COMPARATIVE STUDY OF GIS AND CONVENTIONAL HOUSEHOLD SURVEY SAMPLING METHODS: FEASIBILITY, COST AND FAMILY PLANNING COVERAGE ESTIMATES

by

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Abstract

Background

Household surveys serve as the main source of data on reproductive, maternal, and child health in low and middle-income countries (LMICs). Considering their significant role, ensuring production of high-quality data is imperative. However, the high costs associated with conducting large-scale surveys in LMICs has led to a search for alternative survey sampling methods. This study compared two probability sampling methods: geographic information system (GIS) and conventional sampling. It assessed feasibility of GIS sampling, evaluated equivalence of sampling methods for selected family planning (FP) coverage indicators, and compared implementation costs.

Methods

Concurrent cross-sectional surveys using the two sampling methods were implemented in the same 150 clusters in Burkina Faso. For GIS method, free satellite images were used to digitize cluster boundaries and potentially residential structures. Feasibility was assessed using embedded mixed methods. Equivalence threshold (+/- 5 percentage points) to compare FP indicators was defined using confidence interval (CI) approach. Costs were estimated using micro-costing from international donor's perspective. Average and incremental costs-per-cluster and costs-per-completed-interview were calculated.

Results

In conventional method, 14,610 households were enumerated; 3,021 households sampled. In GIS method, 58,120 structures were digitized; 3,371 households sampled.

There was no statistically significant difference in the survey response rates for occupied dwellings among the two sampling methods (p=0.089). Qualitative results documented the advantages and challenges experienced during implementation of GIS method.

Of the 9,907 eligible women selected, 4,370 were in conventional method, 3,913 in GIS and 1,624 in both methods. The CIs of sociodemographic variables and FP indicators overlapped across both methods. Sampling methods yielded equivalent estimates of modern contraceptive prevalence and unmet need for FP. Cost difference between the methods was $43,529. Relative to conventional method, GIS method was 15% less expensive. Compared to conventional sampling, GIS sampling cost $266 and $314 less per cluster, and $13 and $4 less per completed interview, in the urban and rural areas, respectively.

Conclusion

Using GIS for large-scale, probability-based household surveys is feasible in both urban and rural settings, if recent, high-resolution satellite images are available. It should be considered a valid alternative for deriving unbiased population coverage estimates in resource-constrained settings.

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List of terms and abbreviations

CAPI: Computer Assisted Personal Interviewing

DHS: Demographic and Health Survey

EPI: Expanded Program on Immunization

FP: Family Planning

FP2020: Family Planning 2020 initiative

GAC: Government of Canada

GIS: Geographic Information System

GPS: Global Positioning System

IGB : Institut Geographique du Burkina

IIP: Institute for International Programs

INSD: Institut National de la Statistiques et de la Démographie

ISSP : Institut Supérieur des Sciences de la Population

mCPR: Modern Contraceptive Prevalence Rate

MICS: Multiple Indicator Cluster Survey

ODK: Open Data Kit

PNAPF: Plan National d'Acceleration de la Planification Familiale

PMA2020: Performance, Monitoring and Accountability for FP2020 initiative

RMNCAH: Reproductive, Maternal, Neonatal, Child, Adolescent Health

SDGs: Sustainable Development Goals

WHO: World Health Organization

Chapter 1. Introduction

1.1. *Significance of Family Planning*

Access to and use of family planning methods encompass human rights, equity, women's empowerment, child survival, poverty reduction and sustainable development. At the International Conference on Human Rights in 1968, countries declared family planning a basic human right. [1] Globally, all 192 member countries of the United Nations have pledged to implement the Sustainable Development Goals (SDGs) by 2030. Family planning is entrenched in the SDGs as target 3.7: "*By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes*."[2] According to Bongaarts, the use of contraception is the main determinant of fertility and increasing contraceptive prevalence is associated with lower fertility.[3] Eastwood and Lipton showed the causal link between fertility rates and overall poverty rates.[4] Therefore, prioritizing family planning has the potential to reduce poverty and foster human capital development.

1.2. *Family Planning in Burkina Faso*

Burkina Faso, a French-speaking West African country is a member of the Ouagadougou Partnership, a regional initiative that was launched in 2011 with the aim of adding at least 2.2 million new users of modern contraceptive methods by 2020 among the 9 Francophone member countries.[5] As described in the national plan to accelerate family planning, *Plan National d'Accélération de Planification Familiale du Burkina Faso (PNAPF) 2017-2020*, the country aims to increase modern contraceptive prevalence rate (mCPR) by 2% annually from an estimated baseline mCPR of 22.5% in

2015 to 32% by 2020, and reduce total fertility rate from 5.4 in 2015 to 4.7 children per woman by 2020.[6] Moreover, about two-thirds of the population is less than 25 years old, and more than half of the population is less than 19 years old, therefore their reproductive health choices will affect the country's future development. According to the PNAPF, married adolescents between 15 and 19 years have the lowest mCPR rate – about 12% – across all age groups.[6] One of the top five national priorities are to improve the quality, completeness and timeliness of data on contraceptive use in the population by 2020.[6]

While there is global and national emphasis on increasing access to modern contraceptives, notably the 2012 London Summit on Family Planning which birthed the Family Planning 2020 initiative, there is limited research on comprehensive contraceptive practices in Burkina Faso and several other low and middle-income countries. A study on contraceptive prevalence among 15-19-year-olds in Burkina Faso based on the previous Demographic and Health Surveys of 2003 and 2010 reported an overall mCPR of 11%.[7] They found large variations in mCPR by marital status: married adolescents had mCPR of less than 10% while unmarried adolescents had mCPR up to 50% with no change in overall trend in this age group between 2003 and 2010.[7] The recent annual report from PMA2020 showed mCPR among all women increased by 1.0 – 1.8 percentage points each year between 2013 and 2016, but from 2017 to 2018, the increase was 0.5 percentage points.

