Charcoal production as a means to a valuable end: Scope and limitations of charcoal incometo alleviate acute multidimensional povertyamong the rural population of Mabalane district, southern Mozambique

Summary

The charcoal industry is among the most important economic sectors in Sub-Saharan Africa and a key cash income source for local households who produce it. This has intensified thedebate as to the role of charcoal production in thealleviation of rural poverty. While in a number of casescharcoal production has been identified as a potential alleviator of monetary poverty, this paper identified a lack of analysis on the effect of charcoal production on acute multidimensional poverty, understood as the inability of household members to meet minimum international standards and core *functionings*. This study used primary data at the household level from an important charcoal supplying region in southern Mozambique to evaluate if income from charcoal contributes to the alleviation of AMP.The Alkire-Foster method was used to aggregate AMPin nine composite indicators (sanitation, water, under-five mortality and access to equitable health care, education, food security, access to services, assets ownership and housing). Generalised linear models are used to assess the marginal effect of charcoal income on AMP. Our findings showa positive correlation of charcoal production with personal assets and the level of education of the household members, and we find that charcoal producing households are more resilient to shocks. However,local charcoal production does not contribute to the alleviation of acute multidimensional poverty when additional indicators such as access to equitable health care and food security are also taken into account. Although households in the best-off charcoal income quintile generates half of all charcoal income which puts its members above the Mozambican poverty line (and thus out of extreme monetary poverty), we still find that 59% of these households are in acute multidimensional poverty. Our findings challenge the perception that charcoal income can alleviate poverty if a multidimensional conceptualisation is used. While charcoal making can potentially contribute to an increase in the economic and human capital of the poor, in this region, charcoal income aloneis not found to be sufficient to tackle the structural challenges posed by acutemultidimensional poverty.Policy makers need to account for the structuraldisadvantages poverty poses.

Key words –Acutemultidimensional poverty, charcoal production, southern Mozambique

1. Introduction

Charcoal is one of the most important domestic fuelsused in Sub-Saharan Africa (SSA) (Girard, 2002; Butz, 2013). Charcoal is a popular woodfuel particularlywith urban consumers because of its clean and even burn (Ribot, 1993), and because it is affordable (Iiyama, 2015). Due to population growth and urbanization it is projected that demand for charcoalincreases substantially until 2030 (World Bank, 2011).In consequence, the charcoal sector fulfils an increasingly important role for the economic development of many countries in SSA (Ndegwa*et al.*, 2016; IAE, 2014). In Mozambique for instance, it is estimated that up to 3 million people(approx. 15% of the population) are involved in the semi-legalised charcoal trade (Cuvilas*et al*., 2010), with a contribution of 2.2% to Mozambique’s GDP (van der Plas*et al*., 2012). In Kenya, the charcoal industry was found to parallel in size that of the tea industry (Mutimba and Murefu, 2005), while in Malawi it parallels tobacco and sugar sectors (Kambewa*et al.*,2007).

The economic importance of the charcoal sector in most countries in SSAaccelerated research efforts to analyse the role locally produced charcoal has on rural poverty.Most people engaged in the woodfuel market are based rurally (Openshaw, 2010) in the role of small-scale "casual" producers or transporters (Zulu and Richardson, 2013) where it was found to provide producers a viable opportunity to supplement income from other livelihood activities (Levy and Kaufman, 2014; Jones *et al.,* 2016).Studies then differ in their assessment of the role of charcoal on efforts to reduce poverty. Studies found charcoal producers to be economically better off than non-producers (Ainembabazi*et al*., 2013; Wunder, 2014; Smith *et al*., 2015) with welfare benefits that contribute to poverty reductions (Schure*et al*., 2014: S85). The welfare benefits were found to be in some cases enough to lift certain groups of producers above the poverty line (Ainembabazi*et al*., 2013) whichascertained charcoal as a potential pathway or route out of poverty. Thisintensified calls for a better and more pro-poor regulation of the often unregulated charcoal industry (Schure*et al.*, 2014; Jones*et al.*, 2015).

Although economically better-off, some studies found that the average charcoal producer lives below the international poverty line (Schure*et al*., 2014: S85). Consequently, some studies rather identified charcoal cash income as a safety net (Arnold *et al.*, 2006; Bekele and Girmay, 2014; Zulu and Richardson, 2013) or a coping strategy (Kalaba*et al.*, 2013; Kambewa, 2007), where, for instance, charcoal producing households increase their resilience to idiosyncratic shocks by accumulating household savings. While unable to alleviate poverty, charcoal cash income was found to contribute to the prevention and mitigation of poverty (Khundi, 2007). For some subgroups of producers, particularly for the chronically poor (Hulme, 2007) or the severe poor (Ravallion, 1998), charcoal production was found to be a poverty trap (Angelsen and Wunder, 2003; Ndegwa*et al.,* 2016). They are characterised by an overt reliance on charcoal as a livelihood strategy, and little opportunity to expand their production or diversify into alternative livelihood activities. Returns are used to meet basic subsistence needs.

The predominantly monetary focus deployed in the studies reflect the entrenchment of the discussion in welfare economics, environmental economics and livelihood analyses. Charcoal is one of the most important "environmental income" sources across developing countries (Angelsen, et al., 2014) and the academic debate is rich on the contribution of charcoal income to wealth accumulation (Ndegwa*et al.,* 2016), livelihood diversification (Schure*et al.*, 2014; Zulu and Richardson, 2013), and the heterogeneous dependence of different population subgroup groups on natural resources(Angelsen*et al*., 2014).

Yet the focus on income poverty and derivedwelfare benefits from charcoal making also masks an important question: what is the contribution of income from charcoal production to the alleviation of acute multidimensional poverty? Charcoal is a woodfueland thus a forest provisioning ecosystem service (MA 2005; Kalaba*et al.*, 2013). A systematic review of the empirical links between provisioning ecosystem services and poverty found a lack of analysis of poverty in the multidimensional space (Suich*et al.*, 2015)[i].While most charcoal studies do analyse possible spill-over effects of charcoal cash income onto key indicators of human development - e.g. Ndewgwa*et al*. compare the education of household heads of non-producers versus producers of different charcoal production scales (2016: 172) andSchure analyses spending patterns of charcoal income on food, education and healthcare - the selection of indicators used is selective and usually in a dashboard. To our knowledge data is not systematically aggregated and analysed to account for what is known as the breadth of poverty (Alkire*et al.,* 2015): that is the empirical observation of simultaneous deprivations in key dimensions of well-beingsuch as education, health or standard of livingthat have low inter-correlation and cut across the human, social and economic capital of the poor (Alkire and Foster, 2007).

This is a research gap we wish to explore in this study. Studies that analyse multidimensional poverty and their determinants are deployed more frequently in development and socialeconomics (Mahoozi, 2016; Santos *et al*., 2016; Ataguba, *et al.*, 2013; Reeves, *et al.*, 2016; Wang *et al.*, 2016). Such studies offer methodologically viable analyses of the now widely held view that poverty is a multidimensional phenomenon (as acknowledged as target 1.2 of the Sustainable Development Goals (SDGs) by the United Nations). We argue that the academic debate about the role of charcoal income on poverty alleviation is incomplete unless the instrumental value of charcoal income is systematically assessed as a means to a valuable end. That is the contribution of charcoal income to the achievement of what is known as *functionings*people have identified as valuable and have reason to value (Sen, 1992; 1999; Alkire and Santos, 2014).

We consider Mozambique an illuminating case study to investigate the impact of local charcoal production on acute multidimensional poverty. Given the economic importance of the charcoal sector the Government of Mozambique has identified the inclusive and community-based usage of natural resources as a key priority area in its strategy for rural poverty reduction in its current five year plan 2015-2019 (GoM, 2015). The National Forest Directorate (DINAF) under the Ministry of Land, Environment and Rural Development (MITADER) uses a specially designed programme (*FlorestaemPé*) to ensure sustainability of forest based activities.At the same time, the Government adopted a multidimensional definition of poverty in 2011 (MPD, 2011) and continuous to observe poverty both in the monetary and non-monetary space(MPD, DNEAP, 2010).We consider this to be fruitful policy environment for a study that assesses the scope and limitations of charcoal income to poverty alleviations in the multidimensional space.

As part of an interdisciplinary project entitled Abrupt Changes in Ecosystem Services and Wellbeing in Mozambican Woodlands (ACES) that assesses theimpacts of woodland degradation on rural poverty, we purposefully collected data in an important charcoal supplying region in southern Mozambique, in order to identify and aggregate *acute multidimensional poverty*(subsequently referred to as AMP, which is also used to abbreviate the *acute multidimensionally poor*), and to study the contribution from charcoal income to its alleviation.Based on established differences between income and multidimensional poverty found elsewhere in the literature –e.g. Wang *et al.* identified that 69% of the multidimensional poor in China are not considered to be in income poverty (2016)[ii] - and emerging research findings that thus far suggest that multidimensional poverty has a low elasticity to economic growth (Mahoozi, 2016) and one that is lower in comparison to income poverty (Santos *et al*., 2016), we hypothesise that cash income from charcoal production is not a sufficient condition in the alleviation of acute multidimensional poverty.

2. Methods

(a)*Description of study siteand village selection*

Data collection took place in May-October 2014 in Mabalane district, Gaza province, in southern Mozambique, approximately 300 km north of Maputo (see figure 1).

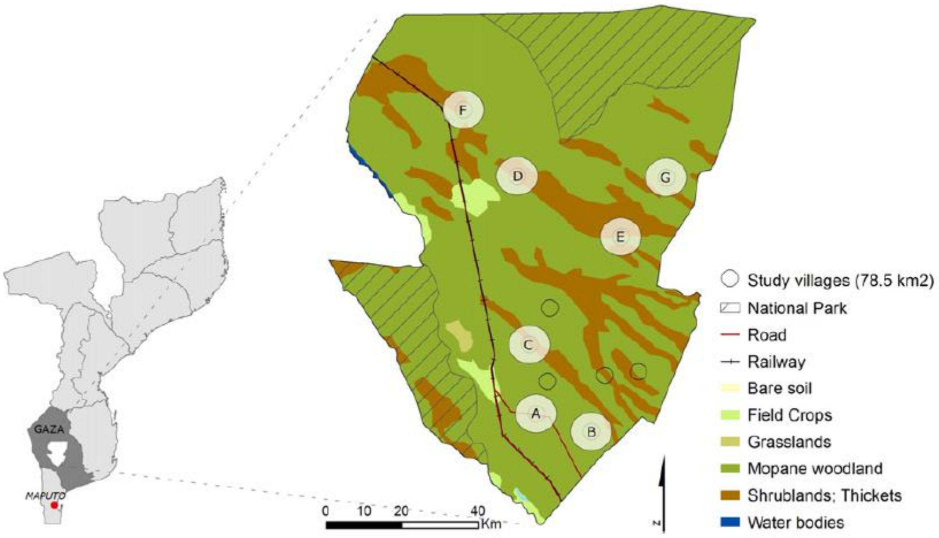


Figure 1:*Land cover and study villages (A-G) inMabalane district, Gaza province, southern Mozambique (Woollen et al., 2016).Village names are abbreviated. A=Matlantimbuti; B= Sangue; C=Tindzwaene; D=Mavumbuque; E=Mabuapense; F=Hochane; G=Matchele*

The area is a semi-arid region (annual rainfall of 505mm)that is prone to frequently occurring hazards including droughts and frequent storms (UNOCHA, 2016). The district is relatively sparsely populated with 5329 households recorded in the Census 2007 (INE, 2007). It is characterised by little market access to the southern commercial centres Chokwe, Xai-Xai and Maputo, due to an insufficient road network. Dirt roads that connect the villages are often impassable during the wet season (Woollen *et al.*, 2016). While the district capital *Mabalane-sede* is connected to the electric grid, most remote villages are not (GENI, nd).

