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Highlights

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The importance of local forest benefits: Economic valuation of Non-Timber Forest Products in the Eastern Arc Mountains in Tanzania

M. Schaafsma *, S. Morse-Jones, P. Posen, R.D. Swetnam, A. Balmford, I.J. Bateman, N.D. Burgess, S.A.O. Chamshama, B. Fisher, T. Freeman, V. Geofrey, R.E. Green, A.S. Hepelwa, A. Hernández-Sirvent, S. Hess, G.C. Kajembe, G. Kayharara, M. Kilonzo, K. Kulindwa, J.F. Lund, S.S. Madoffe, L. Mbwambo, H. Meilby, Y.M. Ngaga, I. Theilade, T. Treue, P. van Beukering, V.G. Vyamana, R.K. Turner

Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich NR4 7TJ, UK

- We value four Non-Timber Forest Products from the Eastern Arc Mountains in Tanzania.
- We transfer spatially explicit models of NTFP collection across a wide area.
- The total annual benefit flow is approximately USD 42 million.
- Households in the lowest income quartiles in the area depend most on these products.
- Conservation initiatives need to be coordinated with poverty and energy policies.

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The importance of local forest benefits: Economic valuation of Non-Timber Forest Products in the Eastern Arc Mountains in Tanzania

Q1 M. Schaafsma[a,*], S. Morse-Jones[a], P. Posen[a], R.D. Swetnam[b], A. Balmford[b], I.J. Bateman[a], N.D. Burgess[b,c,d], S.A.O. Chamshama[e], B. Fisher[a,f], T. Freeman[g], V. Geofrey[h], R.E. Green[b,i], A.S. Hepelwa[j], A. Hernández-Sirvent[k], S. Hess[l], G.C. Kajembe[e], G. Kayharara[h], M. Kilonzo[e], K. Kulindwa[i,m], J.F. Lund[n], S.S. Madoffe[e], L. Mbwambo[o], H. Meilby[n], Y.M. Ngaga[e], I. Theilade[n], T. Treue[n], P. van Beukering[p], V.G. Vyamana[e], R.K. Turner[a]

[a] Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich NR4 7TJ, UK
[b] Conservation Science Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK
[c] Conservation Science Program, World Wildlife Fund, P.O. Box 97180, Washington, DC, USA
[d] Centre for Macroecology, Evolution and Climate, Department of Biology, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen, Denmark
[e] Sokoine University of Agriculture (SUA), P.O. Box 3000, Morogoro, Tanzania
[f] Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, NJ 08544-1013, USA
[g] School of Applied Sciences, Cranfield University, Cranfield MK43 0AL, UK
[h] Centre for Environmental Economics and Development Research (CEDR), Dar-es-Salaam, Tanzania
[i] Conservation Science Department, RSPB, The Lodge, Sandy, Bedfordshire SG19 2DL, UK
[j] Department of Economics, University of Dar es Salaam, P.O. Box 35096, Dar es Salaam, Tanzania
[k] School of Geography and the Environment, University of Oxford, Oxford OX1 3QY, UK
[l] Hess Environmental Economic Analyst, Elzenlaan 17, 1214 KJ Hilversum, The Netherlands
[m] Department of International Environment and Development Studies, Norwegian University of Life Sciences (UMB), P.O. Box 5003, NO-1432 Aas, Norway
[n] Forest & Landscape, University of Copenhagen, DK-1958 Copenhagen, Denmark
[o] Tanzania Forest Research Institute (TAFORI), P.O. Box 1854, Morogoro, Tanzania
[p] Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands

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ABSTRACT

Understanding the spatial distribution of the quantity and economic value of Non-Timber Forest Product (NTFP) collection gives insight into the benefits that local communities obtain from forests, and can inform decisions about the selection of forested areas that are eligible for conservation and enforcement of regulations. In this paper we estimate transferable household production functions of NTFP extraction in the Eastern Arc Mountains (EAM) in Tanzania, based on information from seven multi-site datasets related to the behaviour of over 2000 households. The study shows that the total benefit flow of charcoal, firewood, poles and thatch from the EAM to the local population has an estimated value of USD 42 million per year, and provides an important source of additional income for local communities, especially the poorest, who mainly depend on subsistence agriculture. The resulting map of economic values shows that benefits vary highly across space with population density, infrastructure and resource availability. We argue that if further restrictions on forest access to promote conservation are considered, this will require additional policies to prevent a consequent increase in poverty, and an enforced trade-off between conservation and energy supply to rural and urban households.

1. Introduction

More than 800 million people worldwide live in or near tropical forests and savannas, and rely on these ecosystems and their services and welfare benefits for fuel, food and income (Chomitz et al., 2007; Boyd and Banzhaf, 2007; Fisher et al., 2009). In Tanzania, rural households largely depend on agriculture or natural resources as their main source of income (NBS, 2009). Tanzania is one of the poorest countries in the world, ranked 148th of the 169 countries on the Human Development Index (UNDP, 2010). Eighty-nine percent of the population lives below the $ 1.25/day poverty line (UNDP, 2010). Poverty is mainly a rural phenomenon: 83% of the households below the national food poverty line live in rural areas (NBS, 2009). In Tanzania, direct

* Corresponding author. Tel.: +44 01603 593224; fax: +44 01603 591327.
E-mail address: m.schaafsma@uea.ac.uk (M. Schaafsma).

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dependence on ecosystem services is high; 92% of rural households use firewood as their main cooking fuel, whereas over 50% of the urban population uses charcoal (NBS, 2009). The collection of Non-Timber Forest Products (NTFPs) for house construction and household use is also widespread, driven by poverty and a lack of means to invest in better quality housing and non-wood substitute products (World Bank, 2009). For these communities, ecosystem final services benefits in the form of NTFPs provide a source of complementary cash income, or a safety net when agricultural yields are low (Anthon et al., 2008; Ngaga et al., 2009). In addition to timber extraction, the production of building poles, charcoal and firewood has led to overexploitation of forests and is one of the main immediate drivers (alongside agricultural expansion) of forest degradation and deforestation in Tanzania (Hofstad, 1997; Chiesa et al., 2009; Ahrends et al., 2010; URT, 2010). Rapid population growth puts an additional increasing pressure on these natural resources in the country.

