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Market Signals of Unsustainable and Inequitable Forest Extraction: Assessing the Value of Illegal Timber Trade in the Eastern Arc Mountains of Tanzania

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Summary. — Natural forests and woodlands of the Eastern Arc Mountains (EAM) in Tanzania are under threat from deforestation and degradation. The estimated annual revenues from EAM hardwood for domestic use are USD 10 million in terms of planks, and twice as much when processed into furniture. Timber profits are largely captured by people whose livelihoods do not directly depend on other EAM ecosystem services. Market data, such as declining plank sizes and shifts to low-quality timber species, contain possible early warning signals of unsustainable hardwood harvesting. Policy recommendations include simplifying regulations for legal trade, developing sustainable financing, and increasing softwood supply.

Key words — timber, forest ecosystem services, value-chain analysis, sustainable harvesting, Tanzania, Africa

1. INTRODUCTION

Wherever the lack of or weak enforcement of rules makes illegal trade more profitable than legal trade, illegal resource use and markets are likely to arise (Brack & Hayman, 2002). Many illegal activities in forestry sectors around the world take place in countries with high levels of corruption (FAO, 2001), which either allows logging to occur illegally, or results in no action against transport, trade, and manufacturing of the (illegally) harvested logs or planks. An estimated 15–30% of international wood trade, and 50–90% of timber harvest in tropical countries, is thought to be illegal (Nellemann, 2012). Illegal logging has, therefore, become a policy issue of international importance, and was made a priority area of the British presidency of the G8 in 2005. The IMF–World Bank meeting in 2006 initiated the *G8 Illegal Logging Dialogue* in order to address corruption and promote good governance as well as poverty reduction. The EU has adopted the FLEGT Action Plan under which voluntary partnership agreements can be set up with timber exporting countries to ensure legal trade; and the US Lacey Act (a conservation law) adopted a special amendment to prevent illegal logging in 2008.

Illegal logging generates high private rents for extractors because it avoids the costs of licenses, royalties, and less-intensive harvesting levels, although some bribery is also generally necessary. This opportunity to generate high private rents may lead to higher extraction rates than is optimal for social welfare maximization (Palmer, 2001). Other forest stakeholders are not compensated for the negative impacts of illegal logging. The negative externalities of unsustainable timber harvesting include effects on (non-marketed) ecosystem services of global importance such as biodiversity conservation, carbon storage and emissions, and eco-tourism. Local and regional externalities relate to direct forest uses such as lower harvesting of non-timber forest products, soil degradation, reduced water-regulating capacity of catchment areas, and reduction of pollination and cultural values. However, the timber trade creates jobs and cash income which may be vital to people in rural communities where many live near the poverty line, and provides important material resources to urban people. Enforced regulation of the timber industry thus comes at a cost to some, but provides benefits to other interests, both locally and to the global society at large.

A decline in forest resources represents a major policy problem and urgent action, based on interdisciplinary research, is needed to achieve more sustainable forest management in many parts of Africa, including Tanzania. The largely illegal nature of the forest sector means that there is little market-based evidence to inform decision-making and to estimate the severity of the problem, let alone to assess the distributional effects of possible policy interventions. In addition, biophysical stock assessments, based on large-scale forest

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surveys are costly and often remain unachievable for developing countries, where many of the remaining hardwood resources are located. Moreover, sustainable harvesting or species growth rates are unavailable for many tropical timber species. Alternative, faster and cheaper pragmatic assessment methods may provide a way forward.

This paper addresses hardwood extraction from the natural forests and woodlands of the Eastern Arc Mountains in Tanzania, a global biodiversity hot-spot under increasing pressure from deforestation and forest degradation (see Section 2). The main goal of the paper is to inform policy development and decision-making by assessing (a) the economic value of timber extraction from the Eastern Arc Mountains forests and woodlands, (b) the distribution of the associated benefits throughout the timber commodity chain, and (c) markets signals of the sustainability of hardwood extraction. While under (a) we aim to provide insight into the magnitude and significance of the forest policy issue, under (b) we show how the interests of different actors are served, thereby informing how future forest policies could be developed to ensure a more equitable use of forest resources. By analyzing various market variables (c), which are relatively easy and cheap to collect compared with large-scale physical stock and extraction assessments, we aim to provide policy-relevant information giving us clues about the sustainability of extraction levels. We link our findings to forest policies in Tanzania and suggest changes to simplify legal timber production, to invest in plantation programs and to encourage new organizational and sustainable financing mechanisms.

2. TIMBER TRADE IN THE EASTERN ARC MOUNTAINS OF TANZANIA

As a result of drivers such as population growth, development of infrastructure and competition over resources and agricultural land, forest and woodland cover in Tanzania is being lost at an increasingly rapid rate (Hosonuma *et al.*, 2012). The Eastern Arc Mountains (hereafter EAM) region of Tanzania (Figure 1) harbor some of the most biodiversity rich forests in the world (Burgess *et al.*, 2007), yet they are under severe pressure from conversion for agriculture and degradation due to extraction of firewood, poles, charcoal, and timber (Ahrends *et al.*, 2010; Hall, Burgess, Lovett, Mbilinyi, & Gereau, 2009). The EAM have lost around 70% of their natural forests (Burgess, Doggart, & Lovett, 2002; Green *et al.*, 2013), which poses a threat to many species (Burgess *et al.*, 2007; Hall *et al.*, 2009).

Tanzania has a well-developed forest policy framework and a long history of forest management. In colonial times, forests were considered a valuable resource and logging took place on industrial scales. Forest reserves were established primarily for the purpose of production. This practice continued in the EAM through the colonial and early post-colonial periods, with industrial logging in the EAM area of the East Usambaras, Ulugurus, and the Kilombero valley in the 1970s and early 1980s during and after the construction of the main railway line connecting Dar es Salaam with West-Tanzania (Hamilton & Bensted-Smith, 1989). Extraction shifted westward to Tabora and Rukwa in the early 1990s, but within a decade commercial stocks were largely depleted, and extraction moved on into the coastal forests (Wells & Wall, 2005).

In 1985, the Tanzanian government acknowledged the threat from logging to remaining forests and biodiversity, and implemented a ban on logging in the central government (catchment) Forest Reserves of the EAM and some other mountain areas. This was maintained in the 2002 Forest Act. Forest policies are currently being updated to incorporate concepts of biodiversity, catchment forests and nature reserves, and to recognize the potential of REDD and PES [1] financing of conservation. In total, 75% of the c. 4,000 km^2 forested area in the EAM has been gazetted, i.e., are formally protected (Platts *et al.*, 2011; UNEP-WCMC, 2009). In comparison, only 21% of the surrounding undisturbed woodlands are formally protected (Platts *et al.*, 2011), [2] which cover a larger area and are an importance source of ecosystem services (Green *et al.*, 2013).

Despite the clear policy and legal frameworks, with formal bans on logging in central government protection forest reserves and systems of timber licensing and royalties to regulate harvesting levels outside protection reserves, there is a clear lack of adequate policy enforcement. Estimates for the southern coastal regions in Tanzania suggest that less than 23% of the volume of actual trade is covered by official documents (Milledge, Gelvas, & Ahrends, 2007), although this percentage may be lower with only 4% of potential revenues being collected by the government (Milledge & Elibariki, 2005). Timber and charcoal demand from the city of Dar es Salaam has largely depleted coastal forests from Dar es Salaam to the Rufiji river (Ahrends *et al.*, 2010; Millegde & Kaale, 2005), with the impact spreading south into Rufiji and Kilwa districts in recent years (Sulle, 2013).

The decline in coastal forest resources combined with recent robust economic growth and urbanization (World Bank, 2013) has increased pressure on inland forests, including the EAM which still contain some highly valuable timber species. Indeed, timber harvesting is known to happen on a daily basis across the EAM in protected and unprotected areas alike (Burgess *et al.*, 2002; Makero & Malimbwi, 2012). Pitsawyers operating in small teams of two or more men (Wells & Wall, 2005) without official licenses account for most of the hardwood harvesting and input into the supply chain, mostly in the form of planks rather than logs (see Section 4). The developments raise questions about the sustainability of current harvesting rates in terms of forest ecology, welfare maximization, and distribution across stakeholders and in time.

