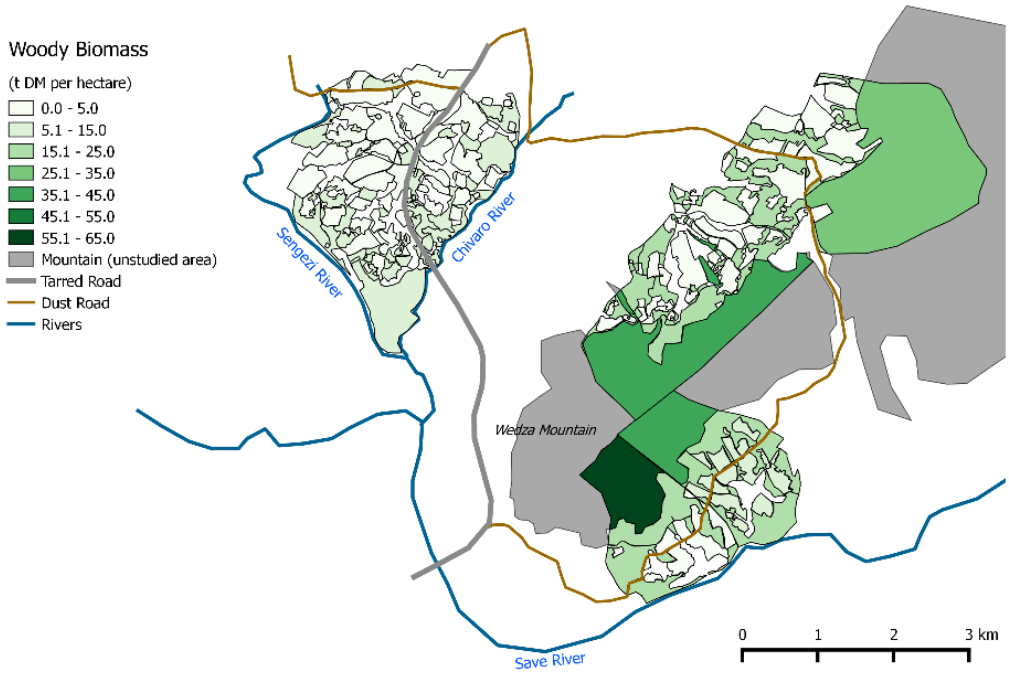

Figure 6.2b: Distribution of aboveground woody biomass in six villages on and around Wedza Mountain, Zimbabwe, calculated from woodland survey plots established in mountain woodland, lowland woodland and agricultural land. No survey plots were established in wet grasslands, so these are left blank.

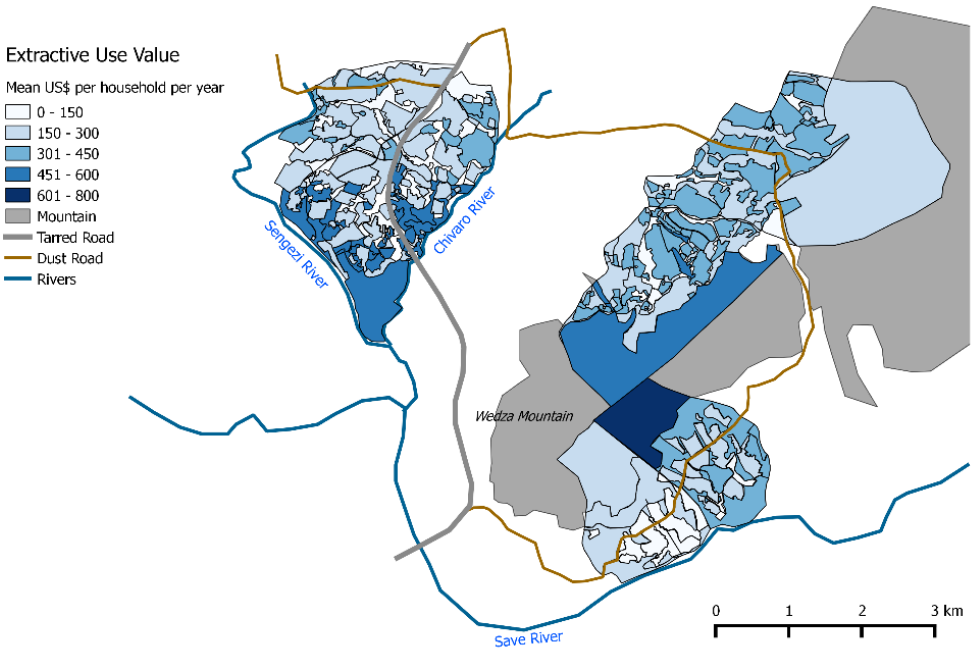

Figure 6.2c: Mean extractive use value (expressed in US$ household^{-1} yr^{-1}) of different land cover types in six villages on and around Wedza Mountain, Zimbabwe. Total extractive use value includes field and horticulture crops, mineral resources such as gold, and non-cultivated environmental resources such as firewood, construction materials and wild foods.

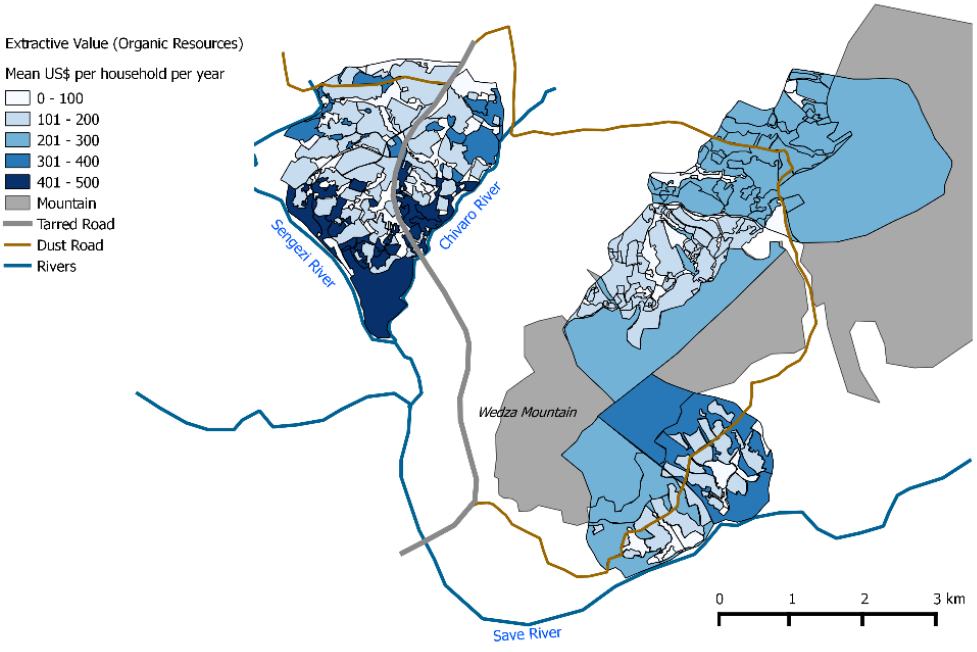

Figure 6.2d: Mean extractive use value (US$ household^{-1} yr^{-1}) of different land cover types in six villages on and around Wedza Mountain, Zimbabwe, including only those organic environmental resources such as firewood, construction materials, wild foods and leaf litter where production is directly related to ecosystem structure.

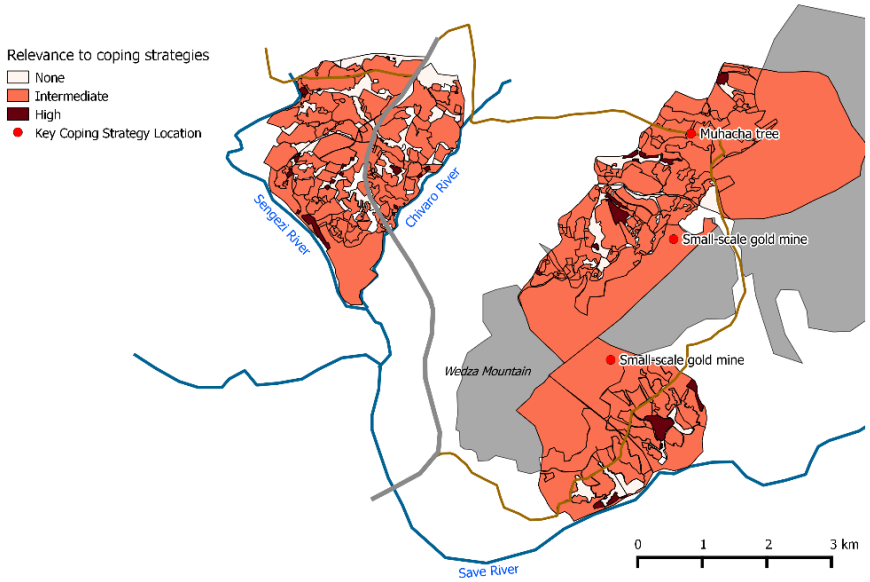

Figure 6.2e: Areas cited as most important for coping with shocks by residents of six villages on and around Wedza Mountain, Zimbabwe. Sales of firewood (from woodlands) and thatching grass (from fields) were stated as important coping strategies by some respondents, but are perceived as being risky strategies due to unreliable markets. The most widely mentioned coping strategies were vegetable gardening, small-scale gold mining, and consumption of wild fruits, particularly from large **muhacha** (Parinari curatellifolia) trees.

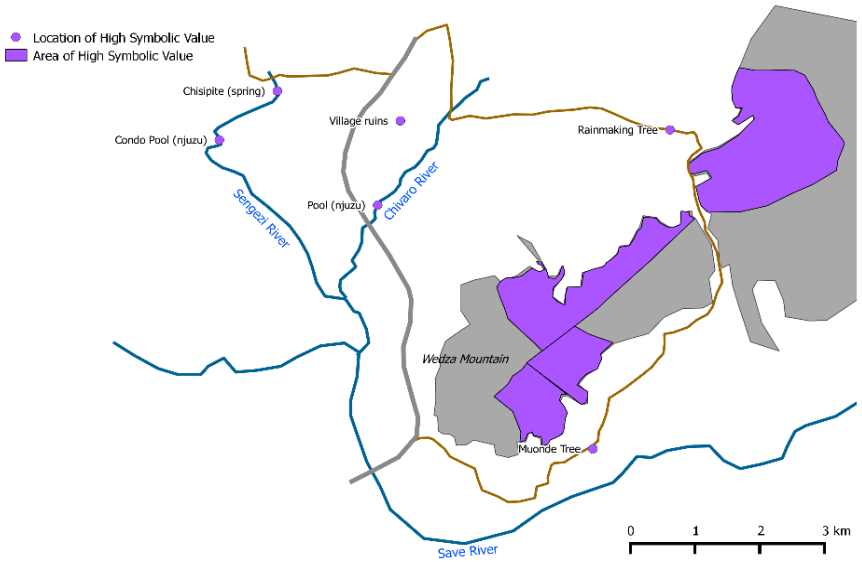

Figure 6.2f: Selected sites of symbolic value on and around Wedza Mountain, Zimbabwe. The perspective-dependent and diffuse nature of symbolic values makes mapping challenging, but we highlight the following locations: **muhacha** (Parinari curatellifolia) and **muonde** (Ficus sp.) trees used for rainmaking ceremonies and village meetings; pools and springs believed to hold **njuzu** and other spirits; ruins of earlier villages which were home to ancestors of present village heads. The mountain is believed by some to host ancestral spirits, and is also used for apostolic church congregations. Sites of importance to individual families such as burial sites are not marked.

6.4 Discussion

6.4.1 Prevalence of literature review discourses

The review of miombo ecosystem services literature showed greatest prevalence of discourses on extractive uses and ecological integrity, and a very low level of discussion of symbolic and spiritual landscape values. Such a pattern is not overly surprising, concurring with the underrepresentation of cultural values in the wider ecosystem services literature (Daniel et al., 2012; Milcu et al., 2013) and reflecting challenges in defining and measuring such values (Chan et al., 2012). This review suggests that, while ecosystem services can be understood as a boundary object (Abson et al., 2014) between ecology and economics, links to other (often more qualitative) social sciences remain tenuous.

Perhaps more surprising is the low representation of socioecological resilience discourses in the published literature. However, this may be an artefact of coding categories. While many publications contained themes which could be linked to resilience, such as food security, biodiversity and ecosystem function, the definition of resilience is highly contested (Carpenter et al., 2001) and the linkages between ecological structure and resilience highly complex (Oliver et al., 2015), and we have therefore only included papers in this category which explicitly discuss resilience and vulnerability, rather than those where the reader would have to infer a resilience link using their own preferred definition of resilience.

6.4.2 Spatial overlaps in landscape values

Many landscape management interventions now seek to achieve both conservation and development objectives, adopting the much critiqued ‘win win’ or ‘pro-poor’ approaches to conservation (Davies et al., 2013). However, our findings indicate only a poor crossover between extractive use values and ecological integrity (we assume here that ecological integrity is the goal of conservation, although recognising that this assumption could be contested). This finding is not wholly unexpected – resource use is not informed purely by resource availability, but also by constraints on access (Ribot & Peluso, 2003). While environmental income studies in the miombo ecoregion often conflate ‘environmental income’ with ‘forest income’ (Ryan et al., 2016), Chapter 4 of this thesis demonstrates why this conflation is not supported in the miombo woodland context. We recognise the importance of compensating rural communities for the direct and opportunity costs of restricting access to woodlands, but engaging local communities with conservation requires a more inclusive approach that recognises the full range of values locally held and felt.

A more promising basis for dialogue may be the regulating functions of ecologically valuable systems. Regulating functions were strongly represented in the literature which used ecosystem services language, being discussed in over 40% of papers, and overlapped strongly in spatial terms with ecological integrity. These functions were also perceived as highly valuable by focus groups. However, much of the literature focus is on carbon, and so a broader approach would be required including functions prized by rural communities, such as rainfall moderation and soil nutrient cycling.

Our results also hint at substantial overlap between symbolic values and ecological integrity. While recognising that symbolic value is entirely perspective dependent, the narratives of symbolic value we recorded while in the field were sufficiently consistent for us to suggest that this is an area meriting further study. The idea that traditional values could contribute to sustainable management in Africa is not new (Infield, 2001; Byers et al., 2001; Mgumia & Oba, 2003; Shackleton & Gumbo, 2010), and yet the potential roles of factors such as place attachment, sense of belonging, aesthetic values and symbolic sites in aiding conservation engagement have been little explored in a southern African context.

6.4.3 Equity impacts of ecosystem service blind spots

Even if local landscape imaginaries conflict with conservation goals, it is still ethically impossible to exclude them from landscape management debates. The wilderness idyll was, and continues to be, a powerful motivating force behind nature conservation in southern Africa, and the ethical and conceptual issues caused by failing to engage with alternative landscape readings are well documented (see e.g. Fairhead & Leach, 1996; Neumann, 1998). We question the extent to which it is possible to negotiate equitable landscape management strategies when the worldviews of a primary stakeholder group – those who live within the landscape – are not well represented in the literature, and suggest that, without greater engagement with symbolic values or improved understanding of the management priorities of rural communities, ecosystem services research risks perpetuating the existing power imbalances which characterise nature conservation in southern Africa (Garland, 2008) and furthering the disempowerment of rural communities. This is not a criticism of ecosystem services as a general concept, nor of much existing ecosystem services scholarship. Instead we suggest a need for greater balance: for greater recognition that choices made in the application of value frameworks are not themselves value-neutral, and that lack of due attention to historical and political context could result in negative ethical outcomes in real world conservation actions.

6.5 Conclusions

Our findings indicate significant spatial associations between ecological integrity, regulating function and symbolic value, but also suggest that blind spots in the miombo ecosystem service literature and an over-emphasis on extractive use value are resulting in missed opportunities for engaging rural communities with conservation action. Addressing the neglect of the social values of ecosystems, particularly in terms of improving understanding of rural African landscape imaginaries and of building on the themes of justice and trust which resonate so powerfully with local communities, could be critical in informing the development of equitable and sustainable conservation management plans in southern African savanna mosaics.

6.6 Chapter 6 References

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7. Ethical and practical perspectives on collaboration with local assistants in interdisciplinary field research

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Abstract

Skilled research assistants have a key role in determining the success of field research projects in developing countries, but to date there has been little discussion in the literature of their influence on research process and outcomes. In this chapter we present a case study of the complexities of researcher-research assistant-respondent relationships, written as a collaboration between a PhD student and two experienced research assistants, and consider how these complexities impacted the fieldwork component of a socioecological research project in rural Zimbabwe. We first discuss the influence of personal characteristics and study location on the power asymmetries in these relationships and then suggest how such asymmetries can be mediated to reduce exploitative behaviour. We highlight the particular pressures associated with an interdisciplinary research context, specifically the shifting orientations of fieldwork actors due to the multiple roles adopted during fieldwork, the challenges of communicating complex interdisciplinary research to gain informed consent from respondents, and the difficulties of adapting to the methods and approaches of new disciplines. We finally consider the ethical question of research ownership claims in the context of mixed methods field research.

Author Contributions

The content of this paper was developed in discussion between RP, NS and CS. RP wrote drafts of the manuscript, which were then checked and edited twice by NS and CS. An edited version of this chapter is intended for submission as an insight article to *Ecology and Society*.

7.1 Introduction

Skilled local assistants are often integral to the success of field research in developing countries. However, it is rare for a researcher to write about the role of their research assistant(s) in data collection, and rarer still for a researcher to write in collaboration *with* a local assistant. While recent years have seen increasing analysis of the role of citizen science (Silvertown, 2009) and paraecologists (local researchers with on-the-job rather than formal training: Janzen, 2004; Schmiedel et al., 2016) in ecological research, this focus has not been extended to the working relationships between researchers and research assistants using mixed methods to explore human-environment interactions. To quote Molony and Hammett (2007; 293):

'*The research assistant is the unspoken rapporteur in fieldwork, absent in pre-fieldwork training, and missing in post-fieldwork writing or viva voce.'*

The invisibility of research assistants in current literature is peculiar given their importance in determining research outcomes. While numerous authors have considered how the characteristics and relative positioning of researcher and respondents shape the quality and interpretation of qualitative data (e.g. Davies & Harré, 1990; Padfield & Procter, 1996; De Andrade, 2000; Haraway, 2003; among many others), this often represents only one aspect of a trio of complex relationships: between researcher and research assistant, research assistant and respondents, and researcher and respondents both directly and via the research assistant as intermediary. This trio of relationships introduces a 'triple subjectivity' (Temple & Edwards, 2002) to data collection, and it is therefore necessary to consider the factors influencing the nature of these relationships and thus the reliability of research conclusions.

Further complexity is introduced to these relationships by the interdisciplinary nature of socioecological research. Many high priority research areas such as climate change adaptation demand cross-discipline collaboration and integration (Ewel, 2001; Nielsen-Pincus et al., 2007), and there is increasing emphasis on interdisciplinary training for postgraduate research students (Golde & Gallagher, 1999; Moslemi et al., 2009). However, interdisciplinary research presents diverse challenges, both theoretical (such as integrating disciplines with conflicting epistemologies and varying methods) and practical (communicating with disciplinary specialists and identifying publication outlets). Although there has been some discussion of the challenges of formulating research questions (Graybill et al., 2006) and the difficulty of finding an academic 'home' within an interdisciplinary research network (Romolini et al., 2013; Record et al., 2016), there has been little exploration of the logistical

and ethical aspects of interdisciplinary fieldwork, or of how the shifting roles and orientations of researcher, research assistants and respondents impact the resultant data set.

Written in collaboration between a PhD researcher and two experienced field research assistants, the objective of this chapter is to provide a critical reflection on the case study presented in this thesis. We first consider the influence of personal characteristics and local contexts in shaping the dynamics of interactions between researcher, research assistants and respondents, before examining the particular pressures placed on these relationships by an interdisciplinary research context.

7.2 The writing process for this chapter

The objective of the research project presented in this thesis was to explore links between miombo woodland change and rural livelihoods around Wedza Mountain, Zimbabwe. The research was organised around four core themes: 1) the spatial patterns of land use intensity and provisioning ecosystem service availability in an African smallholder farming landscape; (2) the importance of woodlands in facilitating livelihood diversification and reducing inequality; (3) the use of woodland resources for coping with multiple interacting hazard exposures; and (4) the broader range of environmental values shaping rural livelihood decisions and their representation in published literature. Fieldwork therefore involved use of a wide range of methods, including woodland surveys, household questionnaire surveys, focus groups, scenario exercises, key informant interviews, and participant observation.

The main research assistant on this project was Nyaradzo Shayanewako, hereafter termed Amai Simba. Amai Simba first began training as a research assistant in 1996 and has since worked on a range of quantitative and qualitative social science research projects. Fieldwork was carried out in Amai Simba's home village and nearby villages in Wedza Communal Area, and so Rose (the PhD student behind this research project) stayed with Amai Simba and her husband Charles Shayanewako (Baba Simba) in their family home for a total of almost a year between October 2013 and May 2017. Baba Simba is the deputy head teacher at the local Rambanapasi Secondary School and has experience in ecological and social science fieldwork, including assisting with the tree surveys on this project. It is the understanding developed through this close working partnership that made it possible to write this paper.

The ideas for this paper were first developed during informal discussions between Rose and Amai Simba in November 2015. Rose prepared an initial draft in June 2016, which was discussed with Amai and Baba Simba. Having integrated the first round of comments, a

subsequent draft was then edited by Amai and Baba Simba in April 2017. Although Rose was responsible for producing the manuscripts, we believe that the development of ideas and subsequent editing process make this paper a genuinely participatory piece of work.

However, because of this writing process and because the conversations informing this chapter were documented in the form of field notes rather than as recordings, authors' opinions are not presented as direct quotes. Instead we use the first person plural when referring to shared opinions, but the third person singular when reporting the viewpoints of individual authors. While Rose has made every effort to try and ensure that her writing has accurately represented the ideas described by Amai and Baba Simba, the absence of Amai and Baba Simba's distinct voices is a definite flaw in this chapter. Future work on this topic would benefit from use of more formal recorded interview methods which can directly capture the voices of all contributors, although we recognise that shifting to a more formal data collection process brings with it a risk of reducing honesty and openness when discussing what can be uncomfortable themes.

The majority of papers discussing the role of research assistants in developing country fieldwork have been from the researcher perspective and have obscured the identity of the research assistant (although see Hapke & Ayyankeril, 2001). Turner (2010) used pseudonyms at the requests of the assistants interviewed, as they feared that negative opinions might impact future work opportunities, while Molony and Hammett (2007) decided that pseudonyms were appropriate as they had already left the field and their research assistants had no right of reply. However, one of the aims of this paper is to reframe the role of the research assistant as collaborator as well as employee, and anything less than co-authorship would not be a fair representation of Amai and Baba Simba's contribution to this paper. Given the intent of this paper, some might also query the appropriateness of the term research 'assistant', which unfairly implies secondary importance to the researcher; however, for better or worse this is the most commonly used term particularly in ecology literature, and so we stick with this role description of the sake of clarity.

7.3 Relational power asymmetries: questions of person and place

Asymmetries in power and their associated practical and ethical consequences were the source of many of the conflicts observed and experienced during the research project. The nature of these asymmetries was shaped by the characteristics of all actors involved in the research and by the particular context of rural Zimbabwe.

Molony and Hammet (2007; 297) characterise the relationship between researcher and research assistant as one of mutual extraction: 'the research assistant get money and experience, the researcher gets knowledge that leads to a degree and a career.' This resonates to an extent with our experiences, but we suggest underestimates the complexity of the relationship. It is inescapable that the foundation of this relationship is a serious imbalance in financial power. Research assistants are often employed by the researcher on a casual basis – a situation which has uncomfortable echoes of paternalistic colonial models of behaviour, and which gives the researcher in their role as employer disproportionate power in employment-sparse rural Zimbabwe. The financial imbalance and the lack of formal employment securities render the research assistant vulnerable to exploitation as they are unwilling to speak out against the employer, a situation Amai Simba recognises from times when she felt tired or unwell but was unwilling to speak out for fear of upsetting her employer. These disparities in financial and decision making power were in part buffered by asymmetries on other axes: while Rose had more formal education, Amai Simba was older and had nearly 20 years of social science fieldwork experience, and these complementarities combined with the long period spent working together went some way to equalising the relationship. However, the financial disparity is impossible to erase entirely, and it is not always easy as a researcher to maintain the mindfulness needed to avoid exploitative behaviour during a highly pressurised field season.

A consequence of the power dynamics in this relationship was the development of a reciprocal duty of care between researcher and research assistant. The duty of care that a researcher has to a research assistant is well-recognised and should be paramount in fieldwork decision-making, particularly when researching emotive subjects or in difficult political contexts (Beale et al., 2004; Michaud, 2010). Less acknowledged is the duty of care taken on by Amai and Baba Simba for the researchers they host. As Robson (1994: 47) points out, 'it is common for the researcher on entering the research environment to find him/herself in the role of naïve idiot', and the researcher is therefore initially heavily dependent on the judgement of the research assistant. The ethical issue here lies in the different scales of impact should either party be perceived to have failed in their duty of care, with any harm to a visiting researcher potentially resulting in total loss of livelihood for Amai Simba. She and Baba Simba recall experiences with researchers travelling late at night (highly dangerous on some of the appalling local roads) or otherwise placing themselves at unnecessary risk, and of their concern for the researchers' wellbeing and the word-of-mouth reputation Amai Simba relies upon to find work. Fieldwork is often a liberation for a researcher and the temptation to push boundaries is high: but if hosted by a research assistant then that temptation needs to be

tempered with a responsibility to be risk averse. This is important from an ethical perspective, but also maintains the trust required to build a strong collaboration.