1.3. Relevance of Household Surveys in Family Planning Programs

An assessment of the 74 countries with the highest burden of maternal and child deaths was conducted by Health Metrics Network and Countdown to 2015. They highlighted household surveys as the main source of good quality, complete and timely information for population-level coverage data, including estimation of coverage of interventions such as family planning, immunization, safe pregnancy, labor and delivery among target populations.[8]

Household surveys can be used to compare coverage, trends and inequalities [9] of interventions across multiple countries and to evaluate programs. The major national household surveys conducted on reproductive, maternal, newborn, child and adolescent health (RMNCAH) in low and middle-income countries, the Demographic and Health Surveys (DHS) and the Multiple Indicator Cluster Surveys (MICS), produce data that are used to develop programmatic targets, identify pockets of greatest need for interventions, and to shape national and global agendas pertaining to women and children.[10] Considering the uses of household surveys, ensuring generation of high data quality is essential and should be paramount when designing surveys and using them. Household surveys also complement the routine health information system because they serve as critical baseline or endline for program evaluations, and provide information on the determinants of intervention coverage in the target population.[10]

In the context of RMNCAH, rapid household surveys supplement the information gap, monitor progress in communities against predetermined global and national targets, and identify and implement course correction during implementation of programs such as family planning programs. Household surveys have been referred to as the "thermometer of global health" but despite its importance and use in public health programs, there is a dearth of research in rapid household survey methodology especially pertaining to low- and middle-income countries.[11]

1.4. Survey sampling

1.4.1. Probability-Based Survey Sampling

In conducting household surveys, one aims to select a sample of the population that is representative of the underlying population characteristics. Probability sampling is the gold standard for household sample surveys.[12,13] The main characteristics of probability-based sampling are: the availability of a sampling frame that comprises all the sampling units at each stage of sampling, every sampling unit has non-zero, known probability of selection and each unit is selected using simple random sampling (SRS) or systematic sampling.[14] A probability-based survey sampling approach is preferred for household surveys because it generates valid estimates for the reference population, and we can quantify sampling error and make inferences bounded by confidence limits.[15]

Conventional household surveys like DHS and MICS are done in three to five year-rounds, for a number of selected low- and middle-income countries in each round. These national surveys use multistage probability sampling designs. After stratification, the primary sampling units (census enumeration areas (EAs)) are selected in the first stage with systematic random sampling or probability proportional to size (PPS) method from the listing frame files.[16] In the second stage, sampled EAs are mapped and their households enumerated. Households (secondary sampling units) are then sampled from the listing using systematic random sampling.[16]

The major drawbacks of these conventional national-level surveys are their high financial cost,[17] and extensive time requirements for completing household enumerations, planning, implementation, and analysis. For instance, the average timeline to completion of a DHS is 18-20 months.[16] To enhance evidence-based decision making annually at national levels, high quality population-based data are essential. Alternative survey design methods, such as WHO's Expanded Program on Immunization *'random walk'* cluster surveys, were designed to address some of the challenges of conventional survey method.[18,19] However, these alternative designs were criticized for their unrepresentativeness and risks of biased estimates.[20–25] Recently, WHO has adopted conventional probability survey for immunization coverage surveys.[26]

One example of rapid data collection is the Performance, Measurement and Accountability 2020 (PMA2020) surveys. PMA2020 are repeated cross-sectional surveys that use a multistage stratified cluster sampling method, and about 33-44 households are randomly selected in each EA. [27,28] The surveys are conducted every 6 months for the first two years, use same enumeration areas (EAs) for the first four rounds of the surveys with resident enumerators conducting the data collection using mobile devices though different households are selected independently in each round.

[27,28] Subsequent surveys starting from round 5 are conducted annually and subsequent clusters are randomly selected either from a list of the clusters that are contiguous to the previous clusters or a new set of clusters are randomly selected as was done in Ghana recently.[27,28]

1.4.2. Novel Probability Survey Sampling

GIS and satellite imagery methods have been used for household surveys conducted in urban and peri-urban areas. For example in peri-urban Lusaka, Zambia, Lowther et al used satellite images to enumerate households for measles vaccine coverage measurement. [29] In Lilongwe, Malawi, it was used for household enumeration for a survey to measure malaria transmission intensity. [30] Gong et al compared a GIS sampling method to a probability segmentation sampling method and the EPI non-probability method to estimate vaccination coverage in peri-urban districts in Pakistan. [31] In Lebanon, Shannon et al used GPS and satellite photographs to randomly select households by randomly choosing a location based on GPS, drawing a 20 meter radius around the location and randomly choosing and interviewing one household within the radius to determine the magnitude of violence the population experienced following the Israeli war.[32] Galway et al used another approach combining gridded population data, GIS, and Google Maps in Iraq to reduce the time the survey enumerators spent in insecure areas.[33]

In rural areas, the use of GIS and satellite imagery for sampling is limited but studies have documented this approach in Latin America and Caribbean region. Kondo et al used ArcMap and Garmin GPS technology to obtain a random spatial sampling of households in rural Guatemala for a health survey.[13] In rural Haiti, Wampler et al used satellite images from Google Earth, ArcMap, GPS and Excel to randomly select and locate households in Deschapelles for a water quality and health education survey [34] and Chang et al used Google Earth and ArcGIS for dengue infection surveillance in Nicaragua.[35]

To my knowledge, no study has empirically compared novel probability sampling using GIS and satellite imagery to conventional probability-based survey sampling for rapid household health surveys for family planning programs and the relative costs of these approaches. Given the demand for timely population-based data and the continued use of non-probability sampling methods for reducing costs, it is useful to assess the feasibility of implementing a novel probability sampling method and estimate the equivalence with conventional sampling method.

1.5. Dissertation goal and specific aims

The goal of this research project is to improve the quality of data that is generated through household surveys for reproductive health programs.

My hypothesis is that spatial technology comprising of satellite images and GIS software, a novel probability sampling method, would be less costly and less time-consuming, could reduce the time that enumerators would spend in the field while providing high quality data comparable to the conventional probability standard sampling method for large-scale household surveys for reproductive health. Specifically, the null hypothesis is the survey sampling methods are not equivalent within margins of $\pm$ 5% while the alternative hypothesis is that the survey sampling methods are equivalent at this threshold.

Aim 1: Develop and implement a protocol to use spatial technology for probability survey sampling and assess the technical and logistical feasibility of the method from the perspective of local implementing organizations.

Aim 2: Compare the estimates of selected indicators of family planning coverage such as modern contraceptive prevalence rate (mCPR) and unmet need for family planning derived from GIS sampling to the conventional sampling method using pre-specified equivalence margins.

Aim 3: Assess the survey implementation costs of the GIS sampling method relative to the conventional sampling method for household surveys using a funder's perspective, stratified by geography.

The dissertation is organized as follows: Chapter 1 presents the introduction and literature review; chapter 2 presents the overall methods including field implementation. Chapters 3 to 5 contain the methods, results, and discussions of each specific aim. Chapter 6 comprises the summary of findings and proposed direction for future research. In chapter 7 policy recommendations for policy makers, donors, implementers, and researchers are presented. The final two sections comprise the references: namely appendices and bibliography.

