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Abstract

Background: Household air pollution (HAP) and poor nutrition have both been identified as leading causes of morbidity and mortality in Sub-Saharan Africa. Although air pollution from cooking is an important source of HAP, the relationship between HAP and nutrition has not been fully explored.

Objectives: The primary objective was to determine whether there is a relationship between HAP and indicators of nutritional status and dietary intake. The study also explored associations of HAP exposure and dietary diversity.

Methods: Data were collected during a household survey (N=193) in Machinga District, Malawi. The survey included socioeconomic and dietary intake questions, and anthropometric measurements of primary cooks and children under 5. Focus groups were held with household cooks to provide qualitative information on the relationship between aspects of cooking, including fuel use and food choice.

Results: We found positive associations of household fuel consumption with maize consumption and with child weight–for-age and weight-for-length z-scores. Household fuel consumption was not associated with dietary diversity or body mass index of household cooks. However, share of high quality firewood used was positively associated with household dietary diversity and child height-for-age z-score.

Conclusions: The findings indicate a connection between dependence on starchy staples and HAP, which suggests that increasing dietary diversity may have a positive effect on reducing HAP. The findings also show that a higher share of high-quality fuelwood is positively associated with child growth, possibly also due to lower HAP.

Introduction

Household air pollution (HAP) is identified as the second leading cause of morbidity and mortality in sub-Saharan Africa in the 2010 Global Burden if Disease Study (Lim et al. 2013). Given that much HAP in sub-Saharan Africa is from cooking, it is surprising how little attention the nexus between household nutritional status and household air pollution has received. It is well known that both household air pollution and poor nutrition have negative health implications. Pneumonia is a leading cause of death among children under five and malnutrition has been calculated to contribute to over half of deaths among children under five (Bryce et al. 2005). Both HAP exposure and malnutrition are risk factors for acute lower respiratory infections (Bhat and Manjunath 2013). Associations between biomass use, a main source of HAP, and child growth faltering have been detected (Kikafunda et al. 1998, Kyu et al. 2009; Machisa et al. 2013; Mishra et al. 2007; Steyn et al. 2005; Tielsch et al. 2009).

At the same time, biomass is the major source of energy for cooking, with 97% of Malawian households relying on solid fuels as their main cooking fuel in 2010 (Bonjour et al., 2013). Previous research in Malawi found that there is a correlation between fuel use increases and energy intake increases, with most energy intake coming from carbohydrates (Brouwer et al. 1996). The healthfulness of a diet is dependent not only on total caloric intake, but also on adequacy of all macro and micronutrients. In this study, we analyzed both intake of maize meal, the local staple, and dietary diversity in relation to biomass use in order to gain a more nuanced understanding of the interaction between fuel use and nutritional intake. Dietary diversity scores can be used to indicate both a household's access to a range of foods and nutritional adequacy of the diet (Kennedy, Ballard, and Dop 2011). Meta-analyses of information from Demographic and Health Surveys in low-income countries have found a positive association between height-for-age z-scores and dietary diversity indicators (Jones et al. 2013), with reductions in underweight and stunting as dietary diversity increased (Marriott, White, Hadden, Davies, and Wallingford 2012). This begs the question, which this research seeks to answer, as to how increasing dietary diversity relates to fuel use and HAP and what the net health impact might be.

Objectives

We explore the relationship between nutrition and HAP, testing the hypothesis that there is an inverted "U" shaped relationship between dietary diversity and HAP. Household air pollution would be expected to initially increase with greater dietary diversity as more fuel would be needed to cook a wider variety of foods. At a certain point, however, the increase in diversity would include eating more raw foods and foods that might require less cooking time than staples such as maize, leading to a decrease in fuel use and consequently household air pollution. Additionally, as dietary diversity increases, nutritional adequacy is likely to increase, resulting in a protective effect from the negative health impacts of household air pollution.

In fuel scarce environments, it is possible that people decide not to cook or may cook different foods depending upon food availability. Given the ubiquity of fuelwood in our study areas we hypothesized that fuel and cooking choices are driven by food availability rather than the inverse relationship. This hypothesis is supported by previous research on a small sample in Malawi by Brouwer et al. (1996) who found that when fuel is easily accessible, use for cooking is determined by food availability. This study goes further than the work by Brouwer et al. by increasing the sample size and looking at health outcomes and other factors related to HAP in addition to quantity of fuel used.