There are additional risks attached to accommodating a researcher within a family home. The level of past fieldwork experience in early career researchers is highly variable, and a first time staying in even a comfortable African rural home can be unexpectedly disorientating. For Rose the primary challenge was the lack of privacy and freedom compared to the independence of home life, an issue also reported by Cupples and Kindon (2003). Amai and Baba Simba recall previous researchers struggling to adapt to a Zimbabwean diet, or trying to navigate problems at home from the comparative isolation of the study area. Until a researcher arrives it is impossible to foresee which challenges will strain the research-research assistant relationships, and at times the frustrations inevitably spill into the data collection process. A benefit in this project of carrying out several stints of fieldwork rather than a single long-term campaign was that lessons learned in the first year could be implemented in subsequent seasons.

The power asymmetries between researcher and research assistant are to an extent replicated between research assistant and respondents. It is often presumed that research assistants recruited in the study area benefit from 'insider' status due to sharing race and language with respondents, but this shows poor understanding of the heterogeneity of rural communities. Research assistants are often more highly educated than respondents (Deane & Stevano, 2015) and are receiving higher cash incomes at least while the research project is in progress, and Baba Simba is also a highly respected local teacher and a close relative of the village head lineage in a local village. These factors were an advantage in establishing initial access to respondents, but made it necessary to guard against respondents feeling coerced to remain involved with the research.

In contrast, Amai and Baba Simba had partial 'outsider' status because they had purchased a stand in the village, rather than inheriting land from relatives, and were also perceived differently because of their long collaboration with foreign researchers. These circumstances could easily have placed a divide between research assistants and respondents which jeopardised respondent openness and honesty, and this could only be avoided through Amai Simba's ability to adapt her behaviour to gain the trust of the respondent: teasing a young man who had just brought home a second wife (and had thus deeply offended his first wife), speaking with deep respect to an elderly traditional healer, or finding common ground with respondents who shared (for example) her home area of Buhera. The importance of these chameleonic abilities was also highlighted by Hapke and Ayyankeril (2001), and is part of the reason that Amai Simba argues researchers should recruit research assistants locally, rather

than bringing student research assistants from the city. A local research assistant is more likely to spot factual inaccuracies, but is also more cognisant of the local behavioural norms which need to be observed to build a strong rapport with respondents.

This was the first project in which Amai Simba had worked in her home area, although she has worked extensively in the adjacent Sengezi resettlement area. Her local knowledge brought definite benefits to the research project, in terms of navigating local power networks and because a research assistant is not just a translator but also a 'cultural broker' (Temple and Young, 2004; 171), illuminating context as well as words. Such a set-up is not, however, without costs for the research assistant. Firstly, she is responsible for maintaining the linkages which could support future research: Amai Simba greets everyone she meets, in case a person who perceives themselves insulted by her lack of greeting becomes a respondent someday. Secondly, while the researcher can leave at the end of the project, the research assistant must deal with any missteps made during the research. In one extreme case this involved a summons by the District Administrator when a project was seen as not having obtained sufficient clearance. In the present project, we made a decision not to report a domestic abuse case discussed with us in one of the villages as local corruption meant that doing so would have placed Amai Simba at risk following completion of the research. Less severe are the impositions of local respondents on Amai Simba's time and energy outside the research structure, perceiving her association with foreign researchers to imply wealth and wisdom and therefore to make her a source of resources and counsel. Such a status is flattering, but also potentially exhausting. Amai Simba gives the example of a respondent from a nearby village who has taken to inviting herself around for tea: 'Sometimes you have to give Amai N jam sandwiches, even if you don't want [to]. But other times you have to hide your bread and jam and pretend that you don't have.'

7.4 The interdisciplinary research context

Many of the issues discussed above are pertinent to any project involving social science data collection. However, the interdisciplinary context of socioecological research introduces particular pressures on the relationships between researcher, research assistant and respondent, related to identity, narrative building, and the crossing of disciplinary boundaries.

Identity is always a prismatic concept, shifting dependent on perspective. For the researcher, Chacko (2004) describes the feeling of being 'caught between worlds and identities', trying to balance their 'home' identity with the persona required to be an effective field researcher. For Amai Simba, working in her home area meant balancing the demands of

her identity as a research assistant with those of her identities as wife, mother and village residents. The shifts in the orientations of different actors were magnified in the interdisciplinary context because of the multiplicity of research roles adopted by each person: so, for example, one Wedza resident Baba T was at varying times household survey respondent, tree survey research assistant, and assistant **Sabhuku** in one of the study villages. Such identity shifts result in concomitant shifts in distributions of power. This raised an issue for Amai Simba: although having strong engagement in the household survey aspects of the project, she struggled with the rough terrain of mountain tree surveys and asked Baba Simba to take on this aspect of the work, which left her feeling disempowered and excluded from a project in which she had to that point participated fully. There is no easy solution for navigating these shifting relationships, but more sensitive allocation of assistants to the roles to which they are best suited and transparency in the reasons behind these allocations could have avoided the conflict in the present case.

Having a clear narrative of the research is important for obtaining genuine informed consents from respondents to engage with the research. However, developing appropriate narratives becomes more challenging for broad interdisciplinary topics, particularly those which are partially responsive to initial findings and which evolve over the course of the research (in the present case, for example, parts of the research were forced to change course by the unexpected discovery in the first season of the small-scale gold mine on the mountain, which has obvious impacts on local livelihoods). Amai Simba chose to use a broad narrative of the research when speaking to potential respondents, explaining that we were studying **miti** (trees) and **zviwanikwa,** a term for natural resources encompassing all wild-sourced goods such as firewood, medicines, fruit and minerals. Although covering the main content of our work and demonstrating that we had no political or developmental intent, this was still an imperfect story. It did not remove potential associations with environmental NGOs (we were asked on several occasions if we would be starting a tree-planting programme), and it only provided respondents with a partial representation of the research focus, although we always provided opportunities for follow-up questions during household survey interviews. Given the difficulties of presenting a clearer narrative when the research narrative inevitably shifts in response to local conditions, in future we would consider disseminating results more regularly over the course of the study to continually affirm the informed consent of respondents, rather than carrying out all feedback sessions at the end of the project when it is too late for the research to adapt if respondents raise valid concerns. In hindsight this might also have reduced the research fatigue that began to become apparent near the end of the study period.

A further challenge for an early career researcher carrying out interdisciplinary work is that they will invariably not have been trained equally in all aspects of the methods they are now applying. In the present case Rose came from an ecology background and was applying social science methods for the first time, while Amai Simba was from a social science background and had rarely carried out ecological fieldwork. For Rose, most challenging was the issue of depth versus breadth of knowledge: in the field, away from internet resources and libraries and often without immediate contact with supervisors due to poor phone network, there is a constant fear of having made an unconscious mistake while applying less familiar methods which will only become apparent on return from the field. For Amai Simba, used to collecting the stories of peoples' lives, the repetitiveness and physical rigour of tree survey work came as a surprise and a source of significant stress. It was also novel for her to be working with a researcher from a natural sciences background: initially she feared that her translations might not be believed, for example when discussing a respondent's relative who had been kidnapped by **njuzu** (water spirits), of the story of the giant sacred python that hailed a minibus to ride from Harare to Gweru, or the woman who would never get married because her father had pledged her as a wife to a **tokoloshi** (goblin) in exchange for wealth and prosperity. Until Rose had become more familiar with the local context, the pressure fell on Amai Simba to translate more carefully to ensure that no detail was missed. While the mixed methods approach presented challenges to both, however, the different background of researcher and research assistant did complement well, and we believe that the final research project became stronger through combination of multiple kinds of knowledge.

7.5 Who owns a research project?

The ownership of a research project is an interesting question, and one which we believe to be key to the quality of research outcomes. Most discussion of research ownership revolves around researchers, research institutes and funding bodies. However, few have considered the ownership claims of a research assistant. For Amai Simba, her degree of ownership over the data collection process strongly impacts her level of engagement in the project. A top-down approach that simply hands research assistant pre-set question lists appears outwardly efficient, particularly when closely supervised as in the current case: but such an approach does not engender any pride in the research assistant which would motivate them to collect high quality data. Over the course of the project in Wedza, it became obvious that question lists combining academic knowledge with Amai Simba's local knowledge achieved a far greater depth of response, and giving Amai Simba freedom to ask follow-up questions and

chase additional points in interviews was far more effective than asking her to be a straightforward translator (if such a thing exists). While such an approach relies upon the researcher being able to communicate their objectives clearly to the research assistant, we suggest that treating a research assistant as collaborator rather than subordinate, and the development of interview schedules as conversation not instruction, can significantly increase the quality of qualitative data.

It is also important to consider the ownership claims of the study communities. Study communities often have little choice over their involvement in research – although we sought permission through the appropriate hierarchies (Research Council of Zimbabwe, District Administrator, Headman, Village Head) and made every effort to gain informed consent from respondents, the study area and project aims were still designated by academic researchers. Such top-down models are still the norm in socioecological research, although participatory methodologies (see e.g. Chambers, 1997) are gaining popularity, and such models mean that the researcher is constantly trying to engage respondents with topics in which they little investment – an issue which would be reduced if projects could be more responsive to local priorities. The 'imposition' of pre-existing research goals on study communities makes it even more important that results are shared with the community: honouring the claim of the community to research outcomes based on their livelihoods is critical from both ethical and practical standpoints, with consistent community engagement preserving a strong relationship that will support future work. Given these benefits, it is surprising that feedback of research results is not more common: in twenty years as a research assistant, this was the first time Amai Simba had run a feedback workshop.

7.6 Conclusion

This chapter presents only a single case study of a researcher-research assistant partnership, and is therefore a product of a highly specific set of circumstances. However, there are a number of key lessons we draw from this project which we believe can be generalised to many studies in rural areas of the developing world. The first is that the relationship between the researcher and research assistant is not always easy; it is an intense relationship, often formed under high pressure circumstances, and being prepared in advance with strategies to alleviate stresses can improve the wellbeing of all involved and therefore the final research product. The second is that the knowledge and characteristics of a research assistant are critical in establishing and maintaining dialogue with respondents, while having researchers and research assistants with complementary disciplinary backgrounds can be highly beneficial to research

outcomes. Finally, despite the power imbalances inherent in the relationship, we argue that a research assistant should be seen as a colleague and collaborator on field research, and as integral to the research process. Skilled assistants deserve far greater acknowledgement and credit in the diverse research literatures which would not be possible without them.

7.7 Chapter 7 References

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8. Synthesis and Conclusions

The objective of this thesis was to explore the dynamic interactions between miombo savanna woodlands and rural livelihoods through a case study of the woodland-agriculture matrix landscape of Wedza Mountain, Zimbabwe. I approached this analysis by addressing four key themes: (1) the spatial patterns of land use intensity and provisioning ecosystem service availability within the Wedza landscape; (2) the importance of woodlands in facilitating livelihood diversification and reducing inequality; (3) the use of woodland resources for coping with multiple interacting hazard exposures; and (4) the broader range of environmental values shaping rural livelihood decisions and the representation of these values in published literature. In this discussion, I firstly summarise the major findings of the five research chapters, before relating the outcomes of this case study to the broader research context on forest-livelihood interactions.

8.1 Key Findings

The focus of **Chapter 2** was on the development and application of a novel method for quantifying Human Appropriation of Net Primary Productivity (HANPP) at the village scale. The value of HANPP is that it is a holistic indicator of land use intensity, integrating the human and ecological elements of complex socioecological systems (Haberl et al., 2007; Erb et al., 2013). While there is one previous village-scale HANPP analysis in Africa (Bartels et al., 2017), ours was the first analysis to apply a 'bottom-up' approach based on high resolution social and ecological field data.

Application of this method resulted in village-scale HANPP estimates of between 48 and 113%, far higher than the estimates of between 12 and 38% in published studies (Haberl et al., 2007; Niedertscheider et al., 2012; Krausmann et al., 2013; Fetzel et al., 2016; Bartels et al., 2017). This finding is of note for several reasons. Firstly, from a methodological perspective this chapter demonstrates the importance of accounting for changes in forest structure when calculating HANPP, as previous studies consider only deforestation and fail to account for loss of NPP due to forest degradation. Also demonstrated is the importance of accounting for subsistence consumption of environmental resources such as firewood and construction materials. Such resources accounted for between 21 and 31% of total harvested aboveground NPP in the current study, but are often not represented in the national statistics used in large-scale HANPP calculations. A second interesting implication of these high

HANPP estimates is that they demonstrate the high levels of heterogeneity in land use intensity over comparatively small scales in African smallholder farming landscapes. This suggests that, while large-scale HANPP estimates are valuable for tracking national and regional scale land-use trajectories (e.g. Kolheb & Krausmann, 2009; Fetzel et al., 2016), high resolution analyses will be necessary to link patterns of land use intensity to patterns in ecosystem service availability and biodiversity.

The findings of this chapter also indicate that wealthier households appropriate a greater quantity of NPP embodied in harvested resources that poorer households, but do not appropriate a greater quantity of NPP due to land-use change. It should be noted, however, that the current method accounts only for NPP appropriated through clearance of agricultural land, and does not quantify individual household appropriation of NPP from common property resource systems. This is one of a number of advancements that could be made upon the methodology in this chapter, with others including approved accounting for patterns of livestock grazing in rural landscapes, and development of methods to reduce uncertainty when estimating appropriation of below-ground NPP. Also important for future research is to improve understanding of displacement of NPP appropriation outside the study landscape. Used in conjunction with household consumption and expenditure data, the method presented here could easily be adapted to better visualise such flows of NPP within and between landscapes.

The objective of **Chapter 3** was to assess whether reduced woodland cover was associated with declines in availability of provisioning ecosystem services within the Wedza landscape. This analysis was timely because a number of ecologists have recently argued that a 'tyranny of trees' in landscape management is resulting in inappropriate tree planting programmes which could jeopardise savanna ecosystem function (Veldman et al., 2015a; b). However, to date, the majority of literature in this debate has focused on the 'ecological' aspects of savanna landscapes such as biodiversity and carbon storage, with lesser attention to the links between woody species composition and rural livelihoods. In this chapter I attempt to address this omission by combining woodland survey data with local assessments of the use values of woody ethnospecies.

Through this analysis I demonstrated that declines in woodland cover are associated with declining per household availability of six provisioning ecosystem services important to Wedza livelihoods: firewood, fibre, construction material, wild fruits, medicinal plants and leaf litter fertiliser. These declines are associated with reduced extent of miombo woodland cover and also with woodland degradation due to the greater use pressure on remnant woodland patches in villages with higher levels of deforestation. Reduced woodland cover

was associated not just with declining abundance of stems of useful ethnospecies, but also with reduced diversity of ethnospecies underpinning service provision. This loss of useful diversity raises concerns over the loss of 'option values' from rural landscapes, and of declines in the quality of ecosystem service provision. This suggests the need for greater acknowledgement of local ethnobotanical knowledge and practice in the 'tyranny of trees' debate, and indicates that tree planting may provide valuable opportunities to rural households if carried out with due attention to extant vegetation structure and local systems of tree tenure.

However, the analysis in Chapter 3 addresses only the *availability* of provisioning ecosystem services, and so the objective of **Chapter 4** was to explore the *use* of these services by rural households through an analysis of household environmental income portfolios. Environmental income has gained increasing prominence as a method of assessing the importance of environmental resources in rural livelihoods, but many studies conflate 'environmental income' with 'forest income', and there are very few detailed analyses of the spatial derivations of environmental income sources in complex matrix landscapes. Equally, while several studies indicate environmental resources to be important in enhancing livelihood diversity, particularly in poorer households (Kamanga et al., 2009; Tesfaye et al., 2011), and to reduce income inequality in rural communities (Mamo et al., 2007; Kalaba et al., 2013a), few studies have compared livelihood diversity and income inequality on gradients of woodland cover.

The analysis in this chapter revealed environmental income to be very important in rural household income portfolios, accounting for on average 31% of total household income. In contrast to previous studies (e.g. Cavendish, 2000; Kamanga et al., 2009; Angelsen et al., 2014), environmental dependence was highest in the middle wealth tercile when terciles were constructed using mean annual household income. However, when wealth terciles were constructed using household scores in a wealth index based on household assets, environmental dependence was highest in the poorest tercile. This suggests that environmental resources are valuable to households barred by low capital holdings from accessing alternative, more lucrative livelihood opportunities.

Two findings from this chapter deserve particular attention. The first is that, while a large proportion of environmental income (67%) was derived from land covers dominated by woody species, much of this income was derived from more "degraded" lowland woodlands, kopjes, and riparian woodland strips, rather than from high biomass mountain woodlands. Wild animals and plants collected from field systems also accounted for a significant proportion of total environmental income. This indicates that conflation of 'forest income' with 'environmental income' results in an inaccurate presentation of human-environment

interactions, and also suggests that rural households in more deforested villages are able to adapt their livelihoods to maintain provision of key resources despite declining resource supply. The second notable finding in this chapter is that livelihood diversification in poorer households and income inequality were not lower in villages with lower woodland cover. This may in part be due to the ability of households to source key resources even from degraded systems, but we suggest that this pattern is also attributable to the broader social processes underpinning changes in both land use and livelihoods in Wedza, where the change trajectories resulting in woodland clearance are also associated with increased access to alternative markets and livelihood opportunities.

While Chapter 4 focuses on the importance of environmental resources in day-to-day subsistence, the objective of **Chapter 5** was to assess the importance of environmental resources for coping with exposure to hazards. Many authors have argued that consumption and sale of natural resources are important coping strategies in rural areas of developing countries (e.g. McSweeney, 2004; 2005; Paumgarten & Shackleton, 2011; Kalaba et al., 2013b), but a recent global analysis by Wunder et al. (2014) suggested that this perceived importance may have been overstated. However, many existing studies consider particular hazard types in isolation, when, in reality, rural households in the uncertain environments of developing countries are often responding to multiple overlapping exposures to multiple hazards acting at multiple spatial scales. In Chapter 5 I therefore drew upon the vulnerability framework developed by Turner et al. (2003) and combined data from recall of past hazard exposures and from a hazard exposure scenario exercise to assess the importance of environmental resources for coping with interacting hazard exposures in Wedza District.

The findings in this chapter support the argument that environmental resources are most important to coping strategies when households are dealing with multiple simultaneous hazard exposures. This is demonstrated firstly by comparison of household coping strategies in response to the drought of 2002 and to the combined drought and economic crisis of 2008. A significantly greater number of households reported dependence on the environment in 2008, when the two covariate hazard exposures were often interacting with household levels hazards such as unemployment. Further evidence is gained by examining individual household case studies, where weightings of coping strategies in the scenario exercise were often informed by the current hazard exposures the household was facing (such as illness or discord with family) as well as by the hazard specified by the scenario. This leads me to suggest that, while the findings in Chapter 4 suggest loss of woodland cover not to have an immediate negative impact on livelihoods, the importance of environmental resources for shock coping

means the loss of option values represented by the loss of species diversity documented in Chapter 3 should be considered a cause for concern.

In **Chapter 6**, the final original research chapter in this thesis, the objective was to assess whether current ecosystem services literature captures the full range of values considered important by rural communities around Wedza Mountain. The research question in this chapter developed through the long period spent resident living within Makumbe village, and through the numerous informal conversations with local residents touching upon the spiritual, historical, ancestral and religious values informing perceptions of landscapes and patterns of landscape use. In order to assess whether these values were reflected in extant literature, I compiled a set of over 300 papers identified using ecosystem services related search terms, initially reading these papers to identify dominant discourse 'clusters' on the main values in miombo landscapes and subsequently coding papers by the discourse clusters with which they were most closely aligned. I then juxtaposed this review with a case study of environmental values in the study communities around Wedza Mountain.

The findings in this chapter indicate that the dominant cluster of value discourses in miombo landscapes centres on extractive values, but that these values overlap poorly with the ecological values prioritised in conservation dialogues. Ecological values were more closely aligned with spiritual landscape values, but these spiritual values were very poorly represented in ecosystem service related literature. This raises serious concerns, firstly that opportunities are being missed to engage rural communities with sustainable resource management, and secondly that a failure to reflect rural African imaginaries of landscapes will result in further disempowerment of rural African communities and the perpetuation of inequitable landscape management policies.

8.2 The case study in the broader context

The approaches adopted in developing this thesis – to examine a single socioecological system from multiple perspectives, and to develop the thesis as multiple self-contained papers – means that there was a risk of the individual chapters seeming narratively disconnected other than their link through the shared study site. However, there a number of cross-cutting themes which run through this thesis, and which link these case study to broader issues in the study of forest-livelihood interactions. These relate specifically to questions of scale, uncertainty, value and equity.

In discussing scale I refer initially to the importance of microscale analysis in understanding woodland-livelihood interactions. Chapter 2 of this thesis indicates that a

village may have land use intensity twice as high as that calculated in a village only 10 km away, while Chapter 3 showed that these same two villages may have markedly different woodland structure and availability of provisioning ecosystem services. Chapters 4 and 5 demonstrated that variation in the importance of environmental resources to livelihood strategies occurs even at the intra-household scale, with household and individual capitals determining livelihood strategies relative to local networks of social power and prevailing behavioural norms. While larger-scale analyses have obvious policy value, there is a continued need to triangulate patterns observed at regional scales with high-resolution local data collection.

However, 'scale' refers also to the importance of nesting analyses of woodland-livelihood interactions within the contexts of multiple larger spatial scales. Many studies of woodland-livelihood interactions present case studies as though in a vacuum, focusing analysis on how the internal characteristics of social units such as wealth and asset holding shape livelihood strategies. As shown in Chapters 4 and 5, land use change and environmental dependence in Wedza can be more clearly understood when placed in the context of broader socioeconomic and political change in Zimbabwe. The importance of placing case study analyses within broader spatial context is also demonstrated in Chapter 6: although not explicitly mentioned within the chapter, the mismatch between the values prioritised by the study communities and those prioritised in the research literature is indicative of the power disparities that exist between local and larger scales.

The research presented in this thesis also highlights the importance of discussing woodland-livelihood interactions within a broader temporal context. Perhaps due to a lack of longitudinal data, many quantitative assessments of woodland and livelihood structure present static snapshots of present patterns. This is perhaps particularly inappropriate in savanna woodland landscapes in southern Africa, which are characterised by continual high uncertainty in both ecological and socioeconomic terms (Scoones, 2004). Past experience of uncertainty and hazard exposures has been critical in structuring present interactions between humans and environment, as demonstrated by the diverse livelihood strategies catalogued in Chapter 4 and by the diverse coping strategies discussed in Chapter 5. This uncertainty also implies substantial temporal variability in the financial and livelihood values of environmental resources: based purely on the data in Chapter 4, for example, the tree *Parinari curatellifolia* might not have appeared particularly valuable, whereas the importance fruit from these trees in coping strategies as documented in Chapter 5 demonstrates how critical it is to allow for temporal variation when assessing the value of resources.

The issue of uncertainty and temporal change in values is also relevant to the findings of Chapter 6, which detailed the diverse spiritual, religious and historic values associated with the Wedza landscape by local residents. These values are highly perspective-dependent, often varying over time even within one individual, but are crucial to understanding the ways in which people relate to the landscape and the evolving interactions between institutions and rural landscape structure. Despite the obvious importance of such values at the local scale, understanding of how these values change over time in conjunction with changes in the land system is challenging due to the lack of representation of spiritual landscape values within published literature on forest-livelihood interactions, reflecting the broader neglect of cultural values within the ecosystem services literature (Chan et al., 2012; Milcu et al., 2013; Pascual et al., 2016). As demonstrated by the literature review in Chapter 6, current research is advancing in illuminating the functional African landscapes of carbon and nutrient cycling, the ecological landscapes of biodiversity, and the economic landscapes of extraction, but the spiritual and aesthetic 'imagined' landscapes of rural African communities remain obscure.

This leads to the final cross-cutting theme in this thesis, that of equity and inequality. Inequality was discussed in both Chapter 2 and Chapter 4, with the analysis in Chapter 2 considering inequalities in appropriation of NPP and Chapter 4 discussing inequalities in total income and environmental income within rural communities. The issue of equity in southern African landscape management, most obviously addressed in Chapter 6, is also pertinent to Chapters 3 and 4, which both touched upon the ongoing 'tyranny of trees' debate as a motivation for analysis. The experiences of the Rural Afforestation Programme in Zimbabwe demonstrate that rural afforestation is not inevitably profitable or beneficial (Jagger & Luckert, 2008), and it is true that inappropriate afforestation may negatively impact diversity in grass-dominated savanna systems. However, this debate is symptomatic of a wider literature which continues to discuss 'ideal' landscape structure in rural Africa in terms of ecological features such as biodiversity and carbon. There is an ethical dissonance in any approach which considers only ecological parameters and fails to acknowledge the legitimacy of the environmental knowledges and values of the rural communities living within savanna socioecological systems.

8.3 Concluding Remarks

In the introduction to this thesis I stated that I hoped to gain insight into the diverse contributions of woodlands to rural livelihoods and into the vulnerability of the human and ecological components of socioecological systems in the contexts of local and global change.

With regards to the first part of this objective, I believe I have shown that miombo woodland do have numerous values to local people in Wedza, but that so also do many other land cover types such as rivers, wetlands and agricultural land. The assumed correlation between high biomass and high value on all other axes is not supported; instead miombo woodlands represent only one component in diverse landscapes and diversified livelihoods.