The Eastern Arc Mountains (EAM) contain over 21,500 km^2 woodlands, which are very important for carbon storage on a landscape scale (Willcock et al., 2012), and 4000 km^2 of tropical forests (Platts et al., 2011), recognised as one of the world's biodiversity hotspots (Myers et al., 2000). Tropical forest ecosystems host at least 60% of the terrestrial biodiversity (Dirzo and Raven, 2003; Myers et al., 2000) and contain around 25% of the carbon in the terrestrial biosphere (Bonan, 2008). Their clearance and degradation account for about 17% of annual CO_2 emissions worldwide (IPCC, 2006). Global concerns about biodiversity conservation and climate change mitigation are leading to rising international demand to reduce degradation and deforestation resulting from the harvesting of timber and NTFPs. However, while the benefits from CO_2 sequestration and biodiversity protection accrue to the entire international community (Balmford and Whitten, 2003; Strassburg et al., 2010), the current welfare of people in local communities in developing countries, many of whom already live near the poverty line, is likely to decrease if NTFP harvesting is restricted (Wunder, 2001). Accordingly, the costs of supplying internationally beneficial conservation services would be carried by the poorest and most vulnerable people.

The trade-offs between socio-economic impacts and forest conservation in forest-rich countries with high levels of poverty and forest-dependency are increasingly being considered in international conservation initiatives, including the UN's programme on Reducing Emissions from Deforestation and forest Degradation (REDD+, see UNFCCC, 2006; Strassburg et al., 2009) and the Convention on Biological Diversity (CBD, 2002). REDD+ is aiming to mitigate climate change for the benefits of the global population by reducing forest degradation, with a payment mechanism yielding co-benefits for poverty alleviation. Similarly, the CBD, in aiming to reduce biodiversity loss, recognises the role of biodiversity for human wellbeing and promotes sustainable use and equitable benefit-sharing (CBD, 2010). The CBD objectives have been integrated in the Millennium Development Goals and its strategies to reduce extreme poverty (Sachs et al., 2009).

To achieve equity and poverty alleviation objectives, effective forest conservation policies should not only be informed by the potential for carbon sequestration and biodiversity protection, but also by the distribution of costs and benefits of forest conservation among stakeholders at different spatial scales (Hein et al., 2006; Turner et al., 2010). This paper aims to provide insight into the distribution of local benefits within the EAM, by modelling and mapping NTFP extraction across a wide spatial scale. A better understanding of the spatial variation in the (opportunity) costs and benefits of conserving ecosystem services, conditioned by factors such as resource availability and population density (Naidoo and Ricketts, 2006; Pagiola and Bosquet, 2009; Turner et al., 2010), can help to define priority areas where limited budgets for forest and biodiversity conservation would have highest overall benefits (Naidoo et al., 2008). This is especially relevant for the montane and sub-montane forests of the EAM in Tanzania, where the benefits of protection of rare and endangered species could render extractive uses of these forests with local and national benefits problematic (Burgess et al., 2007, 2010). However, effective mechanisms for realising stakeholder benefits and their possible redistribution on fairness grounds have to be in place to avoid adverse poverty and equity effects of forest conservation initiatives. The equity effects of conservation management will depend on who is considered to be a stakeholder and how much they gain or lose under a conservation policy.

This paper presents a unique, spatially wide-scale analysis of NTFP collection across the EAM of Tanzania, demonstrating the importance of natural resource extraction for income and sustenance at the local level. Based on a large dataset from a number of household surveys, we estimate spatially explicit, micro-economic models of household NTFP collection, and transfer these models to predict the economic value of the annual flow of NTFP extracted by 2.3 million households across the study area of 50,000 km^2. In the next section, we discuss our modelling approach and its main strengths. The case study is described in Section 3 and the results of our analysis are presented in Section 4. In Section 5, we put our results into a wider policy context and discuss the implications of our findings for forest conservation policy and the links with other policy objectives such as poverty reduction.

2. Methodological approach

Increasing policy interest since the 1980s in sustainable development, social forestry, indigenous people's rights, and the commercialisation of forest products, has stimulated a rapid growth of the number of studies on socio-economic aspects of NTFP collection and forestry dependence (Neumann and Hirsch, 2000). The use of these studies in assessments of natural resources to inform decision-making at national level has been limited for a number of reasons. Most of these studies are qualitative in nature or describe forest dependency in terms of average quantities extracted by households. They are usually also rather localised, focusing on a particular forest or community (Croitoru, 2007) and the results do not capture heterogeneity across forests, communities and other spatial contexts. This inhibits generalisation of their results and the transfer of the models to other locations, or over more extensive spatial scales (Godoy et al., 1993). This lack of generalisable information induces a risk that NTFP values are omitted from strategic decision-making processes altogether if site-specific information is unavailable, with potentially serious effects on local welfare in forest-dependent areas. There is a growing need at national and international policy levels for projections at large spatial scales of the economic values local communities derive from forests, including the collection of NTFPs (Daily et al., 2009). Moreover, in light of the urgency of policies that foster sustainable development in forest rich countries with high poverty rates, such information has to be provided in due time and in a cost-efficient manner.

Our quantitative bottom-up modelling approach uses survey information on actual household behaviour from multiple locations over a wide spatial scale and different spatial contexts to develop a spatially explicit and transferable household production function. A full explanation of this approach is described in Schaafsma et al. (2012), and a detailed description is provided in the Supplementary Material – Methods and Results. Essentially, our approach involves four steps: (1) estimating the household "production function" of NTFP collection; (2) transferring this function across the total study area, using secondary data

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for non-surveyed areas; (3) aggregating household level extraction over all households in the study area, and (4) turning NTFP quantities into economic values.