Chapter 2. Methods

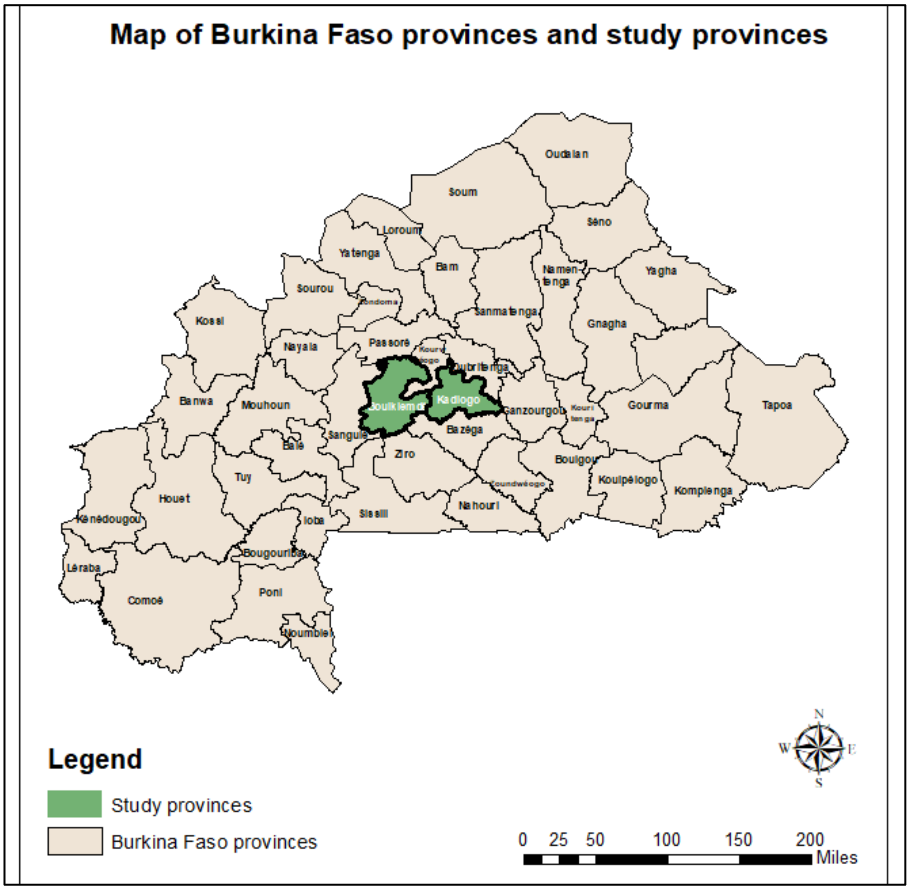
2.1. Overview of Parent Study

This dissertation was nested within the Real Accountability: Data Analysis for Results (RADAR) project in the Institute of International Programs in the Department of International Health. RADAR conducted a study that compared the conventional probability survey sampling method typically used by DHS and MICS to novel probability (satellite images & GIS) and non-probability (WHO/EPI 'random walk') survey sampling methods. Within this three-arm, cross-sectional study, my dissertation specifically assessed the statistical equivalence and costs of the satellite imagery method relative to the conventional method. In addition, the dissertation evaluated the feasibility of implementing the satellite imagery method which had not been previously tested on a large scale.

2.2. Study Site and Population

The study took place in two provinces in Burkina Faso: Kadiogo and Boulkiemdé. Kadiogo province is located in the Centre Region and Boulkiemdé is in the Centre-Ouest Region. (Figure 2.1) Boulkiemdé province is located 99 kilometers (approx. 62 miles) from the capital city of Ouagadougou. Kadiogo province encompasses Ouagadougou, the capital city. These provinces were chosen because of the high donor investment in RMNCH, security concerns in several other provinces, and the recommendations of the Ministry of Health.

Figure 2.1. A map of Burkina Faso showing the study provinces

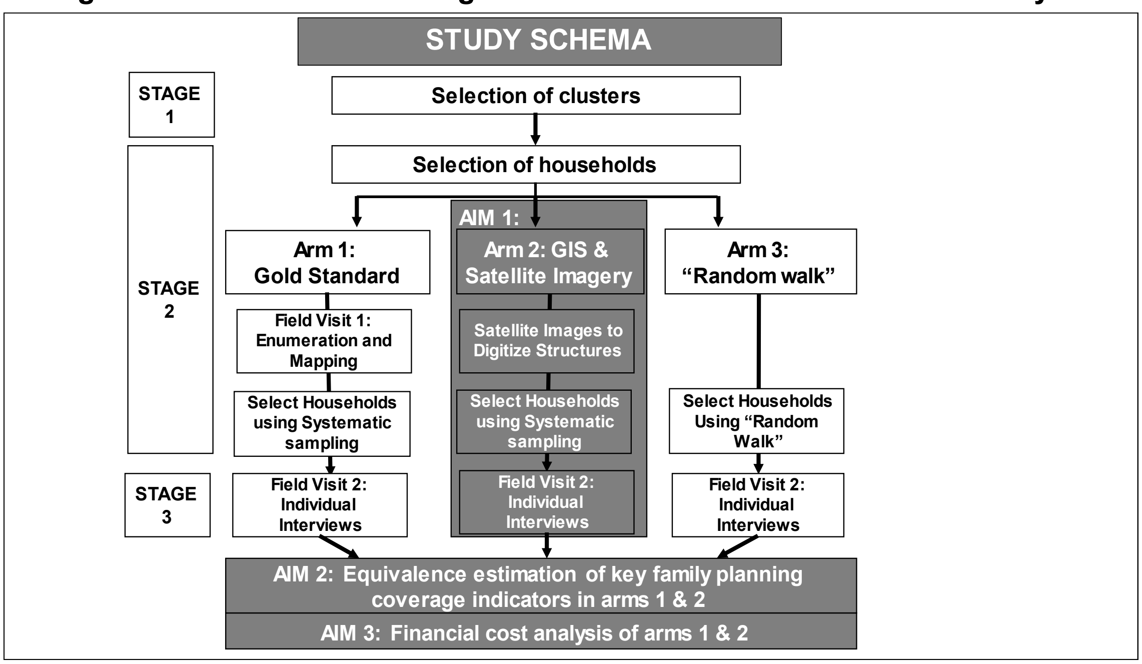


According to the 2020 national population census, Burkina Faso has a population of 20,487,979 and about 51.7% are females.[36] Boulkiemdé's total population is 1,659,339 while Kadiogo, the most populated province has a population of 3,032,668, with the city of Ouagadougou making up 12% of the national population.[36] According to data from the National Institute of Statistics and Demography (*Institut National de la Statistique et de la Démographie,* INSD), in 2019, Boulkiemdé had 954 census enumeration areas, 202 urban and 752 rural while Kadiogo had 3,490 census enumeration areas of which 2,190 were urban and 1,300 were rural. [37] For the study, one census enumeration area represented one cluster. The complete RADAR study was implemented in 150 clusters comprising 75 urban and 75 rural clusters selected from the two provinces.

