Trends in Household Air Pollution Contributed by the Type of Cooking Fuel Used in Ugandan Households from 2000 to 2016 and Associated Household Factors: An Analysis of Demographic and Health Surveys

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Abstract

Background

The type of cooking fuel used in households can expose the members to polluted air which has been shown to have multiple health effects. We describe the trend in household air pollution (HAP) caused by the type of cooking fuel used in Ugandan households from 2001 to 2016 and explore the household factors associated with it.

Methods

This was a retrospective analysis of four datasets of Ugandan demographic and health surveys (DHS) conducted from 2000/2001 to 2016 with the household as the unit of analysis. We included variables that described the households, the type of cooking fuel, and where the food was cooked. A household was considered to have exposure to HAP if they used cooking fuels like coal, charcoal, wood, straw/shrubs/grass, crops, or animal dung for cooking. Bivariate and multivariate logistic regression was used to determine the association between household characteristics and exposure to household air pollution (HAP) from the most recent DHS of 2016.

Results

A total of 45,376 households were included in the study. In all the surveys, the majority of the households were rural (74.33−85.11%), were headed by a male (68.98−72.46%), and with their highest educational attainment as incomplete primary education (37.21−42.44%). In all the surveys, the majority of the households used wood as a cooking fuel (71.69−82.08%). Most of the households were exposed to HAP (96.69−99.80%). From the multivariate logistic regression analysis, households with a household head having attained either complete secondary education [Adjusted Odd ratio: 0.13, 95% Confidence interval (0.03−0.58), p-value = 0.008] or higher education [Adjusted Odd ratio: 0.11, 95% Confidence interval (0.03−0.48), p-value = 0.003] were less likely to be exposed to HAP when compared with households with a household head having no education.

Conclusions

This study revealed that most households in Uganda have exposure to household air pollution caused by the type of cooking fuel used in the household. This underscores the need for innovations in cooking fuels like clean energy stoves that are cost-effective and cause less exposure to household air pollution.

Background

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One of the biggest contributors to air pollution is household air pollution (HAP). HAP refers to the exposure of members of a household to particulate matter with an aerodynamic diameter less than or equal to 2.5 µm ($PM_{2.5}$) mostly due to solid cooking fuels, such as coal, wood, and agricultural residues [1]. According to the 2017 Global Burden of Disease report, exposure to HAP was the second-highest environmental risk factor [2].

Household air pollution is one of the leading causes of diseases and premature deaths in the developing world [3]. Household air pollution has been shown to affect the health of the populations and is associated with disease conditions like cardiovascular diseases, chronic lung diseases, pneumonia in children, and anemia [3, 4]. This increases the morbidity and mortality rates associated with HAP. In 2019, the Disability Adjusted Life Years (DALYs) associated with HAP was 91.5 million DALYs [5]. The major source of HAP is the type of cooking fuel that is used in the household. These cooking fuels include coal, wood, grass/shrubs, animal dung, and crops [3]. To reduce exposure to HAP caused by the type of cooking fuel used in a household, we need to determine the prevalence and describe the factors associated with HAP. There exist large population-based survey datasets that include variables that can be used to monitor the exposure to HAP in countries [6]. For example, the Demographic and Health Surveys (DHS) conducted periodically in the majority of the low- and middle-income countries (LMICs) collect information on the type of cooking fuel used by households.

In this study, we aimed at determining the exposure of households to household air pollution (HAP) caused by the type of cooking fuel used in Ugandan households from 2001 to 2016 and explore the household factors associated with it.

Methods

Study design and setting

This was a retrospective analysis of open access data collected by the Demographic and Health Surveys (DHS) in Uganda. The surveys included in this study were conducted in Uganda at four time points i.e., 2000/2001, 2006, 2011, and 2016. "The Demographic and Health Surveys (DHS) are internationally comparable household surveys that collect information on demographic, socioeconomic, and health-related variables among nationally representative samples of households in developing countries. Details of the DHS sampling design and strategies are described elsewhere" [7].