The area was identified as a stronghold in the regional licensed charcoal trade supplying the capital Maputo. According to Mozambique's Forest and Wildlife Law (GoM, 1999), any commercial woodland extraction needs authorization through a licence (*contrato de exploração*) which is available to national operatorsand local communities for 5 years (Baumert *et al.*, 2016). Mabalane district has the highest licenced charcoal production in Gaza province, the province with thehighest number of charcoal licences throughout the country (Luz, *et al.*, 2015). Following the end of Mozambique's civil war (1997-1992), villagers returned to their home villages and started to produce charcoal in small-scale to supplement their subsistence income from smallholder agro-pastoralism (Levy, Webster and Kaufmann, 2012; Levy and Kaufmann, 2014). Due to recurring droughts in the area, over time charcoal production became more important. According to local forest officers charcoal production started to accelerate in the mid-2000s when more licences were granted to exploit local forests, yet villagers were found to be excluded as most charcoal was produced by migrant workers from the neighbouring province Inhambame under licences hold by commercial operators residing in the capital Maputo (Baumert *et al.*, 2016).

Based on detailed village histories and key informant interviews taken six small charcoal producing villages and one non-charcoal producing village were selected for data collection(the villages displayed as far as possible, similar soil and vegetation typesand had the village leader residing. Participatory land use mapping exercises were utilised to obtain individual village boundaries (see table 1)).

Table 1. *Village selection and their main characteristics. Mabalane district, Gaza province*

Village	MatlA	San B	Tins C	Mav D	MabuE	Hoch F	Match G	Total
Number of households (HH) in village (N)	38	29	63	42	58	55	27	312
HH sampled (n) (% of N)	35 (92)	25 (86)	51 (81)	36 (86)	42 (72)	48 (87)	24 (89)	261 (84)
Households (HH) producing charcoal (% of n)	29 (83)	23 (92)	46 (90)	22 (61)	21 (50)	42 (88)	0 (0)	183 (70)

All data refer to 2013-2014. -: no observation. N: village population. n: sample size. Village names are abbreviated. Matl A=Matlantimbuti; San B= Sangue; Tins C=Tindzwaene; Mav D=Mavumbuque; Mabu E=Mabuapense; Hoch F=Hochane; Match G=Matchele

(b) Data collection methods

A household list was compiled based on a household definition of "eating from the same pot" (Tvedten *et al.*, 2009). Households were then randomly selected for a socio-economic household survey (n=261).Households were questioned on their socio-economic and demographic characteristics for the reference year 2013-2014. The survey was conducted on tablets with six trained enumerators using Open Data Kit software (Brunette *et al.* 2013). The obtained final sample can be considered an "incomplete census" (Dodge, 2003) of our study area (84%). In parallel we ran participatory rural appraisals (PRAs) (Chambers, 1994) to obtain qualitative data in order to a) identify locally relevant parameters of AMP, and b) to study the functional relationships of AMP with demographic and socio-economic characteristics of local households. Poverty focus group discussions and participatory wealth rankings were utilised.

(c) *Identifying charcoal producers*

Charcoal producers are classified by charcoal income quintiles (with mean values±standard deviations given if not indicatedotherwise). Descriptive statistics of households producing charcoal are shown, and livelihood strategies in our study area are described. They were classified into different income categories as popularised by the Poverty Environment Network, where categories range from direct and processed forest income, over income from agro-pastoralism, to non-environmental income from businesses or wage labour (CIFOR, 2008; Angelsen*et al.*, 2011). Producers of charcoal above the mean and median production of charcoal are then depicted (with mean values±standard error given if not indicatedotherwise).The corresponding income distribution from charcoal makingis portrayed with the Lorenz curve (Atkinson, 1970) and the Gini coefficient (Gini, 1914).Households werethen analysed with regards to their monetary poverty status. The notion is to identity the monetary non-poor from charcoal making in order a) toexplore whether that group is also non-poor in the multidimensional space (step d), and if so, b) to analyse whether charcoal production can be attributed to this effect (step e).

(d) Identifying theAcute Multidimensional Poor

The theoretical premise to assess poverty in the multidimensional space, and thus beyond a narrow money-metric assessment, is grounded in Mozambique's official understanding of poverty as a multidimensional phenomenon, as defined in the third Poverty Reduction Action Plan 2011-2014 ("Poverty is a multidimensional phenomenon, and combating poverty goes well beyond a simple discussion of the underlying characteristics of absolute poverty" (MPD, 2011)) and the Government of Mozambique's five year government plan 2015-2019 (GoM, 2015). Also, various multi-stakeholder focus group discussions (FGDs) on poverty deployed at national (Maputo), provincial (Xai-Xai) and at village level for this study establisheda strong link to non-monetary dimensions of poverty, with a strong focus on*functionings*, such as food security, or having access to clean drinking water (please see table 1, SI1).

The Alkire-Foster (AF) method (Alkire and Foster, 2007, 2011a) was then used to identify and aggregate AMP. The method was chosen due to its axiomatic yet decomposable features;its accounting for the breadth of poverty not captured in dashboard and other estimates of multidimensional poverty (Alkire*et al*., 2015: 70-123); its methodological robustness (see Alkire and Santos, 2014, Alkire*et al*., 2015: 233-256); and its overall growing popularity as a scientific supplement to monetary measures of poverty (as it is a direct rather than indirect measure of poverty (Alkire and Santos, 2014: 251))[iii]. The measure relies on *empirical observations* of actual achievements (or the lack thereof) in key dimensions of poverty, and is thus less prone to prediction errors as often found with monetary poverty estimates that rely on imputation methods (Gaddis and Klasen, 2012).It allows for a clear mapping of the multidimensional poor decomposed by village and poverty dimension. Thus, a"high-resolution lense" (Alkire and Santos, 2010b) of acute multidimensional poverty in the study area is given.

Conceptually, the AF-Method is broken into the selection of an identification function ρ and an aggregation step. The identification function comprises of the choice of the unit of analysis$n$, of relevant dimensions$d$ and indicators j of AMP, an indicator specific z_j and cross-dimensional specific cutoff line k (which can range from $k = 1$ (known as "union approach") to $k = d$ (known as "intersection approach")), as well as respective weights across indicators w_j. We utilised a sequenced mixed methods approach (see Hulme, 2007; Shaffer, 2013) to identify ρ. Results from poverty focus group discussions were triangulated with participatory wealth rankings results and a structured secondary literature review. Table 2 presents the identification of dimensions d, respective indicators$j$, indicator specificcutoff lines$z_j$and weightsw_j used to aggregate AMP[iv] (we present the process that led to the identification of ρ, as well as descriptive statistics for each selected indicator j, in SI1). AMP is assessed in nine composite indicators (all of which are categorical), grouped along three dimensions (namely human, social and economic capital).The function is then represented as $\rho: R_{+}^{d} \times R_{++}^{d} \rightarrow \{0,1\}$, that denotes a person's *i's* achievement vector $y_i \in R_{+}^{d}$ and cutoff vector z in R_{++}^{d} . A household n is considered to be acutely multidimensionally poor if and only if a household's weighted deprivation count $c_i$is equal to or greater than k ($c_i \geq k$), and is then given the value of $Y_i = \rho(y_i; z)$ =1, and 0 if otherwise. In this study, the cross-dimensional cutoff line was set at $k \geq$4, which means that ahousehold is in AMP if the sum of weighted indicators in which a household is deprived amounts to at least 40% (thus if a household is deprived in *at least* three indicators *across* two dimensions).A nested weighting structure w_j was chosen that gives each of the three dimensions of AMP the same weight (33%).

Table 2. *List of Acute Multidimensional Poverty dimensions, indicators, cut-off lines and weightings.*

Dimensions ($\boldsymbol{d}$)	Indicators ($\boldsymbol{j}$)	Deprived if…($\boldsymbol{z_j}$)	Nested weighting ($\boldsymbol{w_j}$) scale (%)
Human capital	1. Sanitation	1. The household's sanitation facility is not improved (according to the MDG guidelines), or it is improved but shared with other households *[1]	0.66 (6.7)
	2. Water	2. The household does not have yearlong access to clean drinking water (according to the MDG guidelines) or clean water is more than 30 minutes walking from home (roundtrip)*[1]	0.66 (6.7)
	3. Under-five mortality	3. Any child has died in the household*[2]	0.66 (6.7)
	4. Access to equitable health care	4. The household does not have access to equitable health care	0.66 (6.7)
	5. Formal Education (illiteracy, highest qualification achieved)	5. No household member is able to read and write and achieved at a minimumgrades 1-5 of a primary education degree or attended the Portuguese colonial school system*[2].	0.66 (6.7)
Social capital	1. Food (in)security	1. The household experienced a food shortage in the past	1.665 (16.6)
	2. Access to services, associations and credit	2. The household did not receive advice from an extension agent during the last 12 months, and did not receive a credit in the last 12 months, and is currently not a member in an agricultural or forestry association.	1.665 (16.6)
Economic capital	1. Assets owned	1. The household does not own a motorbike, truck, car, cart, cassette/dvd player, bed or chainsaw, or does not own more than one radio, television, telephone, refrigerator or bicycle*[2]	1.665 (16.6)
	2. Housing (floor, roof, walls)	2. The household has sand or smoothed mud floor, and grass or poles roof,and sand, mud, grass or poles walls*[2]	1.665 (16.6)

Note: *[1] marks selection ofz_j based on MPI (Alkire and Santos, 2010; Alkire*et al.*, 2016); *[2] marks selection of z_j derived from MPI (Alkire and Santos 2010;Alkire*et al.*, 2016);

Data on the household's poverty status are then aggregated into two different classes of AMP at the village level, namely the headcount ratio H (reported in percentage) and the adjusted headcount ratio M_0 (reported as a value). The headcount ratio H reports the incidence of AMP ($H = \frac{q}{n}$, where q are households identified as AMP divided by total number of households n), whereas the breath-adjusted headcount ratioM_0 reports the prevalence of poverty, by which the (weighted) number of dimensions in which each household is deprived are added into H; thus, it calculates into H the average intensity of poverty $A = \sum_{i=1}^{n} c_j \frac{k}{q}$. M_0satisfies dimensional monotonicity, by which societies, under equal incidences of poverty (H), are considered poorer whose intensity of poverty (A) is greater. For a full account of the measurement's properties and mathematical structure, see Alkire and Foster (2007, 2011a). First and second-order stochastic dominance tests, rank robustness analyses and statistical inference tests were applied to ensure that the obtained poverty rankings were robust to changes in key parameters of the identification function ρ. Core findings of this process are presented, while SI2 contains the detailed presentation of the test results. SI2 also contains comparative poverty measures (table 2 in SI2) that place the calculated headcount ratio H in Mabalane next to Mozambique's official poverty headcount$H$, the poor classified based on the international US$1.25/day and US$2.5/day measure (and the adjusted US$1.90/day and US$3.10/day measure), as well as poverty headcountcalculated for the Multidimensional Poverty Index for Mozambique.

