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Household determinants of bushmeat and eru (*Gnetum africanum*) harvesting for cash in the Democratic Republic of Congo

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Abstract Peri-urban pressure on the Luki Biosphere Reserve in Bas-Congo, Democratic Republic of Congo, is fuelled by growing demand in urban markets coupled with easy access. With data from 175 randomly selected households, this paper examines factors that motivate households to collect two major forest products found in the reserve for cash. We analyse the factors determining the choice of engaging in collection of bushmeat and eru (Gnetum africanum) and the factors determining the success (outcome) in collection using the Heckman selection model. This model explicitly separates estimation of selection into the activity from the outcome, to provide unbiased estimates of both. Results show that being local, higher household labour availability and higher asset endowment were positively related to selection into bushmeat hunting, reflecting higher risk-carrying capacities, ease of access to equipment and resources. Greater market distance being a female-headed household and greater age of household heads negatively affected selection into eru collection, reflecting characteristics of cash harvesting activities. Low education and more local knowledge characterised more successful outcome of eru collection, whereas having more household labour tended to lower outcomes of both bushmeat and eru collection suggesting that labour pools engaged in these activities were not sufficiently skilled, or that a higher proportion was consumed in such households. We discuss our findings in relation to the role of these activities in providing a pathway out of poverty and stress the needs for better integration of conservation and development policies.

Keywords Forest products · Heckman model · Conservation · Cash income · DRC

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1 Introduction

Forests are recognised as a significant source of income, food and resources for local communities in developing countries, with its goods contributing on average 28 % of total household income according to a global survey (Angelsen et al. 2014).

Available evidence indicates that collection of non-timber forest products (NTFPs)[1] remains particularly important for poor households, by reducing inequity and providing essential nutrients, food and cash income (e.g. Cavendish 2000; Fisher 2004; Appiah et al. 2009; Fa et al. 2015a). However, although cash income from forest products may contribute to accumulation of wealth, its capacity to contribute to poverty reduction may be less than its contribution to poverty prevention and alleviation (Angelsen and Wunder 2003). Understanding the role of forest products in livelihoods is critical for shaping effective forest management and development policies in the Congo basin (Coad et al. 2010), particularly where the long-term sustainability of exploited resources is a concern. Examining the role of forest products in cash income generation, its contribution to asset accumulation and poverty alleviation, as well as households' decision to choose partaking in one income-generating activity over another, is particularly pertinent. Therefore, in this paper, we focus on two intensely exploited forest products in Democratic Republic of Congo (DRC): bushmeat, defined here as the meat of any wild animal, and eru (*Gnetum africanum*), a wild plant, whose subsistence consumption and trade contribute to food security and livelihoods of households in much of Central Africa (e.g. de Merode et al. 2004; Ingram et al. 2012). These two products are very important in local consumption and trade, and we therefore explore how they contribute to asset accumulation. We also examine the factors motivating households to self-select into these collection activities, as well as what contributes to their success in these activities.

Central African urban populations often prefer bushmeat over domestic meat, due to cultural and taste preferences (Fa et al. 2003; Mbete et al. 2011; van Vliet et al. 2012). Increasing demand from growing urban populations, easier access to remote areas and improved hunting technologies has spurred the commercialisation of bushmeat. The high value to weight (e.g. value per kg.) ratios and low perishability of dried bushmeat make the trade more profitable than unpredictable and irregular wage labour (Bennett et al. 2007; van Vliet et al. 2011; Tieguhong and Zwolinski 2009) or alternative livelihood options that may not exist in rural communities (de Merode et al. 2004; Coad et al. 2010). Bushmeat hunting is thus turning into a multi-million dollar trade supplying urban restaurants and luxury markets as far as Europe (Chaber et al. 2010). The bushmeat trade is considered a major threat to conservation of biodiversity in tropical forests (Milner-Gulland et al. 2002), with 60 % of hunted species in the Congo basin exploited at an unsustainable level particularly in areas with high population density (Fa et al. 2005, 2015b). Numerous mammal species are showing consistent decline and local extinction in what has been termed the 'bushmeat crisis' (Blake et al. 2007; Bouché et al. 2009; Wilkie and Carpenter 1999). Depletion of wildlife will ultimately impact the rural poor to whom bushmeat is an important source of protein and income (de Merode et al. 2004).

[1] Along with the literature we define NTFP as "all biological materials other than timber, which are extracted from forests for human use" (Belcher 2003, p. 161). NTFPs thus include products from roots, fruits, fish and game or 'bushmeat' used for foods, a range of medicinal plants, resins and essential oils, to fibres such as bamboos, rattans and other palms used for structural applications. Measuring the contribution of NTFPs in rural livelihood surveys is a recommended standard (Angelsen et al. 2011).

