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RESEARCH ARTICLE

Tobacco cultivation as a driver of land use change and degradation in the miombo woodlands of south-west Tanzania

Eleanor K.K. Jew | Andrew J. Dougill | Susannah M. Sallu

Sustainability Research Institute, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK

Correspondence
Eleanor Jew, Sustainability Research Institute, School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK.
Email: e.k.jew@leeds.ac.uk

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Abstract

Miombo woodlands support agriculture, biodiversity, and multiple ecosystem services across an extensive part of sub-Saharan Africa. Miombo is frequently overutilised with deforestation and degradation resulting in significant land use and land cover change (LULCC). Understanding the drivers of LULCC is essential to achieving sustainable land management in miombo woodland regions. Within a remote miombo area of south-west Tanzania in the Kipembawe Division, Mbeya Region, social survey and ecological data were used to identify the direct and indirect drivers of LULCC. Our findings show that tobacco (*Nicotiana tabacum*) production results in an estimated annual deforestation rate of 4,134 ± 390 ha of undisturbed miombo woodland, of which 56.3 ± 11.8% is linked to the post-harvest curing process. This deforestation represents 0.55 ± 0.06% of the wooded area of the Kipembawe Division. The perception of high incomes from tobacco cultivation has encouraged migration of both agriculturalists and pastoralists into the area, resulting in higher livestock numbers that lead to further degradation. Higher human populations need more woodland resources such as fuelwood and building materials and more farmland for food crops. Continued deforestation will reduce the long-term profitability of tobacco cultivation due to a lack of fuel to cure the crop and could render production unviable. Action is urgently needed to conserve globally important biodiversity resources while enabling agricultural and pastoral activities to continue. Improved governance, together with sustainable land management strategies and diversification of livelihood strategies, can reduce dependence on tobacco cultivation and contribute to a sustainable future for this ecoregion.

KEYWORDS

biodiversity, carbon, in-migration, mixed methods, pastoralism

1 | INTRODUCTION

Land use and land cover change (LULCC) describes the human-induced alteration of the earth's surface (Ellis, 2013) and often occurs through degradation and deforestation of woodlands and forest. This contributes to global climate change and influences ecosystem service provision (Lambin et al., 2001), in addition to causing a loss in biodiversity and undermining the capacity of ecosystems to support agricultural output (Foley et al., 2005). A driver of change can be natural or anthropogenic, and it causes a change in the state of something else (MEA, 2005). When a driver unequivocally has an influence, it is described as a direct driver, and when they underlie or lead to a direct driver, they are described as an indirect driver (MEA, 2005). Indirect drivers can be classified into five categories (sociopolitical, religious and cultural, demographic, scientific and technological, and economic), which can influence direct drivers (Nelson et al., 2006).

Deciduous miombo woodlands cover 2.4 million km^2 of sub-Saharan Africa (Frost, Timberlake, & Chidumayo, 2003), are home to over 100 million people (Campbell et al., 2007), and contain numerous endemic and threatened species (Conservation International, 2012).

Miombo woodlands are dominated by tree species of the legume subfamily Caesalpinioideae within three genera (*Julbernardia*, *Brachystegia*, and *Isoberlinia*; Frost et al., 2003). They are globally important owing to their capacity to store carbon and influence environmental and socioeconomic systems (Ribeiro, Syampungani, Matakala, Nangoma, & Ribeiro-Barros, 2015). They are locally important due to provisioning ecosystem services including medicinal plants, edible forest products, food for livestock, construction materials, and fuel sources (Dewees et al., 2010; Jumbe, Bwalya, & Husselman, 2008; Malambo & Syampungani, 2008). By 2050, sub-Saharan Africa's population is predicted to increase twofold (Eastwood & Lipton, 2011), leading to increasing pressure upon miombo woodland (Cabral, Vasconcelos, Oom, & Sardinha, 2011). Sustainable management of miombo woodlands is therefore needed, and they are receiving increasing global consideration (Williams et al., 2008). Presently, the greatest research focus in miombo woodland surrounds their role in carbon storage (e.g., Shirima et al., 2011; Williams et al., 2008), with limited understanding of the drivers of land use change.