This approach has three main advantages. The first is that the estimated annual flows of ecosystem values reflect the realised monetary benefits accruing to the local communities, rather than a projected potential flow from the underlying stocks. Potential harvesting rates do not reflect the actual NTFP benefits that can be derived, because they will be constrained by physical access problems such as steep slopes, and because markets may not be sufficiently large (Sheil and Wunder, 2002) or prices not sufficiently high to cover extraction costs in remote areas. So the potential stock will not be fully harvestable, and it is still open to question what the sustainable resource take rate might be. The second related advantage, compared to top-down approaches, is that the modelled household production functions (step 1) are based on micro-level data about individual decision-making and the factors that affect whether and how much to collect. In our bottom-up approach, the models empirically capture values as perceived by local communities. Top-down approaches, on the other hand, typically start with forest availability and production to express values per hectare (Batagoda et al., 2000). However, they fail to capture the effect of typical household characteristics that influence the decision to collect NTFPs, such as the time and costs involved in collection, available labour (after fulfilling other income generating activities) and capital, market access and demand, transportation options, and the potential gains to the household budget of selling NTFPs (de Beer and McDermott, 1989). The third strength is that our approach uses data from different areas with different socio-economic, spatial and biological conditions and can therefore assess whether these factors influence the cost of collection, demand and availability of various NTFPs. NTFP harvesting efforts and forest degradation typically vary spatially (Robinson et al., 2002, 2008). Forest quality, for instance, is often lower near villages or population centres (e.g., Ndangalasi et al., 2007; Ahrends et al., 2010), due to variation in NTFP harvesting behaviour as predicted by economic theory: the distance from the household to the NTFP harvesting location is positively correlated with the opportunity costs of labour and time spent to collect NTFPs (e.g., Amacher et al., 1996; Köhlin and Parks, 2001; Pattanayak and Sills, 2001). The spatial distribution of harvesting efforts is also affected by forest accessibility, forest protection status and enforcement (Robinson and Lokina, 2009, 2011).

The variability of NTFP products in terms of the frequency of collection and use, the areas where they are available, their marketability and legal context, imply that household production functions will differ across NTFPs. Therefore, we develop separate models for each NTFP, showing the relationship between the quantity of a NTFP extracted by an individual household (our dependent variable) and land cover suitability and household characteristics (our explanatory factors). In this NTFP-specific approach, it is possible to capture such differences between the NTFPs, unlike an aggregate model in which estimates of total NTFP income is used as the dependent variable. This may also in turn allow for more targeted restriction on NTFPs where this is deemed necessary for sustainable forest management.

Our approach thus combines the strengths of micro-level analysis of household behaviour with those of large spatial scale projections of forest values. The household production functions provide a spatially explicit evaluation of actual household NTFP collection and production. They can therefore be 'transferred' across the study area, for which the data is representative, to show how NTFP collection varies with socio-economic, biophysical and ecological factors. NTFP collection and its benefits can therefore be estimated for the entire study area in a relatively rapid and cost-effective manner, avoiding the prohibitive costs of interviewing all households in the area.

A limitation of such a spatially extensive estimation of ecosystem use is inevitably its accuracy at local levels. The underlying assumption of function transfer is that the relationship between the explanatory and dependent variables is constant between households in and out of the sample (Rosenberger and Stanley, 2006). Function transfer is expected to lead to more accurate results than value transfer (Navrud and Ready, 2007), where the mean value is taken to estimate the value of a non-surveyed site, because it allows for the effects of contextual factors (but see Rosenberger and Phipps, 2007; Matthews et al., 2009). The validity of our approach hence depends on the quality of the NTFP collection data, the representativeness of the sample, and the specification of the NTFP model (Boyle et al., 2009). To improve accuracy at finer spatial scales, additional local analyses are recommended for local policy development, such as conservation schemes that include some form of compensation to individuals or households.

3. Case study

The EAM consist of 13 mountain blocks extending from southern Kenya to eastern Tanzania with a total area of over 50,000 km^2 (Fig. 1). The dominant natural land cover is miombo

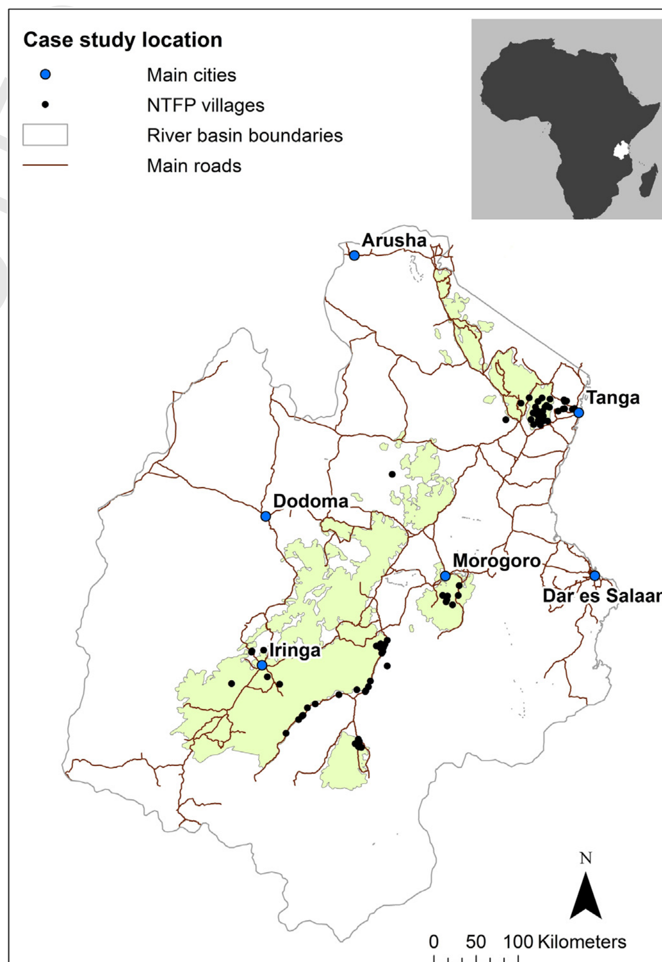

Fig. 1. Case study area. *Note*: The NTFP villages reflect the villages in our datasets where household data on NTFP collection has been collected. The EAM block delineation, based on Platts et al. (2011), reflects the area for which NTFP values are estimated. The river basin boundaries reflect the larger study area of the Valuing the Arc project.
Source: based on Schaafsma et al. (2012).

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woodland, covering approximately 42% of the total area, of which 10% is "disturbed miombo", in the form of woodland with scattered crops. There are various types of forests depending on the altitude: lowland forests at basin levels, sub-montane and montane forests, and upper montane forests at highest elevations (Burgess et al., 2007). Apart from NTFPs, important EAM ecosystem services include the provision of timber, the regulation of river flows for drinking water, irrigation and hydropower, and carbon storage (Fisher et al., 2011a). Approximately 21% of the EAM blocks are protected (Swetnam et al., 2011), including 75% of the remaining forests and 24% of undisturbed miombo woodlands (Platts et al., 2011). Pole cutting, charcoal production and timber harvesting are prohibited in Protected Areas and licensed under other management schemes. Nevertheless, illegal extraction of NTFPs and timber continues in Protected Areas, caused by multiple and interrelated factors, including weak enforcement of conservation policies and poverty.

