



Socioeconomic Factors Determining Extraction of Non-timber Forest Products on the Slopes of Mt. Kilimanjaro, Tanzania

Hawa Mushi¹ · Pius Z. Yanda² · Michael Kleyer¹

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Abstract

Non-timber forest products (NTFPs) from natural forests in sub-Saharan Africa provide significant benefits to rural communities. In this study conducted on the foothills of Mt. Kilimanjaro, Tanzania, we assumed that the extraction of NTFPs by local communities is related to sex, income, age, household size, and distance from the forest. We interviewed 313 household heads from six villages. We employed a logistic regression with a logit link to test the significance among the variables. Younger females of larger households with lower income and less cultivated land cut fodder and collected firewood more frequently than other villagers. Firewood collection frequency decreased with increasing distance from village to forest whereas fodder collection frequency increased. Men collected medicinal plants more frequently than younger women and if the distance from the village was greater. For firewood and fodder extraction, inter-village variation was greater than intra-village variation, suggesting that differences in access to infrastructure and alternative fodder sites also strongly determined NTFP extraction. Our results contribute to a better targeted participatory forest management.

Keywords Fodder · Firewood · Fruits · Vegetables · Medicinal plants · Non-timber forest products forest management · Gender · Age · Income · Logistic regression · Chagga communities · Mount Kilimanjaro · Tanzania

Introduction

The world loses an estimated 13 million ha of forest and up to 40,000 forest dependent species every year (Kremen *et al.* 2000). On the other hand, natural forests provide multiple ecosystem services to local communities (Costanza *et al.* 1997). Households often rely on resources available in forested areas, such as wood for cooking, heating, and construction (Naughton-Treves *et al.* 2007) or forage for livestock (Infield 1988; Neumann 1998). Many protected forests are located in regions of poverty (Sunderlin *et al.* 2005), and local communities that depend on forest products for a large proportion of their subsistence-based livelihoods are often perceived as a threat to forest conservation (Padoch 1992; Carpentier *et al.* 2000; Mbile *et al.* 2005). In 2001 the World Bank assessed the

number of forest-dependent people globally to be 1.6 billion (World Bank 2001, 2004).

Plants harvested in tropical forests in Africa have a range of uses from food to medicine to manufacture of household utensils (Peters and Mundial 1996). Non-timber forest products (NTFPs) embody all biological matter of wild plants and animals other than timber extracted from forests and woodlands, including, e.g., fruits, nuts, vegetables, game, medicinal plants, resins, bark, fibers, palms, grasses, as well as small wood products and firewood, among others. Wild fruits and vegetables are an important source of edible fruits, leafy vegetables, and herbs, and are particularly important in ensuring food security and maintaining nutritionally balanced diets (FAO 2010). During periods of food shortage or famine, wild plants become essential to human survival. They also supplement household cultivation and can provide a source of income to cash-poor households (Emerton 1996).

Recent case studies in Africa have identified NTFPs to be an essential income source in household economy: in Malawi, Kamanga *et al.* (2009) report that wild and planted fruit trees on common land make up to 15% of total income. In the Republic of Congo, de Merode *et al.* (2004) found that wild plants contribute 10% of households' total food consumption. Babulo *et al.* (2009) calculated that consumptive forest

✉ Michael Kleyer
michael.kleyer@uni-oldenburg.de

¹ Landscape Ecology Group, Institute of Biology and Environmental Sciences, University of Oldenburg, 26111 Oldenburg, Germany

² Institute of Resource Assessment, University of Dar Es Salaam, P.O. BOX 35097, Dar Es Salaam, Tanzania

environmental products (i.e., fuel wood, farm implements, construction materials, wild food items, herbs, medicines) constitute 27% of income in rural communities in northern Ethiopia. A comprehensive study of forest environmental income in Zimbabwe by Cavendish (2000) found wild foods (plants and animals), medicinal plants, various wood and grass uses, forage plants as well as soil and termite account for 35% of the average rural income. Although these studies are not directly comparable since they focused on different subsets of forest products, they highlight the economic relevance of NTFPs. Meta-studies indicate that as much as 20–25% of rural incomes may be derived from environmental resources in developing countries (Kideghesho *et al.* 2007).

Dependence on forest resources differs greatly among individuals in terms of tribe, caste, class, and among and within communities and households by sex and age (Babulo *et al.* 2009). Women have traditionally gathered a wide range of NTFPs for both subsistence and income generation through processing and sale (Carpentier *et al.* 2000). Female-dominated households, for example, are more likely to harvest fuelwood while male dominated harvest timber. Sometimes gender roles in forest use can be dynamic and women can take up traditionally male activities. Older people may possess superior knowledge about medicinal plants and their uses and may collect more medicinal plants and wild foods than younger community members (Ndagalasi *et al.* 2007).

Dependence on forest resources may decrease with increasing household wealth and education, suggesting illegal extraction from protected areas could be mitigated by greater access to education and increased opportunities for wealth accumulation (Adams *et al.* 2004). Households with higher education levels often have more reliable sources of non-farm income opportunities (Ellis 2000). And households with more land generate higher agricultural income than households with limited landholdings, decreasing the need for forest resources. Increased household wealth can result in more positive attitudes towards protected areas (Infield 1988), but also an increased awareness of the sale value of protected area resources (Gillingham and Lee 1999). Improved off-farm employment opportunities and access to credit (Godoy *et al.* 1997) may be associated with reduced forest clearance as a supplementary income-generating activity, and may therefore not depend as much on NTFPs as people with lower education levels. Distances to forests and roads and therefore markets are common external forces impacting levels of forest extraction (Mamo *et al.* 2007). Shorter distances to forests may decrease the energy expended collecting the NTFPs, whereas shorter distances to roads may decrease the demand for NTFPs, particularly firewood, because alternative products such as charcoal or petroleum gas are more easily accessed. Conversely, shorter distances to roads may increase demand for NTFPs since they can be more easily transported and sold at markets.