2.3. *Field Study Design*

The main RADAR study was a three-arm cross sectional study, Arm 1 was the conventional survey sampling method, Arm 2 was the satellite imagery survey sampling method, and Arm 3 was the non-probability, 'random walk' method. (Figure 2.2) The survey design was multistage stratified cluster survey sampling. The selection of clusters was the first stage, household selection was the second stage and individual interviews was the third stage. In sampled clusters, households were selected with replacement. All eligible respondents within the household were interviewed. The same clusters were used in the three arms of the RADAR study in order to ensure comparability. My thesis focused on Arms 1 and 2.

Figure 2.2. Schema describing the three arms of the main RADAR study



The in-country activities started in June 2019 with series of planning meetings with collaborating institutions, government, and international development partners (UNICEF, UNFPA, WHO). Survey data collected ended in March 2020, and data analysis for the main RADAR survey is ongoing till June 2021. The field implementation timeline is summarized in Table 2.1.

Table 2.1. Timeline of implementation of field activities in Burkina Faso

Activities	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20
Initial planning meetings with institutional collaborators in Burkina Faso											
JHU/IIP contract negotiations with ISSP											
Develop materials for IRB submission											
Submit IRB application at JHU and Burkina Faso and obtain approval											
Update training manuals											
Update survey questionnaires, CAPI/ODK and setup data management system											
Selection of study clusters using PPS and obtain base map sketches from INSD											
Training of mappers & enumerators for conventional method											
Mapping field work for conventional method & quality control											
Digitizing and creation of sampling frame for GIS method using satellite images & quality control											
Pilot training											
Pilot field work											
Training of survey interviewers for main surveys											
Preparation for field deployment, community sensitization & awareness											
Preparation for survey fieldwork											

Household surveys - main data collection for conventional and GIS sampling methods											
Qualitative interviews with GIS method implementation teams (Virtual via WhatsApp and Skype)											

2.4. Study Procedures and Conduct

2.4.1. First Stage: Selection of Clusters Using Probability Proportional to (Estimated) Size (PPES)

The sampled area was stratified by rural and urban districts to reduce sampling error. Within each stratum (rural / urban), 75 clusters were selected using probability proportional to (estimated) size (PPES) which is self-weighting within each stratum with equal take size. Larger clusters had a higher probability of being selected in the first stage while in the second stage households in smaller clusters had a higher probability of being selected. Since enumeration areas (EAs) represented the clusters, the information on the estimated population size, ***n***, in each cluster and the corresponding official cluster hand-sketched maps were obtained from the National Institute of Statistics and Demography (INSD) in Burkina Faso. The sampling frames were updated in 2019 in preparation for the 2019/2020 national population and housing census.

For the standard probability sampling arm, the probability of selecting a cluster *j* within a stratum *s* was estimated using Equation 2.1 in Appendix C. For the systematic sampling, the sampling interval, ***k***, was calculated by dividing the total number of households in the sampling frame by the total number of sampled clusters. Clusters were selected from the list of EAs by generating a random number which was multiplied by the sampling interval to derive the first cluster, ***r***. The next cluster was selected based on the sampling interval, ***k*** and selection process continued until all the clusters were selected using an interval of *r, r+k, r+2k,......., r+(n-1)k*.

2.4.2. Second Stage: Mapping, Enumeration and Selection of Households

While the definition of a household described below was used for all the arms of the study, the methods for household enumeration and selection varied between the conventional sampling (Arm 1) and satellite imagery sampling arms (Arm 2). These differences are described below after the definition of households.

2.4.2.1. Definition of households

The United Nations Statistics Division (UNSD) standardizes the definition of households across countries to ensure comparability. For the purposes of national population censuses and surveys, the UNSD defines a household as "the arrangements made by persons, individually or in groups, for providing themselves with food and other essentials for living." A household could be a one-person household where a person is the sole provider for his or her food and living essentials, or a multi-person household where two or more persons live together and have a combined provision for food and other living essentials, and they may be related or unrelated.[38] Randall and colleagues showed that this definition does not account for the unique variations in African households and described case studies from Burkina Faso, Senegal, Ghana and

Uganda to demonstrate how different African countries modified the UNSD definition in their context.[39]

According to the 2006 census enumerators manual from the Burkina Faso INSD, a household is the fundamental unit of the census and the two types of households are: ordinary households and collective households. The ordinary household is defined as "the basic socio-economic unit in which the different members are related or unrelated. They live together in the same structure, pool their resources and satisfy their food and other living essentials in common. They recognize one of them as the head of the household, regardless of sex. In general, the household comprises of a man, his wife or wives, unmarried children, other non-married parents and domestic servants who live together."[40] Examples of a household include: a single person living alone, a man, his wife and their unmarried children, an unmarried woman, widow or divorced and her unmarried children, a single man, widower or divorced and his unmarried children, two or more people who are unrelated living together and have a common provision for food and other living essentials, a married man with more than one wife (polygamous) living in the same dwelling unit and his unmarried children.[40] In polygamous households, if each wife has a separate living arrangement, they are regarded as different households, and the husband is counted as the head of the household in which he spent the night preceding the census or survey.[40]

The collective household constitutes a group of people generally unrelated, living together under special conditions, using the common resources made available to them by the establishment for their essential needs of food, accommodation and care.[40] Examples include military barracks, students in boarding schools or university dormitories. Collective households were excluded in this study.[41]

Another unique description of living arrangement in Burkina Faso is called the *concession*. A *concession* is described as “a dwelling unit formed by one or more structures, where one or many households live, with or without a fence.” [40] In rural areas, the *concession* comprises a set of fenced structures with one or many habitations, where the occupants declare they belong to fenced compound. In urban areas, multi-unit apartment buildings will be considered as *concessions*.[40] In *concessions* or in houses inhabited by parents and their married children, parents are generally treated as a different household and each of their married children and their spouses constitute a different household. However, if the parents are dependent on their married child, they are counted as part of their married child’s household.[40] For this study we adopted the national definitions of households and *concessions*.

Where multiple families live together, sharing a common cooking and sleeping quarters and they recognize one household head, they were considered as one household. All eligible women in the household were interviewed.

The probability of selecting households in cluster j, P_{hhj} was estimated using Equation 2.3. in Appendix C. This was modified for the GIS method by estimating an approximate probability of selection using the number of residential buildings as a proxy for household distribution in the population as shown in Equation 2.4 in Appendix C.