The total population of the EAM blocks is estimated at 2.3 million (based on Platts et al., 2011), with a mean household size of 4.6. Most people living in rural Tanzania depend to some degree on the collection of NTFPs, a situation that can also be found in many other African countries (e.g., Shackleton and Shackleton, 2000, 2006; Ambrose-Oji, 2003; Mamo et al., 2007; Kamanga et al., 2009; Palmer and MacGregor, 2009). In the EAM, people collect firewood, charcoal, poles, thatch, fruits, vegetables, honey, bush meat, and medicines, and use a wide range of species (e.g., Luoga et al., 2000; Turpie, 2000; Monela et al., 2005; Anthon et al., 2008; URT, 2008; Robinson and Lokina, 2011). In this study, we focus on the first four of these NTFPs and we therefore provide a short description of their importance for urban and rural livelihoods and the trends in collection.

Firewood is collected by most households themselves, but only 2% of households sell it onwards (NBS, 2003). As demand for firewood has increased due to population growth, the availability of dead wood is now limited in some areas. In such cases, people have increasingly started to collect live wood, which can threaten the sustainability of forest use. Substitution to alternative energy sources or more fuel efficient stoves is still very limited (Arnold and Köhlin, 2003).

Whereas the rural community relies mainly on firewood for cooking, the urban population commonly uses charcoal (75% of households in Dar es Salaam and 54% in other urban areas, NBS, 2009). Charcoal production takes place in rural areas. In the lower woodland and forest areas of the EAM, charcoal production is practised for commercial purposes, mainly by men (Luoga et al., 2000; Anthon et al., 2008). Local communities are seasonally or occasionally involved in charcoal production, primarily outside planting and harvesting seasons. According to official statistics (NBS, 2003), 40% of charcoal-producing households sell their produce, but this proportion is likely to be higher in reality. Charcoal makers sell their products to middlemen who transport it to the major urban centres (Malimbwi and Zahabu, 2008). Full-time charcoal producers often move around the country to new production sites.

Another important NTFP used by many rural families is poles (Burgess and Clarke, 2000; Persha and Blomley, 2009), used for the construction of houses. The commercialisation of pole cutting is small with only 6% of collecting households selling their poles, mainly to neighbours (NBS, 2003). Due to diminishing pole availability near to villages in some areas, villagers are increasingly less likely to sell poles (Robinson and Kajembe, 2009). Some households now prefer to build brick walls, which they sometimes finance by small loans (Freeman, 2010). Bricks are currently more expensive than poles and only available to richer families. Since bricks are usually dried using firewood, increasing brick use may reduce the availability of dead wood for firewood consumption.

Thatch is widely used for roofing, because it is considered to be cheap and also a traditional building material (Monela et al., 2005). In miombo areas, grass species that provide useful thatching material are abundant (Campbell et al., 2008). Thatch collection is expected to have a less detrimental effect on forests than fuel wood or pole collection, and is an important ecosystem service to local communities. Thatch is not traded on a regular basis.

To test and demonstrate our approach, we acquired four existing datasets on NTFP collection in the EAM and set up collaborations with three other projects to supplement these data and extend our spatial coverage (see Supplementary material – Data). From these datasets, household information from villages within 40 km of the EAM boundaries was selected. This selection resulted in a pooled dataset with over 2000 observations from 60 villages. The availability of multiple multi-site datasets of household level observations on NTFP collection in Tanzania provided the opportunity to innovate and develop spatially explicit household production functions.

4. Economic valuation of actual NTFP flows: results

4.1. Forest and woodland income and dependency: sample statistics

The sample statistics show that NTFPs are of great importance to villagers in the EAM area (see Supplementary material – Data). More than 60% of houses are constructed with poles and half of the sample has thatched roofs (see Supplementary material – Table A.2). For 13% of households the main source of household income is forest related, including timber and NTFP collection. NTFP income (cash and non-cash) accounts on average for 20% of total household income, which is comparable to the results of a meta-analysis of over 50 NTFP studies worldwide by Vedeld et al. (2007), which estimated that forest environmental income represented 22% of the total income of communities living near forest in developing countries. The annual median household income of the sample corresponds to $ 1.89 per household per day PPP-corrected, equivalent to a daily income per person far below the poverty line. We used the UNDATA (2010) PPP conversion factor of the local currency to international dollars of 2007: TSH 521,600 = $ 1. The number of people living below the basic needs poverty line in our sample is higher than census data indicate (38% in rural areas, see NBS, 2009); nevertheless it is clear that the households in the sample are very poor.

Income is unequally distributed: the GINI-coefficient of our overall sample is 61% (a Gini coefficient of 0 percent implies perfect equality, whereas 100 percent implies maximal inequality). Excluding NTFP income from the calculation increases inequality and the GINI-coefficient to 65%. Thus, according to our data access to NTFPs reduces inequality. Splitting the sample into income quartiles (Table 1) shows that NTFP income (cash and non-cash) of the poorer groups is lower in absolute terms but higher relative to the total household income, compared to richer households. This result confirms findings by earlier socio-economic studies (e.g., Cavendish, 2000; Mamo et al., 2007; Kamanga et al., 2009). Of course, the terms rich and poor should be interpreted with caution, as the mean annual household income of the richest group is only TSH 2 million (PPP $ 4123). In our sample, richer households are less involved in the collection of firewood and thatch, but they are more likely to produce charcoal. In terms of quantity, they collect more firewood and poles, compared to poorer households. Differences in quantities for charcoal and thatch are not significant at the 5% level. These figures confirm that NTFPs reduce relative inequality, and are an especially important source of income for the poorest in these communities.

Table 1
NTFP collection across income groups.