(e)Determining the marginal effect of charcoal production on AMP

Descriptive statistics were used to place households identified as AMP ($Y_i = \rho(y_i; z) = 1$) next to their calculated income quintile from charcoal making. Two Generalised Linear Modelswerethen used to predict probabilities that Y_i(the bounded and discrete dependent variable) takes the value of one given the use of socio-economic and demographic predictors.Regression analysis was chosen as it is considered the most efficient way to answer the research question whether charcoal income leads to deductions in the likelihood of being acute multidimensional poor, while controlling for alternative determinants.We specify a Bernoulli distribution to model the conditional distribution $p_Y(y_i) = \pi_i{}^{y_i}(1 - \pi_i) \times 0 = \pi_i$with a logit link function that ensures that the conditional meangiven by the conditional probability$\mu_{y_i|x_i} = \pi_i \times 1 + (1 - \pi_i) \times 0 = \pi_i$stays betweenzero and one. We specify$\log_e \frac{\pi}{1-\pi} = \beta_0 + \beta_1 x_{1i} + _{\dots} + \beta_K x_{Ki}$with $\frac{\pi}{1-\pi} = e^{\beta_0}(e^{\beta_1})^{x_{1i}} \dots (e^{\beta_K})^{x_{Ki}}$where the logit of $\pi$is the natural logarithm of the odds that the binary variable $Y_i$takes the value of one. The partial regression coefficients $\beta_j$are interpretedas the marginal changes of the logit due to a one unit increase in x_j, and e^{β_j}as the multiplicative effect on the odds of increasing x_j by one, holding the other predictors K constant. $e^{\beta_j}$is reported as the “odds ratio” in the models, whereas β_j is reported as the “parameter estimates” whose sign (positive or negative) shows increases or deductions in the odds of being multidimensionally poor((1-odds-ratio)×100)). Corresponding standard errors, $z$statistics, and significance levels at 5% are shown(Alkire*et al*., 2015: 306ff).

Two models were specified in that manner with a maximum of elevenpredictors. The selectionof predictors was based on an empirical-theoretical process.We chose indicators that were empirically named as factors in the placement of households in the different wealth clusters (as established via the participatory wealth rankings, where the households were classified from poorest (1) to best-off (4),see table 2 in SI1). The focal explanatory variable is income from charcoal making (see figure 1 in SI1, where charcoal was the singlemost cited explanatory variable for placements of households in the different wealth categories (mentioned 31 times));but given that the chosen unit of analysis was the household, members oflabour age were found to engage in several livelihood activities (where, for instance, men were engaged in charcoal production, women in smallholdings and adolescentsin animal husbandry, among other activities (see analysis of placement into different wealth clusters in SI1). Thus, other indicators of concern were also identified such as the size of the managed farmland (which were mentioned 29 times during the wealth rankings), the holdings of livestock[v],the composition of household members in labour age, thelivelihood diversification and a household's subjective perception of fortune (as a proxy for agency (or work ethic) that was found to be an important factor in the placement of households in higher wealth clusters (mentioned 27 times)). As these covariates explain wealth based clusters but insufficiently explain multidimensional poverty, we also incorporated variables found to hold relevance in similar applications of multivariate analyses into determinants of *multidimensional poverty,* such as status of residency, vulnerability to shocks, or gender of household head (see Betti*et al*., 2002; D'Ambrosio*et al.*, 2011; Alkire*et al*., 2015: 306ff). A number of potential predictors often applied in monetary poverty regressions were excluded due to endogeneity concerns (i.e. indicators in relation to education or health status of household members). A series of regression estimation diagnostics(UCLA, 2016a) were undertaken to ensure the statistical goodness of fit of our model specifications, particularly of the first model that contains all eleven covariates and thus is the most comprehensible[vi]. Given different sample sizes at the village level, model specifications were oriented at the $n/k>15$ rule, where n is the number of observations (that also tend to vary due to missing data) and $k$is the potential number of predictors in the models (Shively, 2011: 62).Exact logistic regression was not applied as the analysis does not accommodate probability weights. As the data collection was confined to the dry season 2014 without a recall component (see de Nicola and Giné, 2014; Jagger *et al.,* 2012; Lund *et al.,* 2008for a debate on the entailed consequences for data accuracy), weusedgross estimates of charcoal income rather than net income (as expenses are harder to recall). Data extrapolation was used only sporadically,while we refrained from data imputationderived from reported values, and monetary valuation of subsistence income from agriculture. Total household income was not calculated and used as charcoal income was not found to be significantly correlated with livelihood diversification, or other livelihood streams, such as value of livestock, business income or wage labour income. Expenditure data was not analysed as it was not systematically collected as part of the household survey.Detailed justifications of indicators that were eventually selected are presented inSI3, complementary with summary statistics about each predictor and aSpearman rank correlation coefficient between all predictors and all nine variables comprising AMP (table 1 in SI3)).

We use thepredictors in tworobust multiple logistic regression (MLR) models to explain the size of the effect of being multidimensionally poor.The objective of this stepwise regression is to analyse 1) the multiplicative effect of charcoal and alternative predictorsin a comprehensive model*(a), ceteris paribus*;and 2) the*joint impact*of interaction terms on predictors found to be significant in a parsimonious second model *(b)*(following the application of a deviance statistic[vii] D^* at a 5% type I error rate that compared the model fit between thecomprehensive model *(a)*and parsimonious model *(b)*). Findings are presented at the aggregate (entire sample size), and disaggregate (village) levelin the parsimonious MLR model*b*. This allowedinterpretation of the data with regard to a possible Yule-Simpson effect that potentially occurs due to different sample sizes[viii] when the data is disaggregated (see David and Edwards, 2001). Results of a robustness test on MLR model *(a)* are provided (where two alternative specifications of the binary variable Y_i are used as the endogenous variable), and an explanation of the relationship between charcoal income and AMP is offered. If not otherwise stated, we report the number of observations n, the pseudo R^2 for the comprehensive models a and the parsimonious model b at the aggregate and disaggregate level, the regression parameter estimates, their standard errors and corresponding *z*statistics, their significance level, and the odds ratios. Both models were tested with a specification link test for single-equation models (where a non-significant *linktest* indicates no-specification error in the model).Standard errors were adjusted through robust estimations.Probability weights were calculated and applied throughout.Data for the analysis were retrieved from a relational database management system using Structured Query Language (Chamberlin and Boyce, 1974). Unless specified otherwise, all analysis were conducted using STATA (StataCorp 2013) and Microsoft excel (2013).

3. Results

(a) Classification of charcoal producers

Charcoal production is the primary means of generating cash income at our study site (n=183). That is 70% of the total sampled (n=261), and 77% of total sampled excluding village Match G where hitherto no charcoal was produced (n=237).Wild fruit collection and other forms of direct forest income from unprocessed forest products, such as from selling or bartering poles,were also utilised by householdsas cash generators, but in most cases were rather used for subsistence (n=78 (29.9%)). Only 17 households were found to have had a cash income from direct forest income, in the form of pole sales. These activities supplemented other environmental and non-environmental activities, foremost smallholder subsistence agriculture (n=217, of which only 12 households were engaged in cash cropping), animal husbandry (n=156), low skilled wage labour (n=25) or business income (n=25). Average number of income streams was found to be 2.9±1.36, with charcoal producing households were found to have on average 3 income streams (cash and subsistence), whereas non-charcoal producing households have on average 2.5 income generators. Charcoal production is predominantly an off-season activity in the dry season (5.6±0.6 months; n=170), yet a number of producers (n=26) produce all year long.

Charcoal producers can then best be classified by income quintile derived from their production quantity[ix]. Income data for households with a gross income from charcoal ≥0MZN areanalysed (n=161;adjusted to missing data from 22 charcoal producing households in Mav D). We find that average income of the first quintile was 5618±2626MZN, whereas of the fifth it was 92164±51493MZN (exchange rate of 1USD=31.35MZN for 2014 (Word Bank, 2016)). Thus, charcoal production is skewed to the right. We find that on aggregate two-thirds of charcoal producing households produced less than the mean number of charcoal sacks in the past year (and half of the sample produced below the median (*n*=160)), whereas the 33% of households who produced on average above the mean were able, in turn, to produce 66% of the total production that year (see table 3)).

Table 3.*Analysis of charcoal production across villages and their main characteristics*

	Matl A	San B	Tins C	Mav D	Mabu E	Hoch F	Match G	Total
Households (HH) producing charcoal (% of n)	29 (83)	23 (92)	46 (90)	22 (61)	21 (50)	42 (88)	0 (0)	183 (70)
Production total (Sacks^{-1})	4355[a]	1979[a]	6837[a]	n.o.	3547[a]	3982[b]	0	20700
Production mean	150±20	90±12	149±24	n.o.	169±36	95±20	0	131±11
Production median	120	83.5	115	n.o.	130	62.5	0	100
No. of HH production total≤ mean production (% of n)	20 (69)	12 (52)	27 (59)	n.o.	13 (62)	27 (64)	0	108 (67)
No. of HH production total≤ median production (% of n)	17 (59)	11 (48)	23 (50)	n.o.	11 (52)	21 (50)	0 (0)	87 (48)
Share (%) of total sack production of HHs producing above the mean (Production sacks^{-1})	56 (2440)	67 (1331)	73 (4965)	n.o.	77 (2715)	75 (2976)	0 (0)	66 (13694)

Different letters indicated significant differences between the villages.All data refer to year 2014. Reported data for producers of charcoal sacks ≥0.*n.o.: no observation. Meanvalue ± standard error. Percentages adjusted for n.o..n: sample size*

Consequently, as can be seen in the Lorenz curve presented in chart 1, we find that the bottom quintile generatesonly 3.1% of the total gross income share, whereas the best-off quintile generates 50%. Thus, 80% of charcoal producing households generate cumulatively only half of the cumulative gross income. The resulting Gini of .479 portrays a higher level of inequality if compared to the official Gini coefficient based on per capita consumption measures (Rural Gini of .377 (2008/09), urban Gini of .506 (2008/09), national Gini 0.458 (2008/09) (Arndt *et al.*, 2015: 460).