2.4.2.2. Survey Enumeration and Mapping for the Conventional Survey Sampling Method (Study Arm 1)

2.4.2.2.1. *Household Enumeration to Construct the Sampling Frame and Systematic Random Sampling to Select Households*

The first step was to enumerate and list all the households in the selected cluster. A household listing team consisting of a cartographer and an enumerator visited each selected cluster to update the household list and sketch a detailed cluster map. The 2019-20 population and housing census in Burkina Faso facilitated this process, as the base maps had been updated so cluster boundaries were mostly accurate. All households within each cluster were listed to create the updated sampling frame. Unique serial numbers were assigned to all households listed in the cluster using the household listing form. The listing form comprised the serial number of the structure, the address or location of the structure, use of the structure (residential or non-residential), serial number of the households in the structure, the name and contact number of the head of the household, and any additional notes that could help interviewers locate and identify the household during the individual interview phase. [42]

Care was taken to locate structures that were hidden or hard to find, if there are pathways or landmarks around those structures, they were documented. The GPS coordinates of the cluster boundaries and landmarks in the cluster were collected. Each listing team covered one cluster per day. Upon completion of the first stage, the second stage of household selection took place in the central office. This was done automatically by systematic sampling using the RADAR's Stata do-file for household selection to select households with a predefined sampling interval. Households were selected with replacement but limited to 20 per cluster to reduce the likelihood of repeat selection.

2.4.2.2.2. *Selection of multi-unit structures, multi-household dwellings, and concessions*

The approach used by standard national surveys such as the DHS to identify households within multi-unit structures, multi-household dwellings and concessions was adopted. [42] All households found within a concession, multi-unit structure or multi-household dwelling were assigned a number from 1 to x. The concession or multi-unit structure number and the number of each household was combined to form a unique identification number for each household within the structure or concession. Enumerators wrote the household numbers at the main entrance or doorposts of the households for ease of identification by the survey interviewers in the subsequent phase.

2.4.2.3. Survey Enumeration and Mapping for the Spatial Survey Sampling Method (Study Arm 2)

2.4.2.3.1. Obtaining Satellite Images, Construction of Sampling Frame and Use of Systematic Random Sampling to Select Potentially Residential Structures

Freely available, high-resolution images were obtained from the satellite view in Google Maps® to identify, map and enumerate potentially residential structures (PRSs) in the selected study clusters. To delineate the selected EAs, the hand-drawn sketch maps obtained from INSD were traced out using the drawing tools in QGIS software[43] to closely resemble the sketches as much as possible. The structures that appeared to be residential were marked with a symbol, structures that appeared to be potential landmarks were marked with a different symbol. Attribute tables that contained the longitude, latitude, and serial numbers of all the identified structures were created for each cluster within QGIS.[43] After quality control, the attribute tables were merged to create a final sampling frame that was exported to Microsoft Excel[44] and eventually to Stata[45] to execute the systematic sampling of potentially residential structures.

In rural areas and unplanned settlements where the resolution of the freely available satellite images was low resulting in blurred images, we superimposed other satellite images from Bing maps and Open Street Map as supplementary sources. No commercial satellite images were procured.

2.4.2.3.2. Identification strategy of potentially residential structures

In the urban EAs, structures that had regular polygon shapes such as rectangles and were of an adequate size (larger than vehicles) were identified and digitized. Digitizing entailed marking each structure with a point in order to create a unique identifier and the corresponding latitude and longitude is automatically generated in the software. PRSs were manually enumerated by placing a marker at the centroid (roof) of each potential residence. Enumerated structures were likely to include both residential and non-residential buildings, and some residential buildings included multiple households which is commonly called '*celibaterium*' in Burkina Faso.

In the rural EAs, many residential structures did not have regular polygon shapes such as rectangles, they were identified by their sparse distribution, smaller sizes, clustered set of 6 or more buildings, and sometimes had a wall built around it commonly referred to as '*concession'*. Similar to the urban EAs, each structure was marked with a point in order to create a unique identifier.

In the peri-urban areas which were mostly unplanned settlements, commonly called *'non-loti'* because residents usually lacked land tenure, identifying buildings was more difficult. The buildings were smaller, numerous and crowded, with little to no formal streets or landmarks. We relied on the institutional knowledge of the mapping team to complete the mapping and enumeration in this location.

Structures that had irregular shapes and unusual sizes were often landmarks such as marketplaces, schools, football fields and served as reference points. Because of the non-uniform shapes and irregular spacing of various structures in urban, peri-urban, and rural areas, manual digitization was done.

2.4.2.3.3. Systematic Random Sampling to Select Households in GIS method

The second step of selection of structures from the sampling frame was done in the central office. This was done automatically by systematic sampling using the RADAR's Stata do-file for household selection to select households with a predefined sampling interval. PRSs were selected with replacement but limited to 22 or 23 per cluster to reduce the likelihood of repeat selection.

Following selection, a list of the selected structures in each cluster was generated and the longitude/latitude were uploaded to the navigation application on the tablets that the survey interviewers used during individual interview phase. The app directed them to locate the structures in the field. The final maps included the boundaries of the EAs and the selected PRSs were printed out as supplementary tools for the interviewers and their supervisors.

2.4.2.3.4. Selection of celibaterieums and concessions in GIS method

We assumed that each PRS fundamentally represents one household. A limitation of the GIS method is that it cannot identify if a residential structure has multiple households residing inside it from aerial images. Also, household enumeration as described under the conventional method was not done prior to the survey interviews. A previous study by Lowther et al instructed interviewers to randomly select two households within the same structure before moving to the subsequent structure in urban Zambia.[29] Wagenaar et al asked research teams to randomly select one household every two floors in Lilongwe, Malawi,[46] and Gong et al instructed interviewers to visit all the households in the building after randomly selecting a direction up or down the stairs.[31] The methods used by interviewers in the field to randomly select households were not documented but it is likely to have been different among interviewing teams.

Interviewing every household in a multi-unit dwelling is likely to be inefficient, just as interviewing every household in a cluster is inefficient, as neighbors are more likely to be homogenous, however it was important to be systematic in knowing which household to select to avoid selection bias. Eckman et al recommended training interviewers to randomly select one unit in multi-unit structure using the Kish grid, which is a random subsampling procedure.[47] The Kish grid is often used to select one respondent when there is more than one eligible respondent in the household.[48]

2.4.2.3.5. Modified Kish grid method

To address the limitation of the GIS method, I modified the Kish grid method to treat these structures as mini-clusters by randomly selecting one dwelling unit when they faced *celibaterieums* or *concession*.