While the relevance of these different social factors in influencing forest policy and traditional rules governing forest use differs worldwide (West *et al.* 2006), there has been little research regarding their interplay at the local community level. In the face of an increasing concern about the preservation of natural forests in the Tropics, it is important to identify the social groups most dependent on forest resources for their well-being. These groups can then be better targeted by education initiatives and effective policies ensuring long term sustainable use (Misana 2001).

In Tanzania, over 90% of the national energy demand for heat and cooking is supplied by wood fuel and charcoal (Milledge *et al.* 2007). The government has made significant steps towards improving the management of forest resources, such as the implementation of Community Based Forest Management and Joint Forest Management Programmes (Blomley and Ramadhani 2006). The contribution of forests to local livelihoods and the Tanzanian national economy is significant but largely undocumented (Mariki 2016). In this research we address to question of how extraction of forest resources is related to the social structure of local communities in Northeast Tanzania. Specifically, we investigate whether certain social groups extract more resources than others and whether this varies in terms of the resources gathered, e.g. fodder, firewood, or medicinal plants. Since land use impacts biodiversity (Peters *et al.* 2016; Schellenberger Costa *et al.* 2017; Peters *et al.* 2019), we make three assumptions: 1) that communities on the upper slopes of Mt. Kilimanjaro depend more on forest products for their livelihoods than those on the lower southern slopes that have better access to the arable land in the surrounding plains; 2) that larger households extract more NTFPs than smaller ones; and 3) that households with larger land holdings and greater income are less dependent on NTFPs than those with smaller land holdings and lower income.

Study Area

Mt. Kilimanjaro is located 300 km south of the equator on the border with Kenya between 2°45' and 3°25' S and 37°00' and 37°43' E (Fig. 1). It is the highest mountain in Africa, composed of three extinct volcanoes, Kibo, Mawenzi, and Shira, respectively 5895, 5149 and 3962 m.a.s.l. Mt. Kilimanjaro is the world's highest freestanding mountain, looming above an open undulating plain that averages around 800 m.a.s.l. The mountain's topography features deep V-shaped radial valleys, particularly on the western and southern slopes, as well as major gorges south of Kibo and east of Mawenzi. The foothills below the Kilimanjaro National Park have three distinct agro-ecological zones: the high zone (coffee, bananas, and home-gardens) with annual rainfall of 1200–2000 mm, the mid-zone (maize, beans) with annual rainfall of 1000–1200 mm and the low zone (savanna, maize, and livestock)