Study population

Data analyzed in this study included information on households found in the final datasets shared on the DHS program website. The unit of analysis was households. During the survey interviews, either the household head or any other consenting adults with knowledge about the household responded to questions about the household.

Study variables

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The variables that described the household included in the study were (1) number of household members, (2) type of place of residence (urban or rural), (3) sex of household head, (4) age of household head, (5) wealth index of the household and (6) educational attainment of the household head.

The variable attributed to household air pollution was the type of cooking fuel used in the household. A household was considered to have exposure to HAP if they used cooking fuels like coal, charcoal, wood, straw/shrubs/grass, crops/crop residues, or animal dung/matter for cooking. Non-exposure of a household to HAP was considered if they used cooking fuels like electricity, liquefied petroleum gas (LPG), or natural gas/biogas. Also, variables on where food was cooked (food cooked in the house, separate building, or outdoors) and whether the household had a separate room used as a kitchen (for those who cook in the house).

Data management

The final DHS datasets were downloaded after obtaining permission from the DHS program website. A new binary variable for measuring exposure or non-exposure to HAP was generated from the variable about the type of cooking fuel used after excluding households in which food was not cooked (coded 95) and those that did not specify the type of cooking fuel used (coded 96).

Data analysis

All the analysis in this study was performed in STATA 13 and each survey dataset was analyzed separately [8]. Weighting was performed for all the descriptive statistics using the weight variable (v005) after dividing it by 1,000,000, as recommended by the DHS statistics guide [9].

$$\text{weight(wgt)} = \frac{\text{v005(weightvariable)}}{1,000,000}$$

For the regression analysis in STATA 13, weighting was also performed using the Primary Sampling Unit (PSU) and Strata as the variables v021 and v022 respectively in the DHS survey datasets for the surveys and weight (wgt) calculated previously. The STATA13 code below was used to apply weights before calculating means, standard deviation, and 95% confidence intervals of continuous variables and regression analysis.

svyset v021 [pw = wgt], strata(v022) singleunit(centered)

where pw is the probability weight (sampling weight), psu is the primary sampling unit, v021 is the variable for the primary sampling unit, and v022 is the variable in the DHS that indicates the strata used in the DHS surveys.

Summary statistics

Categorical variables were summarized as weighted proportions. For the numerical variables such as age, they were summarized as weighted means with 95% confidence intervals [8].

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We used bivariate and multivariate logistic regression to determine the association between household characteristics and exposure to household air pollution (HAP) for each of the individual surveys. We reported crude odds ratios, adjusted odds ratios, p-values, and 95% confidence intervals. First, bivariate logistic regression was used to determine the association between HAP and individual household characteristics. Then, multivariate logistic regression was used including the statistically significant variables (1) type of place of residence (urban vs rural), (2) age of household head, (3) wealth index of the household, and (4) household heads education attainment.

Quality control

To ensure that we are working with the correct DHS dataset for a given year, a test analysis was performed to try to replicate the tables in the respective DHS survey reports for the various years. We created a frequency distribution table for the variable of the type of place of residence for the different years in STATA13 and compared the result with what was reported in the respective DHS survey report. All results from this test analysis matched those in the DHS survey reports.

Results

Household characteristics

A total of 45,376 households were included in the study from the four DHS surveys conducted from 2000/2001 to 2016. The lowest mean number of household members was 4.6 people in 2016. In all the surveys, the majority of the households were in rural areas ranging from 74.33% in 2016 to 85.11% in 2000/2001. For all the surveys, the majority of the households were headed by a male with an average age ranging from 41.54 years in 2000/2001 to 42.23 years in 2016. The majority of the households were in the highest wealth index category. In all the surveys, most of the household heads had their highest educational attainment as incomplete primary education ranging from 37.21% in 2016 to 42.44% in 2000/2001 (Table 1). Household fuel use and household air pollution (HAP)

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Table 1
Demographic characteristics of the households that participated in the DHS surveys of 2000/2001 to 2016.