To our knowledge, no peer-reviewed study exists in the academic literature that combines market and value chain analysis with consumption based volume estimates to assess the sustainability of timber extraction from natural forests. In the gray literature, Wall and Wells (2000) provide an overview of the various supply chain systems from West-Tanzania to Dar es Salaam. Shayo (2006) provides a more detailed supply chain analysis of the hardwood market in Dar es Salaam and supply areas in West-Tanzania, as well as some locations in between and along the main railway line, while Milledge *et al.* (2007) study the hardwood trade in the coastal zone of southern Tanzania. A peer-reviewed study by Wells and Wall (2005) has looked into the sawn timber market and the demand in Dar es Salaam and Mwanza. None of these studies focus on supply and consumption of hardwood from natural forests in the EAM or review the usefulness of a set of market signals related to extraction sustainability.

3. METHODS AND DATA COLLECTION

In many countries, research on hardwood extraction from natural habitats is complicated by the illegality of the sector. A major methodological challenge lies in data collection (Gavin, Solomon, & Blank, 2009). The absence of reliable

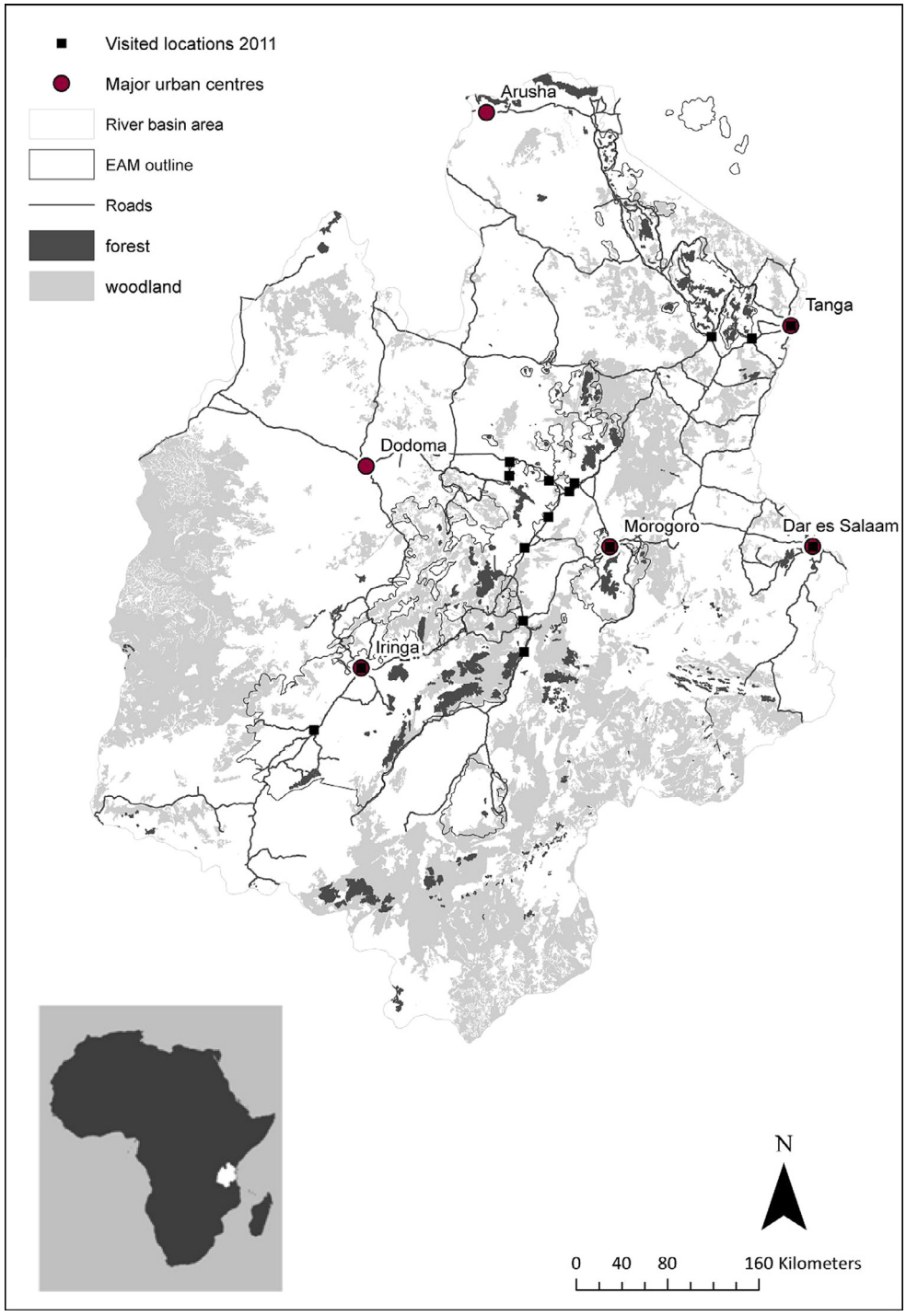

Figure 1. *Map of the study area. Note: The wider study area reflects the three river basins of which the rivers originate in the EAM and covers about 1/3 of Tanzania. The map indicates the sites that were visited during the fieldwork and the major urban demand centers.*

sector data and the difficulties of primary data collection mean that estimates of total volume are hard to generate. National statistics on the contribution of the forestry sector to GDP do not reflect the large illegal proportion (and often high values) of the timber trade. Reliable quantification of the volume of timber trade through interviews with dealers or entrepreneurs also tends to be problematic (Cerutti, Tacconi, Lescuyer, & Nasi, 2012; Shayo, 2006) due to strategic bias. Respondents may be reluctant to talk openly due to fears that they will criminalize themselves by providing information about illegal activities, and cooperation with projects aiming to reduce illegal harvesting reduces their income opportunities. To overcome these challenges, we used a combination of techniques that complement and triangulate one another, and, where we could, used information that either was publicly available or possible to obtain through interviews in a relatively reliable manner. As such, we conducted three lines of analysis to assess the volume and value of hardwood extraction and its sustainability in the natural woodlands and forests of the EAM.

First, we estimated the overall volume of hardwood extraction by modeling the domestic quantity of hardwood bought by Tanzanian households supplied by the EAM. Household data from the 2007 Household Budget Survey (NBS, 2009) and the 2010 Tanzania Demographic and Health Survey (NBS, 2011) were used to estimate the quantity of hardwood bought per household, combined with informed assumptions of the effects of wealth and location. Both surveys are conducted by the Tanzanian National Bureau of Statistics (NBS) using standardized questionnaires with time intervals of 2–4 years and are largely representative at the regional level. Data are collected during multiple appointments, including meetings at home, with the respondents. It was assessed that these surveys would provide more reliable data with a wider spatial coverage than we would be able to collect with a new survey within the time and budget available. Our assumptions were validated by forestry experts in Tanzania.[3] The timber markets supplied by the EAM were identified through estimates of the timber transport distances we obtained during interviews. GIS information was used to assess household timber consumption, transport costs, and the geographical extent of hardwood markets including a population map (Platts, 2012), and land cover and road maps (see Swetnam *et al*., 2011). This part of the assessment relied on relatively reliable sources of data. The estimated volume provides a lower bound estimate of total value of harvesting in the EAM as it excludes timber for commercial or public buildings, and for export. The latter category is expected to be small from the EAM region, although it is known that some timber is exported to Kenya and elsewhere via Zanzibar. Reliable volume estimates of exports are absent and the main export of wood products to Kenya and Zanzibar involves softwood planks from plantations, mangrove poles, firewood, charcoal, and wood for carving (EAWLS & TNRF, 2012; Sulle, 2013).