The assumptions of modified Kish grid method used were:

1. No more than one interview is desired in any household since multiple interviews in the same building was inefficient.[48]
2. Unbiased estimates can be derived by assigning each household a weight based on the number of occupied dwelling units within the structure. The additional sampling weights was calculated for these structures when computing the sampling weights. [48]

During data collection for the household and individual interviews, the navigation app and printed satellite image maps were used to locate each selected PRS within the survey clusters. The study's survey software called Open Data Kit (ODK) Collect[49] app that was installed on tablets allowed survey teams obtain the GPS locations of the sampled households, which was cross-referencing and served as a validity check of the geographic coordinates obtained from the satellite images.

2.4.2.3.6. Qualitative data collection

As part of assessing the feasibility of satellite imagery & GIS sampling method, key informant interviews were conducted for a group of randomly selected implementers of the method. This was done within the first two weeks after they returned from field data collection to ensure the memory was still recent. The interviewees were drawn from those who participated in the mapping & enumeration phase, data collectors in the field who used navigation app and satellite images to locate the households, and the supervisory and quality control teams. They described their experiences using a novel approach, the challenges they encountered during implementation, advantages and disadvantages of the method and areas for future improvement.

2.4.3. Third Stage: Selection of Eligible Household Members

The third stage involves the identification and selection of eligible individuals. To do this, first we defined eligibility criteria using RADAR's definitions showed in Table 2.2.[50]

Table 2.2. Eligibility criteria

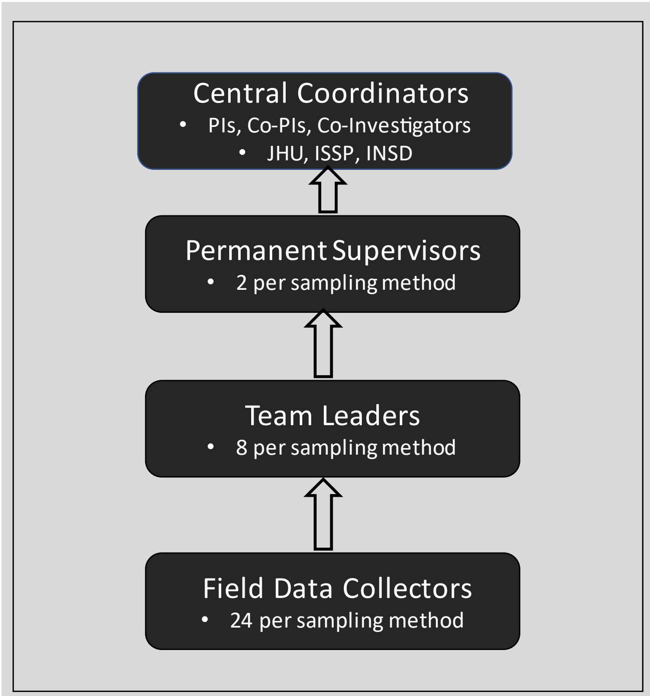
Title	Definition of eligibility
Head of household	Provides main financial support and management of the household and is recognized by other members as the head due to age or respect, or declares him/herself as such

Household member	Lived in a household for 6 months or more, sharing the same pot
Visitor	Not a household member but slept in the household the night prior to the survey interview
Eligible women	All women aged 15 – 49 years who are household members

All sampled households were considered eligible for inclusion in the survey. The head of the household was the lead respondent to the household questionnaire even though s/he could invite other household members to answer specific questions. All the individuals in each sampled household were listed using the household listing form after applying the eligibility criteria. The eligible individuals were identified from the household listing and their consent obtained before they were interviewed.

Field pre-testing, training and pilot exercises were conducted prior to the launch of full-scale implementation. (Table 2.1) Survey teams comprised 3 interviewers and a team leader. (Figure 2.3) Data collection took place over a six-week period. A valid survey or successful recruitment was recorded when interviewers located the household and completed the household and women's questionnaires.

Figure 2.3. Survey Field Personnel Structure



2.4.4. Non-response and multiple selection

For the conventional sampling and satellite imagery sampling arms, if the eligible respondent was not available in a selected household at the time of the visit, interviewers revisited the household for up to a total of three times.[42,51] If there is no response after the third visit, then they were documented as non-response. Replacement of unresponsive respondents in the field was not allowed.

Where no residential structure was found, it was documented as non-residential, or destroyed and unoccupied residential buildings were documented as vacant. [13,21] When participation was declined by potential respondents, the interview team documented the refusal and moved on to the next structure on the list. Selection of replacement households was not allowed for households refusing participation.

In few instances, the same household was selected under both sampling arms since households were sampled with replacement within clusters so any household with multiple selection was deemed as due to chance since the household selection of the two arms were independent. In the chance event that a household was selected more than once, they were interviewed only once. All interviewed households received a copy of the informed consent form so interviewers visiting the same household a second time confirmed that the household has been previously interviewed, and the data was transferred during the analysis.[31]

2.5. Sample Size Estimation

The same sample size was estimated for the survey sampling methods to allow for adequate comparison using the main outcome of modern contraceptive prevalence (mCPR). According to the recent PMA 2020 Burkina Faso data from Dec 2018/Jan 2019, modern contraceptive prevalence rate (mCPR) was 30.7% among women married or in union while it was 27.3% among all women of reproductive age (15-49 years). To estimate the required sample size, we adopted the confidence interval approach recommended by Jones et al for equivalence studies[52] where:

The null hypothesis, H_o: $|P_R – P_{GIS}| \geq \Delta$ (implying nonequivalence)

The alternative hypothesis, H_A: $-\Delta < |P_R – P_{GIS}| < \Delta$ (implying equivalence)

Where P_R indicates the mCPR in the conventional sampling arm while P_{GIS} indicates the mCPR in the satellite imagery sampling arm.

To test the alternative hypothesis that there was no difference among the sampling methods, we estimated the sample size required for a range of equivalence using a threshold margin Δ of ± 5%. Table 2.3 showed the sample size calculated under varying ranges of equivalence. If the 95% confidence interval of the observed difference lied entirely within - Δ and + Δ, equivalence is demonstrated, and if it does not, we cannot however assert that they are not equivalent.[52]

Table 2.3. Range of margin of equivalence and required sample size

Estimated proportion, p	27.3	# of target women / HH	1.185
Estimated design effect (DEFF)	2.161		
Desired margin of equivalence percentage	Individual sample size	Household sample size	Number of clusters
2	18,681	15,770	789
3	8,303	7009	351
4	4,671	3,943	198
4.5	3,690	3,115	156
5	**2,989**	**2,524**	**127**
5.5	2,471	2,086	105

2.6. *Data collection, cleaning, processing, and analysis*

The Open Data Kit (ODK) Collect[49] application was the survey software preloaded on Samsung tablets used for data collection. Data was stored temporarily on the tablets and uploaded every night or whenever there was internet connectivity, depending on which occurs first, to a secure cloud-based RADAR project server. For quality control of uploaded data, a dashboard was created which team leaders, supervisors and central coordination teams logged into daily review data and resolve errors while data collection was still ongoing in the field. After de-identification of personally identifiable information, the database was imported into Stata for cleaning, processing and destringing. Datasets and do-files were created. Data analysis was be done using Stata 14[45] to estimate the family planning indicators, MS Excel[44] models for the costing analysis, ArcGIS[53] and R statistical computing package[54] for analysis of spatial data.