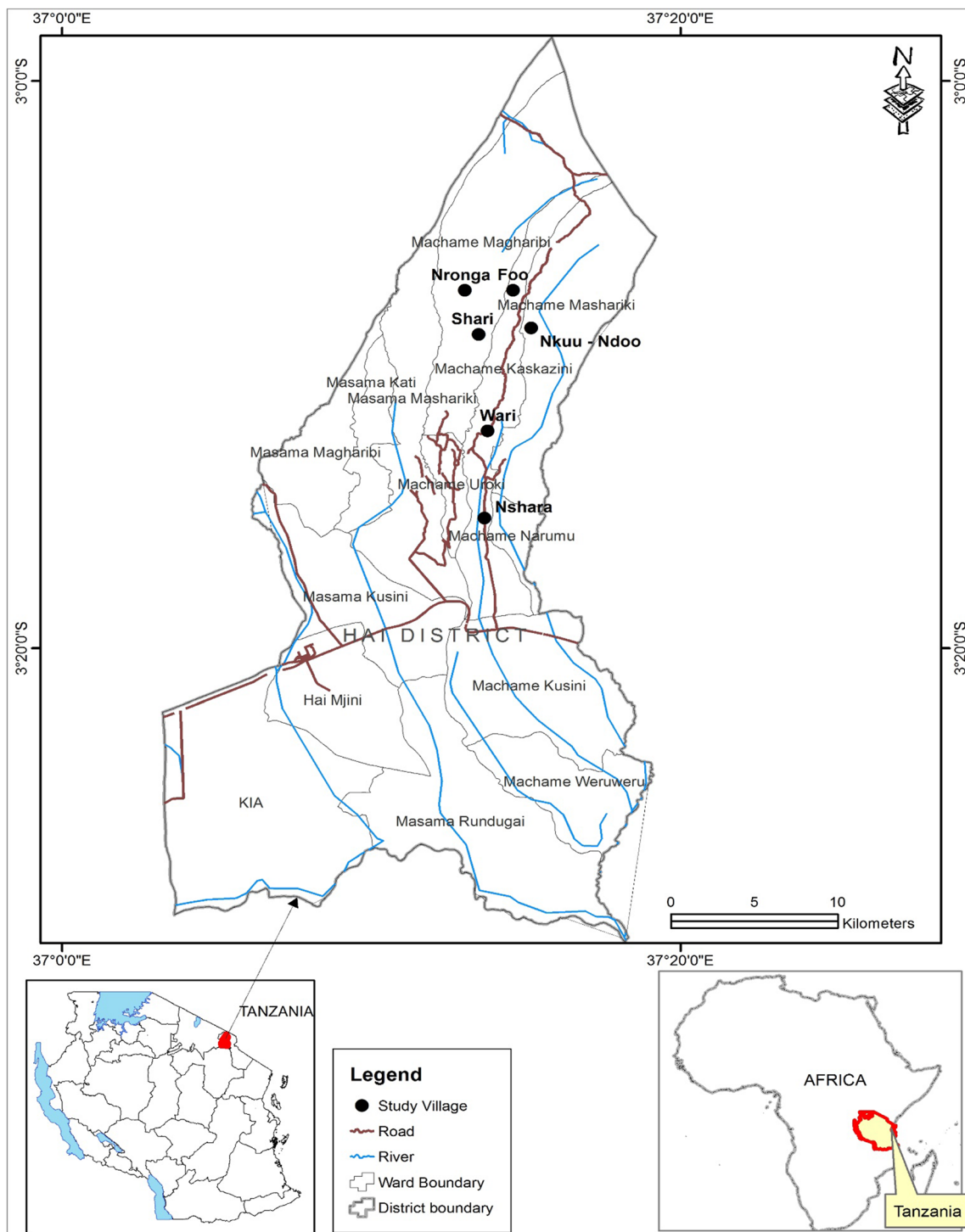


Fig. 1 Location of Study villages on Mount Kilimanjaro in Tanzania

with annual rainfall of 400–900 mm (Zongolo *et al.* 2000). There are two rainy seasons from March–May and from September–October. The majority of the local Chagga communities are farmers who have a long history of cultivating the upper southern slopes of the mountain as home-gardens with

an agro-forestry system intercropping shade trees, banana, coffee, maize, and legumes (Hemp 2006a) that has historically been one of the most productive in the whole country. The farming area per household decreased over time as a consequence of the “Kihamba System” that provides for the

subdivision of the household farm land among its sons (Yanda 2002). Low international prices for coffee have made traditional coffee-banana farming unprofitable, and farmers have turned to other sources of income like vegetable farming and forest related activities like selling timber and poles. Besides their own plots, the farmers can also farm on common land, so increasing their total cultivated land area. The creation of the Mt. Kilimanjaro National Park in 1973 (Katigula 1992) greatly restricted forest resources extraction, and the foothills of Mt. Kilimanjaro are now one of the most densely populated areas of Tanzania.

We conducted our study in Hai District on the southern slopes of Mt. Kilimanjaro, where the national census in 2012 reported a population of 210,533, with an average household size of 4.5 (National Bureau of Statistics 2013). We established a transect covering the three ecological zones: (1) a lowlands zone of extensive livestock farming and open crop fields, with remnant woodland patches comprising the villages of Wari and Nshara; (2) a midland maize-bean zone that is a mosaic of home gardens and open fields interspersed with a few woodland patches, including the villages of Shari and Nkuu-Ndoo; and (3) the villages of Foo and Nronga, located in a highland traditional Chagga home garden area dominated by coffee and bananas, with many large shade trees (Hemp 2006a). The lowlands zone extends up to about 900 m.a.s.l., the midlands up to 1200 m.a.s.l., and the home garden zone to about 1500 m.a.s.l. A tarmac road from the Machame entry gate to the Kilimanjaro National Park at 1800 m.a.s.l. down to the lowlands at 980 m.a.s.l. connects the area to the main road running between the cities of Moshi and Arusha. The area is intersected by several rivers, running in steep forested gorges from the upper part of the mountain down to plains (see Hemp 2006b).

When the National Park was established in 1973, local residents of the highland zone were allowed to collect forest products from a belt of land of about a half mile into the forest called the Half Mile Forest Strip, set aside in 1941 with emphasis on production of wood and NTFPs for local use. Communities in the lowland and midland zones rely mostly on the forested gorges and other small woodland patches for NTFPs.

Forest products we consider in this study are firewood, fodder, medicinal plants, and fruits and vegetables. Most villagers rely on either firewood or charcoal for cooking. Whereas charcoal is a commercial product, firewood can be collected in forests as dead or fallen branches or by felling standing trees. Chagga farmers living in the highland and midland belt rear their livestock mainly in farm stables. Farmers cut grass and herb biomass for fodder from the forest-under storey, from clearings with herbaceous vegetation, or from grassland patches close to the border of the Kilimanjaro National Park, on the slopes of the steep gorges intersecting the cultivated foothills, or on less fertile sites in

the plains below Mt. Kilimanjaro. Herbal medicines are used to prevent and treat diseases of both humans and livestock.¹

Fruits and vegetables, mostly cultivated in home gardens, include mango (*Mangifera indica*), passion fruit (*Passiflora edulis*), banana (*Musa spp.*), and cocoyam (*Colocasia esculenta*). Additional fruits and vegetables such as wild passion fruit and mushrooms are collected in the forests.

Methods

Sampling

The six sample villages were selected to represent ecological zones along transects. We employed purposive sampling to select villages for data collection (Berg 1998). In our case, this helped to locate those villages most useful for the goals of our study. Households were identified with the assistance of members of village governments and their respective “ten cell” leaders (leaders of Tanzania’s smallest administrative units each consisting of ten households), and randomly selected to participate in our questionnaire survey. We selected participants for focus group discussions with the help of village leaders.