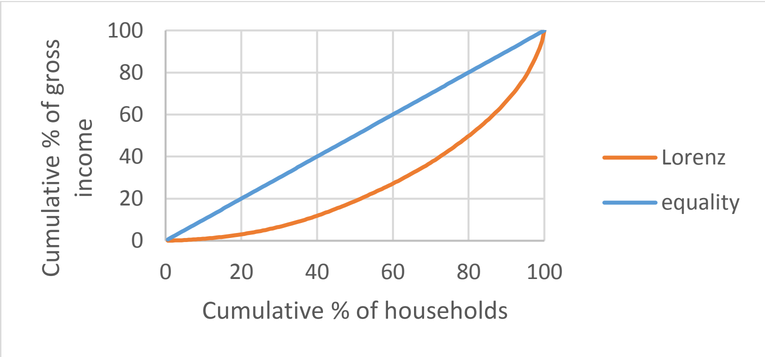


Chart 1. *Lorenz curve of income distribution from local charcoal production (Gini coefficient: .479)*

With regards to monetary poverty, we find that gross income from charcoal making alone is not enough to put members of the average household producing charcoal out of monetary poverty. The average gross income per person per day from charcoal for its producers is11.8MZN (0.73US$(PPP)), thus below the then valid extreme poverty line of 1.25US$/day (PPP), and the very specific Mozambican poverty line of 18.31MZN[x].The best off income quintile however can be considered to be out of monetary poverty. Calculated on a daily basis the best-off quintile generates 252.5MZN/day per household. This converts to 41.8MZN per person/day (2.58US$(PPP)). A corresponding question we subsequently explore is whether the best-off quintile in particular is also out of AMP, and if so, whether charcoal production can be attributed to this effect. To answer these questions, we first map AMP in the study area, and then explore the marginal effect of charcoal income on AMP.

(b) Acute Multidimensional Poverty

With the chosen identification functionρas described in table 2 we find that 167 households in our sample are inAMP. This translates into a headcount ration of H = 63.3% (a similarheadcount to the one calculated for the Gaza provincein the Multidimensional Poverty Index (60.1%) and the government's official$H$(65.2%), see table 2 in SI2 for further information). On average, the AMP are deprived in the weighted sum of 67.7% of indicators (A), thus the breadth-adjusted headcount ratio is calculated as M_0= 0.429 (see chart 2).Decomposed by villages, we find the greatest headcount ratio in San B, followed by Match G, whereas the lowest headcount ratios are in Mabu E and Mav D. With the lowest average deprivation vector A presented in Mabu E, we find this village to be the best-off according to the adjusted headcount ratio (M_0= 0.238), whereas the poorest village is San B (M_0= 0.541), despite having an "average" average deprivation vector of A = 68%.Given a basic dominance analysis we find that results are robust to changes inw_j, meaning that Mabu E (the least poor village by H) dominates San B (the poorest village by H)if given an equal weighing system across indicators (see chart 3).

Decomposed by dimension, we find the greatest relative contributor to M_0onaggregate to be human capital (39%), followed by social (35%) and economic capital (25%)[xi]. Again, findings are robust to an equal weighting scale (see chart 4). As can be seen in chart 5, the greatest individual contributor to M_0onaggregate is "food (in)security" (22%), whereas the least contributor is "under five mortality" (1%). The greatest contributors to M_0under an equal weighting scheme are equally "sanitation" and "access to equitable health care" (18%), whereas the least contributor remains “under-five mortality” (2%).In Mabu E, economic capital contributes only 15%to M_0, which is below the dimensions’ relative contribution of 25% on aggregate (see chart 6). This does not seem to translate to greater food security however, as Mabu E has with 22.2% an above the average relative contribution of food (in)securityto M_0, whereas San B has with 17.8% the least relative contribution of all villagesto M_0 (see chart 7).

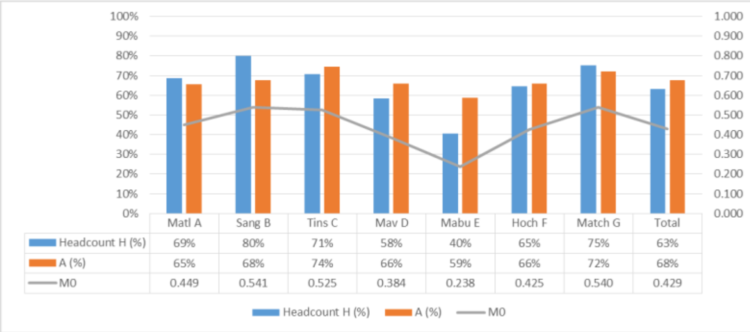


Chart 2.*Headcount ratio H, average intensity of poverty A and breadth-adjusted headcount ratio M_0shown at aggregate and villagelevel for nested weightsat the study site in Mabalane district*

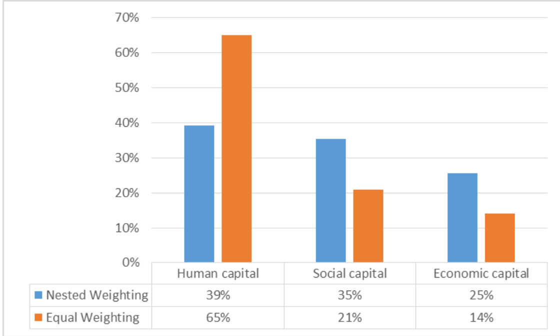


Chart 4: *Dimensional contribution to breadth-adjusted headcount ratio M_0 for nested and equal weights*

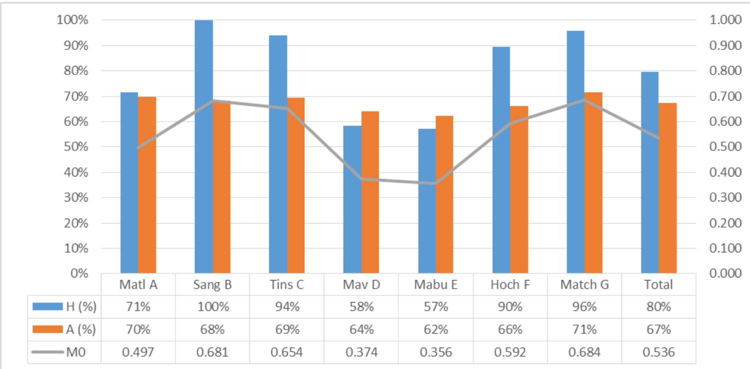


Chart 3.*Headcount ratio H, average intensity of poverty A and breadth-adjusted headcount ratio M_0 at aggregate and village level for equal weightsat the study site in Mabalane district*

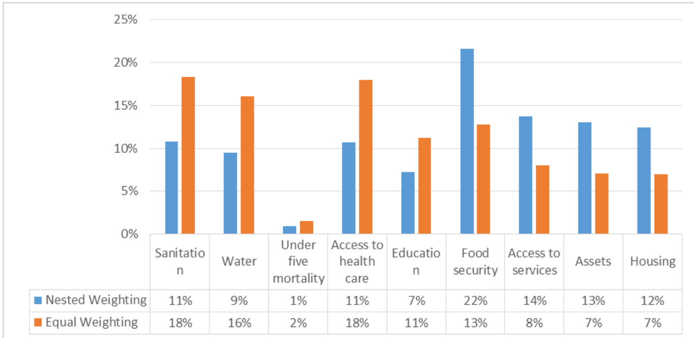
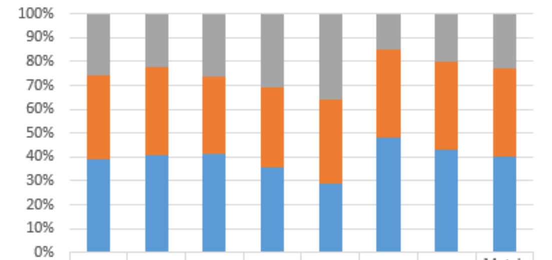
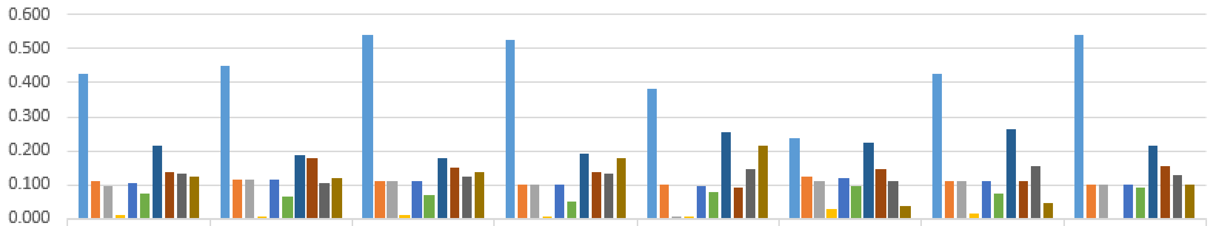


Chart 5: *Contribution of each indicator to breadth-adjusted headcount ratio M_0 for nested and equal weights*



	Total	Matl A	San B	Tin C	Mav D	Mabu E	Hoch F	Match G
Economic Capital	25%	22%	26%	31%	36%	15%	20%	23%
Social Capital	35%	37%	33%	33%	35%	37%	37%	37%
Human Capital	39%	41%	41%	36%	29%	48%	43%	40%

Chart 6.*Dimensional contribution tobreadth-adjusted headcount ratio*M_0*decomposed by village for nested weightsat the study site in Mabalane district*



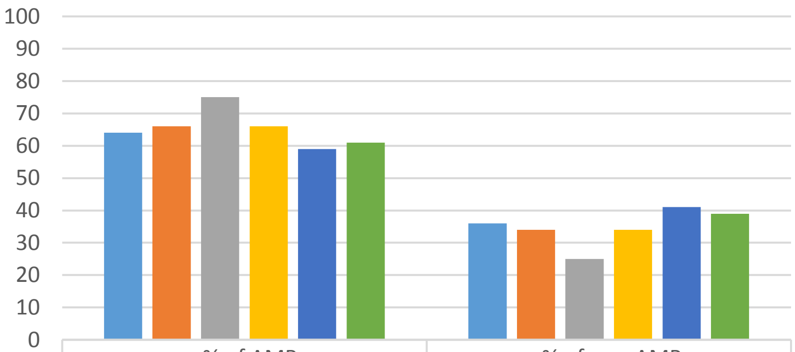
	Total	Matl A	San B	Tin C	Mav D	Mabu E	Hoch F	Match G
M0	0.429	0.449	0.541	0.525	0.384	0.238	0.425	0.540
Sanitation	10.8%	11.3%	11.0%	10.0%	10.2%	12.6%	11.3%	10.3%
Water	9.5%	11.3%	11.0%	10.0%	0.5%	11.1%	11.3%	10.3%
Under five mortality	1.0%	0.5%	1.1%	0.6%	0.5%	3.0%	1.5%	0.0%
Access to health care	10.7%	11.3%	11.0%	10.0%	9.7%	11.9%	11.3%	10.3%
Education	7.3%	6.6%	7.1%	5.3%	8.0%	9.6%	7.6%	9.1%
Food (in)security	21.6%	18.9%	17.8%	19.4%	25.5%	22.2%	26.3%	21.4%
Access to services	13.7%	17.7%	15.1%	13.8%	9.4%	14.8%	10.9%	15.7%
Assets	13.1%	10.6%	12.3%	13.1%	14.7%	11.1%	15.4%	12.9%
Housing	12.4%	11.8%	13.7%	18.0%	21.4%	3.7%	4.5%	10.0%

Chart 7.*Contribution of each indicator to breadth-adjusted headcount ratio*M_0 *decomposed by village for nested weightsat the study site in Mabalane district*

Robustness and statistical inference tests are listed in SI2. There we find that ρ_k, H and ρ_k, M_0 is unambiguously lower (or equal) for all village clusters for $k \in [1, 5]$. We therefore conclude that H and M_0 display robust and confident values of acute multidimensional poverty in the study area.