Second, to understand the distribution of timber-related values, we undertook a commodity chain analysis. Commodity chain analyses can be used to get a better understanding of the nature of payments that various actors, from product conception to the final consumer, in the commodity chain receive, and the distribution of revenues among the actors throughout the process (Ribot, 1998). The technique has been applied to non-timber forest products, e.g., charcoal in Senegal (Ribot, 1998) and Tanzania (van Beukering *et al*., 2013), agarwood in Laos (Jensen, 2009), and bushmeat in Ghana (Cowlishaw, Mendelson, & Rowcliffe, 2005).

For the timber commodity chain analysis, we needed information about the following key issues: what is the production process, which species are targeted, what volumes are extracted, where does extraction occur, who is involved in the various stages of the value chain from felling to consumption, where are products sold, how are benefits distributed, and why does illegal extraction persist. Direct questioning techniques were employed to gather information from stakeholders involved in the timber commodity chain. Aware of the strategic bias that may influence the results from such interviews, we also performed direct observation activities for triangulation purposes (Gavin *et al*., 2009). For each of the actors in the chain, the aim was to quantify the net benefits per plank, i.e., selling prices minus buying prices minus costs. Labor costs were not extracted—the net benefits are assumed to cover labor input and may include profits.

Third, for an assessment of the sustainability of timber extraction in the EAM, we collected a number of market indicators. These types of market data are relatively easy and cheap to collect and generally less sensitive to reporting bias. There are different ways in which signals from hardwood markets in Tanzania may reflect increasing supply shortages: prices are likely to increase, large dimension logs and hence planks become increasingly difficult to obtain, substitute use is expected to increase, product design may change, and harvesting may shift to new areas. In the absence of observed changes in infrastructure, rural unemployment and the legal status of the timber trade, in the context of this study these market indicators may provide early warning signals suggesting decreasing timber stocks.

An initial study was conducted in 2009, when over a period of two weeks, data on plank prices and sizes were collected for hardwood and softwood at different locations in the central and southern part of the study area (Bunduki, Dar es Salaam, Dumila, Ifakara, Iringa, Kilosa, Malila, Mikumi, and Morogoro). In July and August 2011, we (re)visited the main urban areas (Dar es Salaam, Iringa, Morogoro, and Tanga) where timber is supplied by the EAM, and a number of towns that act as trading places (Dumila, Gairo, Ilula, Kilosa, Korogwe, Mafinga, Maguha, Mikumi, Mkundi, Muheza, Mvumi, Ruaha, and Rubeho) that were selected based on expert information (see Figure 1). In the villages and towns visited in 2011, we interviewed 50 carpenters, four pitsawyers, 20 timber dealers, a chainsaw technician and two sawmill owners, using in-depth semi-structured surveys. At furniture markets, we also carried out direct observations. A further 11 interviews were conducted with forest officers, and four interviews were made with sector experts in their offices.

Time-limitations meant that most of the dealers and sawyers were identified through the assistance of district forest officers, but the officials were not present during the interviews. We also interviewed some dealers and sawyers without the help or intervention of officials, although this practice is complicated in Tanzania due to cultural and political rules that require meetings to be arranged in advance through local leaders. Convenience sampling was used to select carpenters, as these are in practice often clustered around the main roads of towns.

The main topics of the interviews included: species used, harvesting locations, transport routes, prices, timber volumes processed, timber requirements for furniture, forest management and enforcement, and changes in species availability and harvesting locations over time. Interviews would start with neutral, "safe" questions, and more sensitive issues were dealt with only if the respondent showed willingness to participate. The district and regional forest officers were interviewed for cross-validation and to give an overview of the timber commodity chain at the larger scale and the policy context.

Timber prices are species dependent. We used a recent timber classification for Tanzania, adapted from several datasets and reports (see Ahrends, 2011 for details). This classification defines five main categories of timber based on a conservative assessment of their commercial importance. Class I to Va contain commercially traded species that are used for furniture and household items, with class I containing the highest quality species. Subclasses Vb and Vc are other species which are mainly used locally. Price information of species was assessed against this timber classification.

4. ANALYSIS OF VOLUMES AND BENEFITS ACROSS DIFFERENT ACTORS IN TIMBER VALUE CHAIN

(a) *A short description of the timber trade in the Eastern Arc Mountains*

Based on interview information as well as the study by Wall and Wells (2000), we were able to characterize the organization

of the timber supply chain in the EAM of Tanzania. Hardwood extraction in the natural forests and woodlands of Tanzania is an informal industry with low capital investments, where most of the timber is pitsawn by hand. Local farmers get involved in pitsawing to earn additional money in-between agricultural seasons. They work either for themselves or for timber dealers and operate away from roads and habitation, where the risk of being caught is low. Pitsawyers spend a few weeks in the forest to select and fell high value trees, cutting the trees into logs and then planks using 2 m-long two-person handsaws. The planks are transported out of the forest to a collection point at the edge of the forest or in the nearest village by carriers on foot, by bicycle or motorcycle depending on the terrain, often between dusk and dawn to avoid police and forest officers. Most planks are transported from the collection points by vehicle onward to local markets and sold to carpenters. The most valuable timber is transported to larger urban areas where the purchasing power of the population is higher. Unlike softwood, which is openly displayed and relatively cheap, hardwood is mainly delivered on demand. Hardwood is publicly displayed or transported only after conversion into furniture, so that official forestry office hammer marks indicating legality can no longer be checked.

The production chain can be organized in different ways (Wall & Wells, 2000). Some chains are relatively short and involve local timber pitsawyers that also operate as dealers and sell directly to carpenters near the forests, and in other cases carpenters organize the harvesting. Longer routes exist for more expensive (higher class) timber, where larger dealers have (in)formal agreements with (groups of) pitsawyers. They deliver planks in response to bids from larger contractors and retailers. In some cases, there are intermediate dealers involved. Typically, the dealers in higher class timber have most power in the supply chain and dominate price setting.

Legal timber traders have to follow complicated systems, and obtain various licenses which vary in price, being higher for more valuable and commercial species (see National Audit Office, 2012). Within the EAM region, licenses are issued by the Tanzania Forest Service (TFS) or the district harvesting committee (of which the district forest officer is a member, REM/HTSPE, 2009) and the village may also be involved in case harvesting is to take place on village land. More specifically, outside reserves on village land, permission from the village representative is required, and this report has to be taken to the district forest office and a ward forest officer has to check if the sought trees are available. In production forest reserves managed by the local authority, only the district forest officer is officially involved. Once harvested, the district forest officer has to mark (hammer) the planks as proof of legality. In production forest reserves managed by the central government, licenses are issued by TFS. In conservation (protection) forest reserves managed by the local authority or TFS, no harvesting is legally allowed. In addition, dealers need transport licenses that should indicate volume, species, and harvesting location, and be registered as a tax paying company and Natural Resource trader. There are several road checkpoints at which the transit passes are checked. However, this complex licensing system is far from watertight and provides a series of opportunities for private rents, as well as corruption. Similar problems with complex licensing systems and corruption have been observed in other African timber sectors, e.g., in Cameroon (Cerutti *et al.*, 2012). Given the high number of illegal traders, the profit margins on legal trade are low or negative according to the interviewed dealers (see for coastal trade also Millegde & Kaale, 2005).

Interviewed experts estimated that up to 90% of timber logging in the EAM is illegal. Dealers, sawyers, and carpenters described various ways to circumvent regulations, sometimes by bribing village, district and TFS officials, and policemen. They described how they ensured that harvested planks were not confiscated, or how they "laundered" timber, for instance by getting a cheap license and harvest larger volumes than allowed and more valuable species, or by using the same license multiple times. Overall, the risk within the illegal timber trade is perceived to be low and it is relatively easy to trade illegal timber.