Regionally, several direct anthropogenic drivers of LULCC have been identified in miombo systems, including overgrazing, agricultural expansion, charcoal, fuelwood, and timber extraction, rising urbanisation, unmanaged fires, and excessive exploitation of valuable animal and tree species (e.g., Cabral et al., 2011; Fisher, 2010; Ryan et al., 2016). Natural drivers of change that are likely to impact miombo woodlands include changes to rainfall patterns and volumes (Seth et al., 2013), rising temperatures (Pienaar, Thompson, Erasmus, Hill, & Witkowski, 2015), and altered fire regimes (Andela & van der Werf, 2014). General descriptions of drivers can provide information to inform regional land management policy, yet they do not identify local-scale nuances necessary for land use and management decisions. To provide effective, enduring management solutions for miombo woodlands, it is necessary to understand both direct and indirect drivers (Nelson et al., 2006), especially as drivers differ substantially from region to region (Bond, Chambwera, Jones, Chundama, & Nhantumbo, 2010; Vinya, Syampungani, Kasumu, Monde, & Kasubika, 2011). This paper addresses this gap by providing empirical data from a miombo woodland landscape in south-west Tanzania, which is currently experiencing rapid land use change. The key anthropogenic drivers of land use change are identified through integrative quantitative and qualitative research methods.

2 | MATERIALS AND METHODS

2.1 | Study area

Miombo woodland represents 95% of forested area in Tanzania (MNRT, 2006). Between 1990 and 2000, it is estimated that 13% of Tanzanian miombo woodland was lost (FBD, 2008). Current estimations of Tanzanian woodland and forest loss range between 372,000 and 580,000 ha/year (FRELT, 2016; MNRT, 2015). The site for this study is located in the Kipembawe Division (8,766 km^2), within the Chunya District, Mbeya Region of south-west Tanzania (7°54′58.44″ S, 33°19′22.84″E, Figure 1). The study area is representative of other

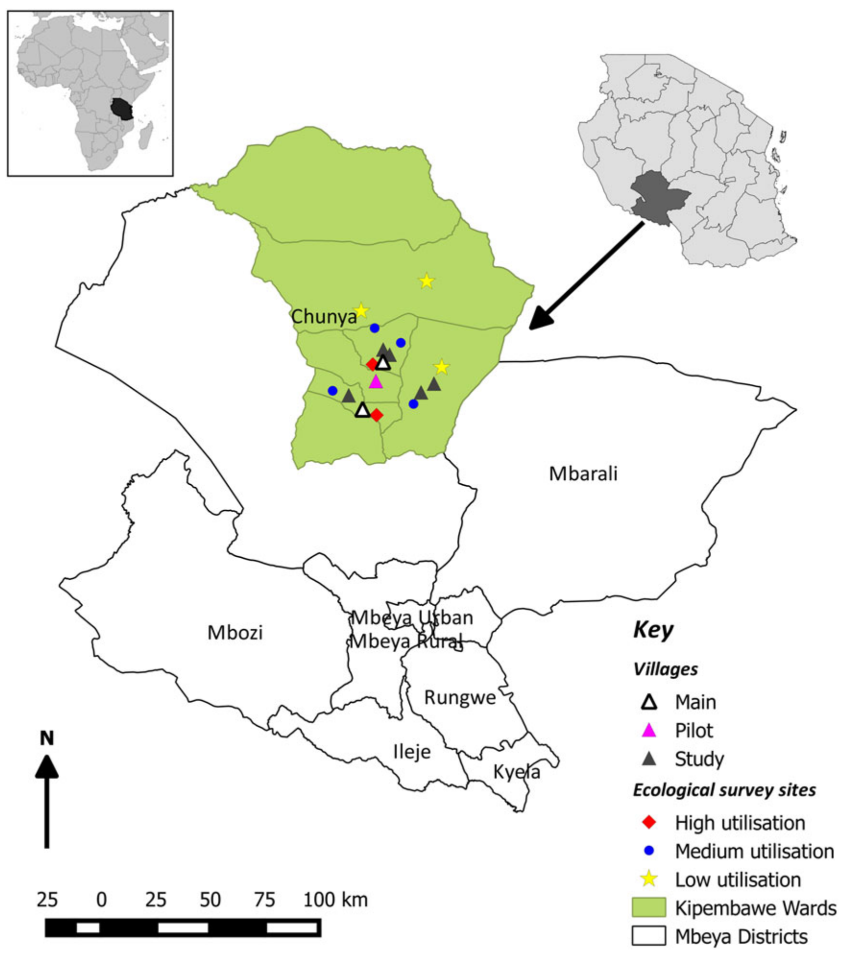

FIGURE 1 Study area (Kipembawe Division) within the Chunya District, Tanzania. The main trading villages, pilot study village, study villages, and ecological survey sites are highlighted (created from GADM, 2015; Sandvik, 2009) [Colour figure can be viewed at wileyonlinelibrary.com]

areas of high rainfall miombo woodland. Farming is the dominant occupation for the estimated population of 66,752, across 16 villages (National Bureau of Statistics, 2013). Within the division, village-level Participatory Forest Management Committees oversee five reserves, and the District Forestry Department governs three forest reserves. However, this study found that the reserves are poorly managed owing to insufficient funding and limited capacity in terms of personnel and transport. Access to woodland is therefore largely unrestricted across both protected and unprotected areas. Average yearly precipitation is 933 ± 36 mm (n = 28 years). Rains typically start in October and occur frequently until May, with very little falling throughout the rest of the year. The soils are shallow and sandy, and the landscape is predominantly flat.