Eru also known as *fumbua* in the DRC is a sub-spontaneous dioecious liana primarily found in disturbed areas of humid tropical lowland forests, including farm fallows, secondary forests, forest openings, but also in closed canopy forests (Clark et al. 2004). Its high nutrition and protein content make it highly valued throughout Central Africa where it is used in food and for medicinal purposes (Ndoye and Awono 2007; Ingram et al. 2012). It is now one of the most commonly consumed plants across the Central African region and amongst the African diaspora in Europe, constituting a sign of higher social status and national and ethnic identity, rather than poverty (Clark et al. 2004; Abia et al. 2007). It is commonly consumed, shredded finely in a stew and eaten with *fumbwa*, similar to the preparation in Cameroon (e.g. Sneyd 2013). Trade in eru leaves is important throughout the Congo Basin, and the *Gnetum* spp. sector directly involves at least 1744 people in DRC representing a valuable trade that is estimated at $ 1.2 million per year in Kinshasa alone (de Wasseige et al. 2012). However, 40 % of *Gnetum* spp. are harvested unsustainably despite available harvesting guidelines (Ndumbe et al. 2009). Such excessive and unsustainable harvesting techniques involve removal of all leaves, which has led to local extinctions in Nigeria and Cameroon, and near-threatened status on the IUCN Red List (Clark et al. 2004; Lakeman and Bachman 2008). Scarcity of supply combined with growing demand and improved access to forests has turned the eru trade into a lucrative business, allowing local smallholders as well as migrant harvesters to engage in eru extraction for sale at high prices in urban markets, as was found in Cameroon (de Wasseige et al. 2012; Sneyd 2013).

In the following sections, we first introduce the study area. Secondly, we present the methods for data collection used in this study and describe the econometric approach taken for data analysis. The analytical approach taken relies on the Heckman model that to date has had limited application in the poverty environment and livelihoods literature (e.g. Palmer and Macgregor 2009). It is an analytical approach that allows the estimation of factors that determine success in collection (the outcome), whilst taking into account the information from households that have not opted into this activity (self-selection), as opposed to, for example, models mainly focused on the outcome of hunting efforts for hunters (see, e.g. Tieguhong and Zwolinski 2009). We also develop a model of household assets dynamics. These models provide the framework for our testable hypotheses about what factors drive, respectively, selection into and success of harvesting the two forest products and the contribution of such activities as a pathway out of poverty, using accumulation of livestock as a proxy for wealth accumulation. Thirdly, we estimate the specified models based on a dataset of 175 rural households in villages around the Luki Biosphere Reserve in DRC to determine (1) the characteristics of households that self-select into a particular collection activity and (2) the characteristics of households that have a better outcome in terms of cash income from this activity. We also present the analysis of factors contributing to livestock asset accumulation, using the change in livestock asset holdings as an indicator of wealth accumulation or liquidation in the rural household economy. We conclude by discussing the limitations of our approach and importance of sustained forest resource extraction in rural livelihoods.

2 Study area

The Democratic Republic of Congo is home to the second largest expanse of tropical forest in the world after the Amazon (Debroux et al. 2007). However, it is one of the poorest countries in the world based on GDP and with poverty affecting 63 % of its 70 million

people (World Bank 2015). Fieldwork was carried out around the Luki Biosphere Reserve, Bas-Fleuve district (Lower-River), Bas-Congo Province (Lower-Congo; see Fig. 1). This reserve is located at 05°30′–05°45′S and 13°07′–13°15′E, approximately 120 km from the Atlantic coast. Luki was a hunting reserve during the colonial period, but in 1937 it was instituted as a research area and was formally designated as a UNESCO Biosphere Reserve in 1976 (Debroux et al. 2007).

The forests of Luki Biosphere Reserve cover an area of 32,968 hectares divided into core, buffer and transition areas characterised as lowland rainforest ecosystem. The majority of the population is engaged in shifting slash and burn cultivation. Main agricultural products are manioc, banana, plantain, beans, maize and rice. Domestic animals mostly include chickens and ducks with a few households owning goats and pigs. Poultry and goats are annually affected by disease during the drier months, resulting in large losses of stocks and making domestic animal rearing a risky activity. NTFP collection is important in the area: products such as bushmeat, fruits, mushrooms and other wild plants are mainly collected for sale and consumption, where occasionally