(c)Determining impact of charcoal production on AMP

Chart 8 places the percentage of households identified as AMP$(Y_i = 1)$ next to their calculated income quintile from charcoal making. While it is not surprising to find the biggest share of non-AMP households being in the 5th quintile from charcoal production (41%), we find that59% of the best-off quintile*are* considered to be in AMP. We also find that39% of households without reported charcoal income are considered non-AMP(which combines data from non-charcoal-producing village Match G (zero charcoal income) and missing data from charcoal producing village Mav D).



	% of AMP	% of non-AMP
1. Quintile (20%)	64	36
2. Quintile (40%)	66	34
3. Quintile (60%)	75	25
4. Quintile (80%)	66	34
5. Quintile (100%)	59	41
Households without reported income from charcoal past 12 months	61	39

Chart 8.*Percentage of households identified as acute multidimensional poor*$(Y_i = 1)$*or otherwise* $(Y_i = 0)$ *placed in their respective income quintile from charcoal production*

Table 4then presents findings of the comprehensive MLR model*(a)*[xii].We find *z*statisticsat the significant level for three covariates. For any given household, the log of the odds of being Y_i=1 decreases by 19%, *ceteris paribus*, with a one unit increase of cropland area size (ha), and by 25%, *ceteris paribus*, with a demographic change that puts more household members into labour age. On the other hand, having experienced an idiosyncratic shock increases the odds of being AMP by 290%, *ceteris paribus*[xiii].

Table 4. *Multiple Logistic Regression (MLR) Model a. n* = 204. *Pseudo* R^2*=0.169.Linktest: n.s.Reported are the regression parameter estimates, their standard errors and corresponding z statistics, as well as the odds ratios*

Variable	Parameter Estimate	Robust Std. Err.	*z*	Significance Level	Odds ratio
1. Gross income from charcoal	3.69	4.42	0.84	n.s	1.00
2. Cropland area size (ha)	-0.21	0.09	-2.28	*	0.81
3. Gross value of livestock	-2.96	1.34	-0.22	n.s.	0.99
4. Number of income streams (diversification)	0.35	0.16	0.21	n.s.	1.04
5. Business owned	-0.41	0.71	-0.57	n.s.	0.67
6. Wage income	0.00	0.00	1.24	n.s.	1.00
7. Female household head	0.52	0.49	1.04	n.s.	1.67
8. Household members in labour age	-0.29	0.1	-2.91	**	0.75
9. Years of residency	0.00	0.02	0.21	n.s.	1.00
10. Subjective perception of fortune	0.00	0.28	0.00	n.s.	1.00
11. Idiosyncratic shock experienced	1.34	0.35	3.88	***	3.90

** denotes significance at P<0.05;** denotes significance at P<0.01; *** denotes significance at P<0.001;n.s. denotes non-significance*

1=100%; 0.81=81%; 3.90=390% ; Para odds faz 100-o valor; ex: para cropland faz 100-81=19% significa aumento em 1unidadena área agrícola reduz a probabilidade de ser AMP; sock aumenta AMC em 290% (100-360=-290%)

Following the application of the deviance statistic D^* we drop[xiv] the non-significant predictors from MLR model *(a)* and use two of them, female household head and diversification, as interaction terms[xv] instead in the more parsimonious MLR Model *b;* as additional interaction terms we use charcoal income (this time as quintiles), and where applicable,household members in labour age.

Findings are presented in table 5. Results are presented at the aggregate and disaggregate level. We find that a one unit (ha) increase in managed cropland area size significantly lowers the log of the odds of being AMP in best-off village Mabu E (by 43%), in contrast to a non-significance in worst-off village San B. However, we also found that labour age drops as a significant predictor in Mabu E. While it seems befitting that an idiosyncratic shock is a non-significant predictor of Y_i=1 in best-off village Mabu E, the non-significance of an idiosyncratic shock in the poorest village San B seems counterintuitive.

When used as interaction terms we found diversification and charcoal income act as coping mechanisms that absorbs the impact of an idiosyncratic shock. While still severe, in both cases the log of the odds of being Y_i=1 decreases by a factor of 2.2 and 1.9, to 43% and 68% respectively, *ceteris paribus*. When disaggregated however, theeffect was only significant in the village Hoch F when adjusted for charcoal income, but not in the best-off village Mabu E. There,the interaction term diversification was in factstatistically significant.

In addition we found that, on aggregate,area size and labour age drop as significant predictors of Y_i=1 given the gender of the household head as an interaction term(a finding that is only non-applicable at the village level for San B, which is indicative of a minor Yule-Simpson effect). Thus, we do not find any covariate, at the aggregate level, that could explain *deductions*at the 5% significance level in the log of the odds of beingY_i=1 for female headed households. On the contrary, we find that the odds ratio of being Y_i=1 after an idiosyncratic shock experienced by the household worsens when female-headed (increases of the odd ratio by a factor of 8.4). This is however softened if additionally accounted for by household composition. Even when female headed, an idiosyncratic shock turns into a statistically non-significant predictor of Y_i=1 given household members of labour age as an interaction term.

Table 5.*Multiple Logistic Regression (MLR) Model b. Linktest: n.s.Data reported at aggregate and disaggregate level. Reported are the regression parameter estimates, their standard errors and corresponding z statistics, as well as the odds ratios.*

Level	**Variable**	***n***	**Parameter Estimate**	**Robust Std. Err.**	***Z***	**Significance Level**	**Odds ratio**
Aggregate	Cropland area size (ha)	259	-0.20	0.81	-2.52	**	0.82
Pseudo	Interaction: ha (gender)	259	-0.90	0.24	-0.37	n.s.	0.91
R^2=0.142	Interaction: ha (diversification)	259	-0.05	0.02	-2.26	**	0.95
	Interaction: ha (charcoal income quintiles)	161	-0.72	0.03	-2.51	**	0.93
	Interaction: ha (labour age)	259	-0.90	0.02	-3.58	***	0.91
	Household members in labour age	259	-0.32	0.87	-3.61	***	0.73
	Interaction: labour age (gender)	259	-0.21	0.16	-1.30	n.s.	0.81
	Interaction: labour age (charcoal income quintiles)	161	-0.06	0.03	-2.38	**	0.94
	Interaction: labour age (diversification)	259	-0.09	0.02	-3.58	***	0.91
	Idiosyncratic shock	259	1.16	0.29	4.01	***	3.2
	Interaction: shock (gender)	259	3.29	0.95	3.45	**	26.8
	Interaction: shock (diversification)	259	0.36	0.10	3.74	***	1.43
	Interaction: shock (charcoal income quintiles)	161	0.52	0.12	4.16	***	1.68
	Interaction: shock (labour age)	259	0.18	0.09	1.91	n.s.	1.19
	Interaction: shock (gender and labour age)	259	0.84	0.77	1.10	n.s.	2.33
Matl A	Cropland area size (ha)	34	-0.49	0.18	-2.72	**	0.61
Pseudo	Interaction: ha (gender)	28	0	-	-	-	1
R^2=0.401	Interaction: ha (diversification)	34	-0.11	0.06	-2.01	*	0.89
	Interaction: ha (charcoal income quintiles)	29	-0.16	0.07	-2.23	*	0.85
	Interaction: ha (labour age)	34	-0.17	0.06	-2.93	**	0.84
	Household members in labour age	34	-0.81	0.26	-3.17	**	0.44
	Interaction: labour age (gender)	28	0	-	-	-	1
	Interaction: labour age (charcoal income quintiles)	29	-0.17	0.10	-1.72	n.s.	0.84
	Interaction: labour age (diversification)	34	-0.36	0.11	-3.38	**	0.70
	Idiosyncratic shock	34	2.17	1.12	1.93	n.s.	8.75
	Interaction: shock (gender)	28	0	-	-	-	1
	Interaction: shock (diversification)	34	1.18	0.47	2.54	**	3.3
	Interaction: shock (charcoal income quintiles)	29	0.50	0.36	1.38	n.s.	1.65
	Interaction: shock (labour age)	34	-0.05	0.32	-0.17	n.s.	0.95
	Interaction: shock (gender and labour age)	30	0	-	-	-	1

San B	Cropland area size (ha)	25	-0.41	0.26	-1.57	n.s.	0.66
Pseudo	Interaction: ha (gender)	24	-14.57	2.11	-6.89	***	4.7
R^2=0.148	Interaction: ha (diversification)	25	-0.20	0.08	-2.40	*	0.82
	Interaction: ha (charcoal income quintiles)	23	-0.18	0.10	-1.88	n.s.	0.83
	Interaction: ha (labour age)	25	-0.06	0.05	-1.12	n.s.	0.94
	Household members in labour age	25	0.13	0.32	0.90	n.s.	1.14
	Interaction: labour age (gender)	24	6.90	0.58	11.98	***	993.2
	Interaction: labour age (charcoal income quintiles)	23	0.05	0.10	0.54	n.s.	1.05
	Interaction: labour age (diversification)	25	0.12	0.09	1.29	n.s.	1.13
	Idiosyncratic shock	25	1.03	1.14	0.90	n.s.	2.79
	Interaction: shock (gender)	24	0	-	-	-	1
	Interaction: shock (diversification)	25	0.03	0.32	0.08	n.s.	1.03
	Interaction: shock (charcoal income quintiles)	23	0.18	0.36	0.49	n.s.	1.20
	Interaction: shock (labour age)	25	0.18	0.28	0.65	n.s.	1.2
	Interaction: shock (gender and labour age)	24	0	-	-	-	1
Tin C	Cropland area size (ha)	51	-0.02	0.22	-0.10	n.s.	0.98
Pseudo	Interaction: ha (gender)	45	2.53	1.4	1.8	n.s.	12.59
R^2=0.123	Interaction: ha (diversification)	51	-0.02	0.07	-0.27	n.s.	0.98
	Interaction: ha (charcoal income quintiles)	46	-0.03	0.06	-0.52	n.s.	0.97
	Interaction: ha (labour age)	51	-0.01	0.05	-0.17	n.s.	0.99
	Household members in labour age	51	-0.58	0.22	-2.60	**	0.56
	Interaction: labour age (gender)	45	-0.99	0.89	-1.12	n.s.	0.37
	Interaction: labour age (charcoal income quintiles)	46	-0.06	0.05	-1.24	n.s.	0.94
	Interaction: labour age (diversification)	51	-0.14	0.05	-2.47	**	0.87
	Idiosyncratic shock	51	0.63	0.65	0.97	n.s.	1.88
	Interaction: shock (gender)	45	0	-	-	-	1
	Interaction: shock (diversification)	51	0.26	0.22	1.04	n.s.	1.25
	Interaction: shock (charcoal income quintiles)	46	0.36	0.20	1.80	n.s.	1.43
	Interaction: shock (labour age)	51	-0.20	0.22	-0.90	n.s.	0.82
	Interaction: shock (gender and labour age)	47	0	-	-	-	1
Mav D	Cropland area size (ha)	36	-0.03	0.14	-0.23	n.s.	0.96
Pseudo	Interaction: ha (gender)	32	0.33	1.05	0.31	n.s.	1.39
R^2=0.07	Interaction: ha (diversification)	36	0.00	0.03	0.02	n.s.	1.00
	Interaction: ha (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: ha (labour age)	36	-0.07	0.03	-2.16	*	0.93