2.2 | Data collection

To identify the drivers of deforestation and degradation, a mixed methods approach was taken, combining social and ecological surveys. This enabled a holistic examination of the drivers of land use change by drawing upon a range of complementary primary data sources.

2.2.1 | Ecological survey

Nine ecological survey sites were selected (described in Jew, Dougill, Sallu, O'Connell, & Benton, 2016), representing low to high levels of human utilisation of the woodland. Within each survey site, five transects were conducted to record land use type and utilisation levels. Transects were 10 m wide and 1.5 km long and split into 20-m sections (Doggart, 2006), sampling 75,000 m^2 at each site. Within each section, all live, dead, and cut poles and timbers were recorded, and the main land cover type documented. Evidence of utilisation or removal of non-timber forest products and other disturbances was noted, for example logging, tree bark removal, and beehives.

2.2.2 | Social survey

The social survey consisted of household questionnaires, village-level focus groups, and semi-structured key informant interviews to obtain information on drivers of land use change and agricultural methods. The five villages selected for involvement in the social survey were in close proximity to ecological survey sites with medium and low utilisation levels, allowing social and ecological survey data to be aligned by comparing quantitative data with qualitative data, particularly in terms of agricultural land cover. The four remaining ecological survey sites were not in close proximity to any village and therefore not suitable for comparable study. Villages were situated within three wards ("study" villages, Figure 1). A further village was selected for piloting the research methods ("pilot" village, Figure 1). Fieldwork took place February–September 2013, when the research team lived within the community, and therefore, field observations were an additional data source. Government census data were also used to determine demographic patterns within the district.

Within each of the five villages, 10% of households (n = 196) were chosen at random to engage in questionnaires (Meshack, Ahdikari, Doggart, & Lovett, 2006). These were undertaken with the head of the household, where a household was defined as containing people who eat at least one meal together and sleep in the same accommodation, and the head is the principal decision maker. Household farming activities were discussed. Questionnaires were conducted in Kiswahili by experienced translators and typically lasted approximately 40 min, including both closed and open questions.

Multiple focus group discussions took place in each village with identified sets of people (e.g., villagers, livestock keepers, and crop producers) determined through key informant interviews with village committee representatives (e.g., Participatory Forest Management Committee and Social Welfare Committee). Focus group discussions lasted for approximately 1 hr, with 2–8 people and an even number of men and women, subject to availability. Overall, 28 focus groups were conducted. The purpose of focus groups was to collect comprehensive qualitative information on relevant issues and to explore key themes and questions that had arisen in household questionnaires. A range of questions was presented, and all answers were considered between group participants with facilitation (Ritchie, Lewis, Nicholls, & Ormston, 2013). Each session was recorded, and the lead researcher took notes through translation.

Semi-structured interviews took place with 41 key informants at all governance levels from village to regional. Key informants were either involved with a particular programme or project or held extensive knowledge on a specific relevant topic (O'Leary, 2013). Snowball sampling was used to identify interviewees within the public, private, and voluntary sectors. Interviews explored key themes of relevance to each individual that had emerged through household questionnaires and focus groups. Interviews and focus groups were coded and grouped into themes for analysis, with direct and indirect drivers emerging from the data and subsequently undergoing comparison with the other data sources to determine validity.

3 | RESULTS

The main indirect drivers of LULCC were identified to be demographic (in-migration) and economic (rising tobacco prices). Direct drivers include the clearing of land for agriculture (in particular tobacco), energy demand for curing tobacco leaves, extraction of wood for household use and construction, and degradation and deforestation caused by livestock and livestock keepers.

3.1 | Indirect drivers

3.1.1 | Demographic: in-migration

Demographic data from household surveys demonstrate high rates of in-migration, with 75% of respondents having migrated to Kipembawe from other regions of Tanzania. The recorded population of Kipembawe in 2012 was 66,752 (National Bureau of Statistics, 2013), having grown by over 60% from 41,493 in 2002 (Central Census Office, 2004). Household surveys indicated that the most likely reason to move to the area was to farm (62%), and of these 74% (67 households) said their main motivation was to cultivate tobacco. A further 27% of household heads moved to join family members who had migrated previously. Other reasons for in-migration included to improve quality of life and for work, mining, education, and government relocation.