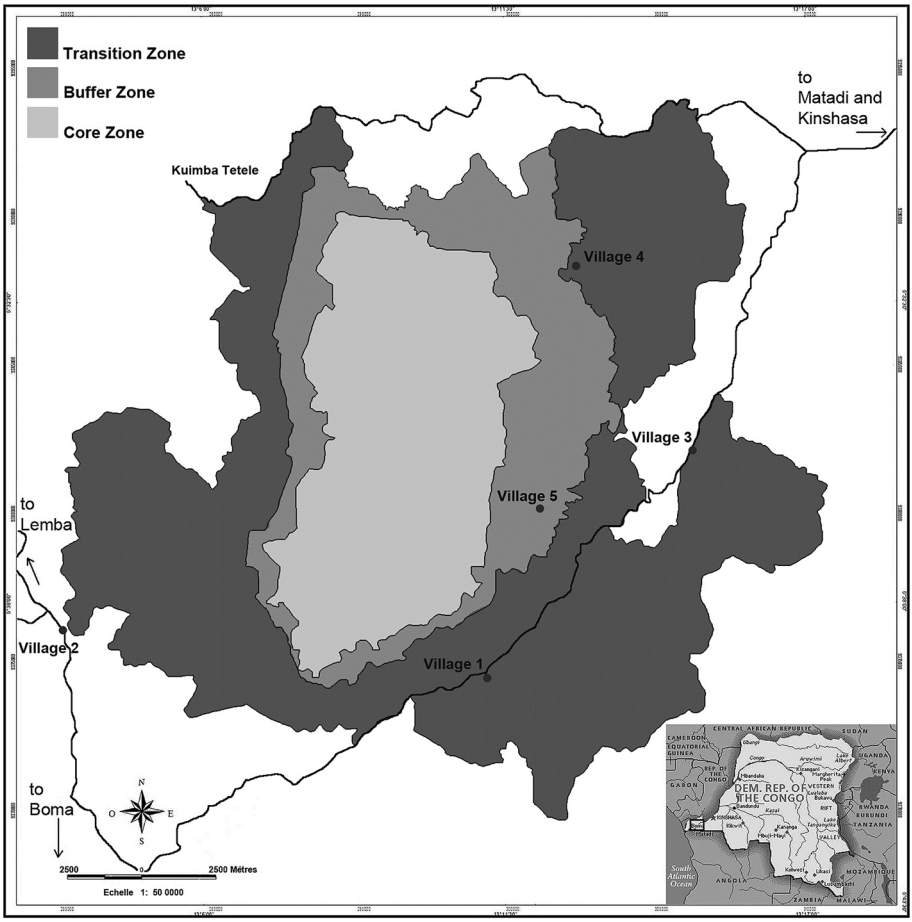

Fig. 1 Map of study area and its location within the Democratic Republic of Congo

leaves (e.g. banana and *Marantaceae* leaves) and rattan are collected for packaging of agricultural products or construction (Bakkegaard 2008). Timber has also long been exploited in the Bas-Congo area due to the province's proximity to the coast (Debroux et al. 2007).

3 Methods

3.1 Data collection

Quantitative data were collected through household surveys as part of the CIFOR Poverty Environment Network (PEN) global comparative study, which applied a standardised set of village and household-level questionnaires to elicit comprehensive data about the importance and role of environmental income in rural livelihoods (Angelsen et al. 2014). Five representative study villages were purposefully selected out of nineteen villages peripheral to Luki. In total, 220 households were randomly selected using a village-stratified sampling strategy. Four quarterly surveys on household income, consumption and expenditure (Q1, Q2, Q3, Q4), two annual surveys on household size, assets and crises (A1 and A2) and two village-level surveys on geographic and socio-economic aspects (V1 and V2; CIFOR 2008) were conducted between November 2007 and August 2008. Final sample size was 175 households after attrition of households who did not take part in all four interviews due to the absence or migration. The main method of valuing environmental goods was own-reported values, as most products are traded regionally or at least locally, providing 'real' farm gate prices as opposed to inflated urban prices. Income data were converted to PPP adjusted USD by a conversion factor of 66.6 Congolese francs (CDF) and converted to adult equivalent units (AEU), which accounts for differences in household composition and size and therefore allows comparisons between households (Cavendish 2002).

3.2 The Heckman selection and outcome model

The collection of quantitative data permits the use of econometric approaches to determine how household characteristics and possessions amongst other factors can explain participation in certain activities. Standard regression models of outcome regressed on household descriptive variables are likely to suffer from selection bias, when households self-select into the activity studied. The Heckman model allows simultaneous estimation of factors determining households' self-selection into bushmeat and eru collection for cash, as well as the factors determining the success or outcome of the collection activity. The model consists of an integrated two-part estimation of selection into the activity and its outcome, which overcomes common issues of endogeneity arising from sample selection in other models. The Heckman model allows us to account for self-selection into activities based on the argument that a household will only opt to select into any activity if it is part of the household's optimal set of income-generating activities. That is, Heckman (1979) importantly notes that when observing households' income-generating activities, the observer only observes effort and outcome of those that self-selected into that activity. The potential outcome of others may not be zero, had they selected into the activities, and thus, the estimation must account for this. Therefore, the selection equation is modelled as:

$$w_i^* = \gamma' Z_i + u_i \tag{1}$$

where w_i^* is the latent variable, related to a set of exogenous variables, Z_i, and $w_i = 1$ if $w_i^* > 0$ and $w_i = 0$ otherwise. The probability of observing participation, i.e. $w_i = 1$, as a function of Z_i is defined as a probit model:

$$\text{Prob}(w_i = 1|Z_i) = \Phi(\gamma' Z_i) \tag{2}$$

$$\text{Prob}(w_i = 0|Z_i) = 1 - \Phi(\gamma' Z_i) \tag{3}$$

when $w_i = 1$, we observe an outcome of bushmeat or eru income for household i, which we call y_i. The outcome part of the model will then describe the outcome of collection in terms of the value of eru and bushmeat, and its relation to a subset of variables x (which may overlap with Z):

$$y_i = \beta' x_i + \varepsilon_i, \quad \forall i, \quad \text{where } w_i = 1 \tag{4}$$

We assume the error terms to be distributed as $(u_i, \varepsilon_i) \sim$ bivariate normal $[0, 0, 1, \sigma_\varepsilon, \rho]$, allowing for possible correlations in the error terms.