(b) *Volume of timber consumption by households and by timber class*

The hardwood extracted from the EAM is mainly turned into household furniture and construction items such as doors and window frames. The total annual benefits of hardwood extraction from the EAM that accrue to the final beneficiaries can therefore be approximated by assessing the annual timber consumption per household and the value of that timber, taking into account that the latter varies across species. To estimate the annual quantity of hardwood bought, we assumed that timber use is a function of location (urban/rural), income stratum, and furniture ownership per household. Household census data were available for furniture ownership (NBS, 2009) and were combined with assumptions about furniture items for which these statistics were unavailable. Statistics on income strata across regions were available from NBS (2011). Carpenters stated that most of their customers were middle- and high-income households, informing our modeling-rule that richer households with more purchasing power own more furniture and bigger houses. Carpenters produce household furniture, including tables, chairs, doors, window and doorframes, and beds, and provided information about the timber volume of these items. Per household estimates vary between 0.0367 and 0.0515 cubic meters (in plank volumes) per year for rural and Dar residents respectively, assuming a product lifetime of 25 years, comparable with published estimates in Wells and Wall (2005).

The value of timber depends on the class of timber and we therefore needed to split the total quantity of hardwood bought into volumes per hardwood class and softwood. We assumed that wealthier households generally prefer higher class timber species over softwood or lower class species, whereas poorer households can only afford softwood and lower class species. Carpenters' statements about their customer characteristics justified such a wealth-based stratification. This assumption is further supported by the study by Wells and Wall (2005) reporting that poorer urban households tend to substitute hardwood for cheaper softwood. Next, we assumed that softwood is only supplied to urban areas, because it is mostly supplied by industrial plantations and transported in large trucks to larger urban centers for economy of scale reasons. Rural households are assumed to use class III–V hardwood as their cheap option.[4]

Moreover, we observed a wider range of low-class timber species in markets in the northern part of the study area,[5] while productive plantations are located in the south.[6] Therefore, we built in the modeling-rule that softwood use is lower in the north among the lowest wealth quintiles of the population. Table 1 gives an overview of the resulting timber use assumptions per quintile.

Finally, to assess the population of beneficiaries of EAM hardwood and select the towns and cities supplied by EAM timber, we used interview information about buying and

Table 1. *Timber use assumptions per quintile of the population of Tanzania*

			Class I (%)	Class II (%)	Class III–V (%)	Softwood (%)
Quintile V (wealthiest)		Urban	40	40		20
		Rural	40	40	20	
Quintile IV		Urban		25	25	50
		Rural		25	75	
Quintile I-III (poorest)	North[a]	Urban			75	25
		Rural			100	
	South[a]	Urban			50	50
		Rural			100	

[a] North refers to the Northern part of the study area, which includes the mountain blocks on the transect from Tanga to Arusha (see Figure 1). South reflects the area of the remaining mountain blocks.

selling locations and transport routes. We found that median transport distances vary little between classes (between 63 and 69 km, based on 113–150 observations per class). Class I timber comes from a wider area with 25% of routes (not reflecting volume) longer than 120 km, compared with 100 km for lower class species. The shortest 25% of routes are up to ~25 km. The population density around the EAM is also highest within the first 25 km around the blocks (Platts, 2012). Both extraction rates and population density are higher closer to roads, with highest extraction rates within 5–10 km from roads according to interviewed experts and a study by Makero and Malimbwi (2012). Roads often follow the boundaries of the mountain blocks (see Figure 1) and link settlements at the foothills of the EAM. We therefore used an 8-km buffer around the EAM so that we would capture the communities that were likely to consume EAM hardwood. Based on this information, we assumed that:

- all timber bought by rural households in the EAM and its 8-km buffer is supplied by EAM production;
- the EAM provide 75% of timber quantity supplied to urban areas inside the EAM (the cities of Iringa and Morogoro); additional supply comes from lowland areas outside the EAM and forests in the south of Tanzania and in Mozambique;
- the EAM provide 25% of timber quantity supplied to larger settlements (>5000 inhabitants) between 8 and 25 km of the EAM boundary (rural and urban);
- the EAM provide 25% of timber quantity supplied to major cities (>100,000 inhabitants) within 100 km of the EAM;
- the EAM provide 10% of Dar's hardwood consumption (beyond 100 km from the EAM).

We then used these rules to select the relevant settlements using EAM hardwood. The volume of hardwood and softwood consumption was based on the households living in the wards where these settlements were located, using the population map (Platts, 2012) converted into a household map based on average household size data (NBS, 2002). The urban–rural/mixed ward classification of the population census (NBS, 2002) was used.

The overall timber requirement met by the EAM is estimated to be approximately 45,000 cubic meters (softwood and hardwood product volume) per year, equivalent to 2.2 million planks[7] (see Table 2). This includes 76% hardwood from EAM forests and woodlands and 24% softwood from plantations. The approach also allows for a breakdown of consumption across different consumer groups, where we identify rural and urban residents in settlements inside and outside the EAM and its 8-km buffer, and in Dar es Salaam. The results show that the largest proportion of benefits of timber class I are enjoyed by the rural population of the EAM (both in total and per household). This is because the rural EAM population is relatively wealthy compared with other rural areas in Tanzania and is therefore able to afford class I furniture items.

As a cross-check of the volume, we estimated the volumes extracted by carpenters and pitsawyers. Based on interviews with carpenters, pitsawyers and forest officers, the total number of pitsawyers in the EAM is estimated to be between 15,000 and 66,000, who harvest on average 150 planks per month (varying between 30 and 300) and operate around four months per year. Product (plank) volumes based on these estimates would range from 42,480 to 1,146,940 cubic meters per year. The estimated number of carpenters ranges from 23,000 to 165,000 who use around 110 planks a month (varying between 25 and 408) and also operate four months per year. These figures would lead to an estimated volume of 54,280–6,355,008 cubic meters. The estimated household consumption volume falls at the low end of these estimates (see Table 2). We do not include commercial timber use in our analysis, and our figures may therefore represent a conservative estimate of the total extraction.

(c) *Value analysis*

To support the economic valuation of timber flows we developed a price model of timber planks based on data from interviews with carpenters, dealers, and sawyers as well as direct

Table 2. *Total annual consumption (in cubic meters) of hardwood and softwood product volumes from the EAM blocks*

	No. of households	Hardwood				Softwood (cubic meters)	Total (cubic meters)
		Class I (cubic meters)	Class II (cubic meters)	Class III–V (cubic meters)	Total (cubic meters)		
Rural households in EAM + 8 km	810,347	3,226	5,115	19,742	28,083	0	28,083
Rural households > 8 km from EAM	106,144	92	152	860	1,104	0	1104
Urban households in EAM + 8 km	59,960	37	129	997	1,163	1,265	2,428
Urban households > 8 km from EAM	157,327	33	92	1,064	1,189	2,549	3,738
Households in Dar es Salaam	621,108	1,194	1,245	66	2,505	7,092	9,597
Total	1,754,886	4,852	6,733	22,729	34,044	10,906	44,950

market observations. The results indicate that market prices (expressed as the price equivalent of a plank size of $1'' \times 10'' \times 12$ feet) for planks vary between classes and across space, with higher values in urban areas, and a price premium in the capital of Dar es Salaam (see Table 3). Prices increase with decreasing distance to urban areas reflecting costs of carrying planks out of the forest, fuel costs for transport to urban areas, and various bribes that have to be paid along the way. This also reflects that prices tend to be lower in remoter places and near forest edges. Furthermore, planks of class I species are sold at significantly higher prices than lower class species, but there is no significant difference between the latter groups (class II–V). Hardwood is sold at higher prices than softwood.

Figure 2 presents the mapped prices per plank for class I timber, based on the model results in Table 3. Distances were calculated in a GIS and based on the Euclidean distance to the nearest road plus the road distance to the city of interest. Major towns included Arusha, Dodoma, Iringa, and Morogoro.