3.1.2 | Economic: rising tobacco prices

Higher tobacco prices encourage in-migration as Ward B Officer 1 (2013) explained: "There is a lot of immigration for tobacco cultivation, when the price is high" (Jew, 2016, p. 95). Additionally, current residents may decide to cultivate tobacco or expand their cultivated area in response to rising prices. This is illustrated in Figure 2, where the average price of tobacco in Tanzania since 1997 is shown in relation to in-migration and initiation of tobacco production in Kipembawe. In years where the tobacco price drops, key informants explained that male household members travel to the Lupa Goldfield near Chunya to practise artisanal gold mining until the tobacco prices rise again; hence, outmigration is not evident in this area.

During the 2012/2013 season, top-grade tobacco was valued at US$1.939 per kg and the lowest at US$0.396 per kg. The price for tobacco was set to increase for the 2013/2014 season, and therefore, Company 1 expected that tobacco would be grown on 10% more land than in 2012/2013. Tobacco farmers (n = 168, household surveys) cited benefits such as abilities to build a house (116 respondents), buy clothes (91), pay school fees (68), and buy food (41). Other benefits cited by fewer than 40 respondents included purchasing livestock, opening a new business, and paying for healthcare.

3.2 | Direct drivers

3.2.1 | Agriculture

In the six ecological survey sites that experienced high and medium levels of woodland utilisation, transect data demonstrated that approximately 30% of land cover was agricultural, 7% was regenerating miombo woodland, and 62% was undisturbed vegetation (Table 1). The two dominant cultivated crops were maize and tobacco. Households on average grow maize over 1.2 ha (mode, n = 194, min = 0.2 ha, max = 8 ha) and cultivate 0.8 ha of tobacco (mode, n = 167, min = 0.2 ha, max= 16 ha). According to interviews with the two tobacco companies, there were 7,800 registered tobacco farmers in Kipembawe Division in 2013 and an estimated area of 8,639 ha under tobacco cultivation (Company 1: 6,088 ha; Company 2: 2,281 ha). According to household surveys where undisturbed vegetation was cleared in the years following original clearance to start the farm, non-tobacco farmers (n = 27) clear 0.09 ± 0.03 ha (M ± SEM) of undisturbed vegetation per year, and tobacco farmers (n = 157) clear 0.53 ± 0.05 ha/year, showing that tobacco farmers clear significantly more woodland than non-tobacco farmers. A further five tobacco farmers did not clear undisturbed vegetation but did clear regenerating woodland, ranging from 0.8 to 1.6 ha annually, and two non-tobacco farmers cleared only regenerating woodland (unspecified amount).

3.2.2 | Tobacco cultivation and energy demand for curing

Tobacco cultivation within Kipembawe was introduced in the 1960s, and people were moved to the area through government relocation schemes to grow tobacco, originally through communal systems. In the recent years, inputs (seeds, fertiliser, and pesticides) have been supplied by two tobacco merchants and are distributed by a Primary Co-operative Society. Seeds are distributed free of charge, and inputs including fertiliser and pesticides are received on loan, which is repaid at the end of the season. The nature of tobacco cultivation is described in the following quote:

> *The normal pattern with land clearance is that tobacco is planted and harvested, and to dry that tobacco another area of land is cleared. The following year the tobacco will be planted on that cleared land, and another crop such as maize is planted on the old land. Then more trees must be harvested to cure that harvest. The year after that the farmer will grow tobacco on the first field. However, the farmer will still need more wood to cure the tobacco, so each year they must remove some trees, even if it is not always a larger block. If they wish to expand their farm they must clear land.*
>
> Tobacco Company 1, 2013 (Jew, 2016, pp. 89–90)

To preserve the tobacco leaves, they need to be dried, or cured. In this area, tobacco is flue cured, where the leaves are hung in burners and the flues are lit below. This process has a high-energy demand, for which wood is used. Farmers tend to build their tobacco burners