From classic household models (e.g. Singh et al. 1986; Deaton 1999), we expect that variables stemming from the sustainable livelihoods framework,[2] such as human capital–education, age, gender and knowledge (ethnicity and migration status) and available household labour, may be important determinants of outcome (in x) and hence also of the decision to participate or not (Z). SLA is useful as a conceptual frame; however, it suffers limitations. For instance, capital possession in itself does not determine the outcome or selection into an activity, as capital often needs to be transformed in some way. Moreover, different forms of capital may influence selection and outcome in different ways (Angelsen and Wunder 2003). Therefore, there are factors likely to determine the decision to select into collection that are not likely to affect the outcome and should therefore only be included in the selection equation as part of Z. These include, for example, economic capital or wealth variables such as non-productive assets, number of dependents (children below 15) as well as the levels of income from salary work, which indicates the shadow value of labour in alternative occupations or income-generating activities. Physical capital including distance to market was also considered. However, distance to the forest was not included as households always conglomerated around a village centre with negligible variance in distance to forests. Finally, some variables may appear with dual effects, e.g. surplus of labour (low opportunity costs of labour) may positively affect selection probability, but may not translate to a good performance due to, for example, issues of skill.

3.3 The asset dynamics model

Asset dynamics, which is how economic capital changes, is an important aspect in credit-constrained households. Assets have several functions in the household livelihood strategy: firstly, in the choice of the productive activities that a household can choose and is able to engage in; secondly in productive use that can enable the household to accumulate wealth; and finally as a buffer against shock through liquidation (Takasaki et al. 2000; Malchow-

[2] Sustainable Livelihoods Approach (SLA) is a concept developed by the British Institute of Development Studies (IDS) describing five factors that represent the main asset categories which contribute to a holistic assessment of the livelihoods of the poor. These include natural, human, social, physical and economic/financial capital (Scoones 1998).

Møller and Thorsen 2005). In the first function, case studies have shown that asset-rich households are more likely to engage in high-return forest activities (e.g. Fisher 2004). In many rural developing contexts, productive assets, such as land, have little immediate value for generating quick cash due to incomplete markets for such goods. More readily liquidated assets, such as cash savings and livestock, are essential in households' ex ante strategies for coping with shocks as well as in assisting in wealth accumulation. Indeed, investing savings as livestock means that part of their income is kept in an easily cashable form, and livestock can be considered a form of banking in contexts where credit and lending institutions are non-existent (van Vliet et al. 2011). In the case of DRC, the households' asset holdings were largely dominated by livestock. Very few other types of assets, such as cash holdings, jewellery and other forms of savings, were found amongst households in the survey. However, livestock assets are often expensive and require significant cash generation to allow acquisition (i.e. accumulation is lumpy). This may cause different sources of income to contribute in different ways to the accumulation of livestock assets (Devereux 2001; Dercon 2002). Some forms of forest products may be more easily traded into cash than others, and this facilitates accumulation of savings that can be used to pre-empt shocks, mitigate risks and fill gaps such as lean season shortages. In particular, low-volume high-value products that can be easily transported and traded for significant cash amounts may be more suitable for financing livestock accumulation. If such dynamics are in play, they may be an important part of the motivation for collection of bushmeat and eru. To test this hypothesis, we ideally need to estimate the relation between the change in livestock assets over the observed period and the income generated by the g activities over the period and the initial livestock, i.e.:

$$\Delta A_{ti} = \sum_{g=1}^{G} \lambda_g p_{t-1}^{g} x_{t-1,i}^{g} + \theta A_{t-1,i} + \varepsilon_i \tag{5}$$

Here, we test the hypothesis that λ_g is the same across all G sources of income, and pay particular attention to the parameter on bushmeat and eru income. Also, one would expect that *ceteris paribus* the parameter θ on A_{t-1} should at most reflect a natural growth rate of livestock assets contributing to accumulation.

It is a major challenge for estimation here that the count of livestock assets cannot be considered equivalent across different livestock types. That is, one chicken cannot be considered as valuable as one goat. Thus, our outcome variable is the increase or decrease in value (in monetary terms) of livestock assets over the year. Moreover, households are typically only active in a subset of income-generating activities, and standard practice in household survey analysis of income contributions is to consider those income sources where the household is non-active as zero (e.g. CEDLAS and World Bank 2012). Thus, for each household there are several unobservables (zero income from zero activity), which affect possibilities for valid inference and led to estimating a stepwise OLS on income contributions to livestock accumulation, corresponding to Eq. (5). In addition, we also estimated pairwise correlations between income by sources and changes in livestock holdings.