My conclusion with regard to the second point is yet more equivocal. This thesis has shown that rural livelihoods are more resilient to loss of woodland cover than would be anticipated from land cover data alone. However, the observed dependence on natural resources during crises situations leads me to highlight once again the importance of having option values in rural African landscapes, and it is these option values which appear to be threatened by changing woodland cover. It appears to me that maximising the livelihood opportunities available to rural communities by maintaining access to a diverse range of common property resource systems is important to reduce vulnerability and aid adaptation in the face of future environmental change.

8.4 Discussion References

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Appendix 1: Chapter 2 Supporting Information

A1.1 Land cover estimates used in HANPP calculations

Table A1.1 Area of land in each category of a locally derived land cover typology in six villages around Wedza Mountain, Zimbabwe

Village	**Area (ha)**						
	Total area	Mountain Woodland	Lowland Woodland	Croplands	Gardens	Wet Grassland	Other
Makumbe	368.4	NA	71.5	199.1	2.0	66.2	29.6
Pfende	322.7	NA	155.5	107.1	10.5	24.1	25.6
Mapfanya	441.3	201.4	100.3	89.9	8.6	20.0	21.1
Betera	635.6	338.3	102.7	163.5	6.8	23.0	1.3
Charambira	248.9	82.1	92.3	45.0	3.0	19.7	6.8
Mbizi	267.9	76.2	99.2	66.4	12.1	5.8	7.7

A1.2 Allometric equations and production factors used in calculations of aHANPP

Table A1.2 Allometric equations and woody growth increments used to calculate standing stock, annual wood production and annual leaf production in dry miombo sites in Wedza District, Zimbabwe

Stem Biomass Allometric Equations			
Source Location	**Species/Size**	**Equation**	**Source**
Nhambita, Mozambique		log(stem biomass)(t C) = 2.601 (log(dbh)(cm)) – 3.269	Ryan et al. (2007)
Zimbabwe		Log10 biomass (kg) = 3.97 + 2.63 log10 (dbh(m))	Grundy (1995)
Zambia	Small trees (dbh <10 cm)	Biomass (kg DM) = brushwood biomass (0.51 dbh (cm) – 0.57) + cordwood biomass (2.23 dbh (cm) – 6.44)	Chidumayo (1997)
	Large trees (dbh > 10 cm)	Biomass (kg DM) = brushwood biomass (2.00 dbh – 9.40) + cordwood biomass (17.43 dbh – 188.84)	

Annual Growth Increments			
Source Location	**Species/Size**	**Increment**	**Source**
Zambia		Relative basal area increment 0.032 $m^2 m^{-1} yr^{-1}$	Chidumayo (1988), in Frost (1996)
Zimbabwe		Relative basal increment 2.7% yr^{-1} for trees with initial dbh 5-10cm 2.0% yr^{-1} for trees with initial dbh >10cm	Frost (1996)
Nhambita, Mozambique		Mean basal area increment (cm^2 yr^{-1}):	Flack (2013)
	Acacia nigrescens	1.2615	
	Azanza garckeana	0.7442	
	Brachystegia boehmii	2.2236	
	Burkea africana	1.5680	
	Combretum adenogonium	0.4512	
	Diplorhynchus condylocarpon	0.5631	
	Julbernardia globiflora	1.5747	
	Pseudolachnostylis maprouneifolia	1.2208	
	Pterocarpus angolensis	2.1460	
	Terminalia stenostachya	0.8956	
	Mean	**1.2639**	

Annual Leaf Production Allometric Equations			
Source Location	**Species/Size**	**Equation**	**Source**
Zimbabwe		Current growth of leaves (kg DM yr^{-1}) = 0.075 * dbh(cm) * 1.443	Frost (1996)
Zambia	Small trees (dbh<10cm)	Leaf production (t DM yr^{-1}):	Chidumayo (1997)
	- *Brachystegia boehmii*	1.49 dbh – 3.94	
	- *Julbernardia globiflora*		
	- Other *Brachystegia*	1.26 dbh – 3.89	
	- *Uapaca kirkiana*	1.51 dbh – 4.31	
	- Other canopy species	0.63 dbh – 0.97	
	- Understorey species	0.62 dbh – 1.45	
	Large trees (dbh >10cm)	0.24 dbh – 0.18	
	- *Brachystegia* and *Julbernardia* sp.		
	- *Uapaca* sp.	1.92 dbh – 7.92	
	- Other canopy species	2.58 dbh – 16.29	
	- Understorey species	1.22 dbh – 0.99	
		1.23 dbh – 4.52	

Table A1.3 Annual grass production in wet grasslands in Zambia and Zimbabwe.

Source Country	Annual grass production estimate (t DM ha^{-1} yr^{-1})	Source
Zambia	3.1	Shea et al. (1996)
Zambia	3.3	Hoffa et al. (1991)
Zambia	3.4	Jeanes & Baars (1991), in Scholes et al. (1996)
Zimbabwe	4.9	Nyamadzawo et al. (2014)
Zimbabwe	6.2	Scoones (1990)
Mean	**4.2±0.6**	

Table A1.4 Residue production factors and residue recovery factors for major crop types in sub-Saharan Africa, adapted from Haberl et al. (2007). Crop residue production (g DM) is equal to crop harvest (g DM) multiplied by crop residue production factor. Recovered residues (g DM) is equal to total residue production (g DM) multiplied by crop residue recovery factor.

Crop Type	Crop Residue Production Factors	Crop Residue Recovery Factors
Maize	3.5	0.9
Millet	3.5	0.9
Rice	1.7	0.9
Sorghum	3.5	0.9
Sugar beans	0.4	0.9
Cowpeas	0.4	0.9
Sunflower	2.3	0.5

A1.3 Calculating village and household firewood consumption in t DM

Annual household firewood consumption was estimated from the three months covered by a household questionnaire based on CIFOR-PEN (2008), including both firewood used domestically and for commercial purposes such as beer brewing and tobacco curing. Firewood consumption was recorded in local units. Headload weight was determined following a review of the literature from Africa, giving an estimated mean weight of 23.0±1.5 (**Table A1.5**).

Table A1.5: Mean headload weight calculated from 14 African studies.

Country	Headload weight	Source
Tanzania	14.0	Wiskerke et al. (2010)
South Africa	14.5	Matsika et al. (2013)
Zambia	15.0	Bwalya (2006)
Uganda	17.5	Tabuti et al. (2003)
Mali	18.0	Johnson & Bryden (2012)
Ghana	23.5	Amoah et al. (2015)
South Africa	24.0	Bembridge & Tarlton (1990)
Botswana	25.0	Jelenic & van Vegten (1981)
Zimbabwe	25.0	Benjaminson (1997) in Woittiez et al. (2013)
Ghana	25.3	Amoah et al. (2015)
Zimbabwe	25.9	Vermeulen et al. (1996)
Tanzania	28.0	Malimbwi & Zahabu (2008)
Tanzania	29.2	Vermeulen et al. (2000)
South Africa	30.0	Liengme (1983)
Zimbabwe	30.0	Whitlow (1979)
Mean	**23.0±1.5**	

Two published estimates for the weight of a wheelbarrow of firewood were 39.6kg (Matsika et al., 2013) and 45kg (Dovie et al., 2004), so the median value of 42.3kg was used. Following Woittiez et al. (2013), who also worked in Wedza District, we estimate that a cartload of firewood weighs 340kg.

The majority of firewood is collected air dried (Vermeulen et al., 2000), and so the mean moisture content of five locally used firewood species following 5 to 8 weeks of air drying were used to calculate dry matter weight (Abbot & Lowore, 1999; **Table A1.6**). Headloads were assigned a weight of 11 kg DM, wheelbarrows 20 kg DM, and cartloads 158 kg DM. Only firewood collected within the village area was included in harvest estimates, excluding purchased firewood and firewood collected in other villages.

Table A1.6: Mean moisture content of five miombo species when collected fresh and after between 5 and 8 weeks of air drying. Adapted from Abbot & Lowore (1999)

Species	Moisture content when green (%)	Moisture content following 5-8 weeks air drying (%)
Combretum apiculatum	56.9	37.6
Combretum molle	65.1	41.5
Acacia amythethophylla	72.8	59.4
Brachystegia spiciformis	77.6	62.5
Brachystegia boehmii	79.4	66.0
Mean		**53.4±5.8**

A1.4 $aNPP_{act}$ estimates in the context of published estimates of annual aNPP in miombo woodlands

Table A1.7: Annual wood and leaf production estimates calculated from miombo woodland reference plots on Wedza Mountain, Zimbabwe, in the context of results from published studies. Where results were originally reported in tonnes of carbon, dry matter was assumed to have a carbon content of 47% (Ryan et al., 2011).

Study Location	**Methods**	**Annual Woody Production Estimate (t DM ha^{-1} yr^{-1})**	**Source**
Multiple miombo sites	Mixed methods, including chronosequence and repeated plot measurements	1.0 – 2.0	Frost (1996)
Mozambique	Chronosequence	1.5 (0.9 – 1.9)	Williams et al. (2008)
Zimbabwe (current study)	Literature derived allometric equations applied to data on current standing stock	*1.6*	Mean annual woody production calculated using Wedza reference plot data and combination of three woody increment estimates: Chidumayo (1997)
Zambia		*2.1 ± 0.2*	Frost (1996)
Zimbabwe		*1.4 ± 0.2*	Flack (2013)
Mozambique		*1.2 ± 0.2*	
SE Tanzania	Chronosequence	1.5 – 1.8	McNicol et al. (2015)
Zambia	Chronosequence	1.2 – 2.0	Chidumayo (1997)
Zambia (rainfall > 1000mm yr^{-1})	Chronosequence	2.1 – 3.0	Kalaba et al. (2013)
Study Location		**Annual Leaf Production Estimate (t DM ha^{-1} yr^{-1})**	**Source**
Zimbabwe (current study)		*1.7 ± 0.2*	*Calculated from Wedza reference plot data using allometric equations from Frost (1996)*
Zimbabwe	Allometric equation applied to size frequency data	2.7	Frost (1996)
Zambia	Direct litterfall measurement	2.5	Chidumayo (1997)
Zambia	Allometric equation applied to size frequency data	2.7	Size frequency data from Chidumayo (1991) and allometric equation from Frost (1996), in Frost (1996)
Zimbabwe (current study)		*3.4 ± 0.3*	*Calculated from Wedza plot data using allometric equations from Chidumayo (1997)*

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Appendix 2: Chapter 3 Supporting Information

A2.1 Structure and composition of woody species around Wedza Mountain

Table A2.1 Mean biomass of woody species in three land cover types in six villages around Wedza Mountain, Zimbabwe. Biomass in mountain woodlands was significantly higher in than in lowland woodlands (ANOVA and Tukey HSD: $p<0.05$).

Village	**Biomass (t DM ha^{-1})**		
	Mountain Woodland	*Lowland Woodland*	*Agricultural Land*
Makumbe	NA	10.1±2.0	1.7±1.4
Pfende	NA	8.7±4.1	2.1±0.7
Mapfanya	41.9±7.5	21.6±5.0	3.3±2.2
Betera	33.6±3.6	15.8±2.2	5.4±2.6
Charambira	60.9±9.0	15.6±3.0	2.3±1.3
Mbizi	38.8±5.1	18.2±4.8	12.3±4.8

Table A2.2 Stem density of woody species in three land cover types in six villages around Wedza Mountain, Zimbabwe. Includes all stems with dbh >= 3cm.

Village	**Stem Density (stems ha^{-1})**		
	Mountain Woodland	*Lowland Woodland*	*Agricultural Land*
Makumbe	NA	1083±326	188±105
Pfende	NA	1139±187	111±32
Mapfanya	1789±298	1914±421	75±35
Betera	1600±337	2761±92	65±46
Charambira	2342±114	2035±409	223±130
Mbizi	2315±544	2092±226	379±215

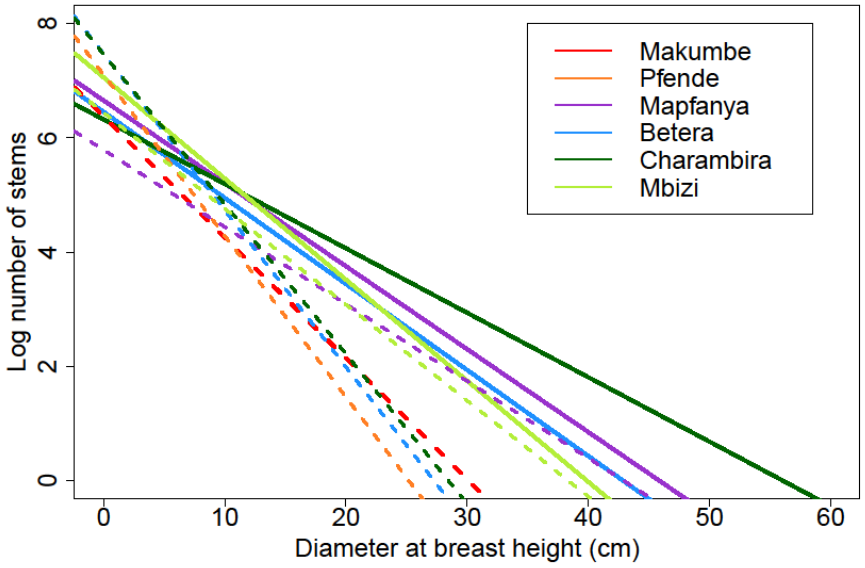

Figure A2.2: Size class distributions of stems in mountain and lowland woodland grazing areas on and around Wedza Mountain. Dashed lines indicate lowland grazing area woodland, whereas solid lines indicate mountain woodland. The steeper gradient of lowland woodland lines indicates higher dominance of smaller stems.

Table A2.3 The top 20 most important species in three land cover types on and around Wedza Mountain, Zimbabwe, calculated using the Importance Value Index.
Importance Value Index = (Relative frequency+relative basal area+relative density)/3 (Curtis & McIntosh, 1951[1])

Rank	Mountain Woodland		Lowland Woodland		Agricultural Land	
	Ethnospecies	*IVI*	*Ethnospecies*	*IVI*	*Ethnospecies*	*IVI*
1	Musasa (*Brachystegia spiciformis*)	49.8	Musasa (*Brachystegia spiciformis*)	57.5	Muunga mutsvuku (*Acacia sp. cf. sieberiana*)	17.1
2	Mupfuti *(Brachystegia boehmii*)	38.5	Mukarati (*Burkea africana*)	31.3	Mubhuku (*Piliostigma thonningii*)	14.1
3	Munondo (*Julbernardia globiflora*)	34.8	Mutufu (*Vangueriopsis lanciflora*)	27.5	Muunga mutema (*Acacia nilotica*)	11.8
4	Mutsatsati (*Faurea* sp.)	33.9	Mupembere (*Combretum molle*)	23.4	Mupangara (*Dichrostachys cinerea*)	11.6
5	Mutufu (*Vangueriopsis lanciflora*)	30.4	Munondo (*Julbernardia globiflora*)	21.0	Musasa (*Brachystegia spiciformis*)	11.3
6	Mushambahuro (*Lannea discolor*)	30.3	Mutsokotsiyana (*Rhus longipes*)	20.7	Muunga muchena (*Acacia karoo*)	10.8
7	Muzhanje (*Uapaca kirkiana*)	28.9	Mushambahuro (*Lannea discolor*)	20.5	Mushambahuro (*Lannea discolor*)	7.9
8	Muunze (*Brachystegia tamarindoides subsp. microphylla*)	22.7	Mupangara (*Dichrostachys cinerea*)	18.9	Mango (*Mangifera indica*)	6.9
9	Mutsokotsiyana (*Rhus longipes*)	22.3	Muunga mutema (*Acacia nilotica*)	17.8	Munzungunzungu (*Senna singueana*)	6.7
10	Munyamharadzi (*Ochna pulchra/ Psorospermum febrigum*)	22.1	Mushava (*Monotes glaber*)	17.4	Mususu (1) (*Terminalia sericea*)	6.6
11	Mupangara (*Dichrostachys cinerea*)	20.5	Muzeze (*Peltophorum africanum*)	17.3	Mutamba muzhumu (*Strychnos cocculoides*)	6.6
12	Muhacha (*Parinari curatellifolia*)	19.7	Munyamharadzi (*Ochna pulchra/ Psorospermum febrigum*)	17.2	Mukonachando (1) (*Euclea divinorum*)	6.4
13	Mukarati (*Burkea africana*)	19.6	Mutsvanzva (*Ximenia caffra*)	16.2	Mutsokotsiyana (*Rhus longipes*)	6.1
14	Mutsvanzva (*Ximenia caffra*)	18.8	Musvovamhungu (*Diospyros lycioides*)	14.4	Mutamba mun'ono (*Strychnos spinosa*)	5.3
15	Mupembere (*Combretum molle*)	15.6	Mukonachando (1) (*Euclea divinorum*)	13.0	Lantana (*Lantana camara*)	5.3
16	Mumhonda (*Protea gaguedi*)	15.4	Mususu (1) (*Terminalia sericea*)	12.5	Mupembere (*Combretum molle*)	5.1
17	Mukwirasvosve (*Pittosporum viridiflorum*)	14.0	Chizhuzhu (*Gymnosporia buxifolia/ G.senegalensis*)	12.5	Mutufu (*Vangueriopsis lanciflora*)	4.9
18	Muunga mutema (*Acacia nilotica*)	13.8	Muwengedza (*Bridelia cathartica*)	11.6	Mukundanyoka (*Turraea nilotica*)	4.2
19	Muwengedza (*Bridelia cathartica*)	13.7	Mutamba mun'ono (*Strychnos spinosa*)	11.6	Musvosvotwe (*Fluggea virosa*)	3.7
20	Mutarara (*Gardenia sp.*)	11.9	Muvengahonye (*Psydrax livida*)	11.2	Guava (*Psidium guajava*)	3.5

[1]Curtis, J.T. & McIntosh, R.P. (2015) An upland forest continuum in the prairie forest border region of Wisconsin. Ecology **32**: 476-496.

A2.2 Uses of woody species around Wedza Mountain

Table A2.5: Mean use scores assigned to each of 87 Shona ethnospecies, with additional qualitative description of tree uses. Numbers in parentheses following medicinal uses indicate the number of respondents identifying that remedy.

Scientific Name	Shona Name	Repetitions	Mean Use Score (between 0 and 2)						Notes
			Firewood	Poles	Fibre	Food	Medicine	Fertiliser	
Acacia karoo	Muunga muchena	15	0.9	0.7	0.0	0.0	0.3	0.3	***Medicinal Uses*** Roots treat anxiety attacks in children (1). Roots used to treat hallucinations (1). Parasite found on *Acacia* species treats headaches (1)
Acacia nilotica	Muunga mutema	14	1.9	2.0	0.0	0.0	0.2	0.4	***Medicinal Uses*** Fruits used as aphrodisiac (2)
Acacia sp. cf sieberiana	Muunga mutsvuku	15	1.0	1.0	0.0	0.0	0.3	0.4	***Firewood/Poles*** Vulnerable to termites, so can't be stored in woodpile or used for construction. ***Medicinal Uses*** Roots treat anxiety attacks in children (2). Parasite found on *Acacia* species treats headaches (1). Roots used as a cure for dogs (1).
Albizia amara	Muora	13	1.4	1.1	0.0	0.0	0.1	0.4	***Firewood/Poles*** Large individuals make good poles, but smaller stems rot quickly. ***Medicinal Uses*** Roots and bark used to treat heartburn (1).
Albizia antunesiana	Mufenje	15	0.9	1.1	0.0	0.0	0.4	1.3	***Medicinal Uses*** Roots used to ease childbirth (1) and as emetic (1). Bark treats stomach pains (1). Treats toothache (1). ***Other*** Roots can be used as floats for fishing lines.
Azanza garckeana	Mutohwe	18	1.8	1.6	0.0	2.0	0.3	1.4	***Food*** Fruits are eaten by adults and children and are sometimes collected for sale – the local clinic recommends them as being high in vitamins. ***Medicinal Uses*** Bark treats stomach problems (1) and pain in feet (1). Used to ease childbirth (1).
Brachystegia boehmii	Mupfuti	16	1.9	1.6	1.9	0.2	0.3	1.8	***Food*** The fibre is sugary and often chewed while herding cattle/collecting firewood.

Brachystegia boehmii (contd)									***Medicinal uses*** Fibre improves immune system (1) and treats stomach problems (1). Leaves used to treat wounds (1). Washing with the parasite specific to *B.boehmii* removes evil spirits (1).
Brachystegia spiciformis	Musasa	15	2.0	1.6	1.7	0.0	0.1	1.5	***Medicinal Uses*** Leaves treat wounds (1). ***Other*** Fresh leaves are an important source of livestock feed. Fruits (tsarimba) are eaten by livestock and also used as kindling for fire starting.
Brachystegia tamarindoides subsp. microphylla	Muunze	14	1.9	1.7	0.6	0.0	0.4	1.5	***Medicinal Uses*** Bark treats stomach problems (2), soft spot[1] (1) and coughs (1). ***Other*** Used in some Shona cultures for rituals.
Bridelia cathartica	Muwengedza	8	1.0	1.5	0.0	1.3	0.4	1.0	***Food*** Fruits are pleasant and are eaten mainly by children. ***Medicinal Uses*** Roots treat dizziness (1). Leaves are an emetic (1), and can also be used to cure the black swellings which occur on the legs when sitting by the fire in cold weather (1).
Burkea africana	Mukarati	17	0.9	1.5	0.0	0.5	0.2	1.1	***Firewood/Poles*** Firewood burns quickly to ashes and therefore rarely used. ***Food*** **Arati** caterpillars are edible and occur during the rainy season. ***Medicinal uses*** Roots used to treat lumps in the veins of the arm (1). Bark used to cure coughs (1).
Carissa bispinosa	Mutsambiringwa	15	1.0	0.9	0.0	0.7	0.7	0.9	***Food*** The fruits are edible but unpredictable, sometimes pleasant but sometimes sour or overly milky. ***Medicinal uses*** Roots treat soft spot (1), chest pains (1), stomach problems (2) and pneumonia (1). Bark treats high blood pressure (1) and pneumonia (1). Bathing a child with the roots will prevent them being hurt if they are left in the care of a witch (1). ***Other*** Giving the roots to hunting dogs will improve their sense of smell (1).
Cassia abbreviata	Muvheneka	15	1.5	1.5	0.0	0.0	0.9	1.0	***Medicinal Uses*** Roots and leaves used as a general cure and to improve strength (2). Treats tooth problems (1), stomach problems (3) and headache (1). Bathing with the pods will help give you clarity in your life (1), and ashes from the pods will cure eye problems (1). Lighting the fruit and walking around the home will keep away witches (1). ***Other*** Pounded pods can be used to kill fish. Seeds can be used to make beads.
Catunaregam taylorii	Mubayamhondoro	14	0.9	0.6	0.0	0.0	0.9	0.4	***Medicinal uses*** Roots are a treatment for menstrual pains (1), stomach problems (2), asthma (1), gynaecological issues (1), heart problems (1), poor appetite (1), anxiety in children (1), soft spot (1), infertility (1) and toothache (1). Soaking the pounded roots in water and then washing your face with the water believed to provide clarity in life (1).

Combretum erythrophyllum	Mutepe	18	1.3	0.8	0.0	0.0	0.1	1.6	***Firewood/Poles*** Firewood too smoky to be used in house and rots quickly in woodpile, but good for brick burning because burns immediately following cutting and doesn't need to be left to dry. Also doesn't need much air to burn, which makes it useful in brick kilns.
Combretum hereroense	Mudotajena	12	1.5	1.5	0.0	0.0	0.3	1.5	***Medicinal uses*** Roots used to treat stomach problems (1). Leaves used to treat wounds (1).
Combretum molle	Mupembere	16	2.0	1.9	0.0	0.0	0.5	1.5	***Firewood/Poles*** Good firewood, with little smoke and good charcoal – named by one respondent as 'the firewood of chiefs.' ***Medicinal uses*** Chewing the leaves treats stomach problems (6) and are also suggested as a remedy for spitting cobra venom (1).
Combretum sp.	Mugodo	16	2.0	1.9	0.0	0.0	0.2	1.5	***Medicinal Uses*** Chewing leaves treats stomach problems (1). Roots and leaves treat heatstroke (1).
Croton gratissimus	Mufarata	14	1.0	1.1	0.0	0.0	0.4	1.3	***Medicinal Uses*** Leaves used to treat toothache and bleeding gums (4). Roots used to treat backache (1). Leaves are also a livestock cure (1).
Dalbergia nitidula	Murima	7	1.1	1.3	0.0	0.0	0.4	1.1	***Firewood/Poles*** Perceived as sacred by some respondents and unlucky by others, so rarely used as firewood. ***Medicinal uses*** Roots used to treat headaches (1). ***Other*** If a deceased person has returned as a vengeful ghost or **ngozi**[2], then a branch of murima should be used to place water on the grave while speaking to appease the spirit.
Dichrostachys cinerea	Mupangara	16	1.8	1.9	0.0	0.0	0.9	0.4	***Firewood/Poles*** Strong, thorny poles are used for fencing gardens. The wood is valued as firewood because it doesn't absorb much water in the rainy season. ***Medicinal Uses*** Fruits treat pneumonia (1), stomach problems (1), backache (1), soft spot (2) and asthma (1). Roots used to cure pneumonia (1) and for general strength (1). Parasite which grows on *D.cinerea* used to treat dizziness (2) and headaches (1). Improves immune system in children (3). ***Other*** Fruits are favoured by cattle and goats, and are collected as chicken feed. Perceived as enriching the soil, so clearing **mupangara** will result in a good area for growing a bumper maize harvest.
Diospyros lycioides	Musvovamhungu	15	1.5	1.5	0.0	0.2	0.5	1.1	***Firewood/Poles*** Good for making **mbariro**[3]. ***Food*** Fruits are edible, but eaten mainly by children. ***Medicinal Uses*** Twigs used as toothbrushes (3). Roots can be used to strengthen back (1) and cure stomach problems (1). Leaves used for treating boils (1). Roots used as a livestock cure (1).