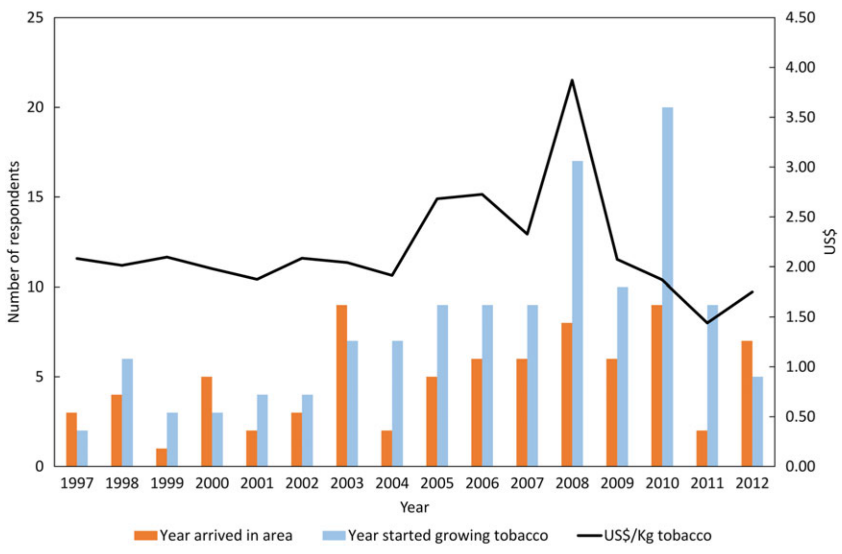

FIGURE 2 The trend in Tanzanian national tobacco prices per kilogram (source: UN Comtrade, 2016), the year respondents arrived in Kipembawe (Household Surveys, 2013, n = 150, 46 respondents born in area), and the year respondents began cultivating tobacco in Kipembawe (source: Household Surveys, 2013, n = 167) [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Land use and percentage land cover percentages determined from ecological survey transects (0.375 km^2) and amount of land cultivated derived from household surveys (n = 196)

Land cover and land use			
Type	**Subtype**	**% cover from transects**	**Total hectares of crop grown**
Under cultivation	Agriculture (maize)	12.10	327
	Agriculture (tobacco)	4.42	245
	Agriculture (beans)	0.31	65
	Agriculture (groundnuts)	0.76	46
	Agriculture (other)[a]	1.21	16
	Agriculture (sweet potato)	1.43	16
	Agriculture (sunflower)	0.71	7
Prepared for cultivation	Agriculture (fallow)	6.21	
	Agriculture (under preparation)	0.40	
	Cleared woodland	1.88	
Cultivated in past	Agriculture (abandoned)	1.16	
	Regenerating miombo woodland	7.23	
Natural vegetation	Open miombo woodland	55.80	
	Riverine forest	0.76	
	Seasonal watercourse	0.22	
	Seasonal floodplain	5.18	
	Tall grasses	0.22	

[a]Other crops grown: cassava (5 ha), millet (4 ha), peas (4 ha), rice (2 ha), and sesame (1 ha).

at the tobacco/woodland interface, where they can be used for at least 2 years. Focus groups identified a key driver of land use change as the curing of tobacco leaves. Harvesting trees for curing contributes to the preparation of land for tobacco in following years, and therefore, harvesting is not selective. Whole trunks are used in the burners and cannot be carried far. Smaller branches are often used as household fuelwood. Each year, farmers must harvest trees to cure tobacco, but whether they choose to clear a larger area in order to expand their cultivated land is optional. Increases in the number of tobacco farmers (Figure 2) result in more land being cleared in this way. Farmers who do not grow tobacco may also clear vegetation to expand their farms, or to find more fertile land (Table 2).

To indicate the average clearance of undisturbed vegetation by tobacco farmers, the figure of 0.53 ± 0.05 ha/year per farmer (from survey respondents) was extrapolated to all 7,800 registered tobacco farmers across the division. This suggests that approximately 4,134 ± 390 ha of undisturbed natural vegetation is cleared by tobacco farmers annually. Approximately 745,110 ha of the Kipembawe Division is covered by miombo woodland (Chunya District Council, 2010); therefore, this deforestation rate equates to an annual loss of

TABLE 2 Reasons for clearing natural and regenerating vegetation (source: Household Surveys, 2013, n = 196)

Tobacco farmers (n = 167, multiple answers accepted)		**Non-tobacco farmers (n = 29, multiple answers accepted)**	
Regularly clear vegetation		Regularly clear vegetation	
For fertile land	54	For fertile land	6
To expand the farmland	53	To expand the farmland	3
To increase production of tobacco	42	For new trees to regenerate	1
For trees to dry the tobacco	15		
Other	5		
Never clear vegetation		Never clear vegetation	
I have enough	2	I don't cultivate tobacco	7
I keep the forest	1	Farmland rented	1
I rotate the crops	1	Neighbour does not allow it	1
My parents cleared the land that I am using	1	I want to plant new trees	1
Don't have any land to clear	2		
Too old	1		
Regenerating only		Regenerating only	
For fertile land	2	No natural forest to clear	1
For trees to dry the tobacco	1		
To increase production of tobacco	3		
To start farm	3	To start farm	4
Don't know	1		
No reason given	11	No reason given	6

0.55 ± 0.06% of the total woodland. If this rate continues, the woodland in Kipembawe will be entirely lost in 180 ± 15 years (Table 3). This does not account for anticipated growth (Tobacco Company 2, 2013) in the number of tobacco farmers, or possible regrowth. Above-ground carbon storage in low utilisation miombo woodland is estimated at 28.5 t C ha^{-1} (Jew et al., 2016); therefore, this deforestation is equivalent to a reduction of carbon storage of approximately 117,819 ± 11,115 t C $year^{-1}$.