4 Results

4.1 Contribution of bushmeat and eru to household income

Descriptive statistics on household characteristics and contribution of income sources to total annual income are presented in Table 1. Cash income from bushmeat and eru

Table 1 Descriptive statistics on socio-economic and income of households (USD PPP and AEU adjusted)

	N	Mean	SD	Min	Max
Household characteristics					
Age of HH head (years)	173	47	13	21	81
Education of HH head (years)	175	4.63	3.39	0	14
Average education > 15 years	175	4.11	2044	0	10
HH members > 15 years	175	2.51	1.07	1	7
HH members < 15 years	175	2.38	1.85	0	10
Assets					
HH assets per AEU	175	128.59	216.39	0	1956.74
Livestock beginning value per AEU	152	108.86	248.08	0	2099.6
Livestock end value per AEU	152	69.75	166.05	0	1620.04
Change in livestock value per AEU (delta_liv)	152	−39.10	267.02	−2009.5	1333.55
Distance to market (km)	164	15.86	15.46	0	45
Household income 2007–2008					
Income per AEU	175	1192.97	1529.01	−4416.9	10,834.45
Net forest income per AEU	175	154.57	144.02	17.26	912.2
Cash (gross)		35.23	82.21	0	649.4
Subsistence (gross)		120.25	90.80	17.26	598.99
Net environmental income per AEU	149	55.86	102.31	0.25	805.34
Cash (gross)		35.95	69.22	0	503.30
Subsistence (gross)		22.37	63.13	0	534.08
Salary income per AEU	47	142.86	171.50	−0.02	741.98
Business income per AEU	163	232.73	487.33	−9.84	4932.61
Net crop income per AEU	175	647.88	1194.46	−4512.91	9885.72
Cash (gross)		793.11	992.88	0	7594.80
Subsistence (gross)		670.55	551.58	34.76	4047.67
Net livestock income per AEU	152	43.87	136.13	−489.64	959.58
Other income per AEU	58	149.98	237.01	3.95	1171.71
*Cash forest product income per AEU**					
Bushmeat	28	67.84	105.11	3.11	401.71
Eru	72	42.47	88.69	0.75	604.4
Fuel wood	10	31.45	39.74	7.18	138.11
Wild foods	33	23.77	30.89	1.27	163.38
Poles timber other forest products	10	10.95	13.79	1.65	48.29
*Subsistence forest product income per AEU**					
Bushmeat	57	58.74	79.21	2.21	451.52
Eru	35	4.52	5.83	0.36	26.48
Fuel wood	175	71.52	48.01	12.99	286.70
Wild foods	128	26.50	32,99	0.24	183.67
Poles timber other forest products	84	19.37	33.47	0.36	259.38

HH household, *AEU* adult equivalent units

* Only includes HH with income from the relevant product

constitutes, respectively, 58 and 73 % of all forest cash income for those involved in these trades and 21 and 31 % of total forest income (which includes cash and subsistence income), showing that these products are significant contributors to forest-derived income. For those harvesting bushmeat and eru, total forest income provides 19 and 16 % of total income, respectively.

4.2 Results of the Heckman model

Results of the Heckman selection and outcome regression model (i.e. determinants for the likelihood of participation in this activity and the magnitude of the resulting income) for bushmeat and eru collection for cash are presented in Table 2. Models for both products were estimated with the same independent variables that were considered important determinants of selection into both bushmeat and eru collection and in explaining the cash outcome of these collection efforts.

On inspection of the variables in the selection function, we find that value of households' assets at the beginning of the year have a highly significant positive influence on selection into bushmeat collection, whereas there is no such effect in the eru model. Being local (which refers to belonging to the local ethnic clan, as opposed to being a migrant) and having higher available labour in terms of household members above 15 years have a significant positive, although weak (i.e. on the 0.10 level), influence on selection into bushmeat hunting. Distance to market had no significant effect on selection into bushmeat activities, but was highly significant in the eru selection model. The head of the household being female and age of the household head had a significant negative effect on selection

Table 2 Results of Heckman model for selection into and outcome of bushmeat and eru cash income

	Log bushmeat		Log eru	
	Coefficients	SE	Coefficients	SE
Selection variables				
Avg. education over 15 years	−0.091	0.060	−0.074	0.045
Local (=1 Migrant = 0)	0.509*	0.278	0.303	0.269
HH assets	0.002**	0.001	−0.001	0.001
HH member over 15 years	0.199*	0.120	0.091	0.102
Distance to market	0.011	0.008	−0.022***	0.008
Female head	–		−0.526*	0.293
Age of household head	–		−0.017*	0.009
Intercept	−1.730***	(0.623)	1.062**	0.526
Outcome variables				
Avg. education over 15 years	–		−0.202**	0.100
Local (=1 Migrant = 0)	−0.684	0.499	1013**	0.455
HH members over 15 years	−0.472**	0.212	−0.317*	0.183
Intercept	5836***	1.083	3100***	0.846
Rho	−0.509		0.528	
Wald Chi square	8.40**		14.38***	
N	164		162	

*, ** and *** Signify statistical significance at 0.1, 0.05 and 0.01 levels, respectively

Italics are the group categories

into eru collection, but were not significant in the bushmeat model and hence dropped using the stepwise process.

In the outcome models, availability of household labour was significantly negative for both eru and bushmeat. For eru, being a local had a significant positive effect on the outcome, whereas higher education levels appeared to have a negative effect.