Variable	Quantiles			
	Poorest	Poorer	Richer	Richest
Mean total NTFP income (TSH × 1000/year)[a]	28 (34)	57 (61)	83 (102)	220 (523)
Mean household income (TSH × 1000/year)[a]	105 (49)	271 (56)	554 (109)	1787 (1391)
% NTFP in total income[a]	26%	22%	15%	12%
% of households collecting				
Firewood[a]	95% (22%)	98% (14%)	96% (20%)	93% (25%)
Charcoal[a]	4% (20%)	5% (23%)	10% (30%)	12% (32%)
Poles	24% (42%)	22% (41%)	28% (45%)	22% (41%)
Thatch[a]	24% (43%)	22% (42%)	14% (34%)	6% (24%)
Mean quantity collected				
Firewood (headloads/week)[a]	1.7 (1.5)	2.1 (1.5)	2.3 (1.8)	2.4 (1.9)
Charcoal (30 kg bags/year)	52 (65)	34 (41)	60 (63)	57 (58)
Poles (poles/year)[a]	0.8 (1.1)	0.7 (1.0)	0.6 (1.0)	1.5 (1.8)
Thatch (bundles/year)	5.9 (9.0)	6.0 (6.5)	7.9 (9.1)	17.1 (24.0)

Notes: Household statistics are not corrected for differences in household size or composition, i.e., not based on adult equivalent units, because the necessary data was unavailable. Standard deviations are presented in brackets.
[a] Indicates that the differences between the income groups are significant at the 1% level according to Kruskal–Wallis tests (with ties), where the critical value of χ^2 (3 d.f.) = 11.35.

4.2. Spatial mapping of economic values of NTFP collection in the EAM: modelling results

The first step of our approach is to estimate a household production function for each NTFP. This model predicts the annual quantity collected per household. We use count-data models to estimate these household production functions for three of our focal NTFPs. When only a small proportion of all households collect an NTFP, such as thatch and charcoal, zero-inflated negative binomial models are employed to accommodate the distribution and the large number of zero observations of the dependent variable (Greene, 1994; Cameron and Trivedi, 2005). For firewood collection, in which 95% of respondents are involved, a negative binomial model is estimated. Poisson models are not suitable in this case, because the dependent variable is overdispersed, which means that the observed variance of this variable is larger than the predicted variance of a Poisson distribution.

We find that firewood collection increases with household size, forest income dependency, and forest availability (Table 2). At the same time, firewood collection is lower among households who live further away from roads, which can be explained by the lower commercial activity that firewood as an input in remote areas. Firewood collection also decreases with the availability of open woodland, which is likely to reflect lower supply (biomass) in this land cover type compared to other types.

The number of households collecting thatch increases with increasing distance to roads and thatch use (Table 3). This may be because alternative roofing material is even more expensive to transport to remote areas, and households that use thatch for roofing often collect this themselves. The quantity of thatch collected increases with the availability of woodland with scattered crops and sub-montane forest around the village.

The number of households involved in charcoal production increases with the number of males in the household, forest-income dependency, the availability of open and closed woodland, but decreases with montane forest availability (Table 4). The quantity produced by these households decreases with the availability of closed woodland and montane and upper montane forest. As explained in Schaafsma et al. (2012), the variable for the availability of closed woodlands in a 10 km range around the village has a significant positive effect on the probability that a household

Table 2
Results for firewood collection (negative binomial model).

Negative binomial: Number of headloads of firewood/household/week	Coefficient (z-score)
Household size (number of household members)	0.154*** (5.34)
Household size squared	−0.008*** (3.57)
Main source of household income: from timber and NTFP (dummy: 1 if yes, 0 otherwise)	0.167*** (3.02)
All forest in a 10 km buffer (DF indicator, sigma = 0.8)	0.00375*** (3.51)
Open woodland in a 10 km buffer (DF indicator, sigma = 5.0)	−0.000114*** (2.58)
Distance to road (ln(km + 1))	−0.198*** (4.01)
Constant	1.765*** (8.80)
Number of observations	1910

Notes: Z-values are presented in brackets.
*** Significance of the parameters is marked with asterisks, which refers to 1%. See Supplementary material – Model Results for full details and explanation of variables.

Table 3
Results for thatch collection (zero-inflated negative binomial model).

Logit: Choice to collect thatch	Coefficient (z-score)
Distance to road (ln(km + 1))	0.715** (2.42)
Roof made of thatch (dummy; 1 = yes; 0 = otherwise)	1.990*** (4.15)
Woodland with scattered crops in 10 km buffer around village (ha/1000)	−0.471*** (2.55)
Lowland forest in 10 km buffer around village (ha/1000)	−1.207*** (2.91)
Constant	−3.368*** (7.59)
Negative binomial: Number of bundles collected/household/year[a]	
Woodland with scattered crops in 10 km buffer around village (ha/1000)	0.114*** (3.65)
Sub-montane forest in 10 km buffer around village (ha/1000)	0.237*** (15.49)
Constant	2.215*** (28.78)
Number of observations	1348

Notes:
[a] The presentation of the logit results is adapted (signs have been switched) to improve the ease of interpretation. Z-values are presented in brackets.
** Significance of the parameters is marked with asterisks, which refers to 5%.
*** Significance of the parameters is marked with asterisks, which refers to 1% See Supplementary material – Model Results for full details and explanation of variables.

Table 4
Results for charcoal production (zero-inflated negative binomial model).

Logit: Choice to produce charcoal	Coefficient (*z*-score)
Number of males in household	0.224*** (3.68)
Main source of household income: from timber and NTFP (dummy; 1 = yes; 0 = otherwise)	2.261*** (5.66)
Woodland (open, closed) in 10 km buffer (ha/1000)	0.178*** (2.83)
Montane and upper montane forest in 10 km buffer (DF indicator, sigma = 2.0)	−0.0195** (2.29)
Sub-montane forest in 10 km buffer (DF indicator, sigma = 7.5)	−0.00512*** (4.36)
Constant	−3.390*** (6.51)
Negative binomial: Number of charcoal bags/household/year[a]	
Closed Woodland in 10 km buffer (sigma = 4)	−0.000789*** (3.61)
Montane and upper montane forest in 10 km buffer (sigma= 5)	−0.00159*** (4.68)
Constant	4.089*** (30.82)
Number of observations	1176

Note:
[a] The presentation of the logit results is adapted (signs have been switched) to improve the ease of interpretation. *Z*-values are presented in brackets.
** Significance of the parameters is marked with asterisks, which refers to 5%.
*** Significance of the parameters is marked with asterisks, which refers to 1%. See Schaafsma et al. (2012) for full details and explanation of variables.

produces charcoal, but a negative effect on the quantity produced. The latter effect decreases with distance, so that the net effect of closed woodland availability on total quantity per household is positive in most areas.

Similar models of the collection of poles were not sufficiently robust. Therefore, we estimate the collection of poles based on the census statistics of pole use for building walls and roofs. Further details of all model results are included in the Supplementary material – Model Results.