Household survey respondents gave wide variations in estimates when asked to approximate the number of trees used to dry tobacco (between 10 and 400 trees per 0.4 ha of tobacco grown). Therefore, industry figures were used to estimate deforestation rates for tobacco curing. According to the Corporate Social Responsibility Programme provided by Tobacco Company 1, 18 m^3 of wood is used to cure 1 t of tobacco. Using average wood density estimations for miombo species present within low utilisation sites obtained through the Dryad Global Wood Density Database (Chave et al., 2009; Zanne et al., 2009), the mean wood density ± *SD* for this site is 0.67 ± 0.14 g/cm^3. Therefore, to dry 1 t of tobacco, an estimated 12.06 ± 2.52 t of wood are required. In 2013, Company 1 expected a tobacco harvest of 8,000 t and Company 2 expected 3,000 t. To dry this harvest of 11,000 t, approximately 132,660 ± 27,720 t of wood will have been burned. Wood biomass is estimated to be 50% carbon (IPCC/OECD/IEA, 1997). Using this figure, the estimated amount of carbon released through the curing process in 2013 was approximately 66,330 ± 13,860 t of carbon. Using the carbon storage estimation of 28.5 t C ha^{-1}, we estimate that approximately 2,327.4 ± 486.3 ha of the 4,134 ha (56.3 ± 11.8%) of miombo woodland cleared in 2013 in the study site was due to curing of tobacco leaves.

The tobacco industry is conscious of this energy demand and the impact that woodland loss will have on the sustainability of production:

> *We need a lot of firewood for tobacco. If they cut the trees it means that trees will be finished and tobacco production will not be there anymore because we need a lot of wood to cure the tobacco. If we don't have wood we don't have tobacco. Kipembawe used to be a very big forest. So it will be in 10–15 years there will be very big problems here, the tobacco production will diminish.*
>
> Tobacco Company 1, 2013 (Jew, 2016, p. 90)

To reduce the extraction of native trees, tobacco companies are encouraging the planting of fast-growing eucalyptus trees as an alternative energy source and the use of "modern" fuel-efficient tobacco burners over traditional burners (Company 1 and 2, 2013). However, throughout this research, only two "modern" burners and one small eucalyptus lot were observed.

3.2.3 | Additional wood extraction

Household questionnaires, focus groups, and key informant interviews also indicate that wood is used for domestic use, including the construction tobacco burners, stores, and houses. According to the ecological surveys, 27% of available poles and 29% of available timber had been harvested. Of the 196 households, 174 indicated that they used poles for domestic use in construction, collecting them from the woodland. Thirty-one households said they used timber for construction, 9 of whom collected it themselves for domestic use, 1 collected it for both domestic use and sale, and 21 bought timber. All timber should be harvested under licence, provided at district level. At the time of study within the division, there was only one timber business and approximately 30 licences had been allocated among five people (District Officer 3, 2013). Each licence lasts for 30 days and costs approximately TSH 1.6 million, within which time 20 m^3 of timber can be harvested (Division Officer 2, 2013). Village Chairperson 1 (2013) explained that "There are few lumberers because the permits are so expensive" (Jew, 2016, p. 93), and this results in high levels of illegal logging. The research team observed two illegal operations where timber was removed by truck. Numerous small-scale pit-saw sites were also observed. All surveyed households reported that they used firewood as their fuel for cooking. Although only 10 houses used charcoal, District Officer 3 (2013) said that 90% of households within Mbeya town

TABLE 3 Summary of deforestation data demonstrating rates of natural vegetation clearance and associated causes and consequences

Deforestation variables	Unit
Size of woodland in Kipembawe	745,110 ha
Carbon storage in low utilisation miombo woodland at this study site	28.5 t/ha
Annual natural vegetation clearance per non-tobacco farmer	0.09 ± 0.03 ha
Annual natural vegetation clearance per tobacco farmer	0.53 ± 0.05 ha
Total annual natural vegetation clearance all tobacco farmers (n = 7,800)	4,134 ± 390 ha
Annual loss of Kipembawe woodland	0.55 ± 0.06%
Annual loss of carbon	117,819 ± 11,115 t C $year^{-1}$
Of which 56.3 ± 11.8% is due to curing:	
Wood required to cure 1 t of tobacco	12.06 ± 2.52 t
2013 tobacco harvest	11,000 t
Wood required to cure 2013 tobacco harvest	132,660 ± 27,720 t
Annual natural vegetation clearance for curing tobacco	2,327.4 ± 486.3 ha
Annual carbon loss from curing	66,330 ± 13,860 t C $year^{-1}$
Length of time to remove all woodland in Kipembawe	180 ± 15 years

are reliant on charcoal and that households to the south of Kipembawe are now allowed to sell charcoal, and this is "very profitable."