2.7. Ethical approval

Ethical approval for the survey was received from the Johns Hopkins Bloomberg School of Public Health Institutional Review Board (IRB 00009713) and the Centre De Recherche de Nouna Ethics Committee (determination 2019·018·/MS/SGIINSP/ CRSN /CIE) in Burkina Faso. The key informant interviews were determined to be non-human subjects research by the JHSPH IRB.

2.8. Contribution to public health

Most of the household survey sampling using satellite imagery has been done in urban and peri-urban settings but very few studies have tested the method in rural settings. This study is the first documented use of satellite images & GIS as a novel method for household survey sampling in rural communities in Francophone West Africa. It is also the first to compare novel probability survey sampling method to the conventional survey sampling method. In addition, the study creates specific feasibility measures for comparing household survey methods in terms of assessing costs, technical and logistical requirements for adoption and implementation.[55] The costing analysis of the survey methods provided real-world implementation evidence to aid decision-making which was not previously documented.

Chapter 3. Assessing the feasibility of using GIS sampling methodology for large-scale household surveys

3.1. Abstract

Background

Household surveys generate data that are used to plan, monitor progress and evaluate the impact of public health programs, and serve as the main source of data on reproductive, maternal, newborn, child and adolescent health (RMNCAH) in low and middle-income countries (LMICs). Considering the important role of household surveys, ensuring generation of high-quality data is essential and should be paramount when implementing them. The large-scale household surveys implemented in LMICs are national, high quality surveys but are expensive, time-consuming, and infrequent. Due to the high-resource requirements, and the need to track health outcomes consistently, Implementing organizations tend to conduct smaller and more frequent household surveys often using non-probability sampling methods for household surveys to reduce time and costs. This study compared a novel probability sampling method based on geographic information system (GIS) techniques to the conventional probability sampling method, documenting our experience using free GIS tools and assessing feasibility of GIS sampling method for large-scale household surveys.

Methods

A retrospective cross-sectional study was designed comprising the conventional probability sampling method and GIS-based, novel probability sampling method. For the GIS method, freely available satellite images were used to digitize boundaries of census enumeration areas (clusters) and potentially residential structures in the rural and urban

study areas in QGIS.[43] Households were located using a free navigation application called Maps.me™. Concurrent household surveys were conducted using the two sampling methods from February to March 2020 in Burkina Faso. Quantitative and qualitative methods were used to assess feasibility of the GIS method.

Results

In the conventional method, 14,610 households were enumerated, and 3,021 households sampled in both urban and rural areas. In the GIS sampling method, 58,120 structures were digitized, and 3,371 structures were sampled in both urban and rural areas. Among the sampled structures, 88.1% were residential. The highest proportion of vacant structures were in rural area, unplanned settlements in urban areas and urban planned settlements under construction. 505 households were selected by both methods. Using a p-value of 0.05, Pearson's chi-square (4.85) was not statistically and significantly different in the survey responses for the two sampling methods (p=0.089). Qualitative results showed the advantages and challenges experienced during implementation. While the GIS method had overall three times lower person-time requirement, field preparation required seven times higher person-time compared to the standard method.

Conclusion

Using GIS for large-scale, probability-based household surveys is feasible in both urban and rural settings, provided recent and good quality satellite images are available. It can be considered a valid alternative to the conventional probability sampling surveys in low resource settings where time, financial and technical resources are limited.

3.2. Introduction

Household surveys are the main source of data on reproductive, maternal, newborn, child, and adolescent health (RMNCAH) in low and middle-income countries. They produce data to plan and define programmatic targets, identify pockets of greatest need for interventions, and shape national and global agendas pertaining to women and children.[10] Household surveys are also used to compare intervention coverage levels, trends and inequalities within and across countries, and to provide baseline or endline estimates for program evaluations.[9,10] Considering the uses of household surveys, ensuring generation of high-quality data is essential and should be paramount when designing and using them.

The households sampled for a population-based survey must be representative of the population in the survey area. Survey researchers use probability sampling approaches in order to generate valid estimates for the reference population, quantify sampling error and make inferences within confidence limits [15]. The main characteristic of probability sampling is that every sampling unit has a non-zero, known probability of selection; related to this are the availability of a sampling frame that comprises all the sampling units at each stage of sampling, and selection of each unit using simple random sampling (SRS) or systematic sampling [14].

The main steps in probability sampling survey are: 1) defining the strata and sampling clusters, which could be census enumeration areas or other defined administrative areas covering the survey area, 2) mapping the sampled clusters and enumerating the households within clusters to create a sampling frame, often done as a first field visit, 3) sampling households from the sampling frame, 4) identifying and locating the selected households on the day of the interview usually during second/subsequent field visit, 5) listing of household members to identify those eligible for individual questionnaires after obtaining consent, and 6) administering household and individual questionnaires (again, after consenting respondents). There are two main drawbacks of the conventional method. First, it is expensive because clusters must be visited at least twice, and second, it places a high demand on time and resources for planning and implementation. [16,17,56] New approaches to the probability-based survey sampling are emerging in response to these drawbacks to complement or supplement the conventional survey method. They include mobile phone surveys, compact segment method, population density grid methods, and the use of geographic information systems (GIS) and satellite imagery.[29–31,33,46,47,57]

GIS-based approaches can be used to create or delineate the limits of the cluster(s), map clusters, enumerate dwellings within the clusters, and identify the selected sample locations. In low-resource settings, researchers have used several different approaches for GIS and satellite imagery methods for household surveys conducted in urban, peri-urban, slums and rural areas. Many studies have used GIS for mapping and/or enumeration and then used other methods for other aspects of implementation such as locating selected residential structures. [29,33]

Studies that have used GIS approaches for household enumeration have used either freely available or paid satellite images of the study zone to enumerate potentially residential structures in the survey areas. [29,30,33,46]. Interviewers then located sampled structures using different approaches. These include using paper printouts of satellite images with teams assigned to locations based on their familiarity with the community [29]. In Lilongwe, Malawi, dwellings were located using Garmin eTrex Global Positioning Systems devices, though this can be costly [30]. While the GIS-based approach has been successfully implemented in urban areas, studies in rural areas using satellite images and GIS are fewer but have been shown to be successful in rural Guatemala, Haiti, Nicaragua and Mozambique [13,34,35,46]

This paper presents a GIS-based sampling method based on freely available satellite imagery, and the feasibility of this method compared to conventional probability sampling for in-person household surveys. We describe the satellite imagery method used to sample and identify households, and examine the feasibility of the method in urban, peri-urban, and rural areas in a large-scale household survey in Burkina Faso.