We multiply the mapped consumption volume estimates (summarized in Table 2) with the plank price map estimates (Figure 2) to estimate the value of the sold planks. The results show that the rural population in the EAM and its 8-km buffer are estimated to spend over USD 7 million annually on hardwood harvested in the EAM (see Table 4, 1 USD = 1500 TSh). This is equivalent to ~8.80 USD/hh/yr. The next major group of beneficiaries is the population of Dar es Salaam who consume the equivalent of USD 1.7 million in hardwood annually. Other urban areas (Arusha, Dodoma, Tanga, Morogoro, and Iringa) spend USD 0.8 million annually on hardwood, while rural households beyond the EAM spend an estimated USD 0.3 million on EAM hardwood. The total value of hardwood from the EAM is estimated at USD 10 million annually. Softwood use by these households represents another USD 4 million per year.

Although class I hardwood reflects only 14% of the total volume of EAM hardwood trade, the value of class I at the market is approximately USD 2.4 million, i.e., a quarter of the total hardwood value. The value of class II timber is slightly lower (USD 2.0 million) despite the higher volume (see Table 2). Lower class timber species generate an estimated USD 5.6 million.

The values in Table 4 represent the market prices of planks. However, most households buy hardwood in processed form, as furniture. Figure 2 shows that prices of planks differ greatly between the forests where they are harvested and the cities further away, where furniture is made and bought. The next section addresses the timber commodity chain and explores the distribution of timber benefits among the different actors involved in harvesting, processing, and selling timber.

(d) *Commodity chain analysis and benefits distribution*

The timber supply chain involves different agents at various locations who all share in the benefits of timber products but to different degrees. The relevant primary actors include pitsawyers, carriers, timber dealers, officers (village, police, district, and TFS), sawmillers, carpenters, and finally furniture consumers. Our data suggest that some payments vary little between timber classes, such as payments to carriers, pitsawyers, and loading (see Table 5). Other payments, however, such as road transport, bribes and margins of middlemen, vary among timber classes. The net benefits in this section reflect profits plus the agents' own labor costs.

Pitsawyers stated that they receive a fixed price per plank of USD 1.67 (median, $n = 19$) for their labor input, varying between USD 0.44 and USD 5.33, which is comparable to previous reports (e.g., Shayo, 2006). In addition, dealers will often provide food for the days spent working in the forest, especially when payments are not upfront. Based on an annual production of 1.44 million hardwood planks (i.e., an annual production of 34,044 cubic meters, and a plank size of $1'' \times 10'' \times 12$ft or 0.0236 cubic meters), the total financial revenues of pitsawyers for hardwood production are estimated around USD 2.4 million per year.

Local villagers are involved in transporting planks out of the forest to the nearest collection point and loading the planks onto the dealer's truck. Around 66,000 people[8] are estimated to be involved in carrying the planks. They earn on average USD 0.67 (median, $n = 16$) per plank, and an additional USD 0.04 per plank for off and uploading (median, $n = 6$). This generates another USD 1.0 million in cash income to these villagers (USD 16 per carrier per year).

Further costs incurred by dealers include equipment, transport, some official licensing, and other transaction costs. Equipment costs are minimal given the simple equipment used. Median transport costs per plank are USD 0.0074/km ($n = 27$) and median distances are 65 km for hardwood to reach the final market (USD 0.7 million). Hence, the overall costs are about USD 4.1 million, excluding bribes, licensing, and other transaction costs.

Dealers stated that some payments have to be made to village officials to be granted access to forests to obtain permits and/or

Table 3. *Price model*

Dependent variable: ln (price per plank, in TSh)	Coef. (*t*-value)
Class I (dummy variable: class I species = 1; otherwise = 0	0.771***
	(12.66)
Class II–V (dummy variable: class II–V species = 1; otherwise = 0)	0.261***
	(4.72)
Dar es Salaam (dummy variable: record from Dar es Salaam = 1; otherwise = 0)	0.298***
	(5.36)
Distance to nearest major city (>100,000 inhabitants) (natural log)	−0.104***
	(−11.87)
Constant	9.244***
	(171.85)
Number of observations	599
R^2	41%
Root MSE	45%

Note: results are based on a linear regression model, estimated in Stata-10 software. Standard errors were estimated using the Huber–White sandwich estimators. Prices were log-normally transformed to ensure normally distributed model errors. Prices reflect market prices for a plank of size $1'' \times 10'' \times 12$ feet.
*** Significance of the parameters is marked with asterisks, which refers to 1%.

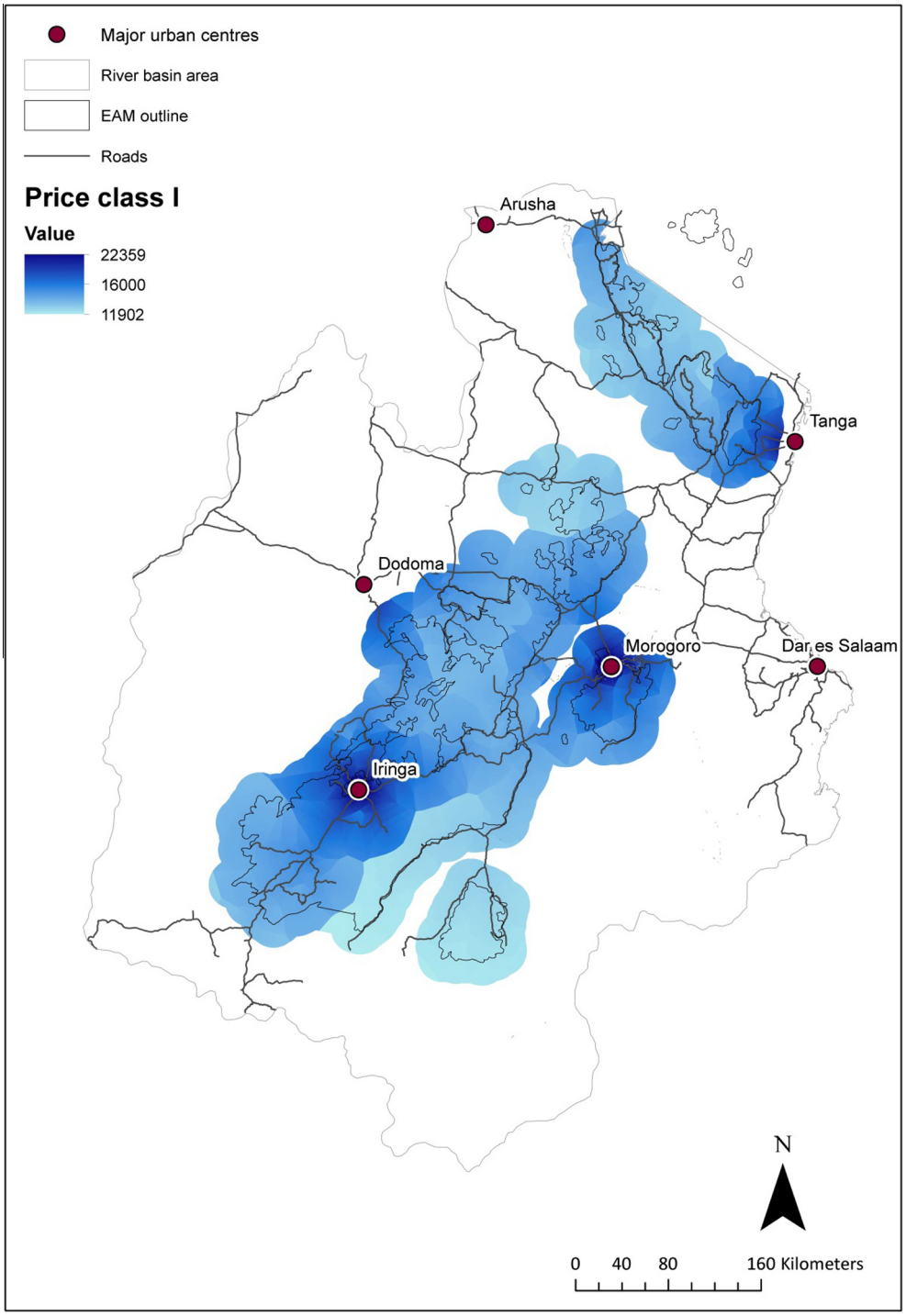

Figure 2. *Map of price per plank of class I timber in and around the EAM (in TSH 2011). Note: Prices reflect market prices in Tanzanian Shillings for a plank of size 1″ × 10″ × 12 feet. Prices are mapped for the area around the EAM plus a 20-km buffer. Urban settlements beyond 20 km from the EAM boundary mainly included major cities for which a distance effect was included to estimate prices (see Table 3), and for the remaining urban wards within the 20–25 km range, the price of the nearest settlement in the 20-km buffer was used.*

access, both for harvesting in village forests and forests managed by the district or regional forest office. These payments are around USD 0.33 per plank and are negotiable (median, $n = 4$). One dealer operating without licenses admitted to paying another USD 0.53 per plank to forest officers in order to harvest and sell timber. Experts stated that bribes of around USD 33–50 paid to forest officers, depending on the number of planks, are usually sufficient. This leads to an estimated total of USD 0.5 million that is paid into local village representatives, and USD 0.8 million to forest officers for timber harvesting.