In the second step of our approach, these household production functions for firewood and thatch collection, charcoal production and pole cutting, are transferred across the study area. Part of this process involves determining for households living near the edges of the EAM the proportion of their NTFP collection which is sourced from within the EAM. In the absence of accurate information about source locations of the NTFPs, we use survey data of travel time to source locations to develop spatial decision-rules to estimate the proportion of NTFP collection that could be attributed to the EAM.

The third step is to aggregate these values per household over the entire population to assess the total annual quantity of NTFPs collected in the EAM. Finally, in step four these aggregated figures are assigned an economic value using NTFP market prices, allowing for spatial heterogeneity in prices if possible and where relevant. For firewood, poles and thatch, which are not traded on a regular basis, price information was difficult to obtain and also rarely reported in either the published or unpublished literature. We use the conservative modal price estimates based on the available information from our dataset to value the different NTFP flows (see Supplementary material – Table A.6). Since these products are mostly sold at local markets or to neighbours (see Section 3), we assume that prices were not dependent on transport costs and do not vary across space. Charcoal prices vary spatially and therefore we develop a modelled price map to value charcoal production (see Schaafsma et al., 2012). The presented economic values are expressed in terms of gross benefits to NTFP producing households, as the production costs are not deducted.

The results show that the total economic value flow of the actual annual extraction of NTFPs considered in this study collected from the EAM blocks is estimated at TSH 59 billion (USD 42 million) per year (see Table 5), equivalent to almost TSH 26,000 per capita per year (USD 18). Compared to the official statistics of mean rural expenditure per capita in rural areas of TSH 213,000 per year (NBS, 2009), total modelled NTFP collection contributes on average around 12% to rural incomes. This is a conservative estimate based on national rural expenditure statistics. Compared to the sample average of income per capita, NTFP collection contributes around 15%.

Firewood provides the main source of cooking fuel for the majority of households and is found to be the most important NTFP for households in the EAM, with a total annual quantity collected of approximately 72 million headloads. In economic terms, firewood collection contributes TSH 16,000 to the annual household budget, and the flow of benefits is in total TSH 36 billion per year (USD 25 million). Pole collection contributes around TSH 957 per capita. The total annual quantity is 3.7 million poles, with a total economic value of TSH 2.2 billion per year (USD 1.6 million). Thatch collection has the lowest annual value with TSH 220 million (USD 0.16 million). Whereas firewood, poles and thatch are mainly collected for consumption purposes and contribute to non-cash household income, charcoal production is a tradable good and provides a source of cash income. The annual flow of benefits to charcoal producers in and around the EAM is 21 billion TSH per year (USD 15 million). These sums are considerable yet provide an incomplete picture of the total value of NTFPs in the EAM, as other NTFPs, such as fruits, vegetables, mushrooms, medicines and honey, are omitted from the analysis.

The results for the four NTFPs are combined in Fig. 2, which depicts the annual economic value of NTFP collection from the EAM. The forests in the study area are also included, showing, for instance, that the NTFP values are particularly high near the forest in the Usambara Mountains in the north (to the west of Tanga) and the Uluguru Mountains near the city of Morogoro. These areas are characterised by high population density.

Ideally, we would extend our approach with an evaluation of the difference between sustainable and actual harvesting rates.

Table 5
Aggregate quantities and economic values of NTFP collection in the EAM.

	Quantity × 1000/year (weight in kg × 1000/year) [a]	Value in TSH × 1 million/year (USD × 1 million/year)[b,c]	Value per capita (TSH/year)[d] (USD/year)[b]
Firewood	71,939 headloads (1,258,923)	35,969 (25.33)	15,639 (11)
Charcoal	2869 bags (86,070)	20,929 (14.74)	9100 (6)
Thatch	734 bundles (18,350)	220 (0.16)	96 (0)
Poles	3670 poles (18,349)	2202 (1.55)	957 (1)
Total		59,320 (41.78)	25,792 (18)

Notes:
[a] Weights are based on survey information and existing literature. See supplementary material – *Calculation of weight of aggregate NTFP estimates.*
[b] Based on a mean 2010 exchange rate of US$1 = TSH1420 (Bank of Tanzania, 2011).
[c] The economic values are expressed in terms of gross benefits to NTFP producing households.
[d] Based on the population estimate of 2.3 million people.

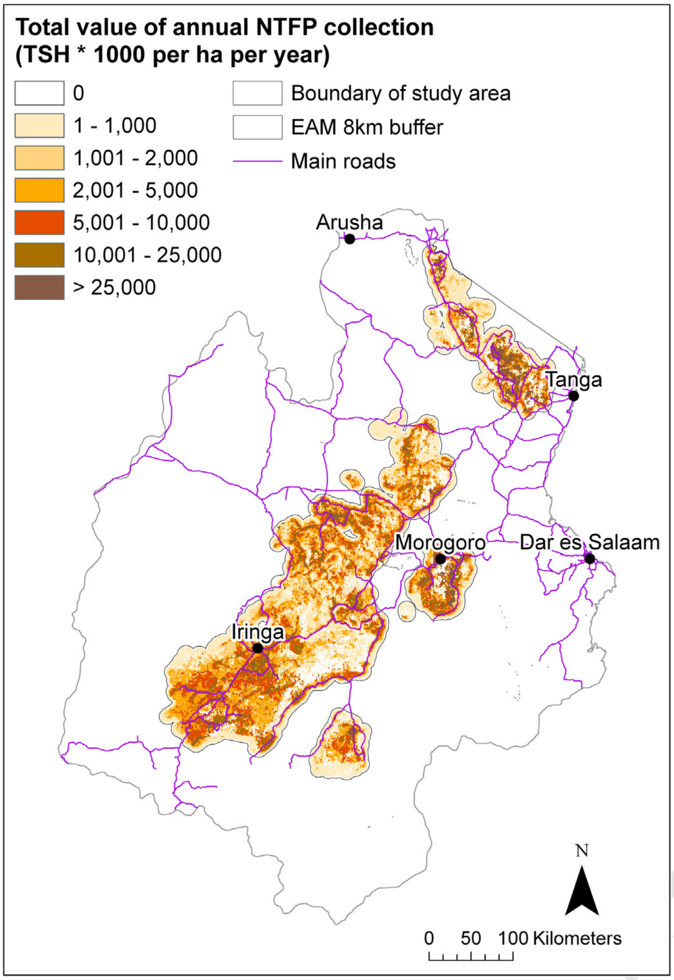

Fig. 2. Total economic value of annual NTFP collection (TSH × 1000 per ha per year).