Several variables that were initially thought to be important for selection into these activities for theoretical reasons (cf. specifications of the Heckman model above) were initially included in the models, but dropped through backward elimination. These include education of the household head, number of children younger than 15, as well as income from salary paid work and agricultural income as indicators of the opportunity costs of labour. In addition, assets and distance to market were insignificant in the outcome equations and hence dropped.

4.3 Contribution of bushmeat and eru to asset accumulation

We used livestock value as an indicator of asset accumulation at the household level. Basic statistics on household livestock assets and their variation between the first and the last quarter of the survey period (i.e. beginning and end values) are shown in Table 1. Pigs, sheep and goats had the highest average price per unit, as well as highest *average* value of holdings at beginning and at the end. Pigs have the highest *total* value of holdings in the beginning and at the end, followed by chickens and then goat holdings across households. There was, however, considerable variation between households in this wealth indicator.

Two methods were applied to test the relationship between livestock asset dynamics and income sources. In the OLS regression (Table 3), several variables were initially included and subsequently dropped. These results show that bushmeat cash income and agricultural cash income have positive and significant correlation with asset accumulation although only on the 0.1 level. Beginning value of household assets and livestock plus fuelwood cash income had a strong negative correlation with asset accumulation.

The corresponding set of simple pairwise correlations between change in value of livestock assets and value of income from various sources shows that an increase in value of livestock assets is positively correlated ($p < 0.05$) with the value of bushmeat sold and negatively correlated ($p < 0.01$) with the beginning value of livestock (Table 4). This confirms that trade in bushmeat does contribute to livestock asset accumulation, and also that asset accumulation occurred at a higher rate amongst the livestock poor (i.e. those that did not own much livestock in the beginning accumulated more).

Table 3 Determinants of livestock asset accumulation

	Coefficient	SE
Intercept	20,713	14,667
Household assets	−0.132**	0.065
Beginning value of livestock assets	−0.944***	0.063
Bushmeat cash	1.857*	1.112
Fuelwood cash	−0.480***	0.133
Agriculture cash income	0.045*	0.024
R squared	0.78	
N	131	

*, ** and *** signify statistical significance at 0.1, 0.05 and 0.01 levels, respectively

Table 4 Pairwise correlation coefficients for livestock asset accumulation

Variable	*N*	Change in livestock value per aeu (Delta_liv)	*p*
Household assets	152	−0.134	0.100
Bushmeat cash	55	0.266	0.049
Eru cash	78	−0.155	0.176
Fuelwood cash	152	0.027	0.743
Wild foods cash	122	0.027	0.769
Other forest cash	81	−0.058	0.608
Forest cash income	152	0.082	0.316
Envl cash income	131	0.001	0.990
Crop cash income	152	−0.029	0.720
Salary income	40	0.066	0.686
Business income	145	0.015	0.858
Other income	49	0.142	0.331
Beginning value of livestock assets	152	−0.795	0

5 Discussion

5.1 Determinants of selection into and outcome of bushmeat and eru harvest

5.1.1 Economic capital

Rising income is often associated with greater livelihood diversity and reduced time spent extracting forest products with low returns (Angelsen and Wunder 2003). However, wealth may also enable investment in hunting equipment and means of transportation (e.g. a bicycle) enabling larger scale extraction and better access to markets. Greater social and financial capital of wealthier households may also enable them to obtain easier access to resources (e.g. through bribes or social networks). Finally, asset-rich households typically have access to a greater pool of labour to hunt and sell bushmeat (Lampietti and Dixon 1995; Arnold and Ruiz-Perez 2001). Our results show that asset endowments are positively correlated with selection into bushmeat hunting as observed in a number of cases (Starkey 2004; Coad et al. 2010; Kümpel et al. 2010).

Asset endowments may importantly represent a buffer against risk. Asset endowments could ensure that households were able to endure the risks involved with returning empty-handed from hunting expeditions, in terms of ensuring food security (through liquidation of assets for cash) and being able to pay fines and bribes. As a result, studies show that within rural communities, middle or even higher income groups harvested the most bushmeat (Coomes et al. 2004; de Merode et al. 2004). In our case, however, we do not find support for the outlined pattern in the outcome models for either bushmeat hunting or eru collection, suggesting that there is no significant difference between the outcome of bushmeat hunting and eru harvesting activities between lesser and better endowed households. Absolute volumes of bushmeat collected will nevertheless differ between asset-poor and asset-rich, as asset-rich are more likely to enter the bushmeat trade.