We again used purposive sampling to select knowledgeable participants for key informant interviews, drawn from the district council, village committees, and non-governmental organizations. We selected a sample size of 10% in each village for household interviews Clarke (1986). In addition, we used key informant interviews and focus group discussions to complement each other in capturing data. The actual number of participating households in each village depended on the total number of households (Tab. 1), for a total of 313 households.

Questionnaires

We obtained socioeconomic data from the heads of households using closed and open ended questionnaires, which captured their main economic activities, land ownership, migration history, land use change, and drivers of change.² We interviewed both male and female household members in particular about the frequency of visits to forests to collect (i)

¹ Among the most common are *Aloe volkensii*, believed to have antibiotic properties for treating various stomach discomforts (pers. observation); the fruits and roots of *Vangueria tomentosa* used to treat snake bites and various kinds of worms; *Trema guineensis*, believed to have anti-insect properties and also used as animal fodder; *Dendrosenecio kilimanjari*, used for kidney ailments; and *Rauwolfia raffra*, known to have anti-pest properties, useful to protect stored maize.

² In this context, a household comprises a husband and/or wife (wives), children, and other dependents living together or in a cluster of several huts around a single compound, sharing common sources of income and livelihood (Mung’Ong’O 1995).

Table 1 Household Questionnaire Sample Size in the Study Villages

No.	Village Name	Total Number of Households	Number of Respondents		% of Respondents
			Females	Males	
1.	Foo	45	32	13	14
2.	Nronga	46	40	6	14
3.	Shari	45	8	37	14
4.	Wari	50	0	50	16
5.	Nkuu-Ndoo	41	13	28	13
6.	Nshara	86	50	36	27

firewood, (ii) fodder, (iii) fruits and vegetables, and (iv) medicinal plants. To explain these frequencies, the questionnaire included questions about sex, age, household size, and household income, total landholdings, and total land cultivated. We conducted unstructured interviews with key informants (landholders, long-term residents, and village officials) knowledgeable about different dimensions of land use change to gather qualitative information on the nature of forest resource use over time, particularly since the 1950s, and the causes of changes. We calculated the distance from village centers to the nearest forests, and the distance of the main road from Machame to the highway between Moshi and Arusha using satellite imagery.

We pre-tested the questionnaire in one of the study villages and subsequently made appropriate modifications. All interviews were performed in Kiswahili. Before conducting the household interviews, we met with village leaders at each village to brief them on the aims of our research as well as seek their advice on locating households to be interviewed.

Statistical Analysis

We used the Statistical Package for Social Sciences (IBM SPSS Statistics 24) and R version 3.5.0 (R Development Core Team 2011) for modelling and descriptive analyses to model the dependence of the frequency of forest resource extractions on multiple socioeconomic parameters. We chose logistic regression with a logit link (glm function, R package stats). It modelled the probability forest visits on a daily basis, with zero days per year as the lower boundary and 365 days per year as the upper boundary. The model takes the form of $y = -1/(1 + \exp.(b_0 + b_1x_1 + b_2x_2 + \dots + b_kx_k))$, where y is the collection frequency of a forest resource, and x_{1-k} are the socio-economic predictors, i.e., sex, age, number of household members, household income, size of landholdings, and distances to the nearest forest and the main road. Stepwise variable selection excluded predictors that did not contribute significantly to the model. Model performance was evaluated using the McFadden pseudo R^2 statistic (R function DescTools), because the normal R^2 cannot be used in logistic

regression. Prior to modelling, the predictor variables were centered and scaled and then transformed to account for non-normality, using the R procedure bestNormalize (Peterson and Cavanaugh 2020).

Results

Differences in Socioeconomic Parameters

Among the study villages, participants mainly differed in terms of sex, whereas mean age, agricultural and economic background expressed in household size, and amount of cultivated land were very similar (Table 2). In Wari and Shari, most interviewees were male, whereas in Nronga and Foo, most were female. Only in Nkuu-Ndoo and Nshara were the samples almost equally in terms of sex. Households in Shari had on average the lowest income, while those in Foo, located close to the Machame entry gate to the Kilimanjaro National Park, averaged the highest. All villages are located in a similar distance from the steep, forested gorges running down the slopes of Mt. Kilimanjaro forests, with the exception of Shari. Distances to the main road range from 0.3 km for Foo to 4 km for Shari.

Average extraction frequency of forest resources differed markedly among villages (Table 3). For instance, Wari households rarely collect firewood from the forest, whereas in the other villages collect forest firewood twice a week. Likewise, Foo, Wari, and Shari households rarely cut fodder in the forests, whereas Nshara, Nkuu-Ndoo, and Nronga households do so frequently.

Although multiple predictors significantly contributed to the firewood, fodder, and medicinal plants models, the predictive power as assessed by the pseudo R^2 was generally not strong (Table 4). The quality of the fruits and vegetable model was too low to be further considered.