Even with the right paperwork, transporters and dealers reported that payments to police and forest officers were still necessary to continue transport and avoid confiscation. These payments have to be made at forest transit and police checkpoints; estimates suggest that these amount to USD 0.20 and USD 0.03 per plank, respectively. However, given their

Table 4. *Value of timber sales based on plank prices (USD)*

	No. of households	Hardwood value (USD * 1000/yr)	Total timber (including softwood) (USD * 1000/yr)	Hardwood value (USD)/hh/yr
Rural households in EAM + 8 km	810,347	7,134	7,134	8.80
Rural households > 8 km from EAM	106,144	332	332	3.12
Urban households in EAM + 8 km	59,960	357	660	5.95
Urban households > 8 km from EAM	157,327	465	1,203	2.96
Households in Dar es Salaam	621,108	1,687	4,478	2.71
Total	1,754,886	9,975	13,808	5.68

Note: exchange rate 1 USD = 1500 TSh.

Table 5. *Distribution of revenues in the timber commodity chain*

	USD/plank	Total (USD million)
Pitsawyers	1.67	2.40
Carriers	0.71	1.03
Transport	0.48	0.69
Village payment	0.33	0.48
Forest officials payment	0.53	0.76
Total dealer costs excluding payments to forest officials	*3.20*	*4.61*
(Total dealer costs including payments to forest officials)	*(3.73)*	*(5.37)*
Dealer profits excluding payments to forest officials	3.72	5.37
(Dealer profits including payments to forest officials)	(3.19)	(4.60)
Dealer revenues/carpenter timber costs	6.91	9.98
Carpenter labor and profit	3.46	4.99
Domestic expenses on furniture	13.83	19.95

illegal nature, the total sum of bribes is hard to estimate and probably depends on the number of encounters with officials between the point of harvesting and sales. A rough estimate is that the total bribes to forest and police officers are about 10% of the value (i.e., 10% of USD 6.91 per plank).

Analysis of carpenter information on timber prices, furniture volume, and selling prices reveals that their average profit margin (including labor costs) is 25% of the final price of furniture items ($n = 142$), equivalent to ~USD 3.46 per plank. Timber inputs constitute on average about 50% of the overall furniture prices ($n = 163$), and are higher for furniture made with class 1 species (58%) than lower class species. Other costs (25% of furniture price) include transport, inputs such as nails and varnish, and rent of sawing and smoothing machines. Hence, at a total annual hardwood plank consumption of USD 10 million (see Table 4), representing the costs of carpenters' timber inputs, and USD 5 million in terms of other costs, carpenters generate a net profit of around USD 5 million, and the final consumer pays USD 20 million in terms of furniture items.

This means that dealers, who receive around USD 10 million from selling planks to carpenters, have a profit margin of about USD 4.6 million (USD 3.19 per plank), that they can either cash in or spend on getting official licenses or bribes. This significant private rent is expected to raise harvesting rates beyond sustainable levels. It is also much higher than the annual per capita revenues obtained by other actors, especially since the number of dealers in the value chain is much lower than the number of sawyers and carpenters.

Despite these low labor costs in timber prices, dealers argued that it is hard, if not impossible, to generate profit from legal timber dealing. Harvesting license fees per cubic meter (measure over bark) for class I were USD 107/cubic meters in 2007–08 (Ngaga, 2011). The log size (diameter, length) and efficiency of converting logs into planks determine the costs per plank, but efficiency estimates vary widely. At 12 planks/cubic meters (RDFAPTF, 2002), the license costs would be USD 8.92 per plank, yet at 30 planks/cubic meters (highest estimate from our interviews) the costs would be USD 3.57. The lower license cost per plank estimate for very efficient conversion is only just below the profit per plank of USD 3.72 (see Table 5). Because additional licenses have to be obtained for transporting timber and general timber trading, legal trade is not profitable according to our calculations. This was expressed during interviews too: all dealers and experts commented that it was hard if not impossible for dealers to make a profit when all required licenses were obtained.

5. MARKET SIGNALS OF POTENTIAL (UN)SUSTAINABILITY

The economic analysis of the timber production chain and the market data in particular reveal some important information about the potential of sustained supply of hardwood from the EAM.

(a) *Price changes*

Price increases can result from an increase in the amount demanded or a decrease in the amount supplied to markets. Compared to the results of the initial market study in 2009, real prices for class I in Dar es Salaam in August 2011 increased by 13% (based on a consumer price index increase of 19.7 points, NBS, 2012) (see Table 6). This may reflect decreased availability of especially class I species in natural forests and woodlands. In Morogoro and Kilosa, two other major timber trade locations that were surveyed in 2009 and 2011, prices also increased. However, in Iringa, which is closer to other supply areas, such as larger areas of woodland and the southern highlands of Tanzania, there was no increase in real prices. Demand for hardwood has been found to be relatively inelastic (UNEP, 2002), meaning that a percentage increase in prices will only lead to a smaller percentage decrease in timber consumption.

However, the observed price increases may in theory also (partly) reflect that the demanded volume has increased with population and economic growth.

(b) *Size of plank changes*

During 2009–11, plank sizes of class I species decreased and are now smaller than for less valuable timber species. The decreasing size of planks provides a plausible indicator for ecologically unsustainable harvesting levels given the explanation provided by respondents. Respondents reported that sawyers are making smaller (narrower) planks ($1'' \times 10'' \times 12$ feet instead of $1'' \times 12'' \times 12$ feet), so that they can get more planks from a single tree and harvest immature trees. According to the interviewed sawyers and merchants, most large class I trees have been harvested in the easily accessible EAM forests and woodlands, and only immature, smaller trees are left. Larger class I trees may only be available in remoter areas as well as better protected forests. This downward trend in the size of harvested trees has been observed elsewhere, e.g., in coastal forests in Tanzania (Ahrends, 2005).

(c) *Perceived availability of species*

Carpenters, sawyers, and dealers were asked if the most frequently used species were still available in the EAM forests and woodlands. Respondents indicated how difficult it was to get these species, which is expected to reflect the physical availability of the timber, although it may relate to the level of enforcement. The 325 species-specific statements were used to build an availability score for the different classes between 0 and 1, using 0.75 for statement "available but very difficult to get", 0.5 for "available but difficult to get" and 0.25 for "available but a bit/sometimes difficult to get". The results suggest that class I species are more often unavailable or hard to obtain, and this holds to a lesser extent also for class II, whereas class V species are generally available across the study area (see Table 7).[9] In class I, the forest species mkangazi (*Khaya anthotheca*) and mvule (*Milicia excelsa*), and the forest/woodland species mninga (*Pterocarpus angolensis*) and mpangapanga (*Millettia stuhlmannii*) are particularly difficult to obtain. In class II, the forest species mkulo (*Ocotea usambarensis*) and podo (*Podocarpus usambarensis*), and the woodland species mkola (*Spirostachys africana*) and msani (*Brachystegia microphylla*) are increasingly scarce, with forest species mkongo (*Afzelia quanzensis*) also becoming more difficult to obtain. Similarly, the further away from forested areas, the lower the market availability is and the harder it is to obtain valuable timber.