5.1.2 Human capital

5.1.2.1 Labour A third of traded bushmeat in Kinshasa comes by road from Bas-Congo, and cash prices fetched can be quite high (Debroux et al. 2007). Since bushmeat is a lucrative trade, it makes sense that households would invest excess available labour in the exploitation of bushmeat. The number of household members above 15 years of age was used as a proxy for labour and was included in both models. This variable showed opposing effects for selection and outcome. For bushmeat, more labour weakly increased the likelihood of selection into bushmeat as observed in other locations (Starkey 2004; Coad 2007), whereas this variable had no significant effect for eru. For both products, however, households with more labour available within the household tended to have lower outcomes (i.e. total value harvest), *ceteris paribus*. Indeed, having more household labour available may reduce the marginal opportunity costs of labour, i.e. the foregone income of an extra household member will mean less in terms of total pool household income, compared to a smaller household with fewer members. This means that more labour can be invested in bushmeat hunting without forgoing income from alternative activities elsewhere (e.g. McElwee 2008). However, once engaged in bushmeat hunting, households with more adults on average obtained less cash income per AEU from bushmeat as well as eru. There are several possible explanations: in these households, the part of the (surplus) labour resources used in these activities may not have been sufficiently skilled; that they were only partly engaged in the collection activities; that a higher proportion of the collected products (in the case of bushmeat at least) were consumed in the household; or that there were diminishing returns to effort.

5.1.2.2 Socio-demographics characteristics Several socio-demographic variables had significant effects on selection into eru harvesting and its outcome than in the case of bushmeat. Studies of gender participation in Cameroon have shown that eru harvest and trade are an important economic activity for women involved in NTFPs and that women dominate the trade at all levels (Henkemans 1995; Clark 2001; Sneyd 2015). However, the escalating value of eru has led to increasing male participation—a trend also seen in DRC (Clark et al. 2004) and reflected in our results. Male-headed and younger households were more likely to select into eru harvesting, which is reflected in the fact that collectors may spend several weeks away at a time (de Wasseige et al. 2012). Eru collection with its physical demands may also be less attractive for aged households (Vedeld, et al. 2004; Mamo et al. 2007), who tend to turn to collection-based activities that demand less physical activity and have lower entry barriers (Cavendish 2000; de Merode et al. 2004; Mamo et al. 2007). Gender differentiation in income generation is furthermore a strong characteristic of African societies (e.g. Cavendish 2000), and lucrative and/or commercial economic activities are often the domain of men (e.g. charcoal making, Fisher 2004; bushmeat hunting, Cavendish 2000). Moreover, women in rural areas typically have lower power and ownership rights over resources, such as land and other productive assets (Paumgarten 2005). This, however, does not rule out that some women may still be involved in this harvesting activity.

Households with higher levels of education tend to depend less on forest income (Cavendish 2000), but may obtain higher absolute forest income by being better able to exploit these income opportunities (Mamo et al. 2007). In our case, the outcome of eru collection for cash was negatively affected by higher education levels amongst household

members above 15 years. This may reflect the increasing opportunity costs of engaging in this lower return activity for more educated households.

5.1.2.3 Local ethnicity Being local as opposed to a migrant household had effects on selection and outcome of bushmeat and eru collection. Selecting into bushmeat hunting was more likely amongst local households and could reflect broader social networks and status as a result of kinship ties, and perhaps local ecological knowledge. These aspects not only facilitate better access to products, harvesting and marketing opportunities, but can also provide a safety net in case of failure of this livelihood strategy (Pattanayak and Sills 2001; Lacuna-Richman 2006). Outcome of eru collection was also higher amongst local households, which could likely reflect possession of local ecological knowledge and experience that has been shown to be an important determinant in exploitation of forest products (Pattanayak and Sills 2001). Conversely, migrants could lack the tradition for forest product collection, the local ecological knowledge (i.e. about the spatial and temporal distribution of the product) or be restricted in their access to forests to intensively harvest such products (Vedeld et al. 2004).

5.1.3 Physical capital

Proximity to markets is the key to 'realising the economic values of wild products' (Vedeld et al. 2004, p. 135), and less distance to market was found to significantly determine selection into eru collection. In the case of eru in other contexts, the price of eru fluctuates according to season and fuel prices, which directly reflect the accessibility to markets (Clark et al. 2004). In our case between the products, proportions of traded eru were higher than traded bushmeat, where some proportion of bushmeat was consumed by 96 % of households involved in hunting (with only 4 % of households selling all harvested bushmeat). Nevertheless, forest product collection, in particular for subsistence, may in some cases be more intensive in remote locations where forest products are more abundant and there are fewer alternative livelihood opportunities (Vedeld et al. 2007).

5.2 Forest products' contribution to accumulation of economic capital

Investment in livestock as a form of reserve banking is common in the Congo basin (van Vliet et al. 2011) since there is little option for saving due to lack of banking facilities (Chambers and Leach 1989; McSweeney 2004). Collection of highly profitable forest products, like bushmeat, can generate larger lump sums of cash. However, some studies have found that income from hunting does not primarily contribute to household food security, but rather to the purchase of consumables like cigarettes and alcohol (e.g. Solly 2004; Coad et al. 2010). In investigating the role of forest products in asset accumulation, we found that asset accumulation occurred at a higher rate in the (livestock) poor households, and that only cash income from bushmeat had a significant effect on livestock asset accumulation. Other cases support this showing that occasionally hunting is conducted for a specific purpose, such as pre-empting or covering a particular expense (Coad et al. 2010).Importantly, this suggests that bushmeat hunting could have a local poverty alleviating effect in the long term if hunting can be maintained at a sustainable level to ensure that households can continually depend on this income source. However, further targeted research and data collection on spending patterns of households from forest

product revenue as well as patterns of bushmeat and eru collection for cash are warranted to explore the long-term poverty alleviating effects of bushmeat hunting in households.