Household characteristics	2000/2001	2006	2011	2016
Number of Households	7885	8870	9033	19,588
Number of household members				
Mean (SD)	4.96 (2.90)	5.13 (2.88)	4.99 (2.81)	4.6 (2.7)
95% Confidence Interval	4.85−5.06	5.03−524	4.88−5.09	4.6−4.7
Type of place				
Urban	1174 (14.89%)	1389 (15.66%)	1691 (18.72%)	5027 (25.67%)
Rural	6711 (85.11%)	7481 (84.34%)	7342 (81.28%)	14561 (74.33%)
Sex of household head				
Male	5714 (72.46%)	6215 (70.07%)	6365 (70.46%)	13511 (68.98%)
Female	2171 (27.54%)	2655 (29.93%)	2668 (29.54%)	6077 (31.02%)
Age of household head				
Mean (SD) in years	41.54 (16.10)	42.13 (15.81)	42.1 (15.63)	42.23 (16.04)
95% Confidence Interval	40.99−42.08	41.59−42.68	41.53−42.66	41.83−42.64
Wealth index of household				
Lowest	1617 (20.50%)	1798 (20.27%)	1719 (19.03%)	3838 (19.59%)
Second Lowest	1203 (15.26%)	1788 (20.15%)	1767 (19.56%)	3753 (19.16%)
Middle	1207 (15.31%)	1709 (19.27%)	1672 (18.51%)	3616 (18.46%)
Fourth	1436 (18.21%)	1650 (18.60%)	1723 (19.08%)	3916 (19.98%)
Highest	2422 (30.72%)	1925 (21.70%)	2152 (23.82%)	4467 (22.81%)
Education attainment of household head				
No education	1853 (23.60%)	1783 (20.19%)	1586 (17.59%)	2932 (14.97%)
Incomplete primary	3332 (42.44%)	3880 (43.93%)	3607 (40.00%)	7288 (37.21%)
Complete primary	892 (11.36%)	1120 (12.68%)	1138 (12.62%)	2759 (14.08%)
Incomplete secondary	1109 (14.12%)	1298 (14.70%)	1668 (18.50%)	3661 (18.69%)
Complete secondary	82 (1.04%)	113 (1.28%)	205 (2.27%)	463 (2.36%)
Higher	492 (6.27%)	588 (6.66%)	759 (8.41%)	2182 (11.41%)

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Household characteristics	2000/2001	2006	2011	2016
Do not know	92 (1.17%)	50 (0.57%)	55 (0.61%)	303 (1.55%)

In all the surveys, the majority of households used wood as a cooking fuel, ranging from as high as 82.08% in 2006 to as low as 71.69% in 2016. The majority of the households cooked their food in a separate building (ranging from as high as 63.62% in 2016 to as low as 59.83% in 2006). For those who cooked their food in the house, the majority did not have a separate room used as a kitchen, ranging from as high as 67.00% in 2006 to as low as 66.13% in 2016. The majority of the households were exposed to HAP with a proportion of 96.69%, 99.80%, 99.03%, and 99.00% in 2000/2001, 2006, 2011, and 2016 respectively (Table 2). Figure 1 illustrates the changes in the proportion of households exposed to household air pollution in Uganda from 2000/2001 to 2016. Figure 2 illustrates the proportions of HAP in the regions of Uganda from 2001/2001 to 2016.

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Table 2
Cooking fuel use and Household Air Pollution (HAP) in the households in Uganda (2000/01 to 2016).