(d) *Changes in products*

Observations in furniture shops showed that the decreasing availability and increasing price of class I timber is resulting in a switch to the use of class II and V species for furniture production. Carpenters in Dar es Salaam reported an increasing use of softwood and class II hardwood species to bring down their costs and the prices of the final products. They also reported that using softwood and class III–V species as cheaper substitutes for class I and II species reduces the quality, prices, and profit margin. Carpenters argued that customers prefer better-known class I and II species and are unfamiliar with class III-V species, which they are not willing to pay as much for.

In the northern part of the study area, a noticeably wider range of hardwood species was used compared to the southern area. Hardwood supply has decreased as the substitution of class I by class II has put pressure on the availability of class II species (e.g., in the Tanga Region). As a consequence of the decreasing availability of class I and class II, a wider variety of species is being used, including class V fruit trees (coconut, jackfruit, and mango). A survey by the Korogwe Forest Office (pers. comm.) found 29 species in use that were not used in the past. In the north, the supply of softwood from nearby plantations is lower, because there are fewer and smaller plantations than in the south and some have been abandoned after management problems. Also, aluminum door and window frames are becoming more popular among richer households, as reported by one carpenter in Tanga.

Table 6. *Class I plank prices changes during 2009–11*

Location	2009	2011	% Difference
Dar es Salaam	29,220	33,162	13
Iringa	31,133	28,928	−7
Morogoro	24,216	26,880	11
Kilosa	11,968	12,401	4

Note: Prices per plank of class I timber, in TSH 2011 prices, converted to same plank size and corrected for inflation rates (19.7% over 2009–2011, NBS, 2012).

Table 7. *Availability score per timber class*

Class	Availability score (0–1)	No. obs.
Class I	0.46	83
Class II	0.75	126
Class V	0.94	60

(e) *Changes in source*

Alternative supplies of hardwood can come from outside the EAM and from imports. Within the EAM, little evidence indicated a shift in harvesting areas despite the decreasing availability. However, five dealers and carpenters reported that they could no longer get timber from the places they used in the past, and harvesting had relocated from Korogwe and Muheza (inside the EAM) to Handeni (outside the EAM).

The demand for timber by Dar es Salaam is increasingly being met by hardwood from coastal forests and miombo woodlands in the south of Tanzania, and from northern Mozambique. This has been driven by improvements in the roads and the construction of bridges over the Rufiji and Ruvuma rivers (Milledge & Elibariki, 2005; Sulle, 2013). Timber dealers in Dar es Salaam argued that there are fewer harvesting regulations and controls in Mozambique and border controls are minimal. The higher imports from Mozambique have increased the supply and competition in the timber market, but prices have not gone down. In addition to imports from Mozambique, imports from Malawi, Zimbabwe, and the Democratic Republic of Congo (DRC) were mentioned by respondents. Although the reliability of these statements is not known, a report by REM/HTSPE (2009) also found evidence of imports from Malawi and DRC.

Carpenters and dealers in Dar argued that the quality of the imported timber is higher, because the trees are bigger and more mature, allowing for longer and wider planks. This is another signal that the stock of mature trees in the EAM, as well as in coastal forests and miombo woodlands of eastern and southern Tanzania, is declining.

6. DISCUSSION AND POLICY RECOMMENDATIONS

In our analysis we have used market-based data to illuminate the largely illegal timber trade from the EAM and highlight some potential signals of unsustainability. Consumption-based assessments of the volume of hardwood extracted from the EAM to supply rural and urban households also show that the forests and woodlands provide a sizable source of financial revenues. The estimated value is about USD 10 million annually, based on the price that the buyers pay for planks, onto which carpenters add another USD 10 million by processing these into household furniture, doors and window frames for the domestic market. These figures provide a lower bound estimate of total value of timber harvesting in the EAM as it excludes wood going into commercial or public buildings, and for export.

Our results indicate, however, that this flow of revenues may not be sustained in the long run. Market data show that prices have gone up and plank sizes have gone down, as the largest trees in the most accessible forests have been harvested. In addition, the use of lower class species has increased, for instance from wild species to fruit trees, from class I to class II, or from class II to class III–V species. This substitution effect is most obvious in the northern part of the study area, where forests and timber stocks are scarcer after intensive historical logging (Willcock *et al*., 2012).

Data deficiencies on reported harvesting locations and amounts mean that we cannot compare the harvested volumes to sustainable harvesting levels. However, our availability indicators suggest that class I species are increasingly hard to find and the market signals related to prices and sizes point in the same direction. Recently, a detailed and multi-million dollar national forest stock assessment has been completed in Tanzania. The final report, as yet unpublished, from this NAFORMA (the National Forest Resource Monitoring and Assessment, MNRT, in press) assessment, led by FAO and the Government of Tanzania, provides clear indications of unsustainable use of forest and woodland timber resources. Results show that the current growing stock of the commercially most valuable timber classes is very low and the standing volume among valuable timber classes is mostly represented by many small diameter trees and a few very large diameter trees. This means that the diameter distribution curve deviates from that of a healthy stock, i.e., the reverse j-shape curve (Hitimana, Legilisho Kiyiapi, & Thairu Njunge, 2004; Vanclay, 1994). The overall NAFORMA inventory data and analysis seem to also support our market-based assessments of unsustainable harvesting levels and thus suggest that the market signals are likely to reflect real changes in timber stock. More research in different contexts will be necessary to learn about the use of market signals for forest policy in other contexts. However, the often prohibitively high costs of conducting forest inventories that yield statistically reliable data at species level merits testing cheaper proxy alternatives such as monitoring prices, species composition, and plank sizes in timber markets, all of which may be recorded without strategic bias. Qualitative information about timber sources and extraction activities may be used for triangulation, although this would be more prone to strategic bias.

Consumer preferences for class I species pose a threat to standing timber in protected areas. For these species, harvesting is expected to continue deeper into forests and woodlands, whether they are formally protected or not, because the market price difference between class I and lower quality hardwood species is sufficient to support higher transport costs within the area of the EAM. Forest officers stated that the higher class I profitability overrides the risk of being arrested for illegal cutting in protected areas, and class I timber has become very scarce in un-protected "general" lands.

Our analysis also shows an unequal distribution of revenues earned by actors in the timber commodity chain. Local revenues include the USD 5.1 million received by pitsawyers, and the USD 2.2 million by carriers. Given the relatively wealthy rural population within the EAM (in comparison with other rural areas in Tanzania), rural consumption of hardwood provides revenues to local carpenters. Local elites may also benefit from village-level bribes (Lund & Saito-Jensen, 2013). However, dealers, often from outside the forest-adjacent villages, receive larger earnings of around USD 4.6–5.4 million, part of which may be paid out in bribes to officials. Dealers' gross earnings per capita are likely to be high given their small number in comparison to pitsawyers, carriers, carpenters, etc. Since dealers and traders have the power to set prices for carpenters and pitsawyers, the higher market prices of class I species are usually not translated into higher prices per plank for pitsawyers. The high percentage of unemployment in rural areas and associated low wages imply that pitsawyers cannot demand higher payments. Unfortunately, it remained impossible in this study to provide a reliable estimate of the number of actors in each stakeholder group due to the illegal nature of the trade. Further research would be necessary to provide more insight into the benefits per capita and the implied wages per actor.