Methods

Study Area and Data

Our study site is in Machinga District in southern Malawi. The study villages are adjacent to Liwonde Forest Reserve, an area of roughly 274,000 hectares of both fully stocked and degraded miobo woodland. The area is roughly 50 kilometers from Zomba, Malawi's fourth largest urban center. Relative to other places in Malawi the area has high population density and good market access. The main livelihood activities in the area are subsistence agriculture, charcoal production, and small-scale business.

Our data collection involved four activities: five focus groups discussing nutrition and factors affecting HAP including fuel and cooking technology choices, household surveys, primary cook surveys, and anthropometry and health indicators for all households. Focus group participants were women selected from the larger study population with assistance from village chiefs to ensure diversity of age, tribe, socioeconomic status, religion, and current cooking technology. An average of 12 women attended each focus group; the average age of participants was 35 years. The discussion guide focused on livelihood strategies, food availability, fuel collection, cooking and food choices, stove type, kitchen design, and health impacts. Focus groups were conducted in Chichewa by a trained facilitator and translated into English with notes taken by a UNC graduate student during the discussions.

Our household survey sample is drawn from a household panel dataset of 200 households interviewed starting in 2002, with the second and third rounds of the panel taking place in 2006 and 2009 (Jumbe and Angelsen 2006; 2007). Our data were collected in October/November 2013, and add a fourth wave to the household panel. We had a 16% attrition rate between 2009 and 2013, with death and rural-rural migration being the major reasons for attrition. Our total sample size is 200 households in 19 villages in Machinga. To account for attrition and to maintain the sample size at 200 households as in previous years the survey was conducted, we augmented the sample with data from 6 new villages, purposively selected if they had a co-management agreement between the Forestry Department and village leadership. Households were randomly selected from lists of all households provided by village leaders. For our study we defined a household as a group of people that regularly eat together. The household survey has modules on household demographics; asset, land and livestock ownership; agricultural production; forest and environmental income; income from other livelihoods strategies, including business income, wage labor, salaries, remittances, gifts etc.; expenditures; access to forest resources; shocks experienced by the household; questions on asthma, rhinitis and eczema for children between 6 and 14; and data on respiratory infection over the past 2 weeks and burns over the past year for children under 5 in the household. The household survey questions were jointly answered by the household head, primary cook, and any other adults living in the household who were available to respond.

In each household selected for the household survey, we also conducted a separate interview with the primary cook in the household. Primary cooks were defined as those who cooked more than 50% of the meals in the household during the past 30 days. The primary cook survey includes modules on primary cook demographics, frequency and seasonality of cooking practices, household food consumption, kitchen design and ventilation, fuel use, cooking technology choices, other environmental exposures, perceptions about the health, environmental and air pollution implications of cooking choices, perceptions of attributes of traditional stoves vs. improved stoves, indicators of health status of the household head including information on respiratory illness, asthma, headaches, burns, and other HAP related illnesses and injuries. The household food consumption segment included a complete 24-hour recall of foods consumed by household members and which members had consumed each food. Cooks were first asked to recall all foods consumed by the household and then prompted food group by food group to ensure completeness. They were then asked to specify how many times each food was prepared and how many household members consumed it. For each food it was recorded whether the food was cooked in the household. The study was conducted in the months of October-November, which are after the post-harvest period of plentiful food availability but before the season of wide-spread food scarcity. The study fell during the dry, hot season when use of fuel for heating is less common.

Finally, we undertook a nutrition status assessment of primary cooks and children under 5 years old in a sub-set of 161 households. Anthropometric data measurements included weight and length/height of children up to 5 years old and weight, height, mid-upper arm circumference

(MUAC), and triceps skinfold (TSF) measures of the primary cook in the household. Weight was measured using a SECA scale (placed on a board for stability and to ensure a flat, unyielding surface) to the nearest 0.05 kg, with infants too young to stand measured using the scale's mother/child function[1]. Height was measured using a SECA stadiometer; recumbent length for infants was measured on a length board (Perspective Enterprises). Children able to stand were preferentially measured using standing height; WHO height standards (available down to heights of 65 cm) rather than length standards were used for children measured in this way. MUAC was measured using a non-stretchable tape measure and TSF was measured with a Lange skinfold caliper; both of these measures were taken twice to ensure accuracy. All measurements (height, weight, MUAC and TSF) were to the nearest millimeter and were carried out jointly by a Malawian nurse and a US dietetic intern. Amputations, edema, or pregnancy/lactation status of cooks were noted when applicable.