	2000/2001	2006	2011	2016
Type of cooking fuel				
Wood	6363 (81.29%)	7074 (82.08%)	6550 (74.35%)	13590 (71.69%)
Charcoal	1200 (15.34%)	1396 (16.20%)	2060 (23.38%)	4980 (26.27%)
Kerosene	192 (2.46%)	104 (1.21%)	97 (1.10%)	140 (0.74%)
Electricity	61 (0.78%)	4 (0.05%)	28 (0.32%)	76 (0.40%)
Lpg/cylinder	2 (0.02%)	9 (0.10%)	40 (0.46%)	96 (0.51%)
Biogas	4 (0.05%)	4 (0.05%)	17 (0.19%)	18 (0.09%)
Straw/shrubs/grass	0 (0.00%)	26 (0.31%)	18 (0.21%)	50 (0.26%)
Agricultural crop	0 (0.00%)	0 (0.00%)	0 (0.00%)	6 (0.03%)
Dung	5 (0.06%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Where food is cooked [a]				
In the house	-	1224 (14.22%)	1020 (11.59%)	2158 (11.39%)
In a separate building	-	5149 (59.83%)	5268 (59.85%)	12049 (63.62%)
Outdoors	-	2233 (2595%)	2513 (28.56%)	4732 (24.99%)
The Household has a separate room used as a kitchen [a]				
No	-	807 (67.00%)	678 (66.44%)	1427 (66.13%)
Yes	-	398 (33.00%)	342 (33.56%)	731 (33.87%)
Cook in house [a]				
Wood	-	924 (75.54%)	419 (41.09%)	645 (29.90%)
Charcoal	-	206 (16.82%)	468 (45.89%)	1279 (59.25%)
Kerosene	-	78 (6.37%)	64 (6.31%)	88 (4.09%)
Electricity	-	4 (0.32%)	23 (2.28%)	50 (2.33%)
Lpg/cylinder	-	7 (0.56%)	32 (3.12%)	72 (3.36%)

Footnote
[a] For the 2000/2001 Uganda DHS survey, there were no variables on where the food in the household

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	2000/2001	2006	2011	2016
Biogas	-	4 (0.32%)	12 (1.14%)	16 (0.73%)
Straw/shrubs/grass	-	1 (0.06%)	2 (0.17%)	7 (0.34%)
Agricultural crop	-	0 (0.00%)	0 (0.00%)	0 (0.00%)
Cook in a separate building [a]				
Wood	-	4804 (93.29%)	4695 (89.20%)	10534 (87.35%)
Charcoal	-	317 (6.17%)	542 (10.30%)	1440 (11.95%)
Kerosene	-	5 (0.11%)	7 (0.14%)	15 (0.12%)
Electricity	-	0 (0.00%)	5 (0.09%)	13 (0.11%)
Lpg/cylinder	-	2 (0.04%)	5 (0.09%)	21 (0.18%)
Biogas	-	1 (0.01%)	4 (0.07%)	2 (0.02%)
Straw/shrubs/grass	-	19 (0.38%)	6 (0.11%)	26 (0.22%)
Agricultural crop	-	0 (0.00%)	0 (0.00%)	6 (0.05%)
Cook outdoors [a]				
Wood	-	1334 (59.75%)	1425 (56.71%)	2405 (50.58%)
Charcoal	-	872 (39.04%)	1047 (41.65%)	2257 (47.71%)
Kerosene	-	21 (0.93%)	25 (1.00%)	37 (0.78%)
Electricity	-	0 (0.00%)	0 (0.00%)	12 (0.25%)
Lpg/cylinder	-	0 (0.00%)	3 (0.14%)	3 (006%)
Biogas	-	0 (0.00%)	2 (0.07%)	0 ((0.00%)
Straw/shrubs/grass	-	6 (0.28%)	11 (0.43%)	16 (0.35%)
Agricultural crop	-	0 (0.00%)	0 (0.00%)	0 (0.00%)
Household Air Pollution				
No	259 (3.31%)	17 (0.20%)	85 (0.97%)	190 (1.00%)
Yes	7568 (96.69%)	8601 (99.80%)	8724 (99.03%)	18766 (99.00%)
Footnote				

[a] For the 2000/2001 Uganda DHS survey, there were no variables on where the food in the household was cooked.