Distances from roads and forests were the main predictors of NTFP collection frequency. Villagers living further away from the main road but closer to the nearest forest more frequently cut fodder (Table 4, Fig. 2). Collection frequency of firewood increased with increasing distance to the main road,

Table 2 Means of socioeconomic parameters per village and transformations used to improve normality

Village	DF	DR	Sex	Age	HS	HI	TL	TLC
Foo	0.6	0.3	0.29	45.13	5.11	613,333	3.10	4.22
Nkuu-Ndoo	0.8	1.7	0.68	39.56	4.80	610,975	2.80	4.14
Nronga	0.5	2.0	0.13	42.07	4.22	590,217	2.16	3.72
Nshara	0.5	1.0	0.43	41.30	4.83	566,666	2.58	3.93
Shari	1.5	4.0	0.82	38.48	4.98	480,681	2.56	4.03
Wari	0.6	1.0	1.00	40.68	4.72	575,000	2.67	3.97
Transformation used	Sqrt	order norm	arcsinh	order norm	order norm	order norm	NA	order norm

Abbreviations: *DF* distance to forest [km], *DR* distance to main road [km], *Sex* proportion of males interviewed, *Age* age of interviewed persons [years], *HS* household size of interviewed persons [number of persons in household], *HI* household income of interviewed persons [Tanzanian Shilling], *TL* total land owned by interviewed persons [acres], *TLC* total land cultivated by interviewed persons [acres], *Sqrt* square root transformation, order norm, ordered quantile normalization transformation, *arcsinh* hyperbolic arcsine transformation.

suggesting that villagers close to the main road used commercially available products, such as gas or charcoal (Table 4, Fig. 3). Distance to the forest was less relevant for collection of firewood than for medicinal plants, which were more frequently collected when the forests were further away. This surprising result is mainly due to data from Shari village, where approximately half of the interviewed households visit the forest on a weekly basis to collect medicinal plants, in contrast to other village households going just a few times per year.

In addition to the constraints of distance to forest, individual household socioeconomic characteristics contribute to the prediction of NTFP collection frequency. Younger married females from poorer households with more members and less cultivated land collected firewood more frequently than older people from wealthier households, in particular males (Table 4, Fig. 3). Likewise, fodder collection frequency decreased on gradient from younger females from poor households with many members to older males from richer households with fewer members (Table 4, Fig. 2). The model for collection frequency of medicinal plants had fewer significant predictors than the firewood and fodder models. Males from households with many members collected more medicinal plants than females and people from smaller households. Other predictors such as cultivated

land (positive), household income (negative), and marital status (married) were selected by the stepwise procedure but were not significant.

The variation in the frequencies of extraction of fodder, firewood, and medicinal plants is mainly explained by the distances to forests and the main road. Household characteristics such as age, size, and income only marginally contributed to collection frequencies, with the exception of sex. To determine whether this result remains consistent in conditions where the inter-village variation is negligible, we repeated our analysis with a subset of villages with almost similar distances to the main road and adjacent forests: Nshara, Nkundoo, and Nronga, covering 173 households (Table 5). The only model that was at least marginally acceptable described the relationship between fodder collection frequency and sex, marital status, age, household size, and income for these villages, similar to the model covering all villages in both significant predictors and their directions.

Discussion

Our results suggest that households in all villages extracted forest products, as described by one respondent:

Table 3 Frequency of forest product extractions per study village and year

	Firewood	Fodder	Fruits and vegetables	Medicinal Plants
Foo	87.82	1.64	2.27	3.67
Nshara	92.05	101.61	2.71	2.92
Nkuu-Ndoo	87.51	98.93	3.78	2.80
Nronga	99.48	101.74	1.43	2.72
Wari	0.94	2.52	2.30	4.16
Shari	93.36	0.41	1.48	21.27

Table 4 Significant socioeconomic predictors of NTFP extraction frequency

Predictor	Firewood		Fodder		Medicinal plants		Fruits and vegetables	
	Coef	P	Coef	P	Coef	P	Coef	P
Intercept	-1.34	***	-1.96	***	-2.58	***	-5.04	***
Sex = Males	-0.26	***	-0.07	***	0.08	*	NS	–
Marital status = Married	0.05	***	NS	–	0.05	–	NS	–
Age	-0.07	***	-0.12	***	-0.09	**	0.07	•
Household size	0.07	***	0.10	***	0.19	***	-0.12	**
Household income	-0.04	***	-0.01	•	-0.04	–	NS	–
Land cultivated	-0.03	***	NS	–	0.05	–	NS	–
Distance to forest	0.06	***	-1.16	***	0.79	***	NS	–
Distance to main road	0.14	***	0.82	***	NS	–	-0.13	**
McFadden pseudo R ²	0.11		0.38		0.22		0.01	

Coef predictor coefficient, NS omitted in the stepwise variable selection, P Significance (***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, •: $p < 0.1$, –: $p > 0.1$). Note that the raw data were centered and scaled prior to transformation. Negative signs indicate a decrease of the predictor variable with increasing collection frequency, whereas positive signs indicate an increase. Negative sign of the sex and marital status coefficients indicate females and unmarried persons, respectively

“We collect almost all that is useful from the forest. This ranges from dry firewood, vegetables, fodder, and also medicinal plants. These forests can be our own small forest gorges nearby or the Kilimanjaro National Park forest. We cannot imagine life without the forests considering that firewood is our main source of energy” (Nronga village).

Fodder and firewood were the most frequently collected forest products. In some villages, people visited forests on average every second to third day to collect fodder and firewood. Thus, these forest products contribute important additional household resources (e.g., Kamanga 2008; Mariki 2016). Fruits and vegetables and medicinal plants were much less frequently collected than firewood or fodder (see also Mutoko *et al.* 2015), with villagers on average visiting forests

only one to four times a year for them. This may be because fruits and vegetables are only available during certain seasons. In addition, once collected medicinal plants can be processed and stored for later use, in contrast to firewood and fodder that is needed daily. This was in line with our expectations and is also found in other areas of Africa (e.g., Leßmeister *et al.* 2018).