	Household members in labour age	36	-0.42	0.22	-1.85	n.s.	0.66
	Interaction: labour age (gender)	32	0.28	0.47	-0.59	n.s.	0.76
	Interaction: labour age (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: labour age (diversification)	36	-0.09	0.06	-1.57	n.s.	0.91
	Idiosyncratic shock	36	0.34	0.73	0.46	n.s.	1.41
	Interaction: shock (gender)	32	0	-	-	-	1
	Interaction: shock (diversification)	36	0.15	0.16	0.93	n.s.	1.16
	Interaction: shock (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: shock (labour age)	36	0.04	0.24	0.16	n.s.	1.04
	Interaction: shock (gender and labour age)	32	0	-	-	-	1
Mabu E	Cropland area size (ha)	42	-0.57	0.26	-2.22	*	0.57
Pseudo	Interaction: ha (gender)	42	-0.34	0.59	-0.57	n.s.	0.71
R^2=0.181	Interaction: ha (diversification)	42	-0.20	0.08	-2.37	*	0.83
	Interaction: ha (charcoal income quintiles)	21	-0.15	0.10	-1.42	n.s.	0.86
	Interaction: ha (labour age)	42	-0.19	0.08	-2.42	*	0.83
	Household members in labour age	42	-0.2	0.21	-0.93	n.s.	0.82
	Interaction: labour age (gender)	42	-0.59	0.48	-1.23	n.s.	0.58
	Interaction: labour age (charcoal income quintiles)	21	-0.05	0.05	-1.14	n.s.	0.95
	Interaction: labour age (diversification)	42	0.03	0.06	0.52	n.s.	1.03
	Idiosyncratic shock	42	1.34	0.73	1.83	n.s.	3.81
	Interaction: shock (gender)	42	2.32	1.39	1.67	n.s.	10.17
	Interaction: shock (diversification)	42	0.71	0.20	3.55	***	2.03
	Interaction: shock (charcoal income quintiles)	21	0.67	0.50	1.34	n.s.	1.96
	Interaction: shock (labour age)	42	0.52	0.25	2.05	*	1.68
	Interaction: shock (gender and labour age)	42	-0.18	0.40	-0.41	n.s.	0.85
Hoch F	Cropland area size (ha)	48	-0.37	0.21	-1.76	n.s.	0.69
Pseudo	Interaction: ha (gender)	41	2.85	1.54	1.85	n.s.	17.24
R^2=0.196	Interaction: ha (diversification)	48	-0.13	0.08	-1.58	n.s.	0.88
	Interaction: ha (charcoal income quintiles)	42	-0.06	0.07	-1.08	n.s.	0.93
	Interaction: ha (labour age)	48	-0.22	0.10	-2.11	*	0.80
	Household members in labour age	48	-0.53	0.23	-2.33	*	0.59
	Interaction: labour age (gender)	41	-0.6	0.78	-0.77	n.s.	0.55
	Interaction: labour age (charcoal income quintiles)	42	-0.04	0.09	-0.45	n.s.	0.96
	Interaction: labour age (diversification)	48	-0.18	0.07	-2.61	**	0.83

	Idiosyncratic shock	48	1.32	0.72	1.84	n.s.	3.76
	Interaction: shock (gender)	41	0	-	-	-	1
	Interaction: shock (diversification)	48	0.32	0.26	1.27	n.s.	1.39
	Interaction: shock (charcoal income quintiles)	42	0.70	0.29	2.44	**	2.02
	Interaction: shock (labour age)	48	0.27	0.24	1.11	n.s.	1.31
	Interaction: shock (gender and labour age)	41	0	-	-	-	1
Match G	Cropland area size (ha)	9	0.43	0.32	1.37	n.s.	1.54
Pseudo	Interaction: ha (gender)	15	0	-	-	-	1
R^2=0.442	Interaction: ha (diversification)	9	0.07	0.09	0.79	n.s.	1.07
	Interaction: ha (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: ha (labour age)	10	-0.07	0.09	-0.72	n.s.	0.93
	Household members in labour age	9	-3.37	2.59	-1.30	n.s.	0.03
	Interaction: labour age (gender)	15	0	-	-	-	1
	Interaction: labour age (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: labour age (diversification)	9	-0.62	0.40	-1.52	n.s.	0.54
	Idiosyncratic shock	9	0	-	-	-	1
	Interaction: shock (gender)	15	0	-	-	-	1
	Interaction: shock (diversification)	9	0	-	-	-	1
	Interaction: shock (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: shock (labour age)	10	0	-	-	-	1
	Interaction: shock (gender and labour age)	16	0	-	-	-	1

** denotes significance at P<0.05;** denotes significance at P<0.01; *** denotes significance at P<0.001;n.s. denotes non-significance; n.o. denotes no observations. Pseudo R^2 for parsimonious model at aggregate and disaggregate level (without interaction terms). n: number of observations* *(d) Explanation of the relationship between charcoal income and AMP*

Charcoal income failed to explain the marginal effect of being AMP, even in best-off village Mabu E - which was the best-off village mainly due to economic capital that contributes only 15% to the adjusted headcount ratioM_0–as well asfor the best off income quintile. Thus,even in the economically best-off village we find a lack of evidence that this is due to charcoal production, and even for the best-off income quintile this does not translate to deductions in the likelihood of being AMP. If charcoal production is applied as an interaction term in MLR model *b*however, it was found to be a statistically significant *coping strategy* that reduces the log of the odds of being *in* multidimensional poverty *if* the household experienced an idiosyncratic shock, such as a serious crop failure. If disaggregated however, this effect was not significant in best-off village Mabu E. In other words, cash income from charcoal production is potentially helpful to prevent descending into multidimensional poverty by increasing the resilience to shocks, yet evidence is weak if the data is disaggregated. Overall, our findings show the importance of local charcoal production as a coping strategy, yet challenges the perception that charcoal income can alleviate poverty if a multidimensional conceptualisation is used.

Two main reasons can explain the observation why charcoal income is not a significant predictor of AMP:

1. A Spearman rank correlation coefficient between all eleven predictors and nine variables comprising the identification function ρ of AMP (see table 1 of SI3) revealed that gross income from charcoal making is significantly and positively correlated with formal education (0.17) and assets owned (0.2). Yet, it is not significantly correlated with food (in)security as well as the combined access to services, associations and credit variable. These are the two biggest contributing variables j toM_0at the aggregate level (with 22%

and 13% respectively)[xvi]. Food insecure households borrow food or money as their main coping strategies, rather than producing more labour intensive charcoal (see summary statistics of sub point food(in)security in SI1). This stands in contrast to the experience of an idiosyncratic shock, where we find that the most applied coping strategy to be the harvest of more forest products (see summary statistics of sub point idiosyncratic shocks experienced in SI3). This explains why charcoal significantly lowers the log of the odds of being AMP if it is used as an interaction term on the experience of an idiosyncratic shock in MLR model *b*. Also, the negative correlation of food (in)security with an idiosyncratic shock (-0.52), the second highest correlation overall, and female household head (-0.16) helps to explains the significant role of these predictors in that model. The moderate correlation of charcoal income with assets can be interpreted as a positive spill over effect on acute multidimensional poverty (with assets being positively correlated with sanitation (0.14), water (0.14), education (0.26), food security (0.22), and housing (0.16)). However, as assets are also positively correlated with a number of other livelihood related predictors such as area size (0.26) or value of livestock (0.35), charcoal income is not solely responsible for that effect.

2. A Kruskal-Wallis H test revealed a statistically non-significant difference in gross charcoal income over Y_i[xvii]; charcoal income quintiles over Y_i were also found to not vary as established by a one-way ANOVA[xviii]. Consequently, a statistically significant variance in charcoal income over Y_i was not identified. The regressed *z* statistic of 0.84 in MLR model *a* is a reflection of this non-variance[xix]. It displays a pattern of charcoal income distribution that could have been the result of a random distribution.

4. Discussion

This paper focused on the scope and limitations of charcoal production to alleviate poverty in the multidimensional space. In Mozambique charcoal production offers a viable opportunity to supplement income from smallholder agro-pastoralism and other livelihood activities (Levy and Kaufman, 2014; Jones *et al.,* 2016), while elsewhere in Sub-Saharan Africa charcoal was clearly identified as a route out of poverty (Ainembabazi*et al*., 2013; Wunder, 2014; Smith *et al*., 2015). Due to growing urban demand, low barriers of access to production and the abundance of *Colosphospernum mopane* as the preferred tree species used in the production (White, 1983; Woollen, *et al*., 2016), it is estimated that up to 3 million Mozambicans (approx. 15% of the population) are involved in the semi-legalised charcoal trade (Cuvilas*et al*., 2010), with a contribution of 2.2% to Mozambique's GDP (van der Plas*et al*., 2012: 59). This has intensified a policy debate about the role of charcoal production in the alleviation of rural poverty. The Government of Mozambique identified the inclusive and community-based usage of natural resources as a key priority area in its strategy for rural poverty reduction in its current five year plan 2015-2019 (GoM, 2015).We used a multidimensional poverty measure given that the GoM adopted a multidimensional definition of poverty in 2011 (GoM, 2011).

While greater income from charcoal can potentially contribute to an increase in the economic and human capital of the poor, our findings suggest that charcoal income alone cannot be perceived as a sufficient condition to tackle the structural challenges posed by acute multidimensional poverty in this region. Although the best-off charcoal income quintile generates half of all charcoal income which puts its members above the Mozambican poverty line, and thus out of extreme poverty as defined by the international poverty line of 1.25(1.90)US$/day, we still find that 59% of these households are*in* acute multidimensional poor.Thus, even for the best-off charcoal producers who we consider to be out of monetary poverty, the production of charcoal is not a clear path towards leaving acute multidimensional poverty.