3.2.4 | Livestock

Livestock grazing was regularly mentioned in interviews and focus groups as causing woodland degradation and as a reason for deforestation. Livestock tracks were recorded in 10.7% of transects within ecological surveys. In 2013, official livestock figures based on registered animals suggested that within Chunya District, there were 186,800 cattle, 46,624 goats, and 22,820 sheep (District Officer 6, 2013). In 2002/2003, a national agricultural census recorded 139,490 cattle (National Bureau of Statistics, 2004), demonstrating a rise of 33.9% in 10 years. Records for Wards within Kipembawe were incomplete. Key informants (including livestock officers and livestock keepers) alleged that livestock is moved into the division but many are not registered, meaning that overall livestock numbers are probably considerably larger. District Officer 6 (2013) explained that "overcrowding of cattle causes environmental destruction, as they damage the land, pasture doesn't regrow, and trees don't regenerate" (Jew, 2016, p. 94). To combat this, government regulations restrict the number of cattle to 70 per keeper. Focus groups indicated that this policy is widely known but typically ignored. District Officer 6 also outlined a programme to encourage livestock keepers to plant 400 trees annually and for each household to have a rainwater harvesting technique. However, he considered that most people were not interested in participation. In addition to damage caused directly by cattle, trees are also thought to be cut down by livestock keepers:

> *Livestock keepers clear the natural [undisturbed] vegetation which leads to environmental degradation because they think that no trees equals no tsetse. It works, but the environment is very degraded because of this. In the north it is now desert because of this, so they have moved here and are doing the same. If there are more tsetse traps there would be no flies [and they would not need to cut the trees down].*
>
> District Officer 4, 2013 (Jew, 2016, p. 94)

Discussions in pastoralist focus groups associated dense vegetation with tsetse fly numbers and therefore a greater risk of livestock loss from trypanosomiasis. To counter this, vegetation is removed to reduce tsetse fly numbers, which results in land cover change. During focus group discussions with agricultural and village groups, environmental damage was often considered to be caused by cattle, particularly around water sources, where examples were given of increased competition for water access, water contamination, and damage to the water sources, leading to conflict between livestock keepers and other villagers.

4 | DISCUSSION

This study identified three direct drivers of land use change: agriculture (particularly tobacco cultivation), wood extraction (for tobacco curing, domestic use, sale, and fuelwood), and livestock keeping. Two main indirect and interlinking drivers were identified, which underlie the three direct drivers: in-migration and the incentive of rising tobacco prices.

Tobacco cultivation in Tanzania began in the early 1960s, where production was approximately 3,000 t/year (~5,500 ha, yield 513 kg/ha; FAO, 2016). Production increased throughout the 1970s and 1980s and fluctuated around 30,000 t/year throughout the 1990s. In 2002, production was 27,423 t/year, cropped on 32,000 ha with a yield of 807 kg/ha. In 10 years (2012), production had more than quadrupled to 120,000 t/year, cultivated on 155,527 ha, with a yield of 771 kg/ha (FAO, 2016). This rapid increase in production without an increase in yield, and a corresponding fivefold increase in cultivated land, demonstrates that rapid land use change has taken place. This matches our findings, which indicate increasing migration into Kipembawe since 2002, and corresponding increases in the number of households cultivating tobacco. Rapid land use change resulting from tobacco cultivation has precedence in Tanzania, where tobacco cultivation rapidly expanded during the 1970s in Tabora, leading to fuelwood shortages and environmental changes including drought, irregular rains, and whirlwinds due to land use change by the 1990s (Maegga, 2011; Waluye, 1994). Similar impacts have also been seen in other miombo regions, such as Malawi (Mandondo, German, Utila, & Nthenda, 2014) and Zambia (Kalaba, Quinn, Dougill, & Vinya, 2013).