Household characteristics associated with HAP.

From the multivariate logistic regression analysis, households located in a rural area were more likely to be exposed to HAP [Adjusted Odd ratio: 1.87, 95% Confidence interval (1.24–2.83), p-value = 0.003] when compared with households located in urban areas. Also, households in the second-lowest [Adjusted Odd ratio: 44.7, 95% Confidence interval (5.98–334.21p value < 0.001], middle [Adjusted Odd ratio: 7.00, 95% Confidence interval (2.86–17.14)p-value < 0.001] and fourth [Adjusted Odd ratio: 9.2, 95% Confidence interval (4.15–20.39), p-value < 0.001] wealth index were more likely to be exposed to HAP when compared with households in the lowest wealth index. Households with a household head having attained either complete secondary education [Adjusted Odd ratio: 0.13, 95% Confidence interval (0.03–0.58), p-value = 0.008] or higher education [Adjusted Odd ratio: 0.11, 95% Confidence interval (0.03–0.48), p-value = 0.003] were less likely to be exposed to HAP when compared with households with a household head having no education (Table 3).

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Table 3
Household Factors associated with Household Air Pollution (HAP) in Uganda (Using Uganda DHS conducted 2016)

	Crude Odd ration (95% CI)	P-value	Adjusted Odd ratio	P-value
Number of household members	1.42 (1.31−1.53)	< 0.001	**1.29 (1.19−1.41)**	**< 0.001**
Age of household head	1.02 (1.01−1.03)	< 0.001	0.99 (0.98−1.00)	0.201
Type of place				
Urban	1		1	
Rural	13.79 (9.54−19.93)	< 0.001	**1.87 (1.24−2.83)**	**0.003**
Sex of the household head				
Male	1		-	-
Female	1.14 (0.82−1.58)	0.44	-	-
Level of education of household head				
No education	1		1	
Incomplete primary	0.29 (0.07−1.26)	0.098	0.46 (0.10−2.02)	0.301
Complete primary	0.56 (0.09−3.34)	0.522	1.41 (0.23−8.66)	0.709
Incomplete secondary	0.09 (0.02−0.37)	0.001	0.48 (0.11−2.14)	0.338
Complete secondary	0.01 (0.003−0.05)	< 0.001	**0.13 (0.03−0.58)**	**0.008**
Higher	0.01 (0.003−0.045)	< 0.001	**0.11 (0.03−0.48)**	**0.003**
Do not know	0.03 (0.006−0.159)	< 0.001	**0.18 (0.03−0.95)**	**0.044**
Wealth index				
Lowest	1 [a]		1 [a]	
Second Lowest	175.00 (24.49−1250.6)	< 0.001	**44.7 (5.98−334.21)**	**< 0.001**

Footnote
[a] Predicts success perfectly (dropped and 4458 observations not used). [b] Omitted because of

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	Crude Odd ration (95% CI)	P-value	Adjusted Odd ratio	P-value
Middle	26.33 (11.64–59.55)	< 0.001	**7.00 (2.86–17.14)**	< **0.001**
Fourth	22.47 (10.53–47.95)	< 0.001	**9.2 (4.15–20.39)**	< **0.001**
Highest	1 [b] (omitted because of collinearity)	-	1 [b] (omitted because of collinearity)	
Footnote				
[a] Predicts success perfectly (dropped and 4458 observations not used). [b] Omitted because of collinearity.				

Discussion

In this study, we describe the trends of exposure of Ugandan households to household air pollution (HAP) contributed by the type of cooking fuel they used over a 16-year period (from 2000 to 2016). We analyzed data from the demographic and health surveys (DHS) conducted in Uganda from 2000/2001 to 2016. Our findings revealed that the majority of the households used wood as cooking fuel, cooked their food in a separate building and those who cooked their food in the house did not have a separate room used as a kitchen. Overall, most of the households were exposed to HAP with an increasing trend from 2000/2001 to 2016. From this study, household characteristics like the number of household members, type of place of residence (rural vs urban), level of education of household head, and wealth index were associated with exposure to HAP.