Diospyros lycioides (contd)									***Other*** A useful livestock feed, particularly the fresh leaves in September/October. Can be used to make sweeping brooms. If a couple wish to choose the sex of their next child e.g. if a girl is wanted, a girl should be sent to dig **musvovamhungu** roots and both partners in the couple take the roots before trying to become pregnant
Diospyros mespiliformis	Mushuma	11	1.4	1.8	0.0	1.9	0.0	1.1	***Food*** A scarce tree in Wedza, so many are unfamiliar with the fruit, but it is starchy and quite filling and can be eaten fresh or dried.
Diplorhynchus condylocarpon	Mutowa	16	1.3	1.6	0.0	0.1	1.1	1.2	***Food*** Caterpillars which feed on the tree are eaten in some areas. ***Medicinal Uses*** Latex used to treat coughs (1), wounds (2), toothache (2), warts (3), headache (1), ringworm (1) and stomach problems (1). An important tree in apostolic church congregations, where bathing with the leaves is believed to chase away evil spirits. ***Other*** Used to make cooking sticks.
Dodonaea viscosa	Munwahuku	10	0.9	0.8	0.0	0.0	0.3	0.8	***Firewood/Poles*** Good for making **mbariro**[3]. ***Medicinal Uses*** Leaves used for cleaning teeth (2).
Dombeya rotundifolia	Munhokotokowa	12	1.3	1.7	0.0	0.3	0.2	1.2	***Food*** Host plant to edible caterpillars.
Dovyalis zeyheri	Mutsvoritsvoto	14	1.2	1.7	0.0	2.0	0.1	1.3	***Food*** The fruits are sour but pleasant and sought after, although trees are locally scarce.
Ekebergia capensis	Muvhuranyimo	12	1.1	1.6	0.0	0.3	0.3	0.7	***Food*** Supports edible caterpillars. ***Medicinal Uses*** Bark cures backache (1).
Erythrina abyssinica	Mutiti	18	0.9	1.4	0.0	0.0	1.4	0.4	***Firewood/Poles*** Poles regerminate following cutting, so good for living fences[3]. Not preferred for firewood because valuable medicine. ***Medicinal Uses*** Bark used to treat chest pains (1), stomach problems (6), toothache (2), STDs (1), backache (1) and post-partum pain (1). Important medicine for livestock and chickens (11). ***Other*** Seeds can be used to make **hosho** (a Zimbabwean musical instrument).
Euclea divinorum	Mukonachando (1)	11	1.6	1.8	0.0	0.0	0.5	1.5	***Medicinal uses*** Cures stomach problems (1). Twigs taken as toothbrushes (1). Roots act as mouthwash (1).
Euclea sp. cf racemose	Mukonachando (2)	11	1.4	1.8	0.0	0.2	0.5	0.8	***Medicinal Uses*** Twigs can be used as toothbrushes (5). Roots used to cleanse stomach (1).

Euphorbia ingens	Mukonde	13	0.0	0.1	0.0	0.1	1.4	0.0	***Medicinal Uses*** Often kept near homesteads and church congregation meeting places as believed to prevent lightning (10).Latex used to treat ringworm (1) and warts (1), and also suggested as a treatment for cavities (1) (but as the latex is poisonous the respondent warned extreme caution). Ashes of the burned plant used as pesticide (6). ***Other*** Mixing latex with cooking oil makes a sticky substance which can be used in bird traps (2). One respondent believed *Euphorbia* to be a cause of drunkenness in rhinos.
*Faurea sp. (*mainly *Faurea saligna)*	Mutsatsati	13	1.3	1.9	0.0	0.2	0.6	0.8	***Firewood/Poles*** The firewood sparks and is therefore not favoured for use in the homestead – elders say that these sparks will cause bad communication between the couple. ***Medicinal Uses*** Treats soft spot. Bathing babies with the leaves cures red spots on body (2) and anxiety (1). Leaves cure stomach problems (2). ***Other*** Flowers are popular with bees, which is good for honey production. Burned bark mixed with cooking oil used to make hair very black and straight.
Ficus sp. (larger fruit)	Mukuyu/Muonde	13	1.0	0.9	0.0	1.7	0.8	1.1	***Food*** Fruit quality is patchy – some trees are very sweet while other are less good, and the fruit often contains worms/ants/wasps. ***Medicinal Uses*** Leaves can treat high blood pressure (5) and asthma. Sap treats eye problems (1). Bark treat child who has had bad milk because mother is pregnant while breastfeeding[4] (1) Fruits boost the immune system (1). Also treats stomach problems (1). ***Other*** Presence of **muonde** signifies water and therefore a good place to dig a well. Important shade trees in fields. Witches are believed to meet under **muonde** trees.
Ficus sp. (smaller fruit)	Mutsamvi	15	1.0	1.5	0.1	1.7	1.1	1.6	***Food*** Fruit are popular with children and eaten by adults, but are eaten in passing rather than collected. ***Medicinal Uses*** Veins used to cure stomach problems in children (7), black veins on babies' stomachs (2) and soft spot (1). Bark is a chicken cure (1). Some believe the tree can prevent lightning (1).
Flacourtia indica	Munhunguru	14	1.4	1.4	0.0	2.0	0.6	0.8	***Food*** Fruits are edible and eaten by both adults and children. ***Medicinal uses*** Roots and leaves cure stomach problems (2) and increase strength in children (1). Bark cures toothache (1) and black veins on childrens' stomachs (1). Trails of worms which live on munhunguru are mixed with other herbs as cancer cure (1).

Fluggea virosa	Musvosvotwe/ Mushagau/ Muchena/ Mutsotso	14	0.9	0.6	0.0	1.1	0.3	0.7	***Food*** Fruits are edible and eaten in passing. ***Medicinal uses*** Used for treating stomach problems (2), backache (1) and menstrual pains (1). When planting fields, take a few seeds of each crop and mix with powdered musvosvotwe roots before planting – this protects the crops from being destroyed by witchcraft (1).
Garcinia buchananii	Mutunduru	15	1.1	1.8	0.0	1.4	0.8	0.9	***Food*** The fruits are edible but very sour – can be eaten mixed with ashes or used to make sour milk. ***Medicinal Uses*** Bark is an aphrodisiac (4). Also treats menstrual pains (1), high blood pressure (1) and stomach problems (1). Used as a livestock cure (2).
Gardenia sp.	Mutarara	18	1.3	1.8	0.0	0.2	1.5	0.3	***Firewood/Poles*** Burns brightly and sometimes used as a candle. Very strong poles. ***Food*** A fw people eat the fruits, and the beetles living on the tree living in some areas. ***Medicinal Uses*** Pegs of **mutarara** placed around the homestead or fields to protect against witchcraft and lightning (14). Bathing with the leaves chases away evil spirits (2). Leaves used to cure soft spot (1) and backache (1). Fruit cures headaches (1) and bark used to treat anxiety in children (1). Leaves used to cure warts in cattle (1) and to make hunting dogs more aggressive (1). When a woman is approaching childbirth, she should mix the pounded bark of mutarara with the pounded bark of musvodzambudzi and drink them while standing in the doorway of the house, and then drop the cup at the doorway. This will protect the baby from envious people who want it to get stuck during birth (1). ***Other*** If a family has an **ngozi**[2], then they should brew beer and take it under the **mutarara**. They should say the name of the deceased person, and then leave them to rest under the tree with the pot of beer.
Grewia bicolor	Muton'olo	13	1.4	1.0	0.4	0.8	0.5	1.1	***Firewood/Poles*** Good **mbariro**[3]**.** ***Food*** The fruits are edible but not particularly tasty and so are mainly taken by children. Leaves can be cooked as vegetable relish. ***Medicinal uses*** Leaves cure backache (1). Roots cure stomach problems (1). Fibre treats coughs (1).
Grewia flavescens	Mufourbuns/ Mumhudzungwa	16	1.1	1.0	0.2	1.0	0.4	1.3	***Firewood/Poles*** Good **mbariro**[3]**.** ***Food*** Fruits are edible and mainly eaten by children. ***Medicinal uses*** Roots treat gynaecological problems (1) Fruits treat arthritis (2). Ashes from roots treat soft spot and vomiting in children (2).

Gymnosporia buxifolia/ G. senegalensis	Chizhuzhu	16	0.5	0.8	0.0	0.0	0.7	0.3	***Medicinal Uses*** Leaves treat eye problems (1), stomach problems (5) and ear problems (1). Roots can cure backache of mother whose daughter has just married (1)[5] and infertility (1). ***Other*** Branches placed on freshly dug graves, some say to keep away cattle and others say to keep away witches.
Julbernardia globiflora	Munondo	14	2.0	1.6	1.4	0.0	0.5	1.7	***Medicinal Uses*** Bark and fibre cure stomach pains (4), heartburn (1) and gynaecological problems (1). Washing with the pounded leaves of the parasite growing on munondo will increase attractiveness (1) and make you lucky (1). ***Other*** Fruits and new leaves are important food for cattle.
Lannea discolor	Mushambahuro	15	1.1	1.5	0.3	1.5	0.8	1.1	***Firewood/Poles*** Poles regerminate on planting, so used for living fences. ***Food*** Fruit is edible and eaten by adults and children, although only in passing. ***Medicinal uses*** Fibres treats coughs (4), leg pain (1), soft spot (1), witchcraft (1) and stomach problems (2).
Lantana camara	Lantana	16	0.4	0.6	0.0	0.9	0.6	0.9	***Food*** Fruits eaten mainly by children. ***Medicinal Uses*** Leaves treat toothache (2), wounds (1), coughs (1) and gynaecological problems (1). Leaves treat ear infections in cattle (1), although some believe poisonous to livestock. Bathing with leaves and roots chases away evil spirits (1). Leaves with water can be used as garden pesticide (1).
Mangifera indica	Mango	16	1.3	1.5	0.0	2.0	0.4	1.3	***Medicinal Uses*** Leaves can be used to treat flu and coughs (5), sometimes mixed with guava leaves.
Melia azerdarach	Mukina	14	1.1	1.4	0.0	0.0	0.9	1.1	***Medicinal uses*** Treats stomach pains (4) and STDs (1). Bark treats toothache (1). Leaves used as livestock cure (2), and fruits are a good livestock feed.
Mimusops zeyheri	Muchechete	11	1.5	1.5	0.0	1.9	0.1	1.3	***Food*** Fruit is good, but a sparsely distributed forest tree rarely found near the homestead. ***Medicinal uses*** Bark treats wounds (1).
Monotes glaber	Mushava	15	1.3	1.7	0.0	0.0	0.5	0.8	***Medicinal Uses*** Bark and leaves cure wounds (3). Treats stomach problems (1). Chewing roots and rubbing on forehead before a fishing trip will bring luck (1).
Ochna pulchra/ Psorospermum febrigum	Munyamharadzi	13	0.1	0.9	0.0	0.1	0.4	0.8	***Medicinal Uses*** Roots used as chicken cure (1). ***Other*** **Munyamharadzi** is a general term for unlucky trees. Bringing the tree into the house, as firewood or otherwise, will cause problems in the family, resulting in divorce (11) and making you commit crimes (1).

Opuntia ficus-indica	Mudorofia	16	0.0	0.1	0.0	1.5	0.4	0.0	***Food*** Leaves are pleasant to eat (although difficult to collect) and are also often eaten by cattle. ***Medicinal Uses*** Leaf treats leg problems (1), tooth problems (1), earache (1) and high blood pressure (1), and boost the immune system (1). Also a chicken cure (1).
Ormocarpum trichocarpum	Musvutaderere/ mupotanzou	16	1.1	1.4	0.1	0.1	0.6	0.4	***Firewood/Poles*** Good **mbariro**[3]. ***Food*** Leaves can be cooked as vegetable relish. ***Medicinal Uses*** Leaves treat stomach (1), soft spot (1), ringworm (1) and warts (1). Also used for baby if breastfeeding while pregnant[4] (1). Steam from boiled leaves used to cure hallucinations (1). Roots used to treat menstrual pain (1). Treats headaches (1).
Osyris lanceolata	Mupetabere	3	0.7	0.0	0.0	0.0	0.3	0.7	***Medicinal Uses*** Used to tame a cheating husband (1). Bathing with the leaves will make others respect you (1). If you cover someone with blankets and then add root powder and charcoal dust, then tell the person to say what is troubling them, then all their problems will go away (1).
Ozora insignis	Murungu/ Mugaragunguwo	13	1.1	1.4	0.0	0.0	0.8	1.0	***Firewood/Poles*** Produces a latex which dries on bark and leaves and protects the pole from termites. ***Medicinal Uses*** Bark treats backache (1) and stomach problems (1). Leaves cure stomach problems (1). Roots treat eczema and stomach problems (1). Roots also used for children who are not growing well (1) or who are breastfeeding while mother is pregnant[4] (1). ***Other*** An unlucky tree in some areas.
Parinari curatellifolia	Muhacha/ Muchakata	17	1.2	1.4	0.0	1.9	1.6	1.2	***Food*** **Hacha** fruit are widely eaten, although they have a pungent flavour which not everyone enjoys. They are particularly important as a famine food, and can also be used to make jam and sweet beer. ***Medicinal uses*** Chases away evil spirits (6). Also treats hallucinations (1), toothache (3), eye problems (1) and stomach problems (1), and used to ease childbirth (1). Apostolic churches use leaves for general healing (3). Pegs put in the thatch of the kitchen will prevent lightning (1). Traces left by the worms which eat muhacha can be used for children struggling with toilet training (1). Putting the leaves in beer will help prevent quarrelling after drinking (1). Writing your name on a leaf while travelling can act as a lucky charm (1). Used as a livestock cure (1). ***Other*** Muhacha was traditionally used for traditional ceremonies such as rainmaking, and was where people would take problems to share with the ancestors. Some suggest twigs can be used as toothbrushes (2), but others suggest that taking things from the tree will bring bad luck because you will also bring home the problems left at the tree.
Pavetta schummaniana	Musauti	8	0.9	0.4	0.0	0.3	1.1	0.6	***Medicinal Uses*** Leaves are salty and cure eye problems (1) and stomach problems (5). Roots cure toothache (1) and heartburn (1). Can be used to treat backache (1).

Peltophorum africanum	Muzeze	14	1.4	1.7	0.0	0.0	1.0	0.5	***Medicinal Uses*** Can cure evil spirits (2), and using **muzeze** to shake water over a dead person's clothes will chase away evil spirits before the clothes are shared (10), although this practice is becoming less common. Used to wash after childbirth to prevent infection (1). Bark used for stomach pains (1). Tiny leaves and fruits treat toothache (4). ***Other*** Pounding leaves and scattering around the homestead will keep away snakes. Hitting a new cow with a branch of muzeze will make it forget its previous owner.
Pericopsis angolensis	Muwanga	11	1.6	1.9	0.0	0.0	0.3	1.4	***Firewood/Poles*** Very strong poles. ***Medicinal Uses*** Bark improves strength (1) and treats stomach problems (1). Treats backache (1).
Piliostigma thonningii	Mubhuku/ Musekese/ Mutukutu/ mukochokocho	16	1.6	1.6	0.8	1.2	1.0	1.1	***Food*** Children often eat the fruits, while adults eat them only during periods of food shortage when they are an important famine food. ***Medicinal Uses*** Fruits treat stomach pains (2) and worms/bilharzia (2). Leaves cure stomach pains (1), cataracts (1) and coughs (1). Tying fibre around a woman's waist eases menstrual pains (1). Fibres treats coughs (2) and backache (1). Roots treat bleeding (1) and ease childbirth (1). ***Other*** All parts of the tree are suggested to prevent crocodile attacks. The author adivses against empirical testing of this hypothesis.
Pittosporum viridiflorum	Mukwirasvosve	10	1.2	1.6	0.0	0.0	0.7	0.9	***Firewood/Poles*** The firewood smells unpleasant and therefore isn't widely used – one respondent suggested that using the firewood will result in divorce. ***Medicinal Uses*** Bark treats stomach problems (2). Pounded leaves taken as snuff treat flu and headaches (1). ***Other*** A tree perceived by some as being vulgar or unlucky and therefore preferably avoided. Wood is difficult to cut because so strong, and can be used for making yokes and cooking implements.
Pouzolzia mixta	Nanzva	14	0.1	0.0	0.0	0.1	0.9	0.6	***Food*** Tender leaves can be cooked as vegetable relish, but rarely done. ***Medicinal Uses*** Roots used to treat painful legs (1) and lumps in the veins of the arms. Pounded roots used as contraceptive (2). Leaves treat soft spot (1). Fibres treats heartburn (1) and menstrual pains (1). Used to purge stomach (1) and ease childbirth (1). The plant is slippery, and can be used to wash hands if cow is struggling to calve (2). ***Other*** Slipperiness means used as sled by children from sliding down hills.
Protea gaguedi	Mumhonda	13	1.2	1.4	0.0	0.0	0.4	1.3	***Medicinal Uses*** Leaves used to improve immune systems of babies moving around community for the first time (1). Bark cures indigestion (1).

Pseudolachnos-tylis maprouneifolia	Mutsonzowa/ Mukuvazviyo	14	1.0	1.9	0.0	0.0	0.8	1.4	***Firewood/Poles*** A sacred tree which should never be used as firewood – taking the tree as firewood will mean that everything you own will be lost and the harvest will fail. ***Medicinal Uses*** Bathing with the leaves will chase away evil spirits (1). Leaves cure coughs (1). ***Other*** The reason for the firewood taboo is that **mutsonzowa** is used for rituals where people leave their evil spirits and their problems under the tree – this will solve the problem for the family doing the ritual, but if you then collect the tree as firewood then you will also collect those problems for yourself. Korekore communities sometimes put **mutsonzowa** on graves.
Psidium guajava	Guava	16	1.4	1.5	0.0	2.0	0.9	1.4	***Medicinal Uses*** Leaves used to treat coughs, sometimes along and sometimes mixed with lemon or mango leaves (14). Also treats rashes on legs (1).
Psydrax livida	Muvengahonye	9	1.2	0.9	0.0	0.0	0.9	0.9	***Medicinal Uses*** Leaves/roots used to prevent infection of wounds with worms in cattle (7). More rarely used to treat wounds in people (2).
Pterocarpus angolensis	Vamaropa	14	1.3	1.9	0.0	0.0	1.1	1.2	***Firewood/Poles*** Poles regerminate, so planted as living fence. ***Medicinal Uses*** Bark and sap treat wounds (2), bark treat stomach pains (2), cataracts (2), coughs (1) and painful legs (1). Sap treats ringworm (2). Fruits treat soft spot (3). Burning the fruits and feeding the ashes to dogs will prevent them being poisoned by other people (1). ***Other*** Tree is popular with carpenters for things like doorframes, although the tree is now scarce in the study area. Vamaropa is also called 'bloodwood' because of the red sap. Some respondents believed that witches will do rituals under the tree when they wish to murder someone – they will go to the bloodwood tree to ask for blood.
Rhus longipes	Mutsokotsiyana	15	1.4	1.5	0.0	1.7	0.3	1.3	***Food*** Fruits are small but taste good, and are collected in passing. ***Medicinal Uses*** Eating leaves cures mother's backache after daughter's marriage (1). Washing face with leaves cure painful eyes (1). Bark cures headache (1).
Schotia brachypetala	Mutondochuro	16	1.8	1.6	0.1	0.6	0.3	1.7	***Food*** The flowers contain sweet nectar and children will climb up to the treetops to collect them. ***Medicinal Uses*** Bark treats stomach problems (2)
Securidaca longepeduncula ta	Mufufu	15	1.1	1.5	0.0	0.0	1.6	0.7	***Medicinal Uses*** Bathing with bark and roots chases away evil spirits (3) and treats anxiety in children (2).Roots also used as soap (2) and to treat heartburn (1), stomach pains (3) and STDs (1). Also a popular general cure (4). ***Other*** Popularity of trees as a medicine means there are few large individuals and most trees have evidence of scarring from removal of bark/roots.

Senna singueana	Munzungunzungu	12	1.1	0.5	0.0	0.1	0.3	0.6	***Medicinal Uses*** Fruits used to treat indigestion (1) and worms (1). Roots used to treat female infertility (2). ***Other*** Pods can be used to kill fish (1).
Steganotaenia araliacea var aralicea	*Musvodzambudzi*	15	0.2	0.2	0.0	0.0	0.7	0.3	***Medicinal Uses*** Used to ease childbirth (1). ***Other*** If accused of a crime and you know you are guilty, carrying a small piece of this tree in your pocket during the court case will make the judge find in your favour (3). Can help prevent problems (2) and deliver you from temptation (1) Some believe cutting the poles will cause miscarriage (1). Children remove the inner part of the stem to make popguns.
Strychnos cocculoides	Mutamba muzhumu	18	1.4	1.6	0.0	1.9	0.2	0.7	***Food*** Fruits are sweeter and preferred to those of *S.spinosa* – widely eaten by both adults and children.
Strychnos spinosa	Mutamba mun'ono	18	1.4	1.6	0.0	1.3	0.6	0.8	***Food*** Fruits are widely eaten, but are less favoured than those of *S.cocculoides*. ***Medicinal Uses*** Unripe fruits used to cataracts in cattle (3) and people (1). Fruits used for curing painful leg – find a mutambe with only two remaining fruits, take one fruit and rub it on the legs (1). Bark treats backache (1). Can be used to make lotion for dry skin (1). Roots of young trees treat STDs (1).
Swartzia madagascarensis	Mucherekesa/ muremberembe	16	1.1	1.4	0.0	0.1	1.2	1.1	***Medicinal Uses*** Used as a livestock cure, particularly for chickens (12). Fruits sometimes given to HIV patients (1). Can also be used to treat stomach problems (2), heartburn (1) and STDs (1). The bark can be used to cure witchcraft – if a piece of clothing has been bewitched, then taking clothing of the same colour and mixing it with mucherekesa bark will cure the witchcraft (1).
Terminala sericea	Mususu (1)	15	1.7	2.0	0.2	0.0	0.7	1.0	See *T.stenostachya*
Terminalia stenostachya	Mususu (2)	15	1.7	2.0	0.2	0.0	0.7	1.1	***Firewood/Poles*** Very strong, straight wood, used for poles, yokes, cooking sticks, hoe handles and pestles. ***Medicinal Uses*** Fibres treat heartburn (2), appetite loss (1), stomach problems (1) and wounds (1) and are used to reduce duration of menstruation (1). Roots used to strengthen back (1). Bark and leaves used to treat stomach problems (2).
Turraea nilotica	Mukundanyoka	6	0.8	1.3	0.0	0.0	0.5	1.3	***Medicinal Uses*** Roots used to cure stomach pains (2) and to draw out a tooth left by a snakebite (1).
Uapaca kirkiana	Muzhanje	14	1.1	1.8	0.0	2.0	0.2	1.1	***Food*** Fruits are very popular and are often taken for sale. ***Medicinal Uses*** Bark treats eye problems (1), eczema (1) and stomach problems (1) ***Other*** Not good to keep near homestead because leftovers from fruits attract lightning (3).

Vangueria infausta	Munzviro	13	1.4	1.6	0.0	1.9	0.3	1.0	***Firewood/Poles*** Used to be used to make matches ***Food*** Fruits enjoyed by adults and children, although eaten in passing rather than being sought out. ***Medicinal Uses*** Roots treat constipation (1)
Vangueriopsis lanciflora	Mutufu	15	1.7	1.9	0.0	2.0	0.1	1.4	***Firewood/Poles*** Poor firewood for cooking, but burns brightly and sometimes used as a torch. ***Food*** Fruits are edible and very popular. ***Medicinal Uses*** Bark used to cure chest pains (1)
Vernonia amygdalina	Sikawakadzi	12	0.2	0.2	0.0	0.0	0.9	0.4	***Medicinal Uses*** Roots treat baby who won't stop crying (1). Leaves boost immune system in HIV patients (1). Women take roots to make their blood warmer and attract a husband (1). Roots also save pregnancy if someone is about to miscarry (1). Leaves treat stomach problems (4) and are also used as a livestock cure (1).
Vitex payos	Mutsubvu	15	1.7	1.7	0.0	2.0	0.6	1.5	***Firewood/Poles*** Twigs used to be used for firestartering because they burn very fast. ***Food*** Very popular fruits, sometimes collected for sale. ***Medicinal Uses*** Leaves smoked as tobacco to treat coughs (4) and chest pains (1). Green leaves can treat anxiety in children (1). Seeds used for toothache (1). Steambath with leaves treats headache (1).
Xeroderris stuhlmanii	Musunganyama	10	1.5	1.4	0.1	0.0	0.8	1.2	***Medicinal Uses*** Fibre and roots treat wounds (2) and eye problems (1). Bark and leaves treat stomach problems (3). Bark treats fatigue (1).
Ximenia caffra	Mutsvanzva	15	1.3	1.5	0.1	1.3	1.2	1.0	***Food*** Fruits are edible but quite sour, so eaten only in passing. They also become sour when removed from the bush, so can't be taken for sale. ***Medicinal Uses*** Leaves treat stomach problems (7), boils (1), ringworm (1), eye problems (1), eczema (1) and heartburn (1). Bark treats stomach problems (3), coughs (1) and backaches (1). Roots treat toothache (1)
Zanthxylum sp.	Muchinanga (chikafutu)	15	0.5	0.9	0.0	0.0	0.4	0.3	***Medicinal Uses*** Can be used to treat snakebites (1), and the pounded roots scattered around the homestead will stop snakes coming close (2). Also used to treat black veins on children's stomachs (1)
Ziziphus mucronata	Muchecheni	16	1.5	1.6	0.0	0.9	1.0	0.6	***Medicinal Uses*** Bark can be used to ease childbirth (2) and to cure stomach pains (1) and backache (1). Leaves can be used to treat boils (3), wounds (2) and headaches (1). Leaves can also be used to help someone give birth quickly – collect the leaves which have fallen from the tree facing upright, pound them and give the water to the pregnant person (2). ***Other*** The tree can be used as a charm to summon people to your business (1)

Unknown	Munyunguhwahwa	4	0.5	0.8	0.0	0.8	0.3	1.0	***Food*** The fruits are edible but sour, and so are eaten in passing rather than deliberately collected ***Medicinal Uses*** Roots can be used as contraceptive (1).
Unknown	Mutandangozi	12	1.2	1.5	0.0	0.0	0.4	1.1	***Medicinal Uses*** Roots used for abortions (1). Also cure stomach problems (1). The name means 'chase away **ngozi'** [2] and some believe bathing with the roots with chase away evil spirits.
Unknown	Indigenous Gum	12	1.6	1.9	0.0	0.0	0.2	1.2	***Medicinal Uses*** Roots cooked with cows' hooves cure can strengthen the backbone in men (1).