5.3 Limitations and sources of bias

There are several limitations to our data analysis and potential sources of bias in the data. Firstly, access to forest resources is an important determinant of forest product collection. Variation in physical distance to the forest between households was too small to have any effect here. Moreover, institutional arrangements governing resource use and subsequent sales are equally important in determining forest product extraction as has been shown in Cameroon where an inefficient regulatory system led to waste and unsustainable harvest rates (Tieguhong et al. 2015). Our study did not collect or analyse information about land, forest and environmental quality or tenure, power structures regulating resource or market access, or the organisation of the institutions governing these aspects (see Scherr et al. 2004; Vedeld et al. 2004), which means that many important contextual factors have been left out of this analysis. Future collection of such data could supplement our econometric analysis and strengthen the analysis and understanding of our data.

Secondly, respondents' willingness to share information could be affected due to the fact that hunting is regulated or illegal in many locations in the African context (Nielsen et al. 2014). In practice, however, hunting regulations in DRC were rarely enforced and respondents were generally unaware of these rules. As a result, underreporting could have factored into the data, but we believe this was minimised by guaranteeing anonymity during the survey, building trust and promoting collaboration and open discussion with the communities through continued interactions with respondents over the course of a year.

Finally, the data contained a large number of 'zero observations', which represent cases where subgroups of the survey population may not engage in a particular income activity, rather than a household that did engage, but did not collect any product. OLS regression results should therefore take this into consideration. For instance, the variable 'fuelwood for cash' in the model of asset accumulation only had ten observations whilst the rest were zero. Since these zero values were 'missing by definition' (Acock 2005), the recording of income was not applicable in these cases.

6 Conclusion and policy implications

Using a dataset collected in the Democratic Republic of Congo on household livelihoods around the Luki Biosphere Reserve, we show that collection of bushmeat and eru is significant components of households' cash income although collection activities are not currently sufficiently lucrative for the average household to rely solely on these. Through applying a selection outcome model, we find that selection into bushmeat depends on asset wealth, local ethnicity and to some extent household labour availability, whereas proximity to markets and being a male-headed younger household made selection into eru collection more likely. Outcomes of bushmeat and eru collection were generally lower for households with more labour, and collection of eru was lower amongst households with higher level of education. Local households on the other hand tended to have better outcomes from eru collection.

Understanding the role that bushmeat and eru play as a source of cash income in households in DRC is an important first step in designing targeted interventions for

sustainable resource management and use. Moreover, such management is essential as bushmeat and eru are gaining social and cultural significance and are becoming luxury goods in urban areas (Fa et al. 2009; Godoy et al. 2010; Brashares et al. 2011). As a result, there is increasing demand for the resources from swiftly growing populations in larger urban areas proximate to the Luki Biosphere Reserve, as well as the growing middle class in DRC's capital city, Kinshasa. With Congo's only national road passing through the area, there is easy access to markets. Combined with lax enforcement of regulations, this creates a *de facto* open access situation, and extractors may have strong incentives to continue harvesting even as the resource base depletes. This will have consequent effects on ecosystem services such as seed dispersal and pollination, which in turn will influence wildlife and forest composition (Nasi et al. 2011). Market regulation for these goods is therefore urgently needed to ensure sustainable resource management and conservation of ecosystems and its services (Stoner et al. 2007; Wang et al. 2007; Vanthomme et al. 2010). Further efforts to mitigate over-exploitation, particularly of eru, could look to the achievements in cultivating the plant in neighbouring countries like Cameroon (see Tchoundjeu et al. 2006). The feasibility of a complementary approach of farming captive bred wildlife is, however, debated (Mockrin et al. 2005; Nogueira and Nogueira-Filho 2011).

Exogenous factors such as the global food crises and changing climate will furthermore redefine the roles of bushmeat and eru in livelihoods. Climate variability in climate-sensitive sectors such as agriculture and food price spikes such as these observed in 2007–2008 and 2010–2011 is changing the availability of staple foods to average households and implies that forest products could become increasingly important as a safety net. However, recent studies (e.g. Sneyd 2013) indicate that these locally available and nutritious foods such as eru are increasingly out of reach of the local population: a side effect of price spikes in food goods that are commonly consumed together with eru.

Policy development should therefore strive to integrate both conservation and development objectives despite historically dubious results in doing so (e.g. Robinson and Redford 2004). Early established biosphere reserves including Luki have been criticised for failing to meet development objectives (Batisse 1997; UNESCO 2012) suggesting that simple demarcation of zones of use alone is insufficient (Sneyd 2015). Undoubtedly, DRC's political instability creates a challenging environment for implementing conservation and poverty alleviation policies. However, policies aimed at managing forest product harvesting that take into account the economic, social and cultural significance of these products need to be developed, in order to ensure the sustainability of forest resource extraction in the face of rapid population increase and growing demand from nearby urban areas.

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