The scale and illegal nature of hardwood harvesting negatively impact on social, economic, and ecological systems. The current level of forest rule enforcement fails to regulate harvesting rates as officially intended, which implies that many of the forest benefits do not go to forest owners and forest-adjacent communities. The on-going and most likely unsustainable harvesting of an increasingly wide range of species for timber might also negatively affect the availability of other forest products, including charcoal, poles, firewood, thatch, mushrooms, medicines, and bushmeat (Ndoye & Tieguhong, 2004; Guariguata *et al*., 2010). Charcoal, pole, and firewood harvesting accounts for around 12–15% of the income of rural communities in the EAM, and the poorest households rely most on these forest resources (Schaafsma *et al*., 2014). Ongoing illegal harvesting may therefore reduce the potential of forests to contribute to poverty alleviation and income equalization (Fisher *et al*., 2014). In terms of ecosystem services, unsustainable timber harvesting has further negative impacts on the carbon sequestration and storage capacity of the forests (Willcock *et al*., 2012), as well as wild species diversity and water-regulation.

(a) *Policy recommendations*

The on-going deforestation in Tanzania is a major threat to its unique biodiversity, as well as the livelihoods of millions of people living in adjacent communities, and further away. It has been claimed that if current rates of deforestation were extrapolated, some coastal Forest Reserves may lose all forest by 2014–2035, while reserves in the EAM will have lost some of their biodiversity value (TFCG, 2012). To address this urgent policy issue, timely information on both ecological and socio-economic aspects of deforestation and forest degradation is needed.

Continued population and economic growth, and further urbanization, will in all likelihood increase the demand for hardwood timber. Better regulation and enforcement may partly help to address unsustainable harvesting. But the EAM forests and woodlands cover a vast area and the budgets at operational levels of forest departments for monitoring and control are small. At the time of study, 95% of the funds collected through licenses and fines at the district level went to the

national level, and only 5% stayed in the district (REM/HTSPE, 2009). Forest offices at district level and below were structurally under-funded and unable to afford regular patrolling. As a result, public (government) revenues remained only a fraction of the potential harvesting revenues under full enforcement of the Forest Act. Stricter enforcement therefore seems to require a change in the financial structure of the governing agencies at national and district levels. Moreover, since illegal or semi-legal logging is part of a wider economic system in Tanzania, with multiple beneficiaries at various scales, addressing illegal activities requires far-reaching changes in the institutional frameworks which regulate access to forest and timber resources as well as associated revenue flows (Colchester *et al.*, 2006). The complications and costs involved in the legal timber trade probably need to be addressed to lower barriers toward legal trade and reduce the incentives for corruption and collusion. The TFS, which started operating in mid-2011, is supposed to address these issues and ensure that government forest revenues are used for enforcement, but it has so far mainly focused on checkpoints and it is still too early to evaluate the further impacts of the policy changes.

Reducing current logging rates through stricter enforcement should be combined with alternative timber or material supply. Larger-scale government plantations are fulfilling an important role in timber supply, but a recent report by Indufor (2011) warns that this supply is expected to collapse due to severe overharvesting and lack of replanting. This warrants urgent investments in restocking. The number of private plantations is rising, but their contribution to softwood supply is still small and the long pay-back period currently discourages investment. Low market prices caused by the sizable supply of illegal timber and relatively low purchasing power drive market prices down and make both plantations and legal trade unprofitable. As a comparison, an almost identical situation applies in Ghana, West-Africa. Here, the commercially most valuable timber species are overharvested, because official logging quotas are acquired almost exclusively by export-oriented timber companies (often through bribing). The domestic market is, therefore, supplied by illegal chainsaw lumber at prices far below the world market level (Hansen, Lund, & Treue, 2009; Hansen & Treue, 2008). Policies to boost timber supply from private plantations outside forest reserves in Tanzania, in order to reduce pressure on natural forests, should therefore provide much stronger incentives. Advice for plantation managers on sustainable harvesting management is also likely to be necessary to close the future timber and fuelwood deficits.

Furthermore, revenue sharing mechanisms, through PES like REDD+ or in the form of payments for water services paid by downstream communities, will be necessary to ensure that the losses local EAM communities may initially face under stricter enforcement of timber conservation rules do not increase poverty levels. Such policies have the potential for local communities to derive benefits from sustainable forest management. However, a risk of an influx of rents through REDD is that it may attract further collusion between private business, political and public institution interests (Bofin, du Preez, Standing, & Williams, 2011) and local benefit sharing may not be realized. To address the organizational and financial challenges of managing forests across the EAM's large geographical scale and in remote areas, further forest decentralization under Joint and Community Based Forest Management arrangements (JFM and CBFM) [10] seem needed as well. Since current JFM projects have not stopped illegal harvesting (FBD, 2007), additional revenues to local forest managers could be made available by allowing for sustainable timber harvesting, shifting part of the profits within the timber value chain to local levels. This involves an officially accepted trade-off with forest integrity, but may be a more practical and preferable alternative to the current regime and its enforcement problems. Furthermore, the success of decentralization will depend on (i) support from the central and district governments to village governments should this be needed to enforce their exclusive forest rights under JFM and CBFM arrangements, (ii) fair and uncomplicated marketing conditions for timber (and other forest products) that village governments want to sell, (iii) fair mechanisms of forest revenue sharing between village and higher levels of government and (iv) good local governance that controls elite capture (Ribot, Lund, & Treue, 2010; Strassburg & Vira, 2012). In the cases of benefit sharing and decentralization, monitoring of forest condition by some central and credible organization would be necessary.

Given the progressive rate of timber extraction and forest loss and degradation, national-level policy makers need to devise more sustainable forest policy approaches to hardwood extraction. This paper presents a rapid, consumption-based assessment of hardwood extraction in the EAM in Tanzania. The market signals evaluated may serve as an early warning system of stock decline or over-harvesting, with certain and possibly negative impacts on a range of other ecosystem services and biodiversity. Monitoring market signals may hence provide a significantly cheaper alternative to monitoring vast and remote areas of natural forests and woodlands. Decision-makers could use such evidence and either take action based on precautionary principles or, if budgets permit so, commission repeated wide-scale forest inventories to collect statistically robust biophysical evidence of changing stock situations. Future work into the spatial distribution of extraction rates may help to direct sustainable forest management efforts to those areas where timber extraction has the most negative impacts on biodiversity, societal welfare, and equity. Above all, however, the bureaucratic and complicated procedures for legal timber harvesting and marketing, combined with substantial revenues associated with the current illegal logging, call for new approaches to timber resource governance.

NOTES

1. REDD: The UN-REDD Program is the United Nations collaborative initiative on Reducing Emissions from Deforestation and Forest Degradation in developing countries; PES: Payments for Ecosystem/Environmental Services.

2. Undisturbed woodland is defined as all woodland that is not scattered with crops.

3. We compared our estimates of demand volume with estimates of the overall extraction, based on expert informed estimates of the number of pitsawyers, and survey information on the annual extracted volume per pitsawyer, but we put more trust in the demand-based volume estimates.

4. We merged classes III–V because during the interviews, carpenters and dealers did not distinguish between these classes, and no price differences were observed.

5. The northern part is defined as the mountain blocks between the cities of Arusha and Tanga (see Figure 1).

6. Softwood is sold by dealers in all towns and cities, as it provides a cheap and accessible alternative for hardwood. License costs are much lower and softwood is mostly legal, displayed openly in timber shops. Most softwood (eucalyptus, cypress, and pine) is coming from Iringa and Mafinga, where the large privately managed plantations of Sao Hill and Mgololo are located.

7. In 2011, the standard plank size was 1″ × 10″ × 12 feet, equivalent to 0.0236 cubic meters.

8. Based on 2% of the population in an 8-km buffer around the EAM and 10-km buffer around forests.

9. Class III and IV were excluded because of the low number of species and observations.

10. Community Based Forest Management (CBFM) is when village governments protect unreserved forest through the establishment of Village Land Forest Reserves (VLFR), which are owned and managed by village governments and Joint Forest Management (JFM), where local village governments and central or district government forest offices co-manage National or Local Government Forest Reserves. Both forms for forest decentralisation are established under the 2002 Forest Act (see Blomley and Ramadhani (2006) for more details).

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