[1]Soft spot, termed **nhova** in Shona, refers to sinking in the fontanelle on a baby's head; it is seen as a serious condition, but does not have a clearly recognised analogue in 'modern' medicine and so is often treated using medicinal plants.
[2]An **ngozi** is a violent and angry spirit, often the ghost of a person who died through murder and returned to seek vengeance.
[3]Poles can be divided into three types. Normal building poles are straight, thick stems used to build structures such as cattle kraals and granaries. **Mbariro** are the thin stems used for constructing the roofs of kitchen huts. 'Living fences' are created by planting stems which resprout from cuttings, such as *Lannea discolor* and *Pterocarpus angolensis*.
[4]Local belief is that breastfeeding while pregnant is harmful to a small child, and the child is therefore given herbs to prevented being poisoned by the milk.
[5]Local belief is that when a woman gets married and sleeps with her husband for the first time, the woman's mother will suffer from backache.

Appendix 3: Chapter 4 Supporting Information

A3.1 Household Survey Example

Below is a reproduction of the survey instrument used to collect data on household assets and income in Wedza District. This specific questionnaire is from the third season (October/November 2015), but the same core questionnaire was used in all three seasons. In seasons two and three all questionnaires were customised for each respondent household, as this permitted immediate clarification of any differences (for example in the number or identity of household residents). Questionnaires were delivered and simultaneously translated by Amai Simba, while I transcribed responses and asked follow up questions.

Village: A Household: 25

Date		Start time		End time		Income Questionnaire		Valuations		Tree Use Survey	

1. Household Residents

a. Resident List

Adult Residents								
Code	**Household member**	**Age**	**Gender**	**Education**	**Main employment**	**Place of Birth**	**Time Resident**	**Involved in interview?**
1	Household Head	70	M	Form 2	Farming, livestock	Makumbe	Whole Life	
3	Wife	67	F	Standard 6	Farming	Kujeke	50 years	
4	Niece	22	F	Form 5	Remittances	Sango, Wedza	18 years	
5	Nephew	19	M	Form 5	Remittances	Sango, Wedza	18 years	

Residents <18 years old				
Code	**Relation to Head**	**Age**	**Attending school?**	**Involved in interview?**

a. Are you a member of any societies, associations, clubs or churches?

Resident(s)	Association
3	Methodist

b. Has anyone in your household been ill and unable to work in the previous month?

Resident(s)	Days Unable to Work

Village: A Household: 25

Section 2: Household Assets

a. Land Holdings

Land Type	Area Owned Feb/March 2015	Any change?
Farmland	8 acres	
Gardens	1 (1 used, 1 unused)	

b. Household Buildings

Building Type	Number	Wall Material	Ceiling Material	Number of bedrooms?
Kitchen	1	Cement/Concrete	Metal	
Main House	1	Bricks	Metal	
Toilet/Bathroom	1	Bricks	None	
Storehouses, granaries and barns	2			

c. How many (asset) do you own?

Asset Type	Number	Asset Type	Number	Asset Type	Number
Plough		Deep well at homestead		Radio	
Cultivator		Gum trees		Television	
Harrow		Shed/Tool Store		Generator	
Hoe		Kraal		Mobile Phone	
Wheelbarrow		Granary		Solar Panels	
Scotch Cart		Beds			
Bicycle		Chairs			
Motor Vehicle		Lounge Suite			

d. Do you have any savings?

e. Do you owe anyone anything, either in cash or kind?

Savings ($)	
Cash debts	
Non-cash debts	

Village: A Household: 25

Section 3: Household Income

a. **Environmental Income**

(i) In the last month, has anyone in your household collected anything from Wedza Mountain?

Unprocessed products (e.g. firewood, poles, thatching grass) – Wedza Mountain

Item	Source Location	Amount Harvested	Collected by	Number of trips made	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Processed products (e.g. axe handles, sweeping brooms) – Wedza Mountain

Raw Material	Source Location	Product Made	Made by	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

(ii) In the last month, has anyone in your household collected anything from contour ridges or unused fields?

Unprocessed products (e.g. firewood, poles, thatching grass) – contour ridges

Item	Source Location	Amount Harvested	Collected by	Number of trips made	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Village: A Household: 25

Processed products (e.g. axe handles, sweeping brooms) – contour ridges

Raw Material	Source Location	Product Made	Made by	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

(iii) In the last month, has anyone in your household collected anything from zvikomo, anthills or rocky places?

Unprocessed products (e.g. firewood, poles, thatching grass) – zvikomo

Item	Source Location	Amount Harvested	Collected by	Number of trips made	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Processed products (e.g. axe handles, sweeping brooms) – zvikomo

Raw Material	Source Location	Product Made	Made by	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

(iv) In the last month, has anyone in your household collected anything from bani or dofonya?

Unprocessed products (e.g. firewood, poles, thatching grass) – bani/dofonya

Item	Source Location	Amount Harvested	Collected by	Number of trips made	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Village: A Household: 25

Processed products (e.g. axe handles, sweeping brooms) – bani/dofonya

Raw Material	Source Location	Product Made	Made by	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

(v) In the last month, has anyone in your household collected anything from streams or rivers?

Unprocessed products (e.g. firewood, poles, thatching grass) – streams/rivers

Item	Source Location	Amount Harvested	Collected by	Number of trips made	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Processed products (e.g. axe handles, sweeping brooms) – streams/rivers

Raw Material	Source Location	Product Made	Made by	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

(vi) In the last month, has anyone in your household collected anything from any other grazing area?

Unprocessed products (e.g. firewood, poles, thatching grass) – other grazing area

Item	Source Location	Amount Harvested	Collected by	Number of trips made	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Village: A Household: 25

Processed products (e.g. axe handles, sweeping brooms) – other grazing area

Raw Material	Source Location	Product Made	Made by	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

(vii) In the last month, has anyone in your household collected anything from any other part of the natural environment?

Unprocessed products (e.g. firewood, poles, thatching grass) – other area

Item	Source Location	Amount Harvested	Collected by	Number of trips made	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Processed products (e.g. axe handles, sweeping brooms) – area

Raw Material	Source Location	Product Made	Made by	Quantity for Own Use	Quantity Sold	Reported Value	Input Costs	Total Value

Prompts: In the last month, has anyone in your household collected any:

- Firewood?
- Construction material – Poles? Thatching grass? Fibres?
- Wild foods – Fruit? Vegetables? Fish? Meat? Insects? Mushrooms?
- Herbs?
- Fertilisers – Leaf litter? Anthill soil?
- Minerals or soils – gold? Pot soil?

Village: A Household: 25

b. Agricultural Income

(i) Have you harvested anything from your fields **since March this year**?

Crop	Total Production since March	Quantity Kept for Own Use	Quantity Sold	Crop Value	Total Value

(ii) Have you spent anything on the following inputs for your fields **since March 2015**?

Fertiliser		Draught power	
Seeds		Hired labour	
Pesticides/Herbicides		Transport/Marketing	
Manure		Other	

(iii) How many contours did you cultivate in the last farming season? _____

Field Crop Income Confirmation (referring to the year from September '14 to September '15

In September/October/November last year you ploughed __ contours using your own cattle.
You planted 40kg of maize seed which cost $10 per 10kg.
For fertiliser you used 4*compound D @ $30 each and 2*top at $36 each. You were given two bags by the government, but didn't use them last year. You used about 7 ngoro of manure. You didn't use any anthill soil or leaf litter.
You did all the work yourself.
You harvested (amounts above). You didn't harvest any of the following: maize, sorghum, rapoko, rice; groundnuts, roundnuts, cowpeas, sugar beans, soya beans, cowpeas; sweet potatoes, mashamba, potatoes, pumpkins, squash, sunflower, ipwa.

Village: A Household: 25

(iv) Have you harvested anything from your garden in the **last month?**

Crop	Total Production in last month	Quantity Kept for Own Use	Quantity Sold	Value of Crop	Total Value

(v) In the last year, how much have you spent on the following inputs for use in your garden?

Fertiliser		Draught power[1]	
Seeds		Hired labour	
Pesticides/Herbicides		Transport/Marketing	
Manure		Other	

(vi) Do you own any fruit trees? How much have you collected from each type of tree in the last year?

Type of Tree	Total Production in last year	Quantity Kept for Own Use	Quantity Sold	Value of Fruit	Total Value

Village: A Household: 25

(vii) Income from livestock since **March 2015**

Animal	Number owned Feb/Mar '15	Number owned October '15	Sold	Own Consumption	Lost/Gifted	Purchased	New from Own Stock	Price per unit
Cattle	17							
Goats	4							
Donkeys	0							
Rabbits	0							
Chickens	3+8							
Turkey	0							
Guinea Fowl	0							
Pigeons	0							
Other	0							

(viii) Income from livestock products in the **last month**

Product	Total Production	Quantity for Own Use	Quantity Sold	Price Per Unit	Total Value
Meat		(Covered above)			
Milk					
Eggs					
Hides/Skins					
Manure					
Draught Power					
Other					

(ix) How much have you spent on the following livestock inputs **since March 2015**?

Food		Veterinary costs	
Barn/Enclosure Maintenance		Hired Labour	
Other			

(x) Did you use anything from your own farm to feed your livestock **since March 2015**, such as maize or pumpkins?

Item	Quantity	Price per Unit

Village: A Household: 25

Livestock Income Confirmation and Follow Ups

You currently own ___ cattle. You mainly look after them yourself. You take them to the dip ____ times a year and give them injections ____ times a year at a cost of ____.

c. Other Income Sources

(i) Has anyone in your household undertaken any paid work since **March 2015**?

Resident Code	Type of Work	Location of Work	Days Worked in Last 4 Months	Hourly/Daily/Monthly Wage Rate (as applicable)	Total Income

(ii) Does anyone run any kind of business that contributed to household income since **March 2015**?

Resident Code	Type of Business	Location of Business	Profit Last Month	Profit since March '15	Capital Value of Stock

(iii) Has the household received any income from remittances since March 2015?

Remittance Source Individual	Remittance Source Location	Remittance Amount

Village: A Household: 25

(iv) Has the house received anything in pension payments since August '14?

Previous Employer	Payment Per Month
Zinwa	$150 per month

(v) Has the household received any income from the following sources in the last four months?

Source	Payments in last 4 months		
Payment for renting out land			
Payment for renting out property		*Property Location*	
Support from government			
Support from other organisation		*Organisation*	

(vi) Have we missed any income sources important to your household?

Income Source	Amount received in last 4 months

A3.2 Household Income Categories

Table A3.1: Categories used to calculate net household income, with associated deducted inputs.

Income Category	Recall Period	Description	Inputs
Environmental Income			
Environmental Income (organic)	One month	Wild-sourced organic resources including woodfuel, wild foods, construction material and leaf litter.	Paid labour **Ngoro**[1] hire
Environmental Income (inorganic)	One month	Gold	Mercury Payments to concession owners Bribes/Fines
		Building materials, painting and plastering soils	Paid labour **Ngoro** hire
Agriculture			
Field Crops	Four to six months	Crops grown in fields during the main farming season including (but not limited to): - Cereals (maize, sorghum, millet, rice) - Legumes (groundnuts, roundnuts, beans, cowpeas) - Tobacco - Sweet potatoes	Seed and synthetic fertiliser, either (a) paid for or (b) given by the government (accounted under government support). Pesticides Livestock manure inputs (accounted for under livestock). Leaf litter fertiliser and anthill soil (accounted under organic environmental). Paid labour, including ploughing. Woodfuel for tobacco curing (accounted under organic environmental). Transport of crops to market. Tobacco deductions[2].
Garden Crops	One month	Horticulture crops including leafy green vegetables, tomatoes, onions and sugar cane. Some households use garden plots as additional fields during the farming season. Crops such as maize grown on garden plots are accounted for under field crops.	Seeds. Pesticides. Fertiliser inputs, either synthetic, livestock manure or environmental. Paid labour, including ploughing.
Livestock	Four to six months for livestock sale and consumption One month for small livestock products One year for manure field inputs	Consumption and sale of own livestock, primarily cattle, goats and chickens. Consumption and sale of milk and eggs. Manure used as agricultural input.	Purchases of livestock. Purchased livestock feed. Use of own crops as feed (accounted under field crops) Veterinary costs. Paid labour (e.g. for herding and constructing livestock pens)

Business and Employment			
Business	Four to six months	Primarily small-scale informal businesses buying and selling groceries and clothes.	All running costs, including costs of purchasing, labour payments and transport.
Skilled regular employment	Four to six months	Higher paid employment requiring formal qualifications or long experience, including teaching and building.	NA
Unskilled regular employment	Four to six months	Lower paid employment not requiring formal training, such as cleaning shops or being a security guard.	NA
Piecework	Four to six months	Informal short-term jobs such as weeding maize, herding cattle or cleaning groundnuts.	NA
Transfers			
Remittances	Four to six months	Gifts in cash or kind (e.g. clothes and groceries) sent by relatives living outside the study area. Also includes payments of lobola (the price paid by the family of a husband to the parents of the wife on marriage).	NA
Pensions	Four to six months		NA
Payments from rental properties	Four to six months	Several households rent out properties in Harare and Marondera, or shops in Garaba.	NA
Government/NGO support	Four to six months	Including fertiliser, seeds, and food during lean seasons.	NA

[1]An **ngoro**, also called a scotch cart, is a small metal cart pulled by cattle.

[2]Tobacco farming is seen as an important driver of woodland degradation in Zimbabwe (Geist, 1999), and smallholder farmers who cannot prove that they used coal or sustainably harvested wood for curing tobacco are often fined at the auction floors.

Appendix 4: Literature review papers compiled for Chapter 6

Table A4.1 Papers identified during literature review carried out to assess prevalence of different value discourses in miombo ecosystem services literature.

Paper reference	Uses Ecosystem Service language?	Ecological Integrity	Regulatory Functions	Extractive Uses	Socio-ecological resilience	Symbolic Values	Justice and Equity
Ahrends, A., Burgess, N.D., Milledge, S.A.H. *et al.* (2010) Predictable waves of sequential forest degradation and biodiversity loss spreading from and African city. *PNAS* **107**: 14556-14561	N	1	1	0	0	0	0
Ajayi, O.C., Akinnifesi, F.K. & Ajayi, A.O. (2016) How by-laws and collective action influence farmers' adoption of agroforestry and natural resource management technologies: lessons from Zambia. *Forests Trees and Livelihoods* **25**: 102-113	Y	0	1	1	0	0	0
Akinnifesi, F.K., Kwesiga, F., Mhango, J. *et al.* (2012) Towards the development of miombo fruit trees as commercial tree crops in Southern Africa. *Forests Trees and Livelihoods* **16**: 103-121	N	0	0	1	1	0	0
Asanzi, P., Putzel, L., Gumbo, D. & Mupeta, M. (2014) Rural livelihoods and the Chinese Timber Trade in Zambia's Western Province. *International Forestry Review* **16**: 446-458	N	0	0	1	0	0	1
Backéus, I., Pettersson, B., Strömquist, L. & Ruffo, C. (2015) Tree communities and structural dynamics in miombo (*Brachystegia-Julbernardia*) woodland, Tanzania. *Forest Ecology and Management* **230**: 171-178	Y	1	0	0	1	0	0
Banda, F. & Jimaima, H. (2015) The semiotic ecology of linguistic landscapes in rural Zambia. *Journal of Sociolinguistics* **19**: 643-670	N	0	0	0	0	1	0
Banda, T., Schwartz, M.W. & Caro, T. (2005) Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania. *Forest Ecology and Management* **230**: 179-185	N	1	0	0	0	0	0
Bandyopadhyay, S., Shyamsundar, P. & Baccini, A. (2011) Forests, biomass use and poverty in Malawi. *Ecological Economics* **70**: 2461-2471	Y	0	0	1	0	0	0
Baudron, F., Corbeels, M., Andersson, J.A. *et al.* (2011) Delineating the drivers of waning wildlife habitat: the predominance of cotton farming on the fringe of protected areas in the mid-Zambezi Valley, Zimbabwe. *Biological Conservation* **144:** 1481-1493	N	1	0	1	0	0	0
Baumert, S., Luz, A.C., Fisher, J. *et al.* (2016) Charcoal supply chains from Mabalane to Maputo: who benefits? *Energy for Sustainable Development* **33**: 129-138	Y	0	0	1	0	0	1
Bayliss, J., Schaafsma, M., Balmford, A. *et al.* (2014) The current and future value of nature-based tourism in the Eastern Arc Mountains of Tanzania. *Ecosystem Services* **8**: 75-83	Y	1	0	1	0	0	0
Bayliss, J., Makungwa, S., Hecht, J. *et al.* (2007) Saving the island in the sky: the plight of the Mount Mulanje cedar *Widdringtonia whytei* in Malawi. *Oryx* **41**:64-69	N	1	0	0	0	0	0
Beymer-Farris, B.A. & Bassett, T.J. (2012) The REDD menace: resurgent protectionism in Tanzania's mangrove forests. *Global Environmental Change* **22**: 332-341	N	1	1	1	1	0	1

Paper reference	Uses Ecosystem Service language?	Ecological Integrity	Regulatory Functions	Extractive Uses	Socio-ecological resilience	Symbolic Values	Justice and Equity
Blaikie, P. (2006) Is small really beautiful? Community-based natural resource management in Malawi and Botswana. *World Development* **34**: 1942-1957	N	1	0	1	0	0	1
Bleyer, M., Kniivilä, M., Horne, P. *et al.* (2016) Socio-economic impacts of private land use investment on rural communities: industrial forest plantations in Niassa, Mozambique. *Land Use Policy* **51**: 281-289	Y	0	0	1	0	0	1
Blomley, T. & Ramadhani, H. (2006) Going to scale with Participatory Forest Management: early lessons from Tanzania. *International Forestry Review* **8**: 93-100	N	1	0	1	0	0	0
Blomley, T., Pfliegner, K., Isango, J. *et al.* (2008) Seeing the wood for the trees: an assessment of the impact of participatory forest management on forest condition in Tanzania. *Oryx* **42**: 380-391	N	1	0	0	0	0	0
Bluwstein, J. & Lund, J.F. (2016) Territoriality by conservation in the Selous-Niassa Corridor in Tanzania. World Development http://dx.doi.org/10.1016/j.worlddev.2016.09.010	N	1	0	0	0	1	1
Brockington, D. (2006) The politics and ethnography of environmentalisms in Tanzania. *African Affairs* **105**: 97-116	N	0	0	0	0	0	1
Brockington, D. (2007) Forests, community conservation, and local government performance: the village forest reserves of Tanzania. *Society and Natural Resources* **20**: 835-848	N	1	0	0	0	0	1
Brockington, D., Sachedina, H. & Scholfield, K. (2008) Preserving the new Tanzania: conservation and land use change. *International Journal of African Historical Studies* **41**: 557-579	N	1	0	1	0	1	1
Bruschi, P., Morganti, M., Mancini, M. & Signorini, M.A. (2011) Traditional healers and laypeople: a qualitative and quantitative approach to local knowledge on medicinal plants in muda (Mozambique). *Journal of Ethnopharmacology* **138**: 543-563	N	0	0	1	0	0	0
Bruschi, P., Mancini, M., Mattioli, E. *et al.* (2014) Traditional use of plants in a rural community of Mozambique and possible links with *Miombo* degradation and harvesting sustainability. *Journal of Ethnobiology and Ethnomedicine* **10**:1-22	N	1	0	1	0	0	0
Burgess, N.D., Butynski, T.M., Cordeiro, N.J. *et al.* (2007) The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological Conservation* **134**: 209-231	Y	1	0	0	0	0	0
Burgess, N.D., Bahane, B., Clairs, T. *et al*. (2010) Getting ready for REDD+ in Tanzania: a case study of progress and challenges. *Oryx* **44**: 339-351	Y	0	1	0	0	0	0
Burgess, N.D., Malugu, I., Sumbi, P. *et al.* (2017) Two decades of change in state, pressure and conservation responses in the coastal forest biodiversity hotspot of Tanzania. *Oryx* **51**: 77-86	Y	1	0	0	0	0	0
Butz, R.J. (2013) Changing land management: a case study of charcoal production among a group of pastoral women in northern Tanzania. *Energy for Sustainable Development* **17**: 138-145	N	1	0	1	0	0	0
Cabral, A.I.R., Vasconcelos, M.J., Oom, D. & Sardinha, R. (2010) Spatial dynamics and quantification of deforestation in the central-plateau woodlands of Angola (1990-2009). *Applied Geography* **31**: 1185-1193	Y	0	1	0	0	0	0
Chagumira, C., Rurinda, J., Nezomba, H. *et al.* (2016) Use patterns of natural resources supporting livelihoods of smallholder communities and implications for climate change adaptation in Zimbabwe. *Environment Development and Sustainability* **18**: 237-255	Y	0	0	1	1	0	0

Paper reference	Uses Ecosystem Service language?	Ecological Integrity	Regulatory Functions	Extractive Uses	Socio-ecological resilience	Symbolic Values	Justice and Equity
Chapungu, L., Tabuka, N. & Zinhiva, H. (2014) A multi-method analysis of forest fragmentation and loss: the case of ward 11, Chiredzi District of Zimbabwe. *African Journal of Environmental Science and Technology* **8**: 121-128	N	1	0	0	0	0	0
Chibwana, C., Jumbe, C.B.L., & Shively, G. (2012) Agricultural subsidies and forest clearing in Malawi. *Environmental Conservation* **40**: 60-70	Y	1	0	1	0	0	0
Chidumayo, E.N. (2013) Forest degradation and recovery in a miombo woodland landscape in Zambia: 22 years of observations on permanent sample plots. *Forest Ecology and Management* **291**: 154-151	N	0	1	1	0	0	0
Chidumayo, E.N. (2013) Estimating tree biomass and changes in root biomass following clear-cutting of *Brachystegia-Julbernardia* (miombo) woodland in central Zambia. *Environmental Conservation* **41**: 54-63	N	0	1	0	0	0	0
Chilima, C., Bulambo, V.M. & Chiotha, S. (2016) The impact of deforestation and forest conversion on abundance and diversit of insects and plants in a miombo forest. *African Journal of Ecology* **54**: 507-509	N	1	0	0	0	0	0
Chilongo, T. (2014) Livelihood strategies and forest relianc ein Malawi. *Forests Trees and Livelihoods* **23**: 188-210	N	0	0	1	0	0	0
Chinangwa, L., Sinclair, F., Pullin, A.S. & Hockley, N. (2016) Can co-management of government forest reserves achieve devolution? Evidence from Malawi. *Forests Trees and Livelihoods* **25**: 41-58	N	0	0	0	0	0	1
Chinigo, D. (2015) Re-peasantisation and land reclamation movements in Malawi. *African Affairs* **115**: 97-118	N	0	0	0	0	0	1
Chinuwo, T., Gandiwa, E., Mugabe, P.H. *et al.* (2010) Effects of previous cultivation on regeneration of Julbernardia globiflora and Brachystegia spiciformis in grazing areas of Mupfurudzi Resettlement Scheme, Zimbabwe. *African Journal of Range and Forage Science* **27**: 45-49	N	0	0	0	1	0	0
Chirozva, C., Black, R. & Higgins, V. (2017) "A place of pain and gain": exploring the dynamics of resistance in the creation of Sengwe Tshipise Wilderness Corridor, Southeast Zimbabwe. *Society and Natural Resources:* DOI: 10.1080/08941920.2016.1265186	N	0	0	0	0	1	1
Chirwa, P.W., Syampungani, S. & Geldenhuys, C.J. (2009) The ecology and management of the Miombo woodlands for sustainable livelihoods in southern Africa: the case for non-timber forest products. *Southern Forests: A Journal of Forest Science* **70**: 237-245	Y	1	1	1	0	0	0
Chungu, D., Muimba-Kankolongo, A., Roux, J. & Malambo, F.M. (2007) Bark removal for medicinal use predisposes indigenous forest trees to wood degradation Zambia. *Southern Hemisphere Forestry Journal* **69**: 157-163	Y	1	0	1	0	0	0
Cliggett, L., Colson, E., Hay, R. *et al.* (2007) Chronic uncertainty and momentary opportunity: a half century of adaptation among Zambia's Gwebe Tonga. *Human Ecology* **35**: 19-31	N	0	0	0	1	0	0
Clover, J., & Eriksen, S. (2009) The effects of land tenure change on sustainability: human security and environmental change in southern African savannas. *Environmental Science and Policy* **12**: 53-70	Y	0	0	1	1	0	1
Danielsen, F., Skutsch, M., Burgess, N.D. *et al.* (2011) At the heart of REDD+: a role for local people in monitoring forests? *Conservation Letters* **4**: 158-167	N	0	1	0	0	0	1
Davies, G.M., Pollard, L. & Mwenda, M.D. (2010) Perceptions of land-degradation, forest restoration and fire management: a case study from Malawi. Land Degradation and Development **21**: 546-556	Y	0	1	1	0	0	0