Extraction frequencies differed between and within villages, particularly for firewood and fodder. Important factors explaining inter-village differences in all resources extracted, with the exception of medicinal plants, were distance to the main road and to the forest. Socioeconomic factors varying both at the inter- and intra-village level provided significant additional explanation. Our results show that fodder and firewood extraction increased with decreasing household wealth as indicated by household income, size, and cultivated land.

Fig. 2 Probability of daily fodder collection in adjacent forests ($p(\text{FreqFodder})$), depending on distance to the main road (ranging from $-1 = \text{approx. } 0.3 \text{ km}$ to $1 = \text{approx. } 4 \text{ km}$) and distance to the adjacent forest (ranging from $-1 = \text{approx. } 0.3 \text{ km}$ to $1 = \text{approx. } 4 \text{ km}$). Left: model calculated for old males with high household income and low size. Right: model calculated for young females with low household income and high household size

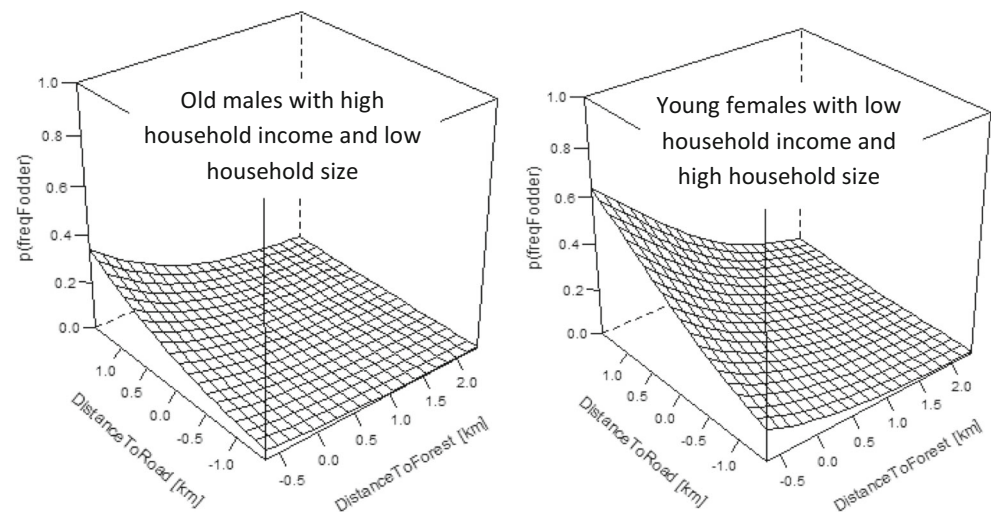
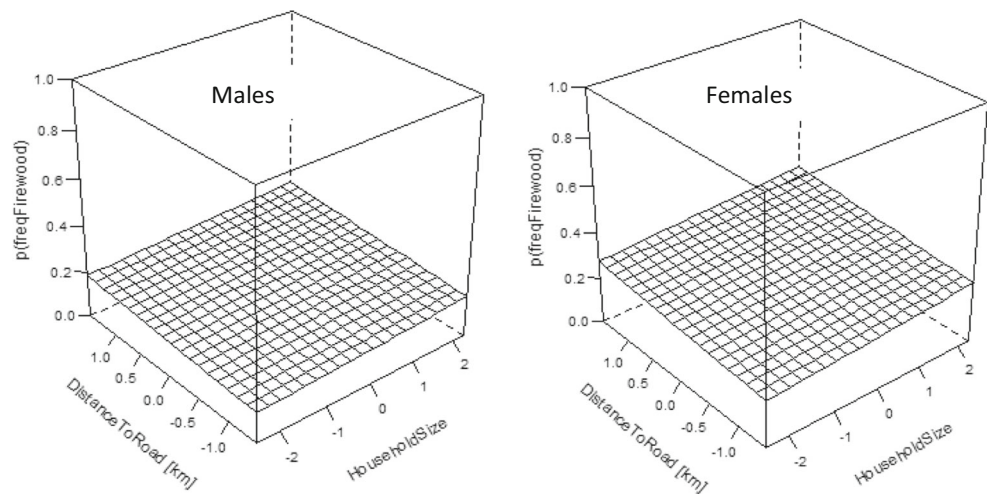


Fig. 3 Probability of daily firewood collection in adjacent forests ($p(\text{FreqFirewood})$), depending on distance to the main road (ranging from $-1 = \text{approx. } 0.3 \text{ km}$ to $1 = \text{approx. } 4 \text{ km}$), household size ($-2 = 2 \text{ persons}$, $2 = 10 \text{ persons}$), and sex (left side: males, right side: females)



This reflects the findings of other studies showing that the extraction of forest resources can contribute significantly to the income of the poorest farmers (Kamanga *et al.* 2009; Mutoko *et al.* 2015). Additionally, younger females collected fodder and firewood more often than older males, highlighting the influence of sex and age on the extraction of NTFPs.