Due to a lack of accurate data about source locations, it is impossible to attribute these benefits to particular areas, such as open access forests, Forest Reserves or other protected lands. Additional information to pinpoint the exact location where the NTFPs are harvested would be necessary for a sustainability analysis. Moreover, a better understanding of sustainable harvesting rates, forest conditions and growth rates than is currently available is necessary to assess the impact of NTFP harvesting on forest quality and potential incomes over time.

5. Discussion and policy recommendations

Analysing the spatial distribution of NTFP collection can help inform the selection of suitable areas for forest conservation initiatives. It shows where the costs of forest conservation (if harvesting restrictions were effectively enforced), in terms of NTFP income losses to the local population, would be high. These costs would require a trade-off with the benefits of climate change mitigation and biodiversity conservation for the global community. As our study shows, the total quantity of NTFPs collected, and hence the pressure on forests and woodlands, is highest in areas with high population densities, because the dependence on ecosystem services from forests and woodlands is high, the opportunity costs of NTFP collection time are low, and people can collect at a relatively small distance from their home. Forest and woodland conservation initiatives aiming at reducing NTFP harvesting rates in such areas would be most effective in terms of potential carbon sequestration, and generate high benefits for the global community in terms of biodiversity conservation and climate change mitigation. Since current extraction rates in some areas are unlikely to be sustainable (Mwampamba, 2007) and might lead to depletion of forest stocks, effective sustainable forest management might be able to secure a minimum flow of harvestable NTFPs and local income in the longer term. However, at the same time, intensified forest protection and enforcement would lead to high short-term costs for the local population and a large number of stakeholders bearing losses. Moreover, these people do not have the means to bridge the time gap between short-term costs and potential long-term benefits. Enforcement of stricter protection policies would be expensive and, because of poverty and population pressure, probably increase illegal harvesting rates and may therefore not be cost-effective or equitable. The inequality of the impact on forest-communities generally (of which around 80% live below the poverty line) and the poorest members in particular (who depend relatively more on forests than the richer members) is even more dramatic when related to per capita income. Hence, forest policy design involves complicated trade-offs between socio-economic and ecological objectives, with implicit concerns about the distribution of costs and benefits across stakeholders at global, national and local (intra-community) levels.

For forest management to be sustainable, both ecological and socio-economic objectives have to be met. The links between poverty and conservation are complex (Adams et al., 2004), but win-win solutions that improve human welfare in the short term and conserve nature are hard to realise in practice (Adams et al., 2004; McShane et al., 2010), and often trade-off decisions between ecosystem conservation and economic development have to be made (Sachs et al., 2009; Blom et al., 2010). The well-known Tinbergen-rule in economics says that a policy would be more efficient if for each objective at least one instrument is available (Tinbergen, 1952). Any secondary objective requires an additional, correcting instrument. Hence, if conservation is the primary goal, additional policy instruments have to be developed to prevent a deterioration of or, if possible, an improvement in the poverty situation. And vice versa: if poverty alleviation is the main objective, additional regulation has to be put in place to ensure ecological sustainability. As an example, Payments for Ecosystem Services (PES) schemes mainly designed to contribute to poverty alleviation are less effective in terms of generating ecosystem services. However, by combining PES with other instruments aimed at socio-economic objectives (Wunder et al., 2008), the legitimacy (Corbera et al., 2007) and ultimately the efficiency and equity outcomes of PES may be improved (OECD, 2007; Pagiola and Platais, 2007; Engel et al., 2008).

Often, the global distribution of conservation benefits is unequal and the costs are mainly borne by local communities (Balmford and Whitten, 2003; Brandon et al., 2005). A more effective and equitable outcome of forest conservation policies requires that the benefits of conservation at the global scale are captured and redistributed to compensate local losses (Naidoo and Adamowicz, 2005). Benefit capture at such a scale involves formal market based mechanisms, including taxes, fees and PES (Fisher et al., 2008), which provide economic incentives to reduce negative external effects of resource use. REDD+ might provide the financial resources for payments to compensate for forest benefits foregone due to harvesting restrictions, or to reward contributions to forest protection (Blomley and Iddi, 2009; Burgess et al., 2010; Pfleigner, 2011). Without proper economic incentives, it is unlikely that forest dependent communities will change their harvesting behaviour. Currently, such incentives are absent in Tanzania, which may explain why NTFP and timber collection continues in Protected Areas, and why participating villages do not adhere to joint management agreements (Veltheim and Kijazi, 2002; Topp-Jørgensen et al., 2005; Blomley et al., 2009).

At the national and intra-community level, payments may increase the unequal distribution of welfare (Zilberman et al., 2008) and thereby hamper policy effectiveness if the poorest groups do not take part in, and hence not benefit from, the payments scheme. The poorest in society often depend most directly on the natural resources, as in our case, and are therefore most vulnerable to increased restrictions on NTFP extraction (Cavendish, 2000). An evaluation of nine communities in Tanzania showed that neither Joint Forest Management (JFM – typically in areas with high biodiversity values, where only dead wood collection is allowed) nor Community-Based Forest Management projects (CBFM – typically in more degraded areas, where NTFP collection is allowed) have been able to ensure an equitable distribution of the benefits and costs of forest management (MNRT, 2008; Vyamana, 2009). The benefit sharing mechanisms in current schemes (both JFM and CBFM) are not considered to be viable in the longer term, because their severe official restrictions on NTFP collection leave local communities with low and unclearly defined benefits (Blomley and Iddi, 2009). Moreover, although CBFM was intended to transfer responsibilities and benefits of conservation to local communities, in reality they have not been pro-poor(est) and tend to exclude the poorest from benefiting (Lund and Treue, 2008). The transaction costs and (upfront) investments of such schemes to people from lower income class are relatively high compared to richer groups (Meshack et al., 2006). Instead, local elites are rewarded for the time and effort put into village committees and forest management and tend to gain most from CBFM in Tanzania (Blomley et al., 2009), similar to CBFM projects elsewhere (Kellert et al., 2000; Sommerville et al., 2010). If the poorest community members cannot participate in rulemaking, achieving sustainable forest management with legitimate and fair incentive structures that is supported by all groups among the local population, will be difficult (Persha et al., 2011). However, the process of establishing participatory forest management schemes may also change (existing) problems of elite capture, and give the poor the opportunity to learn to exercise their democratic rights and over time gain influence (Saito-Jensen et al., 2010).