Interestingly, this confirms and challenges existing studies that found charcoal to be a route out ofpoverty. An increased charcoal production certainly allows for the generation of more cash income;and indeed, the best-off quintile produced enough to leave monetary poverty (this confirms findings in Ainembabazi*et al.*, 2013). However, in our study area, the average charcoal producer stays below the monetary poverty line. Thus, for the average producer in our study site, charcoal production is not a pathway out of monetary poverty (which confirms findings of Schurle*et al.*, 2014). While we find evidence that charcoal producers have more income streams than non-producers, the difference is not significant. We do not find charcoal income to be significantly correlated with diversification, or other livelihood streams, such as value of livestock, business income or wage labour income (see table 1 in SI3).Charcoal production remains the sole cash income source for most households in the study area. This stands in contrast to studies that found charcoal to be a take-off activity to venture into diversified livelihood activities, such as business creation,and eventually to poverty reductions(Smith *et al*., 2015; Schurle*et al.*, 2014)[xx].Most importantly for the analysis in this paper however, we find that charcoal income is not a clear route out of acute multidimensional poverty (even for the best-off charcoal income quintile). In the multidimensional space, charcoal cash income was found to be a coping strategythat is resorted to by households in order to deal with idiosyncratic shocks, such as crop failures. This locates our findings closer to literatureof studies that identified the important role of charcoal cash income on poverty prevention (Levy and Kaufman, 2014; Kalaba*et al*., 2013 or Kambewa, 2007). While charcoal income can act as a coping strategy, evidence is insufficienthowever to label the production of charcoal a safety net from impoverishment in the multidimensional space. Too many charcoal producing households have been found to be*in* AMP in order to justifiably make that claim.

Some studies have found small-scale producers to be trapped in “perpetual poverty” given their reliance on charcoal while lacking alternative off and on-farm income sources (Ndegwa, 2016: 173). In our study site and its focus on AMP, such a finding may be premature. 36% of the lowest income quintile were found to be non-AMP (while being in monetary poverty).However, given that charcoal is the main cash generator in our study site, we find the lack of correlation with other income streams in light of thenon-significant semi-elasticity of AMP to charcoal income worrisome.It requires future analysis with panel data to better understand their varying poverty statuses.

Comparisons of findings are done with the caveat that results are strongly determined by contextual factors, such as geographical location and the entrenchment of local producers in poverty (that is the depth, severity and dynamics of poverty). Studies are also characterised by a strong theoretical and methodological heterogeneity (Angelsen*et al.,* 2014; Veldede*et al.*, 2004). Most studies see the value of charcoal production to poverty reduction in the way producers invest revenues in other household activities. The focus of this study was to purposefully study the contribution of charcoal cash income to AMP in order to complement these existing studies on the value of charcoal to poverty. This necessitates tosituate the findings in context of a multidimensional poverty debate as well.

Our findings suggest some overlap between the monetary poor and the multidimensional poor in our study site; yet, we also detect a great number of non-monetary poor that are in AMP. This confirms findings of Wang*et al.,* 2016 and other authors (seeAlkire*et al*., 2015; Ataguba, *et al.*, 2013; Castro *et al.*, 2012; Ruggeri-Laderchi, *et al.,* 2003) that identified that income and multidimensional poverty does not necessarily overlap. Aswe find no statistically significant reduction in the log of the odds of being AMP with a unit increase in charcoal income, we divert from study findings that identified modest reductions in multidimensional poverty with an additional individual income (Suppa, 2016). The non-significant semi-elasticity of AMP to charcoal income found in this study site[xxi] needs to be seen in light of emergingresearch findings that show that multidimensional poverty measures appear to have a low elasticity to economic growth (Mahoozi, 2016), and one that is lower in comparison to income poverty (Santos *et al*., 2016). In some cases, studies were unable to identify a clear "association of multidimensional measures with GDP p.c. or the growth thereof" (Suppa, 2016: 24). Santos *et al*. interpret the timid elasticity of acutemultidimensional poverty to economic growth as proof that "[economic] growth doesnot seem to be particularly pro-poor when poverty is measured from a multidimensional perspective" (2016: 28). Their results "highlight the need for countries to grow inorder to reduce poverty, but they simultaneously suggest the limited power of economic growth *per se* toachieve grand reductions in poverty" (2016).

These are arguments that can be reiterated here.While we find charcoal income unable to alleviate AMP in this site, charcoal income still leads to improvements in the human and economic capital of the poor. The finding that the poorest income quintile only generates 3.1% of all charcoal income yet has 64% of households in AMP means that their lack of proper inclusion in the charcoal value chain deprives that group in particular of the opportunity to use charcoal income as a means toachievesuch valuable accumulations in assets or education. This being said, on average the acute multidimensional poor in our study site were deprived in 67.7% of indicators. This reflects the great intensity of poverty in Mabalane district. Even with ample resources at the household level is it difficult to fix such deeply entrenched deprivations (as proven by the 34% of AMP households who were non-monetary poor). For instance, while greater charcoal income can bring welfare benefits, access to equitable health care cannot be achieved by greater household income alone, but by improving the physical availability, social acceptability and financial affordability of health care in the region (WHO, 2016; Saksena*et al.*, 2014; McManus, 2013). Households with less members in labour age (15-64) face physical challenges in making charcoal. They should be socially protected (Francisco,2013), rather than encouraged to accelerate efforts to produce labour intensive charcoal.

Policy makers in Mozambique face a new set of challenges with acute multidimensional poverty. Poverty in the multidimensional space is characterised by complexity (Robeyns, 2003), both in measurement, and in strategies to achieve its alleviation and mitigation in a sustainable manner. Recent research by Le Blanc (2015) highlights that "ending poverty in all its forms" (SDG target 1) is linked to progress in ten other SDG goals, with the thickest link to target 10 (reduce inequality within and among countries). This necessitates acoherently designed integration of cross-sectoral policies (LeBlanc, 2015; Janus and Holzapfel, 2016). A mix of market mechanisms and efficient public service delivery is required (see Bourguignon and Chakravarty, 2003; Callan *et al.*, 1993). In Mozambique, this necessitates a stronger role of the Ministry of Coordination of Environmental Affairs and the Ministry of Planning and Developmentin the current reform process.Poverty reductions in this region also necessitates a more equitable and inclusivecharcoal industry. We observe a great unequal income distribution from charcoal production, and other studies of ACES have highlighted that the majority of charcoal income in the study site was generated by non-residents(Baumert *et al.*, 2016a: 137). Concentrated policy interventions are required that target the equitable and inclusive integration of local producers into the charcoal industry (for instance by introducing a quota to obtained licences for hiring local producers, and by adjusting the legal framework to make it easier for small-scalecharcoal producers to participate in the trade).

5. Conclusion

This paper considers income from charcoal making as a means to a valuable end. It analyses the instrumental value of income to alleviate acute multidimensional poverty. We find confirmation for the hypothesis that cash income from charcoal production is not a sufficient condition to alleviate acute multidimensional poverty in rural areas of southern Mozambique. Our findings show a positive correlation of charcoal production with personal assets and the level of education of the household members, and we find that charcoal producing households are more resilient to shocks. However,local charcoal production does not contribute to the alleviation of acute multidimensional poverty when additional indicators such as access to equitable health care and food security are also taken into account. Although households in the best-off charcoal income quintile generate half of all charcoal income which puts its members out of extreme monetary poverty, we still find that 59% of these households and its members are in acute multidimensional poor. This highlights the enormous structural challenges both producers and non-producers of charcoal face alike in this region. Reductions in AMP require a concentrated cross-sectional whole-of-government approach to tackle poverty in its multidimensional complexity, while attempts at making the charcoal industry more inclusive of local producers should be accelerated.

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[i] Suich*et al.* (2015) reviewed 398 refereed studies published from the year 2000 onwards on the empirical links between ecosystem services and poverty, and found that poverty was assessed at maximum in two dimensions of poverty, either relating to income/ assets or food security/ nutrition. Many studies were found to focus "only on income, rather than taking a multidimensional approach to poverty" (2015: 137-138).

[ii] For similar findings seeAlkire*et al*., 2015; Ataguba, *et al.*, 2013; Castro *et al.*, 2012; Ruggeri-Laderchi, *et al.,* 2003.

[iii] Please refer to Ravallion (2011) for a critique on composite indices on multidimensional poverty. For a response on the critique, please refer to Alkire and Foster (2011b).

[iv]Following Alkire et al. (2015) and Alkire and Santos (2014: 253), indicators were chosen to represent as accurately and yet parsimoniously as possible the respective poverty dimension, without displaying a high intercorrelation (Cronbach α = 0.4). Also, wherever possible and logically coherent, indicators were chosen that feature in the Multidimensional Poverty Index in order to increase comparability of our research findings (Alkire and Santos, 2010; 2014). Indicator specific cutoff lines z_j were chosen according to international standards or through inductive reasoning. Overall, indicators were chosen that are susceptible to pro-poor policy prescriptions (e.g. access to equitable health care is improvable upon increasing the physical availability, social acceptability and financial affordability of health care). Most indicators are outcome/achievement indicators (*functionings*), e.g. in relation to formal education, while some are opportunity/input indicators (e.g. access to services, associations and credit).

[v] Cumulatively, pastoralism was the most named covariate for placement in different wealth categories (comprised of cattle and cows (named 34 times), chicken (10), goats (8) and livestock (6)).

[vi] The analysis initially comprised fifteen (non-indicator measurement) predictors (subsequently referred to model *B*), which were reduced in the post-estimation diagnostics to eleven demographic and socioeconomic predictors (subsequently referred to as model *A*). The additional indicators were "net value of livestock", "age of household head", "household size" and a dummy variable taking a value of one if the household did report to have been in "wage labour" and 0 if it did not. The diagnostics comprised a correlation analysis via Cronbach α; a Hosmer-Lemeshow goodness of fit test (where a scaled deviance statistic $D^{*}(y;\hat{\mu}) = 2l(\gamma;\hat{\mu}_{(a)}) - 2l(y;\hat{\mu}_{(b)})$ is twice the difference between the maximum log likelihood of the parsimonious model *A* and the comprehensive model *B.* A Hosmer-Lemeshow x_{df}^{2} with df as degrees of freedom is applied to test the null hypothesis H_0 that model *A* is as good a fit as model *B*(known as the *parsimony* rule)); the variance inflation factor to quantify severity of multicollinearity; a pearson, deviance and pregibon residual analysis; a specification error detection with a linktest; a Receiver operating characteristic (ROC) curve; and a Wald statistic of parameter constraints). The following results can be reported: Cronbach α for model *A* of 0.58 (depicting a desirable low inter-correlation among indicators, one that is lower than for 15 variables in model *B* (0.63)); a Hosmer-Lemeshow χ2(8)=10.50, p=0.23 for model *A* vs. Hosmer-Lemeshow χ2(8)=10.05, p=0.26 of model *B* (both models do not depict evidence of a of lack of fit, yet as the deviance statistic D^{*} of 0.45 at a 5% type I error rate is below the chi-squared statistic of 9.488 at 4 degrees of freedom (the difference in number

of regression parameters), we cannot reject the null hypothesis that the parsimonious model *A* is statistically equivalent to the comprehensive model *B* and thus superior); a mean variance inflation factor for model*A* of 1.21 vs. 22.63 for model *B*; the residual analysis showed that for model *B* two households would have changed the covariate labour age at the 5% significance level (for which they would have needed to be excluded from the model), whereas model *A* does not require any such exclusion as individual households did not impact on the 5% significance levels of covariates; both models showed no specification error (both linktests were statistically non-significant), indicating no significant covariates were omitted (and thus the *parsimony* rule applies); the area under the ROC curve for model *A* is 0.76 vs 0.75 for model *B*(thus both have "fair" test results, and the parsimony rule applies). Finally, a Wald Statistic of parameter constraints shows that the coefficients in model*A* are not simultaneously equal to zero (are insignificant jointly), meaning that including all eleven variables in the model creates a statistically significant improvement in the fit of the model (Wald χ2(11) = 47.08, p = 0.0001).