Analysis

Dietary Diversity

We explored HAP in relation to two dimensions of dietary diversity: total household dietary diversity (HDDS) and cooked food dietary diversity (CDDS). Assessment of dietary diversity was based on the FAO's Household Dietary Diversity Scale (FAO 2011). All foods consumed by the household were categorized into one of the 16 FAO food categories (cereals; white roots and tubers; vitamin A rich vegetables; dark green leafy vegetables; other vegetables; vitamin A rich fruit; other fruits; organ meat; flesh meats; eggs; fish and seafood; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; and spices, condiments and beverages) which were

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[1] The mother/child function measures the weight of the mother and then the weight of the mother and child together and displays the child's weight as the difference.

then recombined into 12 standard FAO Household Dietary Diversity Scale (HDDS) food groups (cereals; white tubers and roots; vegetables; fruits; meat; eggs; fish and seafood; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; spices, condiments and beverages) which were totaled to obtain the household's dietary diversity score over the past 24 hours. As a check, the total number of unique foods consumed in the household was totaled and this result was compared to the calculated HDDS; a clear correspondence between the two assessment methods was evident (results not shown). Second, the dietary diversity from cooked foods alone was assessed using the same method but excluding all foods not cooked in the household (both raw foods and foods cooked elsewhere). This made it possible to determine how much dietary diversity came from foods that were themselves directly contributing to household air pollution through cooking fire smoke. Normal diet in our study area included preparing porridge for breakfast and nsima (stiff maize porridge) for lunch and dinner accompanied by some type of relish, often greens, fish, or beans. In addition to looking at dietary diversity, we also analyzed the relationship between consumption of the local staple, maize, and HAP indicators. Our estimates of maize consumption include all local and hybrid maize produced and consumed within the household over the period of one year.

Nutrition Status

Weight and height status of primary cooks was used to calculate body mass index (BMI), except in the case of pregnant or post-partum women (n=4) and cooks <18 years old (n=5), who were excluded from analysis. For children, weight-for-age (underweight), length/height-for-age (stunting), and weight-for-length/height (wasting) z-scores were calculated using the WHO growth standards (WHO Multicentre Growth Reference Study Group, 2006).

Household Air Pollution

A household's exposure to HAP is a function of fuel type, cooking technology, ventilation, fuel moisture content and other factors. We included five potential indicators of HAP exposure in our models: fuelwood consumption, poor ventilation, share of high-quality fuelwood used, share of low-quality fuelwood used, and share of cooking done on a traditional 3-stone fire. Our estimates of fuelwood consumption included all fuelwood consumed by the household within a one year period. Because the study area is along a forest reserve most cooks gather fuel themselves or with assistance from female children, usually collecting it twice per week.

Data analysis was carried out using STATA statistical software (versions 11 and 12, StataCorp Ltd, College Station, TX, USA). Multivariate linear regression models were used to test associations between HAP indicators and maize consumption or nutrition status indicators. Our dependent variable in the first model was maize consumption per adult equivalent. Our independent variables include several indicators of household air pollution, as well as control variables that reflect household demographics and socioeconomic status (Table 1). We ran a second set of multivariate regression models using data for cooks and for children (e.g. individual level data). Poisson regression was used to investigate the relationship between HAP and dietary diversity. We used a probit model to understand the relationship between stunting and HAP. All models control for the forest management block that the household is situated in, which is a proxy for a number of exogenous variables including market access, population density and biomass availability. Household-level models were estimated with robust standard errors. Individual-level models were estimated with standard errors clustered at the household-level. Notes from focus groups were entered into Excel and coded. To address the research questions concerning dietary practices and preferences and the role of fuel, comments were then grouped thematically using matrices.

Written informed consent was obtained from all research subjects, with consent forms in Chichewa provided and explained to participants. Separate parental consent forms were obtained for minor children. The research received approval from the Institutional Review Board of the University of North Carolina at Chapel Hill.

Results

Demographics

Households within the study sample had a mean size of five members and about one-third (34%) were female-headed. 52% of households responding to the health survey had children under 5 years old; the mean age of these children was 30.4 months (3.5 years) with slightly more boys (60, 54%) than girls (51, 46%). Mean per capita income was 88,939.1 MWK, with mean household assets being 8,309.5 MWK per capita.[2] Primary cooks were almost all women (155 out of 156) and were usually family members within the household. Very few were current or former smokers (97% had never smoked), and most had a low level of education with only 8% having any secondary education. The primary cooking location for households in this study was indoors (81%), while 76% of households exclusively used a traditional 3-stone fire and only 5% did not use a 3-stone fire at all. We focused on fuelwood consumption as an indicator of HAP because 90% of households in our sample indicated they use fuelwood as their primary fuel (Table 1).

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[2] At time of writing, the exchange rate was 420 MWK=1 USD.