Paper reference	Uses Ecosystem Service language?	Ecological Integrity	Regulatory Functions	Extractive Uses	Socio-ecological resilience	Symbolic Values	Justice and Equity
Death, C. (2013) Environmental mainstreaming and post-sovereign governance in Tanzania. *Journal of Eastern African Studies* **7**: 1-20	N	0	0	0	0	0	1
Deininger, K. & Xia, F. (2016) Quantifying spillover effects from large land-based investment: the case of Mozambique. *World Development* **87**: 227-241	N	0	0	1	0	0	1
Dewees, P.A., Campbell, B.M., Katerere, Y. *et al.* (2010) Managing the miombo woodlands of Southern Africa: policies, incentives and options for the rural poor. *Journal of Natural Resources Policy Research* **2**: 57-73	Y	1	1	1	1	0	1
Dodson, Z.M., Dempwolf, J., Silva, J.A. (2016) Does prolonged illness contribute to adaptive land use practices among subsistence agricultural households in rural Mozambique? *Applied Geography* **67**: 109-118	N	0	0	0	1	0	0
Dokken, T. & Angelsen, A. (2015) Forest reliance across poverty groups in Tanzania. *Ecological Economics* **117**: 203-211	N	0	0	1	1	0	0
Dons, K., Panduro, T.E., Bhattarai, S. & Smith-Hall, C. (2014) Spatial patterns of subsistence extraction of forest products - an indirect approach for estimation of forest degradation in dry forest. *Applied Geography* **55**: 292-299	N	0	1	0	0	0	0
Dougill, A.J., Stringer, L.C., Leventon, J. *et al.* (2012) Lessons from community-based payment for ecosystem service schemes: from forests to rangelands. *Philosophical Transactions of the Royal Society B: Biological Sciences* **367:** 3178-3190	Y	0	1	1	0	0	1
Dunkelberg, E., Finkbeiner, M. & Hirschl, B. (2014) Sugercane ethanol production in Malawi: measures to optimise the carbon footprint and to avoid indirect emissions. *Biomass and Bioenergy* **71**: 37-45	N	0	1	0	0	0	0
Dyngeland, C., Vedeld, P. & Vatn, A. (2014) REDD+ at work? Implementing consistent REDD+ policies at local levels - a case from Kilosa District, Tanzania. *International Forestry Review* **16**: 549-562	N	0	1	1	0	0	1
Eilola, S., Käyhkö, N., Fagerholm, N. & Kombo, Y.H. (2014) Linking farmers' knowledge, farming strategies, and consequent cultivation patterns into the identification of healthy agroecosystem characteristics at local scales. *Agroecology and Sustainable Food Systems* **38**: 1047-1077	Y	0	1	1	1	0	0
Eilola, S., Fagerholm, N., Mäki, S. *et al.* (2015) Realisation of participation and spatiality in participatory forest management - a policy-practice analysis from Zanzibar, Tanzania. *Journal of Environmental Planning and Management* **58**: 1242-1269	N	0	0	0	0	0	1
Ekblom, A., Notelid, M. & Witter, R. (2017) Negotiating identity and heritage through authorised vernacular history, Limpopo National Park. *Journal of Social Archaeology* **17**: 49-68	N	0	0	0	0	1	1
Elliot, J.A., Burnside, N.G., Broomhead, T. *et al.* (2006) The nature and extent of landscape change under land resettlement programmes in Zimbabwe. Land Degradation and Development **17**: 495-508	N	0	0	0	0	0	0
Enfors, E.I. & Gordon, L.J. (2007) Analysing resilience in dryland agro-ecosystems: a case study of the Makanya Catchment in Tanzania over the past 50 years. *Land Degradation and Development* **18**: 680-696	Y	0	0	0	1	0	0
Eriksen, S.E.H. & Watson, H.K. (2009) The dynamic context of southern African savannas: investigating emerging threats and opportunities to sustainability. *Environmental Science and Policy* **12**: 5-22	Y	0	0	0	1	0	0
Eriksen, C. (2007) Why do they burn the 'bush'? Fire, rural livelihoods, and conservation in Zambia. *The Geographical Journal* **173**: 242-256	N	0	1	1	0	0	1

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Eriksen, S.H., Browne, K. & Kelly, P.M. (2005) The dynamics of vulnerability: locating coping strategies in Kenya and Tanzania. *The Geographical Journal* **171**: 287-305	N	0	0	0	1	0	0
Exner, A., Bartels, L.E., Windhaber, M. *et al.* (2015) Constructing landscapes of value: capitalist investment for the acquisition of marginal or unused land - the case of Tanzania. *Land Use Policy* **42**: 652-663	N	0	0	1	0	0	1
Fagerholm, N. & Käyhkö, N. (2009) Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania. *Fennia* **187**: 43-60	Y	0	0	1	0	1	0
Fagerholm, N., Käyhkö, N., Ndumbaro, F. & Khamis, M. (2012) Community stakeholders' knowledge in landscape assessments - mapping indicators for landscape services. *Ecological Indicators* **18**: 421-433	Y	0	0	1	1	0	0
Fagerholm, N., Käyhkö, N. & van Eetvelde, V. (2013) Landscape characterisation integrating expert and local spatial knowledge of land and forest resources. *Environmental Management* **52**: 660-682	Y	0	0	1	0	0	1
Falcão, M., Samaila, R., Grundy, I. & Geldenhuys, C. (2007) The impact of policy on resource use in Mozambique: a case study of Savane. *Silva Lusitana* **15:** 89-102	N	1	0	1	0	0	0
Faße, A. & Grote, U. (2013) The economic relevance of sustainable agroforestry practices - an empirical analysis from Tanzania. *Ecological Economics* **94**: 86-96	N	0	0	1	0	0	0
Felix, M. (2015) Future prospect and sustainability of wood fuel resources in Tanzania. *Renewable and Sustainable Energy Reviews* **51**: 856-862	Y	1	0	1	0	0	0
Fisher, M. & Shively, G. (2005) Can income programs reduce tropical forest pressure? Income shocks and forest use in Malawi. *World Development* **33**: 1115-1128	Y	1	0	0	1	0	0
Fisher, M. & Shively, G.E. (2007) Agricultural subsidies and forest pressure in Malawi's 'miombo' woodlands. Journal of Agricultural and Resource Economics **32**: 349-362	Y	1	0	1	0	0	0
Fisher, M., Chaudhury, M. & McCusker, B. (2010) Do forests help rural households adapt to climate variability? Evidence from southern Malawi. *World Development* **38**: 1241-1250	Y	0	0	0	1	0	0
Fisher, B., Lewis, S.K., Burgess, N.D. *et al.* (2011) Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. *Nature Climate Change* **1**: 161-164	Y	0	1	1	0	0	0
Fisher, B., Turner, R.K., Burgess, N.D. *et al.* (2011) Measuring, modelling and mapping ecosystem services in the Eastern Arc Mountains of Tanzania. *Progress in Physical Geography* **35**: 595-611	Y	1	1	1	0	0	1
Fontein, J. (2006) Silence, destruction and closure at Great Zimbabwe: local narratives of desecreation and alienation. *Journal of Southern African Studies* **32**: 771-794	N	0	0	0	0	1	1
Fontein, J. (2006) Languages of land, water and 'tradition' around Lake Mutirikwi in southern Zimbabwe. *Journal of Modern African Studies* **44**: 223-249	N	0	0	0	0	1	1
Fontein, J. (2011) Graves, ruins and belonging: towards an anthropology of proximity. *Journal of the Royal Anthropological Institute* **17**: 706-727	N	0	0	0	0	1	1
Frontani, H.G. & Davis, J.M. (2008) Ideologies of land and place: memories from Zimbabwe's war of liberation. *South African Geographical Journal* **90:** 54-63	N	0	0	0	0	1	1
Frost, P., Campbell, B., Luckert, M. *et al.* (2007) In search of improved rural livelihoods in semi-arid regions through local management of natural resources: lessons from case studies in Zimbabwe. *World Development* **35**: 1961-1974	N	0	0	1	1	0	0

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Funder, M., Danielsen, F., Ngaga, Y. *et al.* (2013) Reshaping conservation: the social dynamics of participatory monitoring in Tanzania's community-managed forests. *Conservation and Society* **11**: 218-232	Y	0	0	0	0	0	1
Gardner, T.A., Caro, T., Fitzherbert, E.B., Banda, T. & Lalbhai, P. (2007) Conservation value of multiple-use areas in East Africa. *Conservation Biology* **21**: 1516-1525	N	1	0	0	0	0	0
Gausset, Q., Lund, J.F., Theilade, I. *et al.* (2007) Why combine private and communal tree management? A case-study based in Majawanga (Gairo, Tanzania). *The Journal of Transdisciplinary Environmental Studies* **6**: 1-18	Y	0	0	1	0	0	1
Gerhardt, J. & Nemarundwe, N. (2006) Participatory planning and management of indigenous trees: lessons from Chivi District, Zimbabwe. *Agriculture and Human Values* **23**: 231-243	Y	0	0	1	0	0	0
German, G., Akinnifesi, F.K., Edriss, A.K. *et al.* (2009) Influence of property rights on farmers' willingness to plant indigenous fruit trees in Malawia and Zambia. *African Journal of Agricultural Research* **4**: 427-437	N	0	0	1	1	0	1
German, L., Schoneveld, G.C. & Gumbo, D. (2011) The local social and environmental impacts of smallholder-based biofuel investments in Zambia. *Ecology and Society* **16**: 12	N	0	0	1	0	0	1
German, L., Mandondo, A., Paumgarten, F. & Mwitwa, J. (2014) Shifting rights, property and authority in the forest frontier: 'stakes' for local land users and citizens. *The Journal of Peasant Studies* **41**: 51-78	Y	0	0	1	0	0	1
Gibbon, H., Mbithi, D., Mugo, E.N. & Phiri, M. (2005) Forest and woodland management in East and Central Africa: emerging models of improvement in livelihoods and natural resource management in Kenya and Zambia. *International Forestry Review* **7**: 193-207	Y	1	0	1	0	0	1
Girvetz, E.H., Gray, E., Tear, T.H. & Brown, M.A. (2014) Bridging climate science to adaptation action in data sparse Tanzania. *Environmental Conservation* **41**: 229-238	Y	1	0	0	1	0	0
Godoy, F.L., Tabor, K., Burgess, N.D. *et al.* (2011) Deforestation and CO2 emissions in coastal Tanzania from 1990 to 2007. *Environmental Conservation* **39**: 62-71	Y	1	1	0	0	0	0
Göhre, A., Toto-Nienguesse, A.B., Futuro, M. *et al.* (2016) Plants from disturbed savanna vegetation and their usage by Bakongo tribes in Uige, Northern Angola. *Journal of Ethnobiology and Ethnomedicine* **12**: 42	N	0	0	1	0	0	0
Gonçalves, F.M.P., Revermann, R., Gomes, A.L. *et al.* (2017) Tree species diversity and composition of miombo woodlands in south-central Angola: a chronosequence of forest recovery after shifting cultivation. International Journal of Forestry Research: https://doi.org/10.1155/2017/6202093	Y	1	0	0	0	0	0
Green, K.E. & Lund, J.F. (2015) The politics of expertise in participatory forestry: a case from Tanzania. *Forest Policy and Economics* **60**: 27-34	N	0	0	0	0	0	1
Green, K.E. (2016) A political ecology of scaling: struggles over power, land and authority. *Geoforum* **74**: 88-97	N	0	0	0	0	0	1
Green, J.M.H., Larrosa, C., Burgess, N.D. *et al.* (2013) Deforestation in an African biodiversity hotspot: extent, variation and the effectiveness of protected aras. *Biological Conservation* **164**: 62-72	Y	1	0	1	0	0	0
Green, E.L., Eigenbrod, F., Schreckenberg, K. & Willcock, S. (2017) Modelling tree growth to determine the sustainability of current off-take from miombo woodland: a case study from rural villages in Malawi. *Environmental Conservation* **44**: 66-73	Y	0	0	1	0	0	0

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Grogan, K., Birch-Thomas, T. & Lyimo, J. (2013) Transition of shifting cultivation and its impact on people's livelihoods in the miombo woodlands of northern Zambia and south-western Tanzania. *Human Ecology* **41**: 77-92	N	0	0	1	0	0	0
Gross-Camp, N. (2017) Tanzania's community forests: their impact on human well-being and persistence in spite of the lack of benefit. *Ecology and Society* **22:** 37	Y	0	1	1	0	1	1
Guedes, B., Olsson, B.A. & Karltun, E. (2016) Effects of 34-year-old *Pinus taeda* and *Eucalyptus grandis* plantations on soil carbon and nutrient status in former miombo forest soils. *Global Ecology and Conservation* **8**: 190-202	Y	0	1	0	0	0	0
Hairong, Y. & Sautman, B. (2010) Chinese farms in Zambia: from socialist to "agro-imperialist" engagement? *African and Asian Studies* **9**: 307-333	N	0	0	1	0	0	1
Hall, J., Burgess, N.D., Lovett, J. *et al.* (2009) Conservation implications of deforestation across and elevational gradient in the Eastern Arc Mountains, Tanzania. *Biological Conservation* **142**: 2510-2521	N	1	0	0	0	0	0
Hall, J.M., Burgess, N.D., Rantala, S. *et al.* (2014) Ecological and social outcomes of a new protected area in Tanzania. *Conservation Practice and Policy* **28**: 1512-1521	Y	1	0	1	0	0	1
Haller, T., Galvin, M., Meroka, P. *et al.* (2008) Who gains from community conservation? Intended and unintended costs and benefits of participative approahces in Peru and Tanzania. *The Journal of Environment and Development* **17**: 118-144	N	0	0	1	0	0	1
Harnish, A. (2014) Extractive workload: a mixed-method approach for investigating the socially differentiated effects of land-use/land-cover changes in a southern Zambian frontier. *Population and Environment* **35**: 455-476	N	0	0	1	0	0	0
Hausser, Y., Weber, H. & Meyer, B. (2009) Bees, farmers, tourists and hunters: conflict dynamics around Western Tanzania protected areas. *Biodiversity and Conservation* **18**: 2679-2703	N	1	0	0	0	0	1
Hausser, Y., Tagand, R., Vimercati, E. *et al.* (2016) Comparing survey methods to assess the conservation value of a community-managed protected area in western Tanzania. *African Journal of Ecology* **55**: 1-11	N	1	0	0	0	0	0
Hegde, R. & Bull, G.Q. (2011) Performance of an agro-forestry based Payments-for-Environmental-Services project in Mozambique: a household level analysis. *Ecological Economics* **71**: 122-130	Y	0	1	1	0	0	0
Hegde, R., Bull, G.Q., Wunder, S. & Kozak, R.A. (2014) Household participation in a payments of environmental services programme: the Nhambita Forest Carbon Project (Mozambique). *Environmental and Development Econoics* **20**: 611-629	Y	0	0	0	0	0	1
Hein, L., de Groot, R. & Soma, K. (2008) Analysing the economic impacts of land use change: a framework and case study for the miombo woodlands, Zambia. *Journal of Land Use Science* **3**: 231-249	Y	0	1	1	0	1	0
von Hellermann, P. (2016) Tree symbolism and conservation in the South Pare Mountains, Tanzania. *Conservation and Society* **14**: 368-379	N	0	0	1	0	1	1
Hofstad, O. & Araya, M.M. (2015) Optimal wood harvest in miombo woodland considering REDD+ payments - a case study at Kitulangalo Forest Reserve, Tanzania. *Forest Policy and Economics* **51**: 9-16	Y	0	1	1	0	0	0
Holdo, R.M. (2006) Tree growth in an African woodland savanna affected by disturbance. *Journal of Vegetation Science* **17**: 369-378	N	0	0	0	1	0	0

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Hughes, D. (2006) Hydrology of hope: farm dams, conservation, and whiteness in Zimbabwe. *American Ethnologist* **33**: 269-287	N	1	0	0	0	1	1
Jagger, P. & Luckert, M.K. (2008) Investments and returns from cooperative and household managed woodlots in Zimbabwe: implications for rural afforestaton policy. *Land Use Policy* **25**: 139-152	N	0	0	1	0	0	0
Jagger, P. & Perez-Heydrich, C. (2016) Land use and household energy dynamics in Malawi. *Environmental Research Letters* **11**: 125004	N	0	0	1	0	0	0
Jansen, L.J.M., Bagnoli, M. & Focacci, M. (2008) Analysis of land-cover/use change dynamics in Manica Province in Mozambique in a period of transition (1990-2004). *Forest Ecology and Management* **254**: 308-326	Y	1	1	1	0	0	0
Jew, E.K.K., Loos, J., Dougill, A.K. *et al.* (2015) Butterfly communities in miombo woodland: biodiversity declines with increasing woodland utilisation. *Biological Conservation* **192**: 436-444	Y	1	0	0	0	0	0
Jew, E.K.K., Dougill, A.L., Sallu, S.M. *et al.* (2016) Miombo woodland under threat: consequences for tree diversity and carbon storage. *Forest Ecology and Management* **361**: 144-153	Y	1	1	0	0	0	0
Jimu, L., Mataruse, L., Musemwa, L. & Nyakudya, I.W. (2017) The miombo ecoregion up in smoke: the effect of tobacco curing. *World Development Perspectives* **5**: 44-46	N	1	1	1	0	0	0
Jindal, R., Kerr, J.M. & Carter, S. (2012) Reducing poverty through carbon forestry? Impacts of the N'hambita Community Carbon Project in Mozambique. *World Development* **40**: 2123-2135	Y	0	1	1	0	0	1
Johanssibm E, & Isgren, E. (2017) Local perceptions of land-use change: using participatory art to reveal direct and indirect socioenvironmental effects of land acquisitions in Kilombero Valley, Tanzania. *Ecology and Society* **22**: 3	Y	0	0	1	0	0	1
Jones, D., Ryan, C.M. & Fisher, J. (2016) Charcoal as a diversification strategy: the flexible role of charcoal production in the livelihoods of smallholders in central Mozambique. *Energy for Sustainable Development* **32**: 14-21	N	0	0	1	0	0	0
Jumbe, C.B.L. & Angelsen, A. (2006) Do the poor benefit from devolution policies? Evidence from Malawi's forest co-management program. *Land Economics* **82:** 562-581	N	0	0	1	0	0	1
Jumbe, C.B.L. & Angelsen, A. (2007) Forest dependence and participation in CPR management: empirical evidence from forest co-management in Malawi. *Ecological Economics* **62**: 661-672	N	0	0	1	0	0	1
Kaczan, D., Swallow, B.M. & Adamowicz, W.L. (2013) Designing a payment for ecosystem services (PES) program to reduce deforestation in Tanzania: an assessment of payment approaches. *Ecological Economics* **95**: 20-30	Y	1	0	0	0	0	1
Kajembe, G.C., Julius, F., Nduwamungu, J. *et al.* (2005) Impact of indigenous-based interventions on land conservation: a case study of a soil conservation and agroforestry project, Arumeru District, Tanzania. *Land Degradation and Development* **16**: 311-325	N	0	1	1	0	0	0
Kalaba, F.K. (2014) A conceptual framework for understanding forest socio-ecological systems. *Biodiversity and Conservation* **23**: 3391-3403	Y	0	1	1	0	1	0
Kalaba, F.K. (2016) Barriers to policy implementation and implications for Zambia's forest ecosystems. *Forest Policy and Economics* **69**: 40-44	Y	0	1	1	0	0	0

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Kalaba, F.K., Quinn, C.H. & Dougill, A.J. (2013) Contribution of forest provisioning ecosystem services to rural livelihoods in the miombo woodlands of Zambia. *Population and Environment* **35**: 159-182	Y	0	0	1	0	0	0
Kalaba, F.K., Quinn, C.H., Dougill, A.J. & Vinya, R. (2013) Floristic composition, species diversity and carbon storage in charcoal and agriculture fallows and management implications in Miombo woodlands of Zambia. *Forest Ecology and Management* **304**: 99-109	Y	1	1	0	0	0	0
Kalaba, F.K., Quinn, C.H. & Dougill, A.J. (2013) The role of forest provisioning services in coping with household stresses and shocks in Miombo woodlands, Zambia. *Ecosystem Services* **5**: 143-148	Y	0	0	1	1	0	0
Kalonga, S.K., Midtgaard, F. & Eid, T. (2015) Does forest certification enhance forest structure? Empirical evidence from certified community-based forest management in Kilwa District, Tanzania. *International Forestry Review* **17**: 182-194	Y	1	0	0	0	0	0
Kalonga, S.K., Midtgaard, F. & Klanderud, K. (2016) Forest certification as a policy option in conserving biodiversity: an empirical study of forest management in Tanzania. *Forest Ecology and Management* **361:** 1-12	Y	1	0	0	0	0	0
Kamanga, P., Vedeld, P. & Sjaastad, E. (2009) Forest incomes and rural livelihoods in Chiradzulu District, Malawi. *Ecological Economics* **68**: 613-324	Y	0	0	1	0	0	0
Kamelarzyck, K.B.F. & Smith-Hall, C. (2014) REDD herring: epistemic community control of the production, circulation and application of deforestation knowledge in Zambia. *Forest Policy and Economics* **46**: 19-29	N	0	0	0	0	0	1
Kamoto, J., Clarkson, G., Dorward, P. & Shepherd, D. (2013) Doing more harm than good? Community based natural resource management and the neglect of local institutions in policy development. *Land Use Policy* **35**: 293-301	Y	0	0	0	0	0	1
Kamusoko, C. & Aniya, A.M. (2007) Land use-cover change and landscape fragmentation analysis in the Binduras District, Zimbabwe. *Land Degradation and Development* **18**: 221-233	N	1	0	0	0	0	1
Kamusoko, C. , Aniya, M.A., Adi, B. & Manjoro, M. (2015) Rural sustainability under threat in Zimbabwe - simulation of future land use/cover changes in the Bindura district based on the Markov-cellular automata model. *Applied Geography* **29**: 435-447	N	0	1	1	0	0	0
Kangalawe, R.Y.M. & Noe, C. (2012) Biodiversity conservation and poverty alleviation in Namtumbo District, Tanzania. *Agriculture, Ecosystems and Environment* **162**: 90-100	Y	1	0	1	0	0	0
Kangalawe, R.Y.M., Christiansson, C. & Östberg, W. (2008) Changing land-use patterns and farming strategies in the degraded environment of the Irangi Hills, central Tanzania. *Agriculture, Ecosystems and Environment* **125**: 33-47	N	0	1	1	0	0	0
Kaonga, M.L. & Bayliss-Smith, T.P. (2009) Carbon pools in tree biomass and the soil in improved fallows in eastern Zambia. *Agroforestry Systems* **76**: 37-51	Y	0	1	0	0	0	0
Katani, J.Z., Mustalahti, I., Mukama, K. & Zahabu, E. (2016) Participatory forest carbon assessment in south-eastern Tanzania: experiences, costs and implications for REDD+ initiatives. *Oryx* **50**: 523-532	Y	0	1	0	0	0	0
Käyhkô, N., Fagerholm, N., Asseid, B.S. & Mzee, A.J. (2011) Dynamics land use and land cover changes and their effect on forest resources in a coastal village of Matemwe, Zanzibar, Tanzania. *Land Use Policy* **28**: 26-37	Y	1	0	1	0	0	0