[vii] Expressed as $D^{*}(y;\hat{\mu}) = 2l(\gamma;\hat{\mu}_{(a)}) - 2l(y;\hat{\mu}_{(b)})$, where the scaled deviance statistic is twice the difference between the maximum log likelihood of the parsimonious model *(b)* and the comprehensive model *(a).* A Hosmer-Lemeshowx_{df}^{2} with df as degrees of freedom is applied to test the null hypothesis H_0 that model *(a)* is as good a fit as model *(b)* (Alkire*et al.,* 2015: 306ff).

[viii] Due to small sample sizes *n* at the village level we also tested MLR model *b* for a 1% type I error rate that yielded no impact on results (not reported).

[ix] Estimated gross income from charcoal making is calculated as quantity of production multiplied byestimated average price per unit (250MZN per charcoal sack in Hochane, Mabuapense and Mavumbuque, 300 MZN in Matlantimbuti, Tindzwaene and Sangue).

[x] The average gross annual income from charcoal making is 26057±36098MZN (n=225, this includes households without a reported income from charcoal making (thus includes village Match G) but excludes missing data from Mav D). Calculated on a daily basis this converts to 71.3MZN/day per household. Given the official exchange rate of 1USD=31.35MZN for 2014 (LCU per US$, period average; Word Bank, 2016a), this converts to 2.3US$/day per household (using the more appropriate 2014 PPP conversion factor of 1US$=16.2MZN (private consumption (LCU per international US$); World Bank 2016b), we find the conversion to be 4.4US$/day per household). With an average household size of 6.03±3.9 in the study area, we calculate

the average gross income per person per day from charcoal for its producers to be 11.8MZN (0.38US$ for the nominal exchange rate; 0.73US$(PPP)). Excluding valuations of other income sources and its imputation in the calculation, we find that gross income from charcoal making alone is not enough to put members of the average household producing charcoal out of monetary poverty, both if the nominal exchange rate is used and when PPP is used (they are below the then valid extreme poverty line of 1.25US$/day (PPP), and the very specific Mozambican poverty line of 18.31MZN). Even if only households are analysed who reported to have a charcoal income ≥0MZN (n=161) the average producer is considered in monetary poverty. The average income of just this subsample is 36415±36098MZN. Calculated on a daily basis the charcoal producing households generates 99.76MZN/day per household. This converts to 16.55MZN per person/day (or 0.52US$ per person/day with nominal exchange rate, and 1.02US$(PPP)).

[xi] This is calculated by multiplying the headcount ratio H with the average deprivation share across the poor in indicator $j(A_j)$ (Alkire and Foster, 2009: 83).

[xii] When Y_i is regressed individually against the 11 variables of MLR model *(a)*, in addition to "cropland area size", "labour age" and "idiosyncratic shock", we find thatthecovariates "diversification", "female household head" and "subjective well-being" also displayed *z* statistics at the significant level at 5%. Hence their continuous analytical usage as interaction terms (in MLR model *b*). Charcoal income failed at the 5% significant level both at the aggregate and disaggregate level and also when normalised, categorised into quintilesand logarithmically transformed to account for the observed skewness and heteroscedasticity(not reported). An ordered logistic regression of charcoal income quintiles using $Y_i$as predictor was found to be statistically non-significant as well (z=-0.41, p=0.68). This eventually means that even for the best-off income quintile charcoal cash income is not a significant route out of AMP.

[xiii] We tested the robustness of the findings in MLR Model *a* by varying the identification function ρ (where $Y_i$taken the value of one if and only if $c_i \geq 3$ and $c_i \geq 5$, and zero if otherwise (not reported)). Thus we test results for a range of k values which displayed the most robust ranking results across the villages (see figure 1 and 2 in SI2)). At the aggregate level, "labour age" dropped as a significant predictor of AMP for $c_i \geq 3$, while "diversification" and the "presence of a female headed household" turned into additional significant predictors of AMP for $c_i \geq 5$ (decreasing the log of the odds by 32%, and increasing them by a factor of 2.6). For bother alterations, charcoal income remains a non-significant predictor at the aggregate level. This finding

was repeated at the disaggregate level, however a minor Yule-Simpson effect was observable for $c_i \geq 3$ (where charcoal income turns into a significant predictor of AMP for Mabu E, however at a size that decreases the odds of merely 1%). Thus, we consider the results obtained in the MLR model *a* to berobust against reasonable alterations of the identification function ρ. Results of MLR Model *a* remain robust as well when analysed only for a subsample of charcoal producers that *sold* their charcoal by the time the data collection took place (and thus reported to have a gross income from charcoal ≥0MZN ((*n*=161; *Pseudo* R^2=0.177*)*). Area size, labour age and idiosyncratic shock remain significant predictors of AMP, whereas charcoal income remains a non-significant predictor at the aggregate level. However, in just analysing that subsample, we find regression results on AMP less robust to changes in the identification function when charcoal income quintiles are used as predictor (not reported). We find a significant effect of charcoal income quintiles on reducing the odds of being $Y_i = 1$for $c_i \geq 3$, namely by 37%, *ceteris paribus (Pseudo* R^2*=0.251*).We find an additional 32 households becomingmultidimensionally poor ($H_{c_i \geq 3}$ =86%). This constitutes an increase of 30% (from $H_{c_i \geq 4}$=67%). While we observe a moderate comparative reduction in the average intensity of deprivations A (from $A_{c_i \geq 4}$=67% to $A_{c_i \geq 3}$=60%), the prevalence of poverty M_0 for $c_i \geq 3$ is with 0.516 greater than for $c_i \geq 4$ (M_0 =.449). Thus, we find that with a greater prevalence of poverty (driven by a move towards a *union approach* in the identification function ρ), the role of charcoal making for its producers in predicting deductions in the log of the odds of being AMP increases. A one-way ANOVA between charcoal income quintiles over $Y_i = c_i \geq 3 = 1$ reveals a significant difference across the sample (*F*(4,156) =2.81, p=.02). A Tukey post-hoc test revealed that $Y_i = c_i \geq 3 = 1$ was statistically significantly lower in the 5thquintile compared to 1st(-.25±0.9, p=.029). This translates to a significant low-to-moderate semi-elasticity of 0.68 of AMP when charcoal income data is logarithmically transformed.

[xiv] The deviance statistic D^* of 2.25 at a 5% type I error rate was identified between the comprehensive MLR model *(a)* (Hosmer-Lemeshowχ2(8)=10.50, p=0.23) and an alternative parsimonious MLR model *(b)*, one that contained only the three significant predictors of AMP (Hosmer-Lemeshow χ2(8)=8.25, p=0.40). As the deviance statistic D^* is below the chi-squared statistic of 15.507 at 8 degrees of freedom we cannot reject the null hypothesis that the parsimonious model is statistically equivalent to the comprehensive model.

[xv] While interaction terms were included in MLRmodel *b*, second-order terms were excluded as their inclusion would have not improved the model fit and the parsimonious rule applies (scaled deviance statisticD^*

between MLR model *b* and potential MLR model *b.2* of 1.55 at a 5% type I error rate is below the chi-squared statistic of 5.991 at 2 degrees of freedom).

[xvi] In contrast, the two predictors found to show deductions in the likelihood of being Y_i=1 at the aggregate level, namely cropland area size and labour age, were found to have significant correlationswith indicators across all three dimensions of AMP (cropland area size with sanitation (0.18), water (0.16), access to services services, associations and credit variable (0.36) and assets (0.26), and labour age with sanitation (0.18), education (0.39), assets (0.45) and housing (0.26)).

[xvii] $\chi 2(1)=.009$ $p=.92$. AShapiro-Wilk W test for normality revealed a non-normal distribution of charcoal income(W=0.737,p=.00001).

[xviii] $F(4,156) = 0.46$, $p=.77$. A Shapiro-Wilk W test for normality revealed a normal distribution of charcoal income quintiles (W=0.99,p=.68)

[xix] This also helps to explain why the gross value of livestock was not a significant covariate in the MLR model *a* (*z* statistic of -0.22). While livestock is positively correlated with sanitation (0.18), under five mortality (-0.14), food (in)security (0.19), access to services (0.25), assets (0.35) and housing (0.32), thus with six out of nine variables across all three dimensions of AMP, a one-way ANOVA was unable to establish a statistically significant difference between quintiles over Y_i ($F(4,143) = 2.14$, $p = .07$).

[xx] Only if part of a strategy to diversify the livelihood portfolio which eventually leads to a business creation is charcoal making useful in the potential alleviation of AMP. We used confirmatory principal component factoring(Costello and Osborne, 2005)to collapse the eleven covariates into latent variables (not reported). This was done to understand the effect of latent variables that connect the eleven covariates. PCF revealed four uncorrelated factors with an *eigenvalue* equal to or greater than one, which were retained following the *Kaiser* criterion (see Costello and Osborne, 2005). Together, they explain 55.8% of the total variance in the observed variables. Each factor is comprised of observed variables that hold the strongest factor loadings (or standardised regression coefficients). The strongest correlation of factor 1 is with years of residency and labour age, factor 2 with business ownership and diversification, factor 3 with shock and subjective perceptions of fortune, and factor 4 with wage income and area size. Charcoal income was found to have a low regression coefficient that prevents the variable being identified in the factor loadings with an *eigenvalue* greater than one.The identified factors are then used in another MLR model. For any given household, the log

of the odds of being AMP decreases, *ceteris paribus*, with an increase in factor 1 (by 40%) and factor 2 (by 35%), yet increases by 60% with an increase in factor 3. Factor 4 produced a *z* statistic that failed the 5% significance level. We conclude that if business income is aspired to, income diversification is more important than increased charcoal production (income diversification and business ownership is significantly and positively correlated (0.29) (see table 1 in SI3)).

[xxi] When charcoal income data is logarithmically transformed we detect a significant low-to-moderate semi-elasticity of 0.54 of the participatory wealth rankings to charcoal income. This observation is worth exploring further. Other future research suggestions comprise a) an assessment and further exploration of the significant predictor “cropland area size” and its possible trade-offs with forest conservation and thus sustainable development; and b) the exploration of the new AF method for ultra-deprivations used to obtain the depth of AMP (Alkire and Seth, 2016).