Maize and fuelwood consumption

We first explored the relationship between maize consumption and fuelwood use. For all households in our sample maize was the dominant starchy staple consumed. We found a strong positive association between fuelwood consumption and per capita maize consumption (Figure 1).

Dietary diversity and fuel consumption

In our sample, the food groups most commonly consumed were cereals, extras (such as seasonings, tea, or alcohol), fruit (in this case, chiefly mangoes), and eggs (Figure 2). Of these, cereals and eggs would generally require cooking, while fruits rarely would and extras would often be added to or eaten with cooked foods. However, there may be a non-linear relationship between fuelwood consumption and dietary diversity. Mean fuelwood consumption fell from 500 kg at 3 food groups to 316 kg at 7 food groups and then rose for 8 food groups (peaking at 510 kg) or 9 food groups consumed. Median fuelwood consumption was consistently lower than mean, but follows a similar trend with the exception of a rise in fuelwood consumption at 6 food groups (Figure 3). The overall trend is towards decreasing fuelwood consumption as dietary diversity rises from 3 to 7 food groups, and fuelwood consumption appears to be higher with consumption of foods from a large number of food groups (8 or 9), but there are very few observations at these high dietary diversity levels. The pattern is similar for CDDS with mean per capita fuelwood consumption decreasing between 3 and 6 cooked food groups, but a small spike in median consumption at 5 cooked food groups and few observations at the ends of the distribution.

Multivariate regression analysis

We found a positive association between them (0.055, SD 0.020, p<0.01) when controlled for confounding variables (Table 2). Maize consumption was negatively associated with using a 3-stone fire for a larger share of cooking (-0.959, SD 0.402, p<0.05). It was also positively associated with income and negatively associated with female household leadership and household size.

Analysis of fuelwood consumption and HDDS and CDDS found no association; the only significant correlation between dietary diversity scores and indicators of household air pollution was a weak negative relationship between HDDS and share of high-quality fuelwood used in the home (Table 2).

Per capita fuelwood consumption showed a weakly significant positive relationship with child weight-for-age (0.0005, SD 0.0002) and weight-for-height (0.0006, 0.0003) but not height-for-age (Table 3). In contrast, there was a positive relationship between share of high-quality fuelwood used in cooking and child height-for-age but not weight-for-age or weight-for-length. When child height was analyzed dichotomously at the household level as presence of a stunted child, both share of high-quality fuelwood (-0.021, SD 0.009) and poor ventilation (1.015, SD 0.508) showed significance (Table 2). Analysis of BMI against household air pollution factors found a positive relationship between poor ventilation and BMI. There was no clear association between dietary diversity and BMI or children's z-scores (data not shown).

Perceived influence of nutrition on HAP vs. HAP on nutrition

Given our findings of significant relationships between indicators of household air pollution and dietary diversity and health, a central question is the direction of influence between nutrition and HAP. As this was a cross-sectional study, we are unable to answer this question definitively, but used focus groups to explore the relationship. The majority of focus group participants stated that fuelwood availability only rarely influences food choice. The only instance in which a desire to reduce fuel use did impact nutritional choices was in the case of beans, which require both greater time and greater fuel to prepare, but even in this case not all women agreed that they would alter their meal plans for the sake of saving fuel. Instead, many stated that they would prefer to collect more fuel so that their families would be able to eat the foods they wanted and which were available. In fact, some women said that if they had already prepared food but their husbands brought home something else they would not hesitate to cook a second time, regardless of fuel requirements. The main factor affecting fuel use was desired speed of cooking, with women stating they would use two fires to prepare meals if they were in a hurry. Food choice, on the other hand, was seen as fully dependent on food availability, with many women stating that they had no choice but took whatever they could find or afford. When asked how they would determine what to eat if given a choice, most women said they would like variety in the foods they ate and cited the six Malawian food groups (staples, legumes, vegetables, fruits, animal products, fats) as the pattern they would like to follow. This statement was made on the assumption that nsima (stiff maize porridge) was prepared daily before branching into relishes. In fact, women consistently pointed to the months of December-February as hungry season, when food was scarce, but also said they had easy access to greens throughout this time. The scarcity was only in maize, which households then prioritized their food budgets to obtain. When listing foods they would like to eat more of if available, the majority of women started by listing animal products (eggs, meat, or fish) and also mentioned that they would like more sweets; none specifically named any fruits or vegetables. When asked about less-preferred foods, vegetables, especially okra, were commonly listed.