Inter-Village Variation: Distance to Forests and the Main Road

With increasing distance to the main road, extraction frequency of firewood, fodder, and fruits and vegetables increased. The main road connects the study area with the larger settlements and cities surrounding Mt. Kilimanjaro. Roads serve as marketplaces where commodities such as charcoal or gas are sold as alternatives to firewood. For example, Wari is located close to the main road, which may explain why households in Wari collected relatively little firewood and probably used

charcoal as an energy source. Charcoal producers often prefer old-growth hardwood trees and their extraction has a much greater impact on long-term forest sustainability than the fast-growing species favoured by local consumers for firewood (Naughton-Treves *et al.* 2007). As a caveat, we note that the National Park administration considers collection of firewood in the Half Mile Strip illegal (see also Mariki 2016). Hence, many of our informants were reluctant to reveal the frequency of their firewood collections, particularly in Foo and Nronga. Consequently, we clarified and elaborated the nature of our research and our goals to make respondents more comfortable in answering the most critical questions about forest extraction activities and create mutual trust. We also made efforts to conduct some focus group interviews with village leaders and elders to ensure their responses corresponded to those provided by other informants.

Fodder extraction frequency increased with increasing distance to the main road and decreasing distance to the forest.

Table 5 Significant socioeconomic predictors of the NTFP's extraction frequency for the villages "Nshara", "Nkuu-Ndoo", and "Nronga"

Predictor	Firewood		Fodder		Medicinal plants		Fruits and vegetables	
	Coef	P	Coef	P	Coef	P	Coef	P
Intercept	-1.08	***	-0.97	***	NS	–	-3.17	***
Sex = Males	0.02	•	-0.10	***	NS	–	0.13	•
Marital status = Married	NS	–	0.08	***	NS	–	-0.38	***
Age	-0.13	***	-0.11	***	NS	–	-0.15	*
Household size	0.05	**	0.09	***	NS	–	NS	–
Household income	0.02	–	-0.01	***	NS	–	-0.10	–
Land cultivated	0.03	*	-0.06	–	NS	–	-0.13	•
McFadden pseudo R ²	0.07		0.1		–		0.06	

Coef predictor coefficient, NS omitted in the stepwise variable selection, P Significance (***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$, •: $p < 0.1$, –: $p > 0.1$). Note that the raw data were centered and scaled prior to transformation. Negative signs indicate a decrease of the predictor variable with increasing collection frequency, whereas positive signs indicate an increase. Negative sign of the sex and marital status coefficients indicate females and unmarried persons, respectively.

Proximity to the forest allows households to extract more resources with lower labour and transportation costs (Ndagalasi *et al.* 2007). Remoteness impedes extraction not only through increased costs but also through lower probability of entitlement to the resource. We also found an influence of age in relation to distance, as younger persons have more energy to walk long distances for firewood collection (Piland 1991 cited in Godoy *et al.* 1997). Age of the head of household may even be positively related to forest resource utilization until a peak of physical strength is passed.

Besides distance, access to grassland sites could explain differences between firewood and fodder extraction frequencies. Households of Foo and Shari rarely cut fodder in forests, but frequently extract firewood. The difference may be due to fact that forests are their only source of firewood whereas fodder can also be produced on meadows. Meadows are mainly found on very steep slopes along gorges and on the upper border of the settled area where the population density is lower. People of Foo and Shari living close to sites with meadows are probably less inclined to visit forests for fodder collection (Naughton-Treves *et al.* 2007).

Intra-Village Variation: NTFP Extraction in Relation to Sex, Age and Marital Status

Married females more often collected firewood in forests than males or unmarried females. They are likely to have larger households and thus greater demands on their energy. While it is a commonplace that women in rural areas work just as hard as men do, much of their work in household maintenance, such as collecting fuel and water, cooking, looking after children, is unacknowledged (Mariki 2016). An investigation conducted in Gujarat revealed that a substantial portion of women's working time and energy is devoted to such tasks (Nagbrahman and Sambrani 1983). Women often have a higher workload and are often poorer than their male counterparts (e.g., Kamanga *et al.* 2009). This is partly due to social traditions that do not allow female involvement in income generation activities as much as males (Mariki 2016). One female respondent explained further that:

“We women are more concerned with almost all household activities, from cooking, collecting firewood, feeding cows, tending to chickens, cleaning. Sometimes we are also involved in income generating activities like when we cultivate a little more and sell out the rest of the harvest, but all the income is for the man. He plans how to spend it for all of us. It has always been like that, from our ancestor's time up to now” (Nkuundoo village)

There is, however, no overall consensus that females collect more forest resources than males. A study in Malawi did not

find any significant relationship between sex of household heads and income from forest products (Kamanga *et al.* 2009).

In our study, younger people more frequently collected NTFPs than older ones. This may be the case for several reasons. First, fodder and firewood are both heavy and more easily carried by younger, able-bodied persons. Second, the forested slopes of the gorges forming the supply base for firewood and fodder are very steep and therefore harder for older people to access. Third, younger households may be more dependent on wild-collected products, as they care for younger children and have fewer agricultural assets than older, longer-established households (Coomes and Ban 2004). Even medicinal plants were more frequently collected by younger persons, although Ndagalasi *et al.* (2007) found that age is an important factor for extraction frequency of medicinal plants. In a study in the Philippines, elderly people were more likely to collect forest goods because of their more extensive knowledge of forest plants and wildlife (Lacuna-Richman 2002). This is explained by one of our respondents, a female elder who collects medicinal plants for family and village use:

“This is the knowledge I inherited from my grandmother from when I was a young girl. I still practice it now that I am 56. I collect all sorts from barks of trees, seeds, fruits and leaves. I have to go far into the forest to collect them. Usually once to twice a year. I mostly have to boil and smoke-dry [them] to preserve. My medicinal portions heal a range of diseases from simple stomach complications to joint pains and even malaria. Most people are not concerned with traditional medicine anymore, there are better health options and people have better income nowadays to accommodate other health benefits. It is unfortunate that very few young people are showing interest [in] alternative medicine, these are people who would otherwise teach the next generation about this kind of knowledge” (Nronga village).