From this study, the most used cooking fuel in Ugandan households was wood with the proportion of households using it ranging from 71.69–83.08%. It is consistent with studies from other low- and middle-income countries (LMICs) like in Malawi, and Zimbabwe where wood is the most common cooking fuel due to its affordability and easy accessibility [10–14]. Using wood as a cooking fuel has been shown to contribute greatly to pollution in households [15]. Innovations to reduce exposure to pollution caused by wood for example the use of briquettes and improved wood-burning stoves have been developed for use in LMICs [16, 17]. Also, our study found that slightly more than half of households who cooked outdoors used wood while 87.35–93.29% of those who cooked in a separate building used wood. Previous studies have shown that cooking using wood in a building has been found to have greater exposure to household pollution when compared with outdoor cooking [18].

From our study, the proportion of households exposed to HAP caused by the type of cooking fuel used was high, ranging from 96.69–99.80%. This is consistent with findings from studies from other LMICs where the proportion of households exposed to HAP caused by the type of cooking fuel was high [12, 19].

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From this study, households located in a rural area were more likely to be exposed to HAP as compared to those located in urban areas. It is consistent with studies from countries in Africa and Asia where households in rural areas were more likely to use cooking fuels that expose them to HAP [12, 19, 20]. This could be because the cooking fuels that cause greater exposure to HAP are cheap and easily accessible in low-income settings like rural areas [10, 11, 13]. Also, this study found that households in the second, middle and fourth wealth index were less likely to be exposed to HAP when compared with those in the lowest wealth index. This could also be explained by the affordability of cleaner cooking fuels by households with an increasing wealth index which has shown to be a determinant of household fuel use [21, 22].

Another finding from this study was that households with a household head having attained either complete secondary education or higher education were less likely to be exposed to HAP when compared to those with no education. This accords with findings from studies in other countries like China, and Malawi [23, 24]. Household heads who have completed secondary or higher education like university education have been found to have better knowledge of the source of HAP [25, 26]. A possible explanation for this might be that they have better decision-making in using a cleaner source of energy for cooking in their households.

Conclusion

Most households in Uganda have exposure to household air pollution caused by the type of cooking fuel used. This justifies the need for innovations that can reduce the exposure to household air pollution caused by cooking fuels.

Declarations

Ethics approval and consent to participate

Ethical approval for the Demographic and Health Surveys is obtained from relevant research ethical approval committees and research regulatory bodies before data collection. We obtained permission to use the DHS survey datasets from the DHS program website. No personally identifiable information is available in the used datasets.

Consent for publication

Not Applicable

Availability of data and materials

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The datasets generated and/or analyzed during the current study are available in the Demographic and Health Survey program website, https://dhsprogram.com/data/available-datasets.cfm and can be accessed after obtaining approval.

Competing interests

The authors declare that they do not have any competing interests.

Funding

Authors contributions

DBA, NR, SBW, and AS conceived the study. DBA and AS requested data from the DHS program website, performed statistical analysis, interpretation of data and spearheaded the writing of the manuscript.AP, EKN, AM, RKK, YAA, and DELP discussed the relevant results. DBA, NR, SBW, AS, PA, EKN, AM, RKK, YAA, and DELP contributed to the writing of the manuscript, read, and approved the final manuscript.