Discussion

The increase in fuelwood use with increasing maize consumption is unsurprising as maize preparation involves cooking, generally requiring at least 20-30 minutes on the fire. However, the positive relationship between maize consumption and fuelwood consumption detected in this study is an important confirmation that heavy reliance on a maize-based diet may have serious implications for increasing HAP and the associated health risks. While the low number of observations at the tails of the analysis make it difficult to interpret effects at the highest and lowest levels of dietary diversity; there appears to be a clear downward trend in total fuelwood use with increasing total household dietary diversity or cooked food dietary diversity at the center of the distribution. There appears to be a change to an upward trend in fuelwood use at the highest levels of dietary diversity but there are too few observations to tell if this is a true effect. An intuitive explanation is that as households prepare more foods the increase in diversity is likely to come from foods cooked together in the same pot or additional raw foods, but as more foods are added fuel needs rise to accommodate a larger number of cooked items.

Although increasing dietary diversity is positive in many ways and could improve health in Malawi, where stunting and anemia are prevalent (Republic of Malawi, 2007), the quality of foods that make up that diversity is important. Women's desire to include more animal-source foods could have a positive impact and have been found to improve nutrition status (Bwibo and Newman 2003, Grillenberger et al. 2006, Sari et al. 2010, Dror and Allen 2011), but an increase in more micronutrient-poor foods, such as sweets and sugary drinks, could indicate a future nutrition challenge, with Malawi experiencing the nutrition transition to a double burden of malnutrition and obesity (Popkin, Adair, Ng 2012).

We did not find any association between increasing dietary diversity and children's growth. There are several possible explanations, a main one being that there are many factors affecting child growth; the effect might be too small to detect with a limited sample size and wide age range of children included in the survey. We did, however, find positive associations between child weight-for-age and weight-for-height z-scores and fuelwood consumption; this may in part be due to the association between fuelwood and maize consumption. Stunting was not associated with fuelwood consumption but was negatively associated with share of high-quality firewood used and positively associated with poor ventilation. Thus, as might be expected, stunting is increased in households with poor ventilation and less high-quality fuel where HAP exposure would likely be higher. The positive relationship between poor ventilation and cook BMI may be influenced by the impact of income as wealthier households are more likely to have fully-built (and more poorly ventilated) kitchens.

The generalizability of our findings may be limited because the study was conducted in areas with relatively easy access to forest products, including fuelwood, and many other areas in Malawi and other countries do not have bountiful fuel. Additionally, food consumption information included the variety and frequency of foods eaten but not precise quantities. Finally, as this study was cross-sectional, although following up on previous surveys, it is not possible to infer causality. While it appears from focus group discussions that food choices generally impact fuel use more than the reverse, this needs to be confirmed with further research.

Conclusions

This research indicates that improving dietary diversity may lead to a reduction in HAP, while increasing dependence on starchy staples may lead to an increase in HAP. Starchy staples such as maize require fuel and time spent next to the fire to prepare. This point is particularly salient in the context of Malawi's Farm Input Subsidy Program (FISP), which has a strong focus on increasing maize production and consumption country-wide. As dietary diversity increases, more uncooked foods or foods that require less cooking time may be added to the diet, leading to a decrease in biomass use and a resulting decline in household air pollution.

Although this study was too small to show a clear relationship between increasing dietary diversity and nutrition status, these relationships have been documented elsewhere (Jones et al., 2013; Marriott, White, Hadden, Davies, Wallingford, 2012). This study does offer promise that increasing dietary diversity need not negatively impact other aspects of health as affected by household air pollution. Instead, increases in dietary diversity may improve not only nutrition but also decrease household air pollution, leading to a double benefit for households reliant on biomass fuel.

Our study found statistically significant relationships between fuelwood consumption, poor ventilation, and share of high-quality fuelwood and standard child growth indicators. This reinforces the need for further research on strategies to mitigate the effects of HAP on the health of young children.

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Table 1: Household and individual characteristics