Extraction of NTFPs in Relation to Land Cultivated, Household Size, and Income

Household size was a consistent significant predictor across all NTFPs investigated, whereas both extent of cultivated land and income marginally contributed to the models. Where significant, the coefficients showed that collection frequency increased with decreasing income and decreasing area of cultivated land, reflecting findings of other studies. For instance, in the Philippines Siebert and Belsky (1985) found the households with the lowest level of rice self-sufficiency relied most on rattan harvesting for income, and in Sri Lanka Gunatilake *et al.* (1993) found that contributions of NTFPs to incomes declined as incomes rose. Similar arguments have been made

elsewhere that the poor are more dependent on forest goods than better-off households (Hegde and Enters 2000), and the poor particularly rely on forest income in times of extreme need (McSweeney 2002). However, we found the relationship between income and NTFP extraction frequency was only marginally significant, indicating a relatively homogeneous income distribution within villages (see also McElwee 2008).

Additional Factors Affecting the Extraction of Forest Products

The Kilimanjaro National Park administration controls which resources are permitted to be extracted, especially at the former Half Mile Strip, and intensive and widespread exploitation of the forest in the National Park is considered illegal. This has not stopped the villagers from extracting non-timber forest products, leaving patches of deforestation in the lower montane forest that lead to soil erosion and a decrease in water discharge from the mountain. According to Yanda and Shishira (2001), there have been significant changes in land cover on the slopes of Mt. Kilimanjaro since the 1950s. Natural forest on the southern slopes has decreased by about 41.04 km². Some areas that were under natural forest in 1952 were already under cultivation or degraded in 1982.

Education plays an important role in NTFP extraction, since educated individuals may be in a better position to tap into income flows from natural stocks. Godoy and Contreras (2001), however, found that a higher level of formal schooling is associated with less forest cutting. Adhikari *et al.* (2004) argued that a higher level of education makes fuel wood collection increasingly unprofitable due to higher opportunity costs of labour. Improved off-farm employment opportunities and access to credit (Godoy *et al.* 1997) may reduce forest clearance as a source of supplementary income. The World Bank (1992) suggested that markets enhance conservation where there are secure property rights. On the other hand, greater access to forests and markets may often accelerate forest extraction (Angelsen and Kaimowitz 1999). Nevertheless, the role played by non-educated people, particularly the elderly, in sustainable forest management and the importance of traditional knowledge for the protection of biodiversity cannot be underestimated (Gadgil *et al.* 1993). At the farm level, promotion of other income-generating activities such as beekeeping, mushroom farming, and agroforestry may reduce the exploitation of forest resources. Community policies should facilitate tree planting in home gardens and the use of energy saving stoves to reduce energy dependency on the forest.

Cavendish (2000) has noted that the contribution of forest resources to the welfare of rural households is regularly overlooked in poverty surveys. Empirical investigation of dependency on forest resources may help to improve macro-level poverty estimates and improve policy planning and

execution. The quantification of environmental income (Sjaastad *et al.* 2005) may serve as an input into conservation policy, and particularly establishment of protected areas, by determining the potential loss to rural dwellers of reduced access to environmental resources.

Conclusions

We found evidence of considerable community dependence on NTFPs on the slopes of Mt. Kilimanjaro. Firewood is collected frequently in the forests, underlining the energy needs in many households. Except for one study village, charcoal, gas, or electricity has not replaced firewood as the primary source of energy for cooking. Forests provide over 90% of the Tanzanian national energy supply through wood fuel and charcoal (Milledge *et al.* 2007). In three out of six villages, people also visited forests on average twice a week to cut fodder for livestock. Fruits and vegetables as well as medicinal plants are collected less frequently, probably due to their seasonal availability. Our results demonstrate that natural forests can provide important provisioning services for local communities (Heubach *et al.* 2011). On the other hand, extraction of non-timber forest resources can strongly impact the structure and biodiversity of natural forests (Ticktin 2004). Apart from logging, firewood collection is the most detrimental use of natural forests as it weakens adult trees, destroys young trees, and diminishes nutrient flows through biomass removal (Chettri *et al.* 2002). On Mt. Kilimanjaro, NTFP extraction thus exacerbates the negative effects of land use on ecosystem functions (Peters *et al.* 2019). Conservation methods should be incorporated into forest resource management policies in order to ensure sustainability (Mackenzie and Hartter 2013). Sustainable forest management requires capacity building, awareness raising, and participatory involvement of the local communities (e.g., Agrawal and Ostrom 2001). Tanzania has made significant steps towards improving participatory management of its forest resources through the implementation of Community Based Forest Management and Joint Forest Management Programmes (Blomley *et al.* 2008). Our study may help to better target local community participation. Regarding the sustainable management of NTFP collection, all households should be engaged, in particular women in poor households with many members. Changes in road infrastructure and market access can strongly impact rates of local extraction and consumption of forest products. Socioeconomic and infrastructure contexts at both the inter- and intra-village level are important to understand the benefits local communities obtain from natural forests.

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Author’s Contribution All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Hawa Mushi. The first draft of the manuscript was written by Hawa Mushi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent Participation in the study was voluntary and anonymous. Informed consent was obtained from all individual participants included in the study. The data and personal information collected through this study were treated confidentially.

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