A further impediment for poor rural households to benefit from compensation schemes is the current property right system, on which many market-based mechanisms including PES are based (Fisher et al., 2008; Wunder et al., 2008). Although the legal and policy framework in Tanzania is one of the most advanced in Africa, tenure arrangements are still not sufficiently secure for the poor to market their land (Korongo Ltd and REPOA, 2003). If REDD+ is implemented using a PES-like compensation mechanism for NTFP harvesting based on property rights, only those few large-scale forest owners with secure rights may benefit, and inequality and conflict over resources may increase (Sunderlin et al., 2009). Further recognition of local individual and/or community rights to the ecosystem services provided by forest, and development of the legal system to secure these rights, will be necessary for the poor to benefit from such payments (Clements et al., 2010). Combined with profitable forest products, property rights may generate funds that would stimulate villagers to contribute to sustainable forest management (Hofstad, 2008).

Since population growth and the demand for energy continue to increase, a final consideration is whether both the urban and rural population will be able to switch to non-forest energy sources before most of the forests have been cut down beyond their threshold levels (Chiesa et al., 2009; Mwampamba, 2007). However, simplistic, total restrictions on fuelwood collection to reduce forest degradation and mitigate climate change may serve to exacerbate the nationwide energy problem, because alternative sources of energy, such as jatropha or electricity, are hardly available or very costly, both in urban and rural areas (Wiskerke et al., 2010), and sustainable harvesting levels of fuelwood are unlikely to be sufficient to supply a growing population. Providing direct financial payments as compensation for benefits foregone will not be effective if no substitute products are available. It seems, therefore, unrealistic to attempt a complete ban on fuelwood collection as it would be impossible to enforce.

Accepting that conservation objectives may have to be compromised in places, a more realistic solution would be to allow for NTFP and timber collection in some areas, while simultaneously stimulating the adoption of more efficient charcoal and firewood stoves in order to limit demand and reduce pressure on forests (Hofstad et al., 2009; Fisher et al., 2011b). Since private investments in fuelwood supply are likely to remain unprofitable under current fuelwood prices, licence requirements and de facto open access of the remaining forests and woodlands (Wiskerke et al., 2010), additional policies on the fuel supply side could be developed to encourage, for instance, more efficient charcoal production methods and fuelwood and pole plantations.

Beyond the forest sector, poverty alleviation initiatives focused at productivity improvements in the agricultural sector could help to reduce agricultural encroachment of forests and forest-dependency. Options include subsidising fertilizers, pesticides, seeds and technology, improving market access and reducing taxes and levies on agricultural products, combined with projects to increase technical skills, which are currently the main obstacles for profitable small-scale farming (Korongo Ltd and REPOA, 2003). Since new production methods, substitute products and income generating activities require capital, incentives should be sufficient to ensure that the poorest have access to substitute products (Pirard et al., 2010). Overall, a strong institutional framework is required to achieve sustainable, effective and equitable forest management, where different governmental sectors, including energy and agriculture, cooperate to address the various drivers of poverty and deforestation and forest degradation. In light of current institutional structures and limited budgets, improving the conservation of the EAM calls for the international community to support the redistribution of conservation benefits, and provide financial and technological transfers, including access to alternative energy sources. In order to deal with existing problems related to property rights and elite capture, transfers should be directly paid to those people who would change their behaviour upon receiving incentives, where payments should be conditional on effective contribution to forest conservation. An equitable and effective transfer scheme should attempt to reach the poorest, who are facing highest relative losses, but the transaction costs may be high. Changing national and international institutional arrangements is an enormous, long-term challenge. The main recommendation for more practical actions in the short-term is to attempt to circumvent problems related to property rights, elite capture and limited or costly alternatives to NTFPs into account, and involving the poorest in affected communities.

6. Summary and conclusions

NTFP collection in the Eastern Arc Mountains in Tanzania is an important source of income for many rural communities. Based on a unique large dataset of different household surveys, this study highlights that the annual economic value of NTFP collection varies across households and geographical areas. Our methodological approach is based on consideration of spatial characteristics, such as forest availability and distance to roads and markets. This allows us to generate spatially explicit household production functions that are transferable over the total study area, and thereby provide policy information in a relatively cost-effective and rapid manner for decision-making at the national level. The resulting maps of economic values of NTFP collection demonstrate that the importance of spatially explicit approaches becomes ever more apparent when the spatial distribution of the population is taken into account and the household production model is applied over a wide area with the mean quantity collected aggregated over the total population.

The total benefits of the four NTFPs included in the analysis accruing to the local population are approximately TSH 59 billion per year (USD 42 million), with firewood and charcoal collection as the largest contributors. Using the data of a national household survey, roughly comparable results of TSH 48 billion (USD 33 million) were obtained (Schaafsma, 2012). This figure shows the magnitude of the economic loss that local households would bear if NTFP collection was fully and effectively banned across the EAM blocks. Without any interventions, current unsustainable extraction rates and over-harvesting in some areas are likely to worsen the longer-term poverty situation. However, in the short-term, before potential local benefits of sustainable forest management can be captured, imposing stricter forest access regulation will also increase poverty levels. Given that the relative contribution varies across income groups and is higher for the poorer part of the population, any policy that changes forest access and NTFP collection possibilities is likely to hit the poorest hardest. Reducing current NTFP collection rates in an equitable manner requires the design of payments schemes that actively involve and compensate the losers from conservations efforts.

The rapid deforestation and degradation rate spurs a sense of urgency to protect forests. However, the design of effective, equitable and efficient forest policies to reduce current harvesting levels involves complicated trade-offs between ecology and poverty objectives, and decisions on who will benefit or loose. It requires a policy mix involving coordinated interventions across forest, energy and agriculture sectors. Moreover, unprecedented levels of legally binding cooperation are needed between governance levels to promote an equitable sharing of costs and benefits of forest conservation between the international community, the national and local governments in Tanzania, and rural as well as urban households who need to change their harvesting of NTFPs and energy consumption.

The results presented here are part of a wider programme of work in progress, in which we aim to assess the benefits of forest protection, such as carbon sequestration and biodiversity conservation, and the opportunity costs of forest protection related to alternative land uses, such as agriculture. This should allow policy makers to compare the estimated total economic value of NTFP harvest to other ecosystem services under different land use scenarios.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2013.08.018.

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