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Käyhkö, N., Fagerholm, N. & Mzee, A.J. (2015) Local farmers' place-based forest benefits and government interventions behind land and forest cover transitions in Zanzibar, Tanzania. *Journal of Land Use Science* **10**: 150-173	Y	0	0	1	1	0	0
Khatun, K., Gross-Camp, N., Corbera, E., Martin, A., Ball, S. & Massao, G. (2015) When participatory forest management makes money: insights from Tanzania on governance, benefit sharing, and implications for REDD+. *Environment and Planning A* **47**: 2097-2112	N	0	1	0	0	0	1
Khatun, K., Corbera, E. & Ball, S. (2017) Fire is REDD+: offsetting carbon through early burning activities in south-eastern Tanzania. *Oryx* **51**: 43-52	Y	0	1	1	0	0	0
Kideghesho, J.R. (2009) The potentials of traditional African cultural practices in mitigating overexploitation of wildlife species and habitat loss: experience of Tanzania. *International Journal of Biodiversity and Science and Management:* **5**: 83-94	N	1	0	1	0	1	0
Kijazi, M.H. & Kant, S. (2010) Forest stakeholders' value preferences in Mount Kilimanjaro, Tanzania. *Forest Policy and Economics* **12**: 357-369	Y	1	1	1	0	1	0
Kijazi, M.H. & Kant, S. (2011) Evaluation of welfare functions of environmental amenities: a case of forest biomass fuels in Mount Kilimanjaro, Tanzania. *Ecological Economics* **72**: 129-139	Y	0	0	1	0	0	1
Kijazi, M.H. & Kant, S. (2011) Social acceptability of alternative forest regimes in Mount Kilimanjaro, Tanzania, using stakeholder attitudes as metrics of uncertainty. *Forest Policy and Economics* **13**: 242-257	N	0	0	0	0	0	1
Kitula, R.A. (2007) Use of medicinal plants for human health in Udzungwa Mountains Forests: a case study of New Dabaga Ulongambi Forest Reserve, Tanzania. Journal of Ethnobiology and Ethnomedicine **3**: 7	N	1	0	1	0	0	0
Koch, S. (2016) International influence on forest governance in Tanzania: analysing the role of aid experts in the REDD+ process. Forest Policy and Economics http://dx.doi.org/10.1016/j.forpol.2016.09.018	N	0	0	0	0	0	1
Krog, M., Theilade, I., Hansen, H.H. & Ruffo, C.K. (2005) Estimating use-values and relative importance of trees to the Kaguru People in semi-arid Tanzania. *Forests Trees and Livelihoods* **15**: 25-40	N	0	0	1	0	0	0
Kukkonen, M. & Käyhkö, N. (2014) Spatio-temporal analysis of forest changes in contrasting land-use regimes of Zanzibar, Tanzania. *Applied Geography* **5**5: 191-202	Y	1	0	1	0	0	0
Kuntashula, E. & Mungatana, E. (2014) Estimating the causal effect of improved fallows on environmental services provision under farmers' field conditions in Chongwe, Zambia. Environment and Development Economics **20**: 80-100	Y	0	1	1	0	0	0
Kuntashula, E. & Mungatana, E. (2016) Understanding the trade-offs between environmental service provision through improved fallows and private welfare using state preference approach: a case study in Chongwe - Zambia. *Sustainable Agriculture Research* **5**: 124-141	Y	0	1	1	0	0	0
Kuntashula, E., Chabala, L.M., Chibwe, T.K. & Kaluba, P. (2015) The effects of household wealth on adoption of agricultural related climate change adaptation strategies in Zambia. *Sustainable Agricultural Research* **4**: 88-101	Y	0	0	1	1	0	0
Kuyah, S., Sileshi, G.W., Nholoma, J. *et al.* (2014) Estimating aboveground tree biomass in three different miombo woodlands and associated land use systems in Malawi. *Biomass and Bioenergy* **66**: 214-222	Y	1	1	0	0	0	0

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Kwashirai, V.C. (2007) Indigenous management of teak woodland in Zimbabwe, 1850-1900. *Journal of Historical Geography* **33**: 816-832	Y	0	0	1	0	1	1
Kwayu, E., Paavola, J. & Sallu, S.M. (2017) The livelihood impacts of the Equitable Payments of Watershed Services (EPWS) Program in Morogoro, Tanzania. *Environment and Development Economics* **22**: 328-349	Y	0	1	1	0	0	1
Landry, J. & Chirwa, P.W. (2011) Analysis of the potential socio-economic impact of establishing plantation forestry on rural communities in Sanga district, Niassa province, Mozambique. *Land Use Policy* **28**: 542-551	N	0	0	1	0	0	1
Lawi, Y.Q. (2007) Tanzania's operation Vijiji and local ecological consciousness: the case of Eastern Iraqwland, 1974-1976. *Journal of African History* **48**: 69-93	N	0	0	0	0	0	1
Leventon, J., Kalaba, F.K., Dyer, J.C. *et al.* (2014) Delivering community benefits through REDD +: lessons from Joint Forest Management in Zambia. *Forest Policy and Economics* **44**: 10-17	Y	0	1	1	0	0	1
Liwenga, E.T. (2009) Livelihood diversification and implications on dryland resources of central Tanzania. *African Journal of Ecology* **47**: 142-146	N	0	0	1	0	0	0
Locher, M. (2016) 'How come others are selling our land?' Customary land rights and the complex process of land acquisition in Tanzania. *Journal of Eastern African Studies* **10**: 393-412	N	0	0	0	0	0	1
Lopa, D., Mwanyoka, I., Jambiya, G. *et al.* (2012) Towards operational payments for water ecosystem services in Tanzania: a case study from the Uluguru Mountains. *Oryx* **46**: 34-44	Y	0	1	1	0	0	0
Lund, J.F. & Treue, T. (2008) Are we getting there? Evidence of decentralised forest management from the Tanzanian Miombo woodlands. *World Development* **36**: 2780-2800	N	1	0	1	0	0	1
Lund, J.F., Burgess, N.D., Chamshama, S.A.O. *et al.* (2013) Mixed method approaches to evaluation conservation impact: evidence from decentralised forest management in Tanzania. *Environmental Conservation* **42**: 162-179	Y	1	0	0	0	0	0
Lund, J.F., Sungusia, E., Mabele, M.B. & Scheba, A. (2017) Promising change, delivering continuity: REDD+ as conservaton fad. *World Development* **89**: 124-139	N	0	1	0	0	0	1
Luoga, E.J., Witkowski, E.T.F. & Balkwill, K. (2005) Land cover and use changes in relation to the institutional framework and tenure of land and resources in eastern Tanzania miombo woodlands. *Environment Development and Sustainability* **7**: 71-93	N	0	0	1	0	0	1
Luoga, E.J., Kajembe, G.C., Shemweta, D.T.K. *et al.* (2012) Assessment of tree stocking and diversity for joint forest management (JFM) in Nkweshoo Village Forest Management Area, Kilimanjaro, Tanzania. *Forests Trees and Livelihoods* **15**: 259-273	Y	1	0	0	0	0	0
Madoffe, S., Hertel, G.D., Rodgers, P. *et al.* (2006) Monitoring the health of selected eastern arc forests in Tanzania. *African Journal of Ecology* **44**: 171-177	N	1	0	0	0	0	0
Mwageni, N., Shemdoe, E.S. & Kiunsi, R. (2015) Assessment of change sin provision of forest ecosystem goods and services and benefit sharing mechanisms in the Ugalla-Masito Ecosystem: a case of Ilagala and Karago villages in Kigoma Region, Tanzania. *International Journal of Biodiversity and Conservation* **7**: 290-298	Y	0	1	1	0	0	0
Makero, J.S. & Malimbwi, R.E. (2012) Extent of illegal harvesting on availability of timber species in Nyanganje Forest Reserve, Tanzania. *International Forestry Review* **14**: 177-183	N	1	0	1	0	0	0

Paper reference	Uses Ecosystem Service language?	Ecological Integrity	Regulatory Functions	Extractive Uses	Socio-ecological resilience	Symbolic Values	Justice and Equity
Mandondo, A. & German, L. (2015) Customary rights and societal stakes of large-scale tobacco cultivation in Malawi. *Agriculture and Human Values* **32**: 31-46	Y	0	0	0	0	0	1
Mandondo, A., German, L., Utila, H. & Nthenda, U.M. (2014) Assessing societal benefits and trade-offs of tobacco in the Miombo Woodlands of Malawi. *Human Ecology* **42**: 1-19	Y	1	0	1	0	0	1
Mandondo, A. & Kozanayi, W. (2006) A demand-driven model of decentralised land-use planning and natural resource management: experiences from the Chiredzi District of Zimbabwe. *Africa Development* **31**: 103-122	N	0	0	0	0	0	1
Mangora, M.M. (2005) Ecological impact of tobacco farming in miombo woodlands of Urambo District, Tanzania. *African Journal of Ecology* **43**: 385-391	N	1	0	1	0	0	0
Mapanda, F., Munotengwa, S., Wuta, M. *et al.* (2013) Short-term responses of selected soil properties to clearing and cropping of miombo woodlands in central Zimbabwe. *Soil and Tillage Research* **129**: 75-82	Y	0	1	0	0	0	0
Mapedza, E. (2006) Compromised co-management, compromised outcomes: experiences from a Zimbabwean forest. *Africa Development* **31**: 123-146	N	0	0	0	0	0	1
Maravanyika, S. & Mutimukuru-Maravanyika, T. (2009) Resource-based conflict at the local level in a changing national environment: the case of Zimbabwe's Mafungautsi State Forest. *African Economic History* **37**: 129-150	N	0	0	0	0	1	1
Maroyi, A. (2011) The gathering and consumption of wild edible plants in Nhema Communal Area, Midlands Province, Zimbabwe. *Ecology of Food and Nutrition* **50**: 506-525	N	0	0	1	0	0	0
Maroyi, A. (2012) Local plant use and traditional conservation practices in Nhema communal area, Zimbabwe. *International Journal of African Renaissance Studies - Multi-, Inter- and Transdisciplinarity* **7**: 109-128	N	1	0	1	0	0	0
Maroyi, A. (2013) Use and management of homegarden plants in Zvishavane district, Zimbabwe. *Tropical Ecology* **54**: 191-203	N	0	0	1	0	0	0
Maroyi, A. (2013) Use of weeds as traditional vegetables in Shurugwi District, Zimbabwe. *Journal of Ethnobiology and Ethnomedicine* **9**: 60	N	0	0	1	0	0	0
Martin, A., Caro, T. & Mulder, M.B. (2012) Bushmeat consumption in western Tanzania: a comparative anaysis from the same ecosystem. *Tropical Conservation Science* **5**: 352-364	Y	1	0	1	0	0	0
Matavire, M.M., Sibanda, M. & Dube, T. (2015) Assessing the aftermath of the fast track land reform programme in Zimbabwe on land-use and land-cover changes. *Transactions of the Royal Society of South Africa* **70**: 181-186	N	1	0	0	0	0	0
Mathew, M.M., Majule, A.E., Sinclair, F. & Marchant, R. (2016) Relationships between on-farm tree stocks and soil organic carbon along an altitudinal gradient, Mount Kilimanjaro, Tanzania. *Forests Trees and Livelihoods* **25**: 255-266	Y	0	1	0	0	0	0
Matose, F. & Watts, S. (2010) Towards community-based forest management in southern Africa: do decentralisation experiments work for local livelihoods? *Environmental Conservation* **37**: 310-319	Y	0	0	1	0	0	1
Mazunda, J. & Shively, G. (2015) Measuring the forest and income impacts of forest user group participation under Malawi's Forest Co-management program. *Ecological Economics* **119**: 262-273	N	1	0	1	0	0	0

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Mbwambo, L., Eid, T., Malimbwi, R.E. *et al.* (2012) Impact of decentralised forest management on forest resource conditions in Tanzania. *Forests Trees and Livelihoods* **21**: 97-113	Y	1	0	0	0	0	0
McGregor, J. (2005) The social life of ruins: sites of memory and the politics of a Zimbabwean periphery. *Journal of Historical Geography* **31**: 316-337	N	0	0	0	0	1	1
McNally, C.G., Gold, A.J., Pollnac, R.B. & Kiwango, H.R. (2016) Stakeholder perceptions of ecosystem services of the Wami River and Estuary. *Ecology and Society* **21**: 34	Y	1	1	1	0	1	0
McNicol, I.M., Ryan, C.M. & Williams, M. (2015) How resilient are African woodlands to disturbance from shifting cultivation? *Ecological Applications* **25**: 2330-2336	Y	1	1	0	1	0	0
Meijer, S.S., Sileshi, G.W., Catacutan, D. & Nieuwenhuis, M. (2016) Farmers and forest conservation in Malawi: the disconnect between attitudes, intentions and behaviour. *Forests Trees and Livelihoods* **25**: 59-77	Y	1	0	1	0	0	0
Menéndez, A. & Curt, M.D. (2013) Energy and socio-economic profile of a small rural community in the highlands of central Tanzania: a case study. *Energy for Sustainable Development* **17**: 201-209	Y	0	0	1	0	0	0
Meshack, C.K., Adhikari, B., Doggart, N. & Lovett, J.C. (2006) Transaction costs of community-based forest management: empirical evidence from Tanzania. *African Journal of Ecology* **44**: 468-477	N	0	0	1	0	0	1
Mfune, O. (2014) Managing common pool resources without state support: insights from Shisholeka community in central Zambia. *Environment Development and Sustainability* **16**: 1263-1280	Y	0	1	1	0	1	0
Mhango, J. & Dick, J. (2011) Analysis of fertiliser subsidy programs and ecosystem services in Malawi. *Renewable Agriculture and Food Systems* **26**: 200-207	Y	0	1	1	1	1	0
Mitchard, E.T.A., Meir, P., Ryan, C.M. *et al.* (2013) A novel application of satellite radar data: measuring carbon sequestration and detecting degradation in a community forestry project in Mozambique. *Plant Ecology and Diversity* **6**: 159-170	Y	0	1	0	0	0	0
Mligo, C., Lyaruu, H., Ndangalasi, H. & Marchant, R. (2009) Vegetation community structure, composition and distribution patterns in the Zaraninge Forest, Bagamoyo District, Tanzania. *Journal of East African Natural History* **98**: 223-239	N	1	0	0	0	0	0
Monson, J. (2012) From protective lions to angry spirits: environmental degradation and the authority of elders in the Kilombero Valley, Tanzania. *Journal of Eastern African Studies* **6**: 336-350	N	0	0	1	0	1	1
Morgan-Brown, T., Jacobson, S.K., Wald, K. & Child, B. (2010) Quantitative assessment of a Tanzanian integrated conservation and development project involving butterfly farming. *Conservation Biology* **24**: 563-572	N	1	0	1	0	0	0
Mpanda, M.M., Luoga, E.J., Kajembe, G.C. & Eid, T. (2012) Impact of forestland tenure changes on forest cover, stocking and tree species diversity in Amani Nature Reserve, Tanzania. *Forests Trees and Livelihoods* **20**: 215-229	Y	1	0	0	0	0	0
Mpanda, M.M., Munjuga, M., Reyes, T. *et al.* (2014) Allanblackia, butterflies and cardamom: sustaining livelihoods alongside biodiversity conservation on the forest-agroforestry interface in the East Usambara Mountains, Tanzania. *Forests Trees and Livelihoods* **23**: 127-142	N	1	0	1	0	0	0

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Mponela, P., Jumbe, C.B.L. & Mwase, W.F. (2011) Determinants and extent of land allocation for *Jatropha curcas L.* cultivation among smallholder farmers in Malawi. *Biomass and Bioenergy* **35**: 2499-2505	N	0	0	1	0	0	0
Msuya, T.S., Kideghesho, J.R. & Mosha, T.C.E. (2010) Availability, preference and consumption of indigenous forest foods in the Eastern Arc Mountains, Tanzania. *Ecology of Food and Nutrition* **49**: 208-227	N	0	0	1	1	0	0
Mthatiwa, S. (2014) Africa's natural heritage and ecological vision in the work of Bart Wolffe. *Imbizo* **5**: 34-51	N	0	0	0	0	1	1
Mubaya, C.P. & Mafongoya, P. (2016) Local-level climate change adaptation decision-making and livelihoods in semi-arid areas in Zimbabwe. Environment Development and Sustainability: DOI 10.1007/s10668-016-9861-0	N	0	0	0	1	0	0
Mudaca, J.D., Tsuchiya, T., Yamada, M. & Onwona-Agyeman, S. (2015) Household participation in Payments for Ecosystem Services: a case study from Mozambique. *Forest Policy and Economics* **55**: 21-27	Y	0	1	1	0	0	0
Mudombi, S., von Maltitz, G.P., Gasparatos, A. *et al.* (2016) Multi-dimensional poverty effects around operational biofuel projects in Malawi, Mozambique and Swaziland. Biomass and Bioenergy http://dx.doi.org/10.1016/j.biombioe.2016.09.003	Y	0	0	1	0	0	0
Mufandaedza, E., Moyo, D.Z. & Makoni, P. (2015) Management of non-timber forest products harvesting: rules and regulations governing *(Imbrasia belina)* access in south-eastern lowveld of Zimbabwe. *African Journal of Agricultural Research* **10**: 1521-1530	N	0	0	1	0	0	0
Mujuru, L., Gotora, T., Velthorst, E.J. *et al.* (2014) Soil carbon and nitrogen sequestration over an age sequences of *Pinus patula* plantations in Zimbabwean Eastern Highlands. *Forest Ecology and Management* **313**: 254-265	N	0	1	0	0	0	0
Mukwada, G. (2009) The influence of anthropogenic phenomena and contingency in tree resource distribution in Mufurudzi resettlement area, Zimbabwe. *Journal for Nature Conservation* **17**: 1-14	Y	1	0	1	0	0	0
Mukwada, G., Taru, P. & Chingombe, W. (2014) Role of socio-ecological systems in forest and woodland conservation in Zimbabwean resettlement areas. *Journal of Asian and African Studies* **40**: 276-288	N	1	0	1	0	1	0
Mulenga, B.P., Richardson, R.B., Tembo, G. & Mapemba, L. (2013) Rural household participation in markets for non-timber forest products in Zambia. *Environment and Development Economics* **19**: 487-504	Y	0	0	1	0	0	0
Munishi, P.K.T., Phillipina, F., Temu, R.P.C. & Pima, N.E. (2008) Tree species composition and local use in agricultural landscapes of west Usambaras Tanzania. *African Journal of Ecology* **46**: 66-71	Y	1	0	1	0	0	0
Muposhi, V.K., Chademana, T.C., Gandiwa, E. & Muboko, N. (2016) Edge effects: impact of anthropogenic activites on vegetation structure and diversity in wetern Umfurudzi Park, Zimbabwe. *African Journal of Ecology* **54**: 45-459	Y	1	0	0	0	0	0
Mustalahti, I. & Lund, J.F. (2009) Where and how can participatory forest management succeed? Learning from Tanzania, Mozambique and Laos. *Society and Natural Resources* **23**: 31-44	N	0	0	0	0	0	1
Mustalahti, I. & Rakotonarivo, O.S. (2014) REDD+ and empowered deliberative democracy: learning from Tanzania. *World Development* **59**: 199-211	Y	0	0	0	0	0	1
Mustalahti, I., Bolin, A., Boyd, E. & Paavola, J. (2012) Can REDD+ reconcile local priorities and needs with global mitigation benefits? Lessons from Angai Forest, Tanzania. *Ecology and Society* **17**: 16	Y	0	1	1	0	0	1

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Mutekwa, V.T. & Gambiza, J. (2016) Assessment of governance principles application in forest protected areas: the case of six state forest in western Zimbabwe. *International Forestry Review* **18**: 466-484	Y	1	1	1	0	0	1
Mutenje, M.J., Ortmann, G.F. & Ferrer, S.R.D. (2011) Management of non-timber forestry products extraction: local institutions ecological knowledge and market structure in south-eastern Zimbabwe. *Ecological Economics* **70**: 454-461	Y	1	0	1	0	1	0
Mutimukuru, T., Kozanayi, W. & Nyirenda, R. (2006) Catalysing collaborative monitoring processes in Joint Forest Management situations: the Mafungautsi Forest Case, Zimbabwe. *Society and Natural Resources* **19**: 209-224	N	0	0	1	0	0	0
Mwakaje, A.G. (2012) Can Tanzania realise rural development through biofuel plantations? Insights from the study in Rufiji District. *Energy for Sustainable Development* **16**: 320-327	N	0	0	1	0	0	0
Mwampamba, T.H. (2007) Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. *Energy Policy* **35**: 4221-4234	Y	0	0	1	0	0	0
Mwampamba, T.H. & Schwartz, M.W. (2011) The effects of cultivation history on forest recovery in fallows in the Eastern Arc Mountains, Tanzania. *Forest Ecology and Management* **261**: 1042-1052	Y	1	0	0	1	0	0
Mwase, W.F., Bjørnstad, A., Bokosi, J.M. *et al.* (2007) The role of land tenure in conservation of tree and shrub species diversity in miombo woodlands of southern Malawi. *New Forests* **33**: 297-307	N	1	0	0	0	0	0
Mwitiwa, J., German, L., Muimba-Kankolongo, A. & Puntodewo, A. (2012) Governance and sustainability challenges in landscapes shaped by mining: mining-forestry linkages and impacts in the Copper Belt of Zambia and DR Congo. *Forest Policy and Economics* **25**: 19-30	N	1	0	1	1	0	1
Ndangalasi, H.J., Bitariho, R. & Dovie, D.B.K. (2007) Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. *Biological Conservation* **134**: 242-250	N	1	0	1	0	0	0
Nelson, V. & Stathers, T. (2009) Resilience, power, culture and climate: a case study from semi-arid Tanzania, and new research directions. *Gender and Development* **17**: 81-94	N	0	0	0	1	0	1
Newmark, W.D. (2006) A 16-year study of forest disturbance and understory bird community structure and composition in Tanzania. *Conservation Biology* **20**: 122-134	N	1	0	0	0	0	0
Nielsen, M.R. & Lund, J.F. (2012) Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania. *Conservation and Society* **10**: 1-14	Y	1	0	0	0	0	1
Nielsen, M.R. & Meilby, H. (2013) Determinants of compliance with hunting regulations under Joint Forest Management in Tanzania. *South African Journal of Wildlife Research* **43**: 120-137	Y	1	0	1	0	0	1
Nielsen, M.R. & Treue, T. (2012) Hunting for the benefits of Joint Forest Management in the Eastern Afromontane Biodiversity Hotspot: effects on bushmeat hunters and wildlife in the Udzungwa Mountains. *World Development* **40**: 1224-1239	Y	1	0	1	0	0	1
Nielsen, S.T. (2007) Deforestation and biodiversity: effects of bushland cultivation on dung beetles in semi-arid Tanzania. *Biodiversity and Conservation* **16**: 2753-2769	Y	1	1	0	0	0	0
Njana, M.A., Kajembe, G.C. & Malimbwi, R.E. (2013) Are miombo woodlands vital to livelihoods of rural households? Evidence from Urumwa and surrounding communities, Tabora, Tanzania. *Forests Trees and Livelihoods* **22**: 124-140	Y	0	0	1	0	0	0

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Nkhata, B.A. & Breen, C.M. (2010) Performance of community-based natural resource governance for the Kafue Flats (Zambia). *Environmental Conservation* **37**: 296-302	N	0	0	0	0	0	1
Nolte, K. (2014) Large-scale agricultural investments under poor land governance in Zambia. *Land Use Policy* **38**: 698-706	N	0	0	0	0	0	1
Nyamadzawo, G., Wuta, M., Nyamangara, J. *et al.* (2015) Optimising dambo (seasonal wetland) cultivation for climate change adaptation and sustainable crop production in the smallholder farming areas of Zimbabwe. *International Journal of Agricultural Sustainability* **13**:23-29	Y	1	1	1	1	0	0
Nyanga, A., Kessler, A. & Tenge, A. (2016) Key socio-economic factors influencing sustainable land management investments in the West Usambara Highlands, Tanzania. *Land Use Policy* **51**: 260-266	N	0	1	1	0	0	0
Ojoyi, M., Mutanga, O., Aynekulu, E. & Abdel-Rahman, E. (2015) The effect of forest fragmentation on tree species abundance and diversity in the Eastern Arc Mountains of Tanzania. *Applied Ecology and Environmental Research* **13**: 307-324	N	1	0	0	0	0	0
Ojoyi, M.M., Mutanga, O., Odindi, J. *et al.* (2017) Implications of land use transitions on soil nitrogen in dynamic landscapes in Tanzania. *Land Use Policy* **64**: 95-100	Y	1	1	0	0	0	0
Olwig, M.F., Noe, C., Kangalawe, R. & Luoga, E. (2015) Inverting the moral economy: the case of land acquisitions for forest plantations in Tanzania. *Third World Quarterly* **36**: 2316-2336	N	0	0	0	0	0	1
Osbah, H., Twyman, C., Adger, W.N. & Thomas, D. S.G. (2008) Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum* **39**: 1951-1964	N	0	0	0	1	0	0
Östberg, W. & Siegers, M.F.W. (2010) Losing faith in the land: changing environmental perceptions in Burunge country, Tanzania. *Journal of Eastern African Studies* **4**: 247-265	N	0	1	0	1	1	0
Otsuki, K., Achá, D. & Wijnhoud, J.D. (2016) After the consent: re-imagining participatory land governance in Massingir, Mozambique. Geoforum http://dx.doi.org/10.1016/j.geoforum.2016.09.011	N	0	0	0	0	0	1
Paavola, J. (2008) Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy* **11**: 642-654	N	0	1	1	1	0	0
Palmer, C. & Silber, T. (2012) Trade-offs between carbon sequestration and rural incomes in the N'hambita Community Carbon Projest, Mozambique. *Land Use Policy* **29**: 83-93	N	0	1	1	0	0	0
Patenaude, G. & Lewis, K. (2014) The impacts of Tanzania's natural resource management programmes for ecosystem services and poverty alleviation. *International Forestry Review* **16**: 459-473	Y	1	1	1	0	0	1
Persha, L. & Blomley, T. (2009) Management decentralisation and montane forest conditions in Tanzania. *Conservation Biology* **23**: 1485-1496	Y	1	0	0	0	0	0
Phiri, M., Chirwa, P.W., Watts, S. & Syampungani, S. (2012) Local community perception of joint forest management and its implications for forest condition: the case of Dambwa Forest Reserve in southern Zambia. *Southern Forests: a Journal of Forest Science* **72**: 51-59	Y	1	0	1	1	0	0
Poppy, G.M., Chiotha, S., Eigenbrod, F. *et al.* (2014) Food security in a perfect storm: using the ecosystem services framework to increase understanding. *Philosophical Transactions of the Royal Society B - Biological Sciences* **369**: 20120288	Y	1	1	1	1	1	1