Acknowledgements

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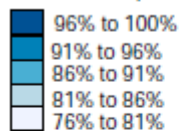
Figures

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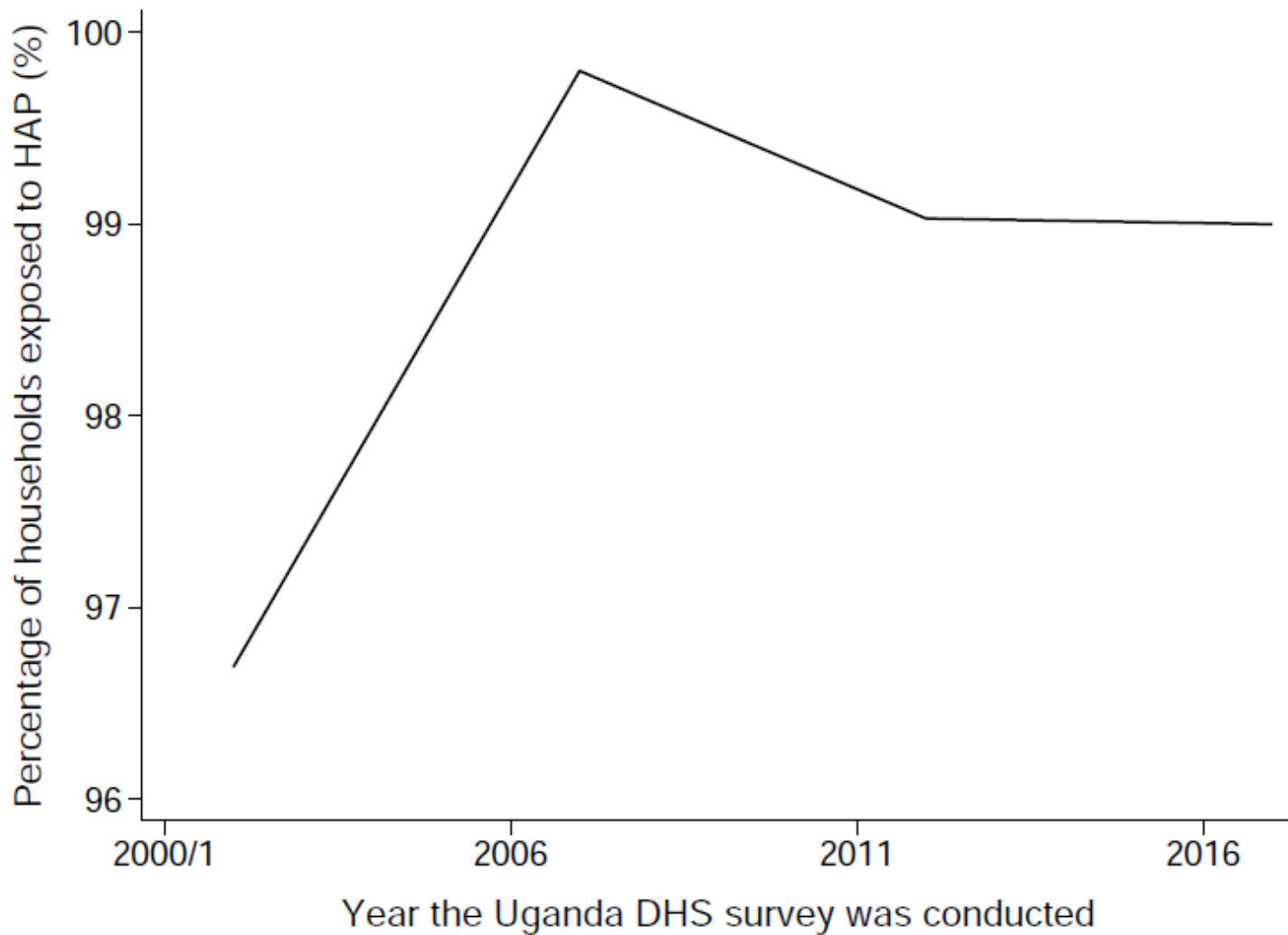
Figure 1