Household Characteristics	*n*	*Mean ± SD*	*Min*	*Max*
Household size	193	5.04 ±2.13	1	13
Total income	194	318,049 ±342,196	-122,260	2,703,140
Age of head	194	48.32 ±17.77	19	99
Education of head	194			
Some primary (c.f. none)		135 (70%)	0	1
Some secondary (c.f. none)		24 (12%)	0	1
Female head	194	65 (34%)	0	1
Primary cook demographics				
Age (years)	202	41.23 ±16.93	10	96
Education	202			
Some Primary (c.f. none)		131 (65%)	0	1
Some Secondary (c.f. none)		16 (8%)	0	1
Smoker	199			
Ever smoked (c.f. nonsmoker)		6 (3 %)	0	1
Child demographics				
Age (months)	111	30.40 ±15.90	0.5	60
Gender	111			
Male		60 (54%)		
Female		51 (46%)		
HAP variables				
Fuelwood consumption per capita (kgs)	193	394.59 ±395.56	0	3714.29
Share of high quality fuel (%)	199	22.54 ±30.13	0	100
Share of low quality fuel (%)	199	63.58 ±32.91	0	100
Share of cooking on three stone fire (%)	199	88.14 ±27.80	0	100
Poor ventilation	202	46 (23%)		
Dietary variables				
Maize consumption per capita (kgs)	193	164.52 ±160.36	0	1020
HDDS	200	5.31 ±1.40	1	9
CDDS	200	4.23 ±1.25	0	8
Nutrition status variables				
BMI	156	22.04 ±15.66	13.1	70.65
Child height/length for age	110	-1.72 ±1.54	-5.84	2.36
Child weight for age	110	-0.69 ±1.18	-4.86	1.76
Child weight for height/length	110	0.43 ±1.21	-2.24	4.86
Prevalence of having a stunted child <5 in households with children <5	83	43 (52%)		

Table 2: Relationship between household dietary factors and indicators of household air pollution

VARIABLES	Maize consumption per capita (kgs) (OLS)	HDDS (Poisson)	CDDS (Poisson)	Prevalence of stunting in <5 (Probit)
Fuelwood consumption per capita (kgs)	0.055*** (0.020)	-4.80e-05 (6.27e-05)	-6.32e-05 (6.86e-05)	0.000204 (0.000320)
Poor ventilation (0/1)	0.246 (26.77)	0.029 (0.040)	-0.040 (0.051)	1.015** (0.508)
Share of high quality fuel (percent)	-0.550 (0.610)	0.001* (0.0008)	0.0009 (0.0009)	-0.021** (0.009)
Share of low quality fuel (pecent)	-0.688 (0.628)	-0.0005 (0.0007)	-0.001 (0.0009)	-0.004 (0.008)
Share of cooking on 3-stone fire (percent)	-0.959** (0.402)	-0.0006 (0.0007)	-0.0003 (0.0006)	0.009 (0.009)
Age of household head (years)	0.098 (0.581)	-0.002 (0.001)	-0.001 (0.001)	-0.027** (0.014)
Household head has some education (c.f. none)	23.55 (22.21)	0.052 (0.037)	0.051 (0.045)	0.288 (0.429)
Female household head (0/1)	-33.83* (19.88)	-0.038 (0.043)	-0.044 (0.050)	0.103 (0.463)
Household size (number of people)	-40.63*** (14.86)	-0.020 (0.034)	0.001 (0.041)	0.609* (0.327)
Household size squared	1.897* (1.060)	0.003 (0.003)	0.001 (0.003)	-0.039* (0.022)
Total Income (MK)	0.0001** (4.82e-05)	7.64e-08 (5.69e-08)	5.44e-08 (5.47e-08)	2.35e-07 (6.24e-07)
N	193	191	191	78
R-squared/Pseudo R-squared	0.339	0.017	0.012	0.251
*** p<0.01, ** p<0.05, * p<0.1				

1. We did not run a model with wasting as DV because we had only one household in the sample with a child who was wasted.
2. Our models also control for the forest management block that the household falls within. There are 5 blocks in total. Results are not reported.
3. Robust standard errors calculated.