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Powell, B., Hall, J. & Johns, T. (2011) Forest cover, use and dietary intake in the East Usambara Mountains, Tanzania. *International Forestry Review* **13**: 305-317	N	1	0	1	0	0	0
Prins, E. & Clarke, G.P. (2007) Discovery and enumeration of Swahilian Coastal Forests in Lindi Region, Tanzania, using Landsat TM data analysis. *Biodiversity and Conservation* **16**: 1551-1565	N	1	0	0	0	0	0
Pullanikkatil, D., Palamuleni, L.G. & Ruhiiga, T.M. (2016) Land use/land cover change and implications for ecosystem services in the Likangala River Catchment, Malawi. *Physics and Chemistry of the Earth* **93**: 96-103	Y	0	1	1	0	0	0
Purdon, M. (2013) Land acquisitions in Tanzania: strong sustainability, weak sustainability and the importance of comparative methods. *Journal of Agricultural and Environmental Ethics* **26**: 1127-1156	Y	1	1	1	0	0	1
Quinion, A., Chirwa, P.W., Akinnifesi, F.K. & Ajayi, O.C. (2010) DO agroforestry techniques improve the livelihoods of the resource poor farmers? Evidence from Kasungu and Machinga districts of Malawi. *Agroforestry Systems* **80**: 457-465	N	0	1	1	1	0	0
Rantala, S. & German, L.A. (2013) Exploring village governance processes behind community-based forest management: legitimacy and coercion in the Usambara Mountains of Tanzania. *International Forestry Review* **15**: 355-367	N	0	0	0	0	0	1
Rantala, S., Kontinen, T., Korhonen-Kurki, K. & Mustalahti, I. (2015) Equity in REDD+: varying logics in Tanzania. *Environmental Policy and Governance* **212**: 201-202	Y	0	0	0	0	0	1
Rantala, S., Bullock, R., Mbegu, M.A. & German, L.A. (2012) Community-based forest management: what scope for conservation and livelihood co-benefits? Experience from the East Usambara Mountains, Tanzania. *Journal of Sustainable Forestry* **31**: 777-797	Y	1	0	1	0	0	1
Rantala, S. & Di Gregorio, M. (2014) Multistakeholder environmental governance in action: REDD+ discourse coalitions in Tanzania. *Ecology and Society* **19**: 66	N	0	1	0	0	0	1
Ratnasingam, J., Ng'andwe, P., Ioras, F. & Abrudan, I.V. (2014) Forestry and forest product industries in Zambia and the role of REDD+ initiatives. *International Forestry Review* **16**: 464-484	Y	0	1	1	0	0	0
Revermann, R., Wallenfang, J., Oldeland, J. & Finckh, M. (2016) Species richness and evenness respond to diverging land-use patterns - a cross border study of dry tropical woodlands in southern Africa. *African Journal of Ecology* **55**: 152-161	Y	1	0	0	0	0	0
Reyes, T., Quiroz, R. & Msikula, S. (2005) Socio-economic comparison between traditional and improved cultivation methods in agroforestry systems, East Usambara Mountains, Tanzania. *Environment Management* **36**: 682-690	N	1	0	1	0	0	0
Ribeiro, N.S., Saatchi, S.S., Shugart, H.H. & Washington-Allen, R.A. (2008) Aboveground biomass and leaf area index (LAI) mapping for Niassa Reserve, northern Mozambique. *Journal of Geophysical Research* **113**: 1-12	Y	1	0	0	0	0	0
Robinson, E.J.Z. & Lokina, R.B. (2011) A spatial-temporal analysis of the impact of access restrictions on forest landscapes and household welfare in Tanzania. *Forest Policy and Economics* **13**: 79-85	Y	1	0	1	0	0	0
Robinson, E.J.Z. & Maganga, F. (2009) The implications of improved communications for participatory forest management in Tanzania. *African Journal of Ecology* **47**: 171-178	Y	0	0	1	0	0	1

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Robinson, L.W., Bennett, N., King, L.A. & Murray, G. (2012) "We want our children to grow up to see these animals:" values and protected areas governance in Canada, Ghana and Tanzania. *Human Ecology* **40**: 571-581	N	0	0	0	0	1	1
Robinson, E.J.Z. & Lokina, R.B. (2011) Efficiency, enforcement and revenue tradoffs in participatory forest management: an example from Tanzania. *Environment and Development Economics* **17**: 1-20	Y	0	0	1	0	0	1
Robinson, E.J.Z., Albers, H.J., Meshack, C. & Lokina, R.B. (2013) Implementing REDD through community-based forest management: lessons from Tanzania. *Natural Resources Forum* **37**: 141-152	Y	0	1	0	0	0	0
Robinson, E.J.Z., Albers, H.J., Ngeleza, G. & Lokina, R.B. (2014) Insiders, outsiders, and the role of local enforcement in forest management: an example from Tanzania. *Ecological Economics* **107**: 242-248	Y	1	0	1	0	0	1
Robledo, C., Clot, N., Hammill, A. & Riché, B. (2012) The role of forest ecosystems in community-based coping strategies to climate hazards: three examples from rural areas in Africa. *Forest Policy and Economics* **24**: 20-28	Y	0	0	1	1	0	0
Romeu-Dalmau, C., Gasparatos, A., von Maltitz, G. *et al.* (2016) Impacts of land use change due to biofuel crops on climate regulation services: five case studies in Malawi, Mozambique and Swaziland. Biomass and Bioenergy https://doi.org/10.1016/j.biombioe.2016.05.011	Y	0	1	1	0	0	0
Romijn, H.A. (2011) Land clearing and greenhouse gas emissions from Jatropha biofuels on African miombo woodlands. *Energy Policy* **39**: 5751-5762	Y	0	1	0	0	0	0
Rufino, M.C., Dury, J., Tittonell, P. *et al.* (2011) Competing use of organic resources, village-level interactions between farm types and climate variability in a communal area of NE Zimbabwe. *Agricultural Systems* **104**: 175-190	N	0	1	1	1	0	0
Rutten, G., Ensslin, A., Hemp, A. & Fischer, M. (2015) Forest structure and composition of previously selectively logged and non-logged montane forests at Mt. Kilimanjaro. *Forest Ecology and Management* **337**: 61-66	N	1	0	0	0	0	0
Ryan, C.M. & Williams, M. (2011) How does fire intensity and frequency affect miombo woodland tree populations and biomass? *Ecological Applications* **21**: 48-60	N	1	0	0	0	0	0
Ryan, C.M., Berry, N.J. & Joshi, N. (2014) Quantifying the causes of deforestation and degradation and creating transparent REDD+ baselines: a method and case study from central Mozambique. *Applied Geography* **53**: 45-54	N	0	1	0	0	0	0
Ryan, C.M., Pritchard, R., McNicol, I. *et al.* (2016) Ecosystem services from southern african woodlands and their future under global change. *Philosophical Transactions of the Royal Society B - Biological Sciences* **371**: 20150312	Y	1	1	1	1	1	0
Salerno, J. (2016) Migrant decision-making in a frontier landscapes. *Environmental Research Letters* **11**: 044019	Y	0	0	1	0	0	0
Sauer, J. & Abdallah, J.M. (2007) Forest diversity, tobacco production and resource management in Tanzania. *Forest Policy and Economics* **9**: 421-439	Y	1	0	1	0	0	0

Paper reference	Uses Ecosystem Service language?	Ecological Integrity	Regulatory Functions	Extractive Uses	Socio-ecological resilience	Symbolic Values	Justice and Equity
Schaafsma, M., Burgess, N.D., Swetnam, R.D. *et al.* (2014) Market signals of unsustainable and inequitable forest extraction: assessing the value of illegal timber trade in the Eastern Arc Mountains of Tanzania. *World Development* **62**: 155-168	Y	1	0	1	0	0	1
Schaafsma, M., Morse-Jones, S., Posen, P. *et al.* (2014) The importance of local forest benefits: economic valuation of non-timber forest products in the Eastern Arc Mountains in Tanzania. *Global Environmental Change* **24**: 295-305	Y	1	1	1	0	0	0
Schaafsma, M., Morse-Jones, S., Posen, P. *et al.* (2012) Towards transferable functions for extraction of non-timber forest products: a case study on charcoal production in Tanzania. *Ecological Economics* **80**: 48-62	Y	1	1	1	0	0	0
Scheba, A. & Mustalahti, I. (2015) Rethinking 'expert' knowledge in community forest management in Tanzania. *Forest Policy and Economics* **60**: 7-18	N	0	0	0	0	0	1
Scheba, A. & Rakotonarivo, O.S. (2016) Territorialising REDD+: conflicts over market-based forest conservation in Lindi, Tanzania. *Land Use Policy* **57**: 625-637	Y	0	0	0	0	0	1
Scoones, I., Chaumba, J., Mavedzenge, B. & Wolmer, W. (2012) The new politics of Zimbabwe's lowveld: struggles over land at the margins. *African Affairs* **111**: 527-550	N	0	0	0	0	1	1
Senganimulanje, T.C., Chirwa, P.W., Babalola, F. & Graham, M.A. (2016) Does participatory forest management program lead to efficient forest resource use and improved rural livelihoods? Experiences from Mua-Livulezi Forest Reserve, Malawi. *Agroforestry Systems* **90**: 691-710	N	0	0	1	0	0	0
Senzota, R. & Mbago, F. (2009) Impact of habitat disturbance in the wetland forests of East Usambara, Tanzania. *African Journal of Ecology* **48**: 321-328	N	1	0	0	0	0	0
Sheridan, M.J. (2009) The environmental and social history of African Sacred Groves: a Tanzanian Case study. *African Studies Review* **52**: 73-98	Y	1	1	0	0	1	1
Sheridan, M.J. (2012) Global warming and global war: Tanzanian farmers' discourse on climate and political disorder. *Journal of Eastern African Studies* **6**: 230-245	N	0	1	0	0	1	1
Sheridan, M. (2008) Tanzanian ritual perimetries and African landscapes: the case of Dracaena. *The International Journal of African Historical Studies* **41**: 491-521	N	0	0	1	0	1	1
Shirima, D.D., Pfeifer, M., Platts, P.J., Totland, Ø & Moe, S.R. (2015) Interactions between canopy structure and herbaceous biomass along environmental gradients in moist forest and dry miombo woodland of Tanzania. *PLoS ONE* **10**: e0142784	N	1	0	0	0	0	0
Shirima, D.D., Totland, Ø, Munishi, P.K.T. & Moe, S.T. (2015) Relationships between tre species richness, evenness and aboveground carbon storage in montane forests and miombo woodlands of Tanzania. *Basic and Applied Ecology* **16**: 239-249	Y	1	1	0	0	0	0
Sileshi, G., Akinnifesi, F.K., Ajayi, O.C. *et al.* (2007) Contributions of agroforestry to ecosystem services in the miombo eco-region of eastern and southern Africa. *African Journal of Environmental Science and Technology* **1**: 68-80	Y	1	1	1	0	0	0
Sitoe, A. & Guedes, B.S. (2015) Community forestry incentives and challenges in Mozambique. *Forests* **6**: 4558-4572	Y	0	0	1	0	0	1

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Smith, H.E., Eigenbrod, F., Kafumbata, D. *et al.* (2015) Criminals by necessity: the risky life of charcoal transporters in Malawi. *Forests Trees and Livelihoods* **24**: 259-274	N	0	0	1	0	0	0
Smith, H.E., Hudson, M.D. & Schreckenberg, K. (2017) Livelihood diversification: the role of charcoal production in southern Malawi. *Energy for Sustainable Development* **36**: 22-36	Y	0	0	1	1	0	0
Sneddon, C. & Fox, C. (2008) Struggles over dams as struggles for justice: the World Commission on Dams (WCD) and anti-dam campaigns in Thailand and Mozambique. *Society and Natural Resources* **21**: 625-640	N	0	0	1	0	1	1
Speelman, S., Mombo, F., Vandermeulen, V. *et al.* (2015) Capturing and explaining preference heterogeneity for wetland management options in the Kilombero Valley, Tanzania. *Environmental Management* **55**: 100-112	Y	0	1	1	0	0	0
Standa-Gunda, W., Bond, I., Campbell, B.M. & Petheram, L. (2007) Exploring woodcarving markets to determine the potential of fiscal instruments for improving woodland management: the case of woodcarving in southern Zimbabwe. *Forests Trees and Livelihoods* **17**: 61-73	N	1	0	1	0	0	0
Strauch, A.M., Rurai, M.T. & Almedom, A.M. (2016) Influence of forest management systems on natural resource use and provision of ecosystem services in Tanzania. *Journal of Environmental Management* **180**: 35-44	Y	1	1	1	1	1	0
Stringer, C.E., Trettin, C.C., Zarnoch, S.J. & Tang, W. (2015) Carbon stocks of mangroves within the Zambezi River Delta, Mozambique. *Forest Ecology and Management* **354**: 139-148	Y	0	1	0	0	0	0
Sungusia, E. & Lund, J.F. (2016) Against all policies: landscape level forest restoration in Tanzania. World Development Perspectives 3: 35-37	N	1	0	0	0	0	1
Sunseri, T. (2005) 'Something else to burn': forest squatters, conservationists, and the state in modern Tanzania. *Journal of Modern African Studies* **43**: 609-640	N	1	0	1	0	0	1
Sunseri, T. (2007) 'Every African a nationalist': scientific forestry and forest nationalism in colonial Tanzania. *Comparative Studies in Society and History* **49**: 883-913	N	0	0	1	0	1	1
Swai, G., Ndangalasi, H.J., Munishi, P.K.T. & Shirima, D.D. (2014) Carbon stocks of Hanang forest, Tanzania: an implication for climate mitigation. *Journal of Ecology and the Natural Environment* **6:** 90-98	N	0	1	0	0	0	0
Swetnam, R.D., Fisher, B., Mbilinyi, B.P. *et al.* (2011) Mapping socio-economic scenarios of land cover change: a GIS method to enable ecosystem service modelling. *Journal of Environmental Management* **92**: 563-574	Y	0	1	0	0	0	0
Syampungani, S., Chirwa, P.W., Akinnifesi, F.K. *et al.* (2009) The miombo woodlands at the cross roads: potential threats, sustainable livelihoods, policy gaps and challenges. *Natural Resources Forum* **33**: 150-159	Y	1	0	1	0	0	0
Syampungani, S., Clendenning, J., Gumbo, D. *et al.* (2014) The impact of land use and cover change on above and below-ground carbon stocks of the miombo woodlands since the 1950s: a systematic review protocol. *Environmental Evidence* **3:** 25	N	0	1	0	0	0	0
Syampungani, S., Tigabu, M., Matakala, N. *et al.* (2017) Coppicing ability of dry miombo woodland species harvested for traditional charcoal production in Zambia: a win-win strategy for sustainaing rural livelihoods and recovering a woodland ecosystem. *Journal of Forestry Research* **28**: 549-556	Y	0	0	1	1	0	0

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Syampungani, S., Geldenhuys, C.J. & Chirwa, P.W. (2016) Regeneration dynamics of miombo woodland in response to different anthropogenic disturbances: forest characterisation for sustainable management. *Agroforestry Systems* **90**: 563-576	N	1	0	1	1	0	0
Tambara, E., Murwira, A., Kativu, S. & Torquebiau, E. (2012) Farming does not necessarily conflict with tree diversity in the mid-Zambezi valley, Zimbabwe. *Agroforestry Systems* **84**: 299-309	N	1	0	1	1	0	0
Tambara, E., Murwira, A. & Kativu, S. (2012) From natural woodlands to cultivated land: diversity of fruit-feeding butterflies and beetles in the mid-Zambezi valley, north Zimbabwe. *African Journal of Ecology* **51**: 263-269	N	1	0	0	0	0	0
Tembani, M., Madhibha, T., Marunda, C.T. & Gapare, W.J. (2014) Sustaining and improving forest genetic resources for Zimbabwe: lesosns from 100 years. *International Forestry Review* **16**: 615-632	Y	1	0	1	0	0	0
Temu, R.P.C. & Andrew, S.M. (2008) Endemism of plants in the Uluguru Mountains, Morogoro, Tanzania. *Forest Ecology and Management* **255**: 2858-2869	Y	1	0	0	0	0	0
Temudo, M.P. & Silva, J.M.N. (2012) Agriculture and forest cover changes in post-war Mozambique. *Journal of Land Use Science* **7**: 425-442	N	1	0	1	0	0	1
Theilade, I., Hansen, H.H., Krog, M. & Ruffo, C.K. (2007) Use-values and relative importance of trees to the Kaguru people in semi-arid Tanzania: part II woodland species. *Forests Trees and Livelihoods* **17**: 109-123	N	0	0	1	0	0	0
Thondhlana, G. (2015) Land acquisition for and local livelihood implications of biofuel development in Zimbabwe. *Land Use Policy* **49**: 11-19	N	0	0	1	0	0	1
Timko, J.A. (2013) Exploring forest-related coping strategies for alleviating the HIV/AIDS burder on rural Malawian households. *International Forestry Review* **15**: 230-240	N	0	0	1	1	0	0
Timko, J.A. & Kozak, R.A. (2016) The influence of an improved firewood cookstove, *Chitetzo mbaula*, on tree species preference in Malawi. *Energy for Sustainable Development* **33**: 53-60	Y	0	0	1	0	0	0
Topp-Jørgensen, E., Poulsen, M.K., Lund, J.F. & Massao, J.F. (2005) Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands of Tanzania. *Biodiversity and Conservation* **14**: 2653-2677	N	1	0	0	0	0	0
Torquebiau, E., Cholet, N., Ferguson, W. & Letourmy, P. (2013) Designing an index to reveal the potential of multipurpose landscapes in southern Africa. *Land* **2**: 705-725	Y	1	1	1	1	1	0
Treue, T., Ngaga, Y.M., Meilby, H. *et al.* (2014) Does participatory forest management promote sustainable forest utilisation in Tanzania? *International Forestry Review* **16**: 23-38	N	1	0	1	0	0	0
Urso, V., Signorini, M.A., Tonini, M. & Bruschi, P. (2016) Wild medicinal and food plants used by communities in *Mopane* woodlands of southern Angola: results of an ethnobotanical field investigation. *Journal of Ethnopharmacology* **177**: 126-139	N	1	0	1	0	0	0
van der Horst, D., Vermeylen, S. & Kuntashula, K. (2014) The hedgification of maizescapes? Scalability and multifunctionality of *Jatropha curcas* hedges in a mixed farming landscape in Zambia. *Ecology and Society* **19**: 48	Y	0	1	1	0	0	0

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van Eijck, J., Romijn, H., Smeets, E. *et al.* (2013) Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania. *Biomass and Bioenergy* **61**: 25-45	N	1	1	1	1	0	1
Vasco, H. & Costa, M. (2009) Quantification and use of forest biomass residues in Maputo province, Mozambique. *Biomass and Bioenergy* **33**: 1221-1228	N	0	0	1	0	0	0
Vedeld, P., Jumane, A., Wapalila, G. & Songorwa, A. (2012) Protected areas, poverty and conflicts: a livelihood case study of Mikumi National Park, Tanzania. *Forest Policy and Economics* **231**: 20-31	N	1	0	1	0	0	1
von Maltitz, G.P., Gasparatos, A., Fabricius, C. *et al.* (2016) Jatropha cultivation in Malawi and Mozambique: impact on ecosystem services, local human well-being, and poverty alleviation. *Ecology and Society* **21**:3	Y	1	1	1	0	1	1
Vyamana, V.G. (2009) Participatory forest management in the Eastern Arc Mountains of Tanzania: who benefits? *International Forestry Review* **11**: 239-253	N	1	0	1	0	0	1
Walelign, S.Z. & Øystein, J.N. (2013) Seasonal household income dependency on forest and environmental resources in rural Mozambique. *International Journal of AgriScience* **3**: 91-99	Y	0	0	1	1	0	0
Walelign, S.Z. (2016) Livelihoods strategies, environmental dependency and rural poverty: the case of two villages in rural Mozambique. *Environment, Development and Sustainability* **18**: 593-613	Y	0	0	1	1	0	0
Walker, P.A. & Peters, P.E. (2007) Making sense in time: remote sensing and the challenges of temporal heterogeneity in social analysis of environmental change - cases from Malawi. *Human Ecology* **35**: 69-80	N	0	0	1	0	0	1
Wallenfang, J., Finckh, M., Oldeland, J. & Revermann, R. (2015) Impact of shifting cultivation on dense tropical woodlands in southeast Angola. *Tropical Conservation Science* **8**: 863-892	Y	1	0	0	1	0	0
Wegner, G., Howell, K.M., Davenport, T.R.B. & Burgess, N.D. (2009) The forgotten 'coastal forests' of Mtwara, Tanzania: a biologically impoverished and yet important ecosystem. *Journal of East African Natural History* **98**: 167-209	Y	1	1	1	0	0	0
Wells, J. & Wall, D. (2005) Sustainability of sawn timber supply in Tanzania. *International Forestry Review* **7**: 332-341	N	0	0	1	0	0	0
Wertz-Kanounnikoff, S., Falcão, M.P. & Putzel, L. (2013) Facing China's demand for timber: an analysis of Mozambique's forest concession system with insights from Cabo Delgado Province. *International Forestry Review* **15**: 387-397	N	0	0	1	0	0	1
Wilfred, P., Madoffe, S.S. & Luoga, E.J. (2006) Indigenous plant uses and use values in Uluguru Mountains, Morogoro, Tanzania. *Journal of East African Natural History* **95**: 235-240	Y	1	0	1	0	0	0
Williams, M., Ryan, C.M., Rees, R.M., Sambane, E., Fernando, J. & Grace, J. (2008) Carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique. *Forest Ecology and Management* **254**: 145-155	Y	1	1	0	1	0	0
Willcock, S., Phillips, O.L., Platts, P.J. *et al.* (2014) Quantifying and understanding carbon storage and sequestration wtihin the Eastern Arc Mountains of Tanzania, a tropical biodiversity hotspot. *Carbon Balance and Management* **9**:2	Y	0	1	0	0	0	0
Willcock, S., Phillips, O.L., Platts, P.J. *et al.* (2016) Land cover change and carbon emissions over 100 years in an African biodiversity hotspot. *Global Change Biology* **22**: 2787-2800	Y	1	1	0	0	0	0

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Winowiecki, L., Vågen, T-G. & Huising, J. (2016) Effects of land cover on ecosystem services in Tanzania: a spatial assessment of soil organic carbon. *Geoderma* **263**: 274-283	Y	0	1	0	0	0	0
Witter, R. & Satterfield, T. (2014) Invisible losses and the logics of resettlement compensation. *Conservation Biology* **28**: 1394-1402	Y	0	0	0	0	1	1
Woittiez, L.S., Rufino, M.C., Giller, K.E. & Mapfumo, P. (2013) The use of woodland products to cope with climate variability in communal areas in Zimbabwe. *Ecology and Society* **18:** 24	Y	0	0	1	1	0	0
Wolmer, W. (2005) Wilderness gained, wilderness lost: wildlife management and land occupations in Zimbabwe's southeast lowveld. *Journal of Historical Geography* **31**: 260-280	N	0	0	0	0	1	1
Woollen, E., Ryan, C.M. & Williams, M. (2012) Carbon stocks in an African Woodland Landscape: spatial distributions and scales of variation. *Ecosystems* **15**: 804-818	N	0	1	0	0	0	0
Woollen, E., Ryan, C.M., Baumert, S. *et al.* (2016) Charcoal production in the Mopane woodlands of Mozambique: what are the trade-offs with other ecosystem services? *Philosophical Transactions of the Royal Society B - Biological Sciences* **371**: 20150315	Y	0	0	1	1	0	0
Zia, A., Hirsch, P., Songorwa, A. *et al.* (2011) Cross-scale value trade-offs in managing social-ecological systems: the politics of scale in Ruaha National Park, Tanzania. *Ecology and Society* **16**: 7	Y	1	1	1	0	1	1
Zimudzi, C. & Chapano, C. (2016) Diversity, population structure, and above ground biomass in woody species on Ngomakurira Mountain, Domboshawa, Zimbabwe. International Journal of Biodiversity http://dx.doi.org/10.1155/2016/4909158	Y	1	0	1	0	0	0
Zisadza-Gandiwa, P., Mabika, C.T., Kupika, O.L. *et al.* (2013) Vegetation structure and composition across different land uses in a semiarid savanna of southern Zimbabwe. International Journal of Biodiversity http://dx.doi.org/10.1155/2013/692564	Y	1	0	0	0	0	0
Zulu, L.C. (2008) Community forest management in southern Malawi: solution or part of the problem? *Society and Natural Resources* **21**: 687-703	Y	1	0	0	0	0	1
Zulu, L.C. (2009) Politics of scale and community-based forest management in southern Malawi. *Geoforum* **40**: 686-699	Y	0	0	0	0	0	1
Zulu, L.C. (2010) The forbidden fuel: charcoal, urban woodfuel demand and supply dynamics, community forest management and woodfuel policy in Malawi. *Energy Policy* **38**: 3717-3730	N	0	0	1	0	0	1
Zulu, L.C. (2012) Neoliberalisation, decentralisation and community-based natural resources management in Malawi: the first sixteen years and looking ahead. *Progress in Development Studies* **12**: 192-212	N	0	0	0	0	0	1
Zulu, L.C. (2013) Bringing people back into protected forests in developing countries: insights from co-management in Malawi. *Sustainability* **5**: 1917-1943	Y	1	0	1	0	0	1