Percentage of households exposed to HAP in Uganda for the period 2000/2001 to 2016.
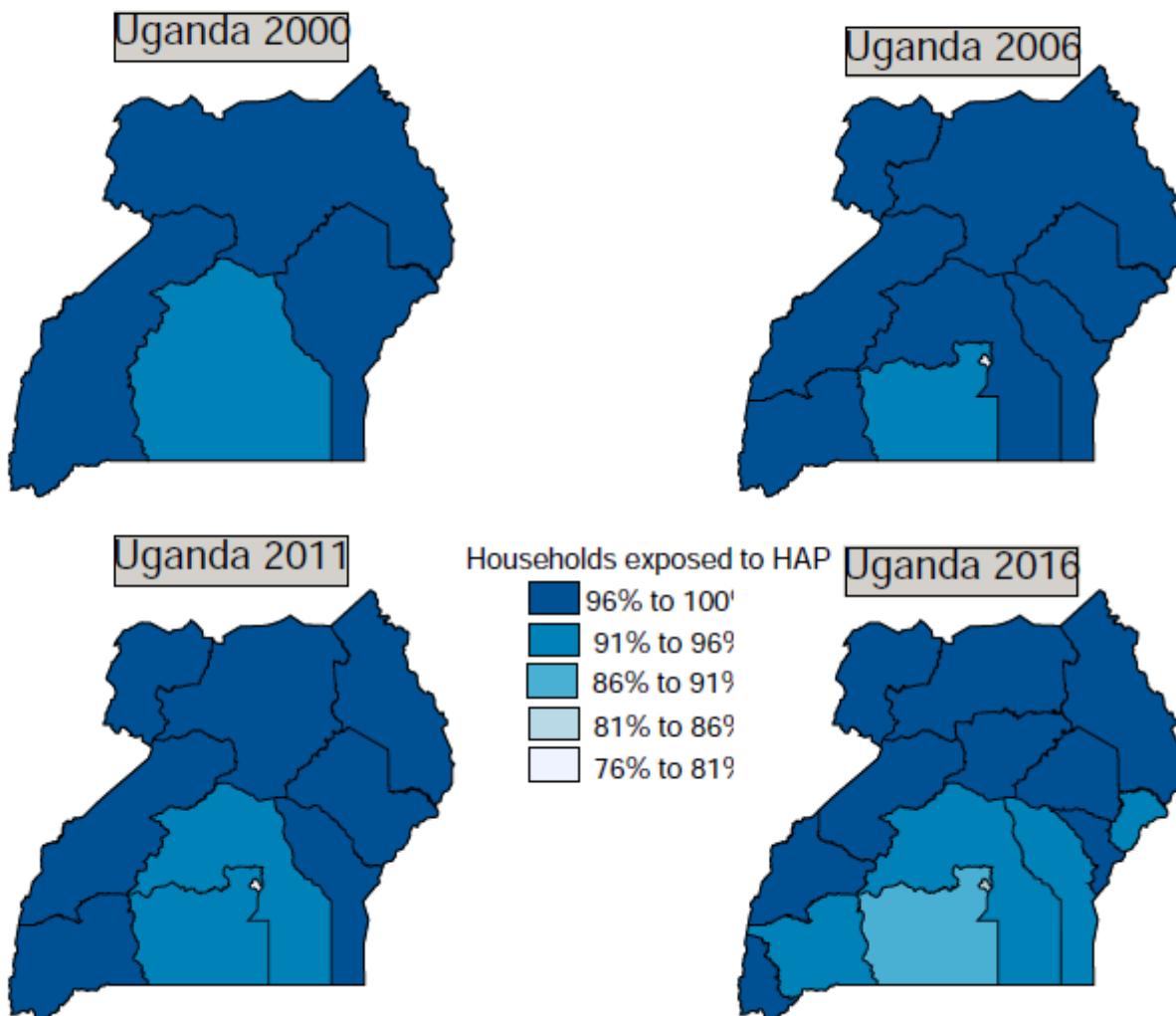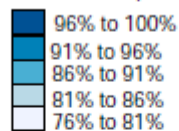
Figure 2

Proportion of households exposed to household air pollution in Uganda by region from 2000/2001 to 2016.