Table 3: Linear regression of nutritional status and indicators of HAP

VARIABLES	Cook BMI	Child height (length) for age z-score	Child weight for age z-score	Child weight for height (length) z-score
Fuelwood consumption per capita (kgs)	-0.0004 (0.001)	7.77e-05 (0.0002)	_0.0005*_ _(0.0002)_	_0.0006*_ _(0.0003)_
Poor ventilation (0/1)	_3.807**_ _(1.658)_	-0.305 (0.386)	-0.185 (0.257)	-0.0918 (0.299)
Share of high quality fuel (percent)	-0.011 (0.027)	_0.013*_ _(0.007)_	0.008 (0.006)	-0.0002 (0.006)
Share of low quality fuel (pecent)	-0.027 (0.021)	0.008 (0.006)	-8.99e-05 (0.005)	-0.005 (0.005)
Share of cooking on 3-stone fire (percent)	-0.014 (0.015)	-0.004 (0.006)	0.0009 (0.005)	0.007 (0.006)
Age of household head (years)	0.035 (0.042)	_0.022*_ _(0.012)_	_0.021**_ _(0.008)_	0.012 (0.012)
Household head has some education (c.f. none)	0.217 (1.110)	-0.159 (0.306)	-0.050 (0.249)	0.116 (0.269)
Female household head (0/1)	-0.454 (1.046)	0.707 (0.430)	0.0816 (0.291)	_-0.531*_ _(0.268)_
Household size (number of people)	-0.139 (0.564)	0.080 (0.263)	-0.125 (0.170)	-0.273 (0.252)
Household size squared	-0.0002 (0.047)	-0.001 (0.017)	0.011 (0.011)	0.018 (0.016)
Total Income (MK)	9.14e-07 (1.51e-06)	5.48e-07 (3.83e-07)	-3.04e-07 (4.92e-07)	-8.60e-07 (5.85e-07)
Age of cook	-0.029 (0.032)			
Education level of cook	-1.383 (1.489)			
Smoking status of cook	_-3.143*_ _(1.602)_			
HIV status of cook	-1.852 (1.511)			
Age of child		-0.0006 (0.012)	-0.014 (0.008)	_-0.019**_ _(0.007)_
Gender of child		0.327 (0.303)	-0.064 (0.191)	_-0.433**_ _(0.198)_
Constant	_26.11***_ _(3.596)_	_-3.865***_ _(1.436)_	-1.169 (1.080)	1.288 (1.121)
N	148	105	105	105
R-squared	0.172	0.167	0.192	0.235
*** p<0.01, ** p<0.05, * p<0.1				

1. Our models also control for the forest management block that the household falls within. There are 5 blocks in total. Results are not reported.
2. Clustered standards errors are calculated – clustering is at household-level.

Figure 1: Linear regression model with annual per adult equivalent fuelwood consumption (kgs) and annual per capita maize consumption (kgs)