In addition to the conversion of undisturbed vegetation to farmland to cultivate tobacco, curing of leaves uses 200,000 ha of woodland a year globally (Geist 1999), accounting for 1.7% of global net forest cover loss. The figure estimated here is that 1 kg of cured tobacco requires 12.06 ± 2.52 kg firewood is similar to that found in other studies (Otanez, 2008; Siddiqui & Rajabu, 1996). This suggests that, in the absence of empirical data from curing barns, 12.06 ± 2.52 kg is a suitable estimate for the amount of firewood required to cure tobacco in Kipembawe. Traditional tobacco burners lose ~98% of the energy supplied; "modern" tobacco burners are 44% more thermally efficient, losing 55% of energy supplied (Musoni, Nazare, Manzungu, & Chekenya, 2013). Should demand remain the same, encouraging the building of "modern" tobacco burners will significantly reduce the use of fuelwood for curing in Kipembawe. Current barriers to this include lack of awareness of modern burners and the skills needed to construct them. The annual carbon losses calculated in this study (117,819 ± 11,115 t C year^{-1}) support other research that demonstrates the value of managing miombo woodlands to reduce carbon emissions (Burgess et al., 2010; Munishi, Mringi, Shirima, & Linda, 2010). The possibility of doing so through sustainable land management and technological developments (notably with "modern" burners) means that funding from carbon finance initiatives (REDD+, Voluntary Carbon Markets & Payment for Ecosystem Service Schemes) needs to be explored, and multi-stakeholder partnerships established to ensure successful implementation of projects capable of realising carbon mitigation benefits (Mathur, Afionis, Paavola, Dougill, & Stringer, 2014).

Rapidly increasing populations in poor rural areas without corresponding out migration as seen in this study leads to agricultural expansion (Rudel, 2013) and puts further demands onto the surrounding environment for ecosystem services such as wood for building materials and fuel, leading to further degradation. Within

Southern Africa, fuelwood or charcoal provides 70% of the energy consumed (Syampungani, Chirwa, Akinnifesi, Sileshi, & Ajayi, 2009). In other parts of Chunya, 88.3% of harvested timber is converted to charcoal (Sawe, Munishi, & Maliondo, 2014). The remoteness of Kipembawe and high availability of firewood contribute to the low extraction of charcoal. However, this is likely to change with increasing urban demands, few affordable alternatives (Ahrends et al., 2010), and an improving road network.

Similarly, increasing livestock numbers in Kipembawe have resulted in further demands upon the surrounding environment. Livestock numbers have increased due to the in-migration of members from the agro-pastoralist *Sukuma* tribe, searching for grazing and water due to displacement from their traditional lands in northern Tanzania (Charnley, 1997). The expansion of the Ruaha National Park has led to further displacement of *Sukuma* from the Mbarali District in Mbeya, adjacent to Kipembawe (Sirima & Backman, 2013). Such sociopolitical drivers are an additional indirect driver of land use change.

Miombo woodlands are well known for their ability to regenerate (Kalaba et al., 2013), and this is a vital component of the dynamics within miombo woodlands. In this study area, there was little evidence of regenerating land being "reused" for cultivation, and the continued deforestation of undisturbed vegetation leads to losses of endemic flora and fauna (Jew et al., 2016; Jew, Loos, Dougill, Sallu, & Benton, 2015). A study by Prins and Kikula (1996), also within the Chunya District, found that tobacco cultivation ceased in some areas during the 1980s when tobacco prices dropped. However, the land was not left to regenerate but was used for the cultivation of other crops. They also found that areas that had been cultivated for over 7 years did not regenerate even when they had been left fallow for at least 15 years (Prins & Kikula, 1996) as a result of damage to the rootstocks (Boaler & Sciwale, 1966). As such, a reliance on the regrowth properties of miombo woodland to mitigate woodland loss is inadvisable.

5 | CONCLUSION

Land use change in Kipembawe results from increases in tobacco cultivation driven by rising prices and in-migration to cultivate the crop. This has led to an increase in population, which drives further direct land use change through the extraction of wood resources to provide housing and firewood, in addition to clearance and degradation of woodland for cultivation and livestock keeping. Given that tobacco cultivation is linked to the majority of LULCC changes within Kipembawe, it is the main driver of land use change leading to woodland degradation. Due to the Tanzanian government's current positive support for tobacco production, it is probable that tobacco cultivation will continue to increase, driving further woodland degradation and deforestation. Action is required to avoid these impacts. Tobacco companies and government forestry and livestock departments have policies in place (e.g., "modern" burners, woodlots, livestock movement, and logging restrictions), but there is little evidence of their implementation. This must be addressed, in addition to the development of land management strategies that regulate woodland utilisation and alternative methods for drying the tobacco crop. Encouraging the development of diverse livelihood approaches and limiting the top price of tobacco could reduce the incentive to cultivate tobacco and limit further degradation of the miombo woodland system.

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ORCID

Eleanor K.K. Jew http://orcid.org/0000-0003-0241-404X

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