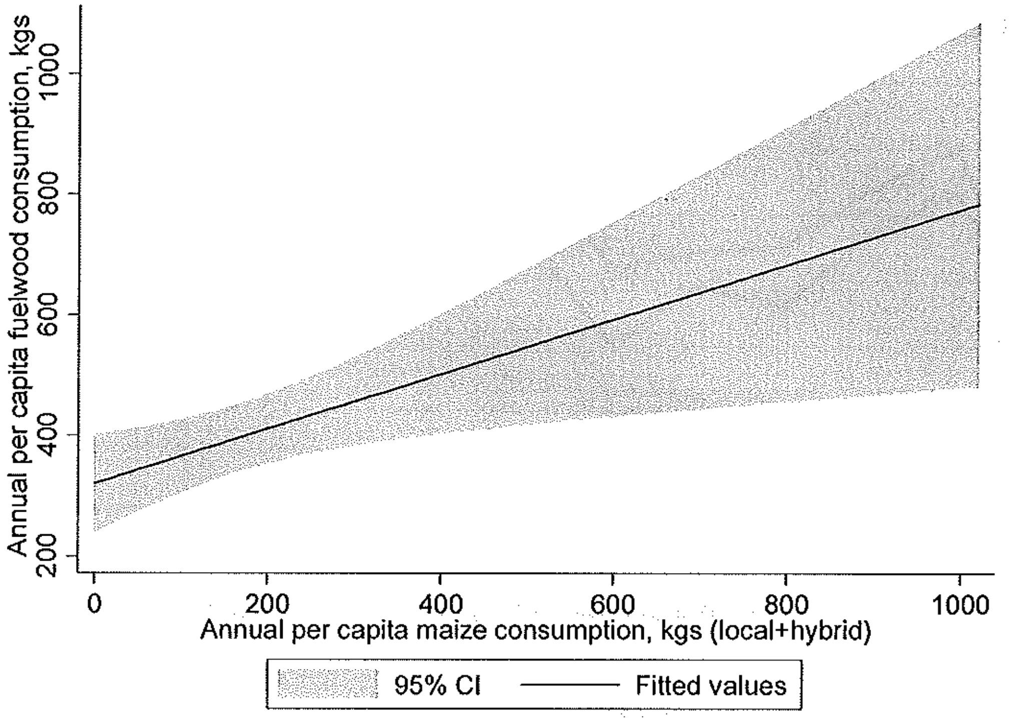

Figure 2a: Household Dietary Diversity and Per Capita Fuelwood Consumption

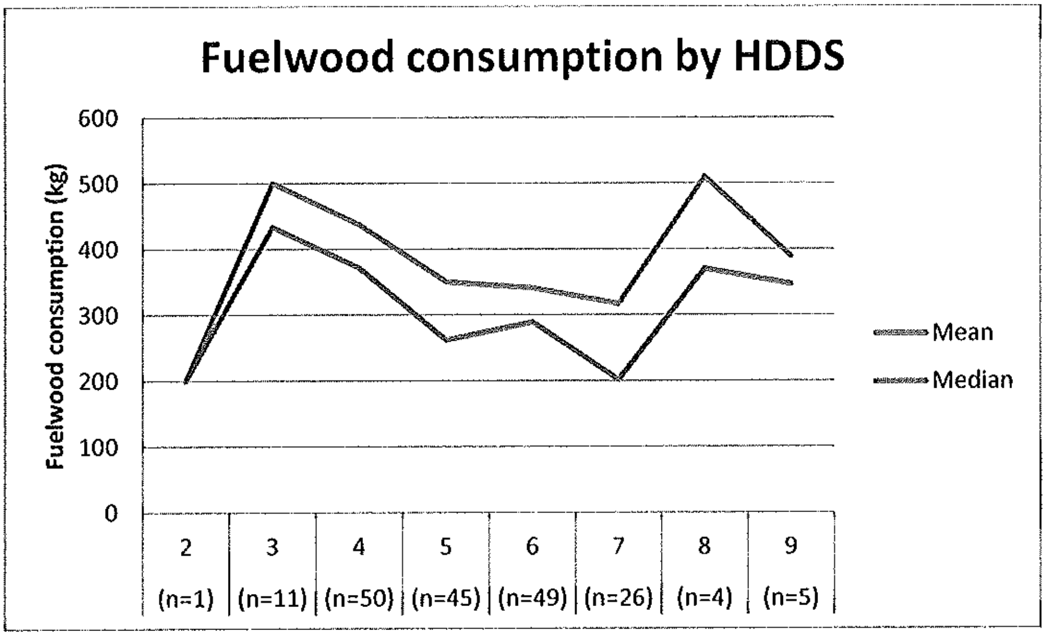

Figure 2b: Household Cooked Foods Dietary Diversity and Per Capita Fuelwood Consumption

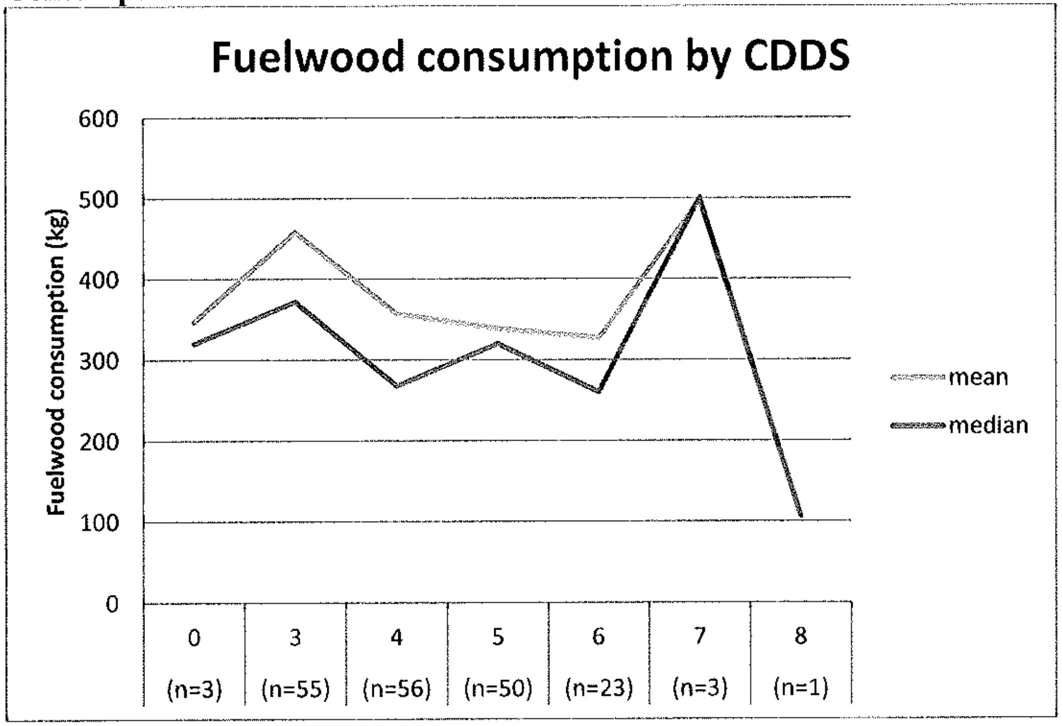

Figure 3: Household dietary diversity by food group