3.3. Methods

3.3.1. Study setting

The study was conducted in the urban and peri-urban Kadiogo and rural Boulkiemde provinces of Burkina Faso. We chose rural and urban areas to understand how the GIS sampling method would perform in different geographic settings. These provinces were also recommended by the Ministry of Health and other country partners because of the high donor investment in reproductive, maternal, neonatal and child health, as well as the ongoing security issues in the other provinces in the country. Kadiogo province is in the Centre region and included the capital city of Ouagadougou. Boulkiemde province, in the Centre-Ouest region, is predominantly rural.

Seventy-four percent of Burkina Faso's population lives in rural areas. [36] In the rural areas, families generally occupy a set of buildings that are clustered together called '*concession*'. They are often spread out from their neighbors, surrounded by farmland that is used for subsistence farming or raising livestock. Each *concession* often has multiple generations of the same family cohabiting.

Like many major African cities, Ouagadougou is comprised of two geographic components: a well-planned, gridded part of the city called the '*loti'* area which has modern infrastructure of roads, bridges, and other landmarks. The second component is the peri-urban area, referred to as *'non-loti'* which typically have limited to no infrastructure or landmarks. These are the unplanned, spontaneous settlements growing rapidly as a result of increased rural-urban migration, complicated by the internal displacement from the security challenges in the north and eastern regions of the country.[58–60] In the *non-loti* areas, typically inhabited by lower-income populations, residential buildings are often much smaller, more clustered together and tightly packed within a small area.

3.3.2. GIS sampling method: objective and feasibility

Our objective was to draw a probability sample of households in urban and rural strata, with the urban stratum composed of the well-planned and spontaneous settlements. Using GIS and satellite images, we aimed to compare costs, implementation time, and coverage estimates from a household survey measuring RMNCAH coverage indicators in sampled households. We aimed to develop a method feasible for implementation by program implementers and local non-profit organizations, with limited training on GIS techniques, in low-resource settings. We adopt the definition of feasibility as the 'extent to which an innovation can be successfully used in a specific setting' while accounting for the resource and training requirements.[61]

To ensure the GIS method would yield a probability sample, the five main steps were: 1) sampling census enumeration areas (EAs) using probability proportional to estimated size (PPS) sampling; 2) obtaining satellite images and base maps of sampled EAs; 3) digitizing the sampled EAs and georeferencing all potentially residential structures within sampled EAs to create the sampling frame; 4) drawing a probability sample of potentially residential structures from the sampling frame; 5) implementing the survey using navigation application and satellite images during a single field visit.

3.3.3. Sampling clusters

One hundred and fifty EAs chosen with PPS sampling, divided equally in urban and rural strata, were the primary sampling units (clusters) for the survey. The population size was obtained from the 2019-2020 national census mapping data made available by the national statistics office (INSD). [62]

3.3.4. Obtaining satellite images

We used freely available satellite images and free GIS software to ensure that the approach would be replicable for organizations with limited resources. The satellite view in Google Maps was the predominant source of the images of selected provinces which was imported into QGIS software, (version 3.4.12 long-term release Madeira) a freely available GIS software, using via a plug-in of the XYZ tiles feature.[43] We used the Universal Transverse Mercator geographic coordinate reference system 30 N (WGS 84 / UTM zone 30 N) for Burkina Faso. At the start of the study, the most recent Google Maps® aerial images were from February 2019 (Kadiogo) and November 2018 (Boulkiemdé), but Google updated the images in January 2020, so the more recent images were used during fieldwork in February/March 2020.

We also used complementary satellite images from Google Hybrid®, which labels major landmarks automatically; Open Street Map®, for landmarks and road networks; and

Microsoft Bing® aerial map, whose images were taken mostly in the dry season when there was less vegetation and structures were more visible. At the time of our study, Bing map was last updated in 2018, so recently constructed structures were not represented.

3.3.5. Digitization of the census EAs and georeferencing of all potential residential structures in study provinces

We created digital versions of the hand-drawn base maps of EAs from the 2019 census mapping provided by the National Statistics Office (INSD). The digital mapping team comprised of a mix of GIS skill level varying from novice to expert. It included three GIS experts from the Geographic Institute of Burkina (IGB), masters-level research assistants from the University of Ouagadougou (ISSP) and INSD who were GIS novices, and a doctoral student from Johns Hopkins University (JHU). A training-production training approach was used where the trainees created some of the maps as part of their training. Formal training lasted 3 days, during which about 15 EAs were digitized. After training, each mapper was assigned EAs to be digitized on daily basis. EAs were delineated using the 'Add polygon' tool in the editing features in QGIS®.

Using the sketched base maps as a reference, the name of the village or city neighborhood was first identified on the google satellite base map layer, then the landmarks within the EA and finally the limits of the EA. The identifiers for each EA were inputted in the attribute table which formed the sampling frame. EAs were equally assigned so every team member worked on EAs in the urban, peri-urban, and rural areas. For areas that were difficult to delineate, the team held regular plenary sessions to review and resolve them. Each EA had a separate shapefile which was finally merged to create a single shapefile comprising all the 150 EAs used for the study.

Following the digitization of the EAs, the team proceeded to digitize the structures that appeared to be potentially residential within the EAs. In the urban EAs, structures that had regular polygon shapes such as rectangles and were an adequate size (larger than vehicles) were digitized. In the rural EAs, many residential structures did not have regular polygon shapes but were sparsely distributed, smaller, and grouped together in *concessions*. Irregularly shaped or unusually big structures were digitized as potential landmarks such as markets, schools, football fields and places of worship.

Digitizing entailed manually marking the roof top of each structure using the 'Add points' tool in QGIS®, creating a unique identifier with corresponding geographic coordinates. Together with the digitized EAs, these points formed the attribute table in QGIS®. Enumeration was done systematically by drawing a quadrant over each cluster, and starting from the most distant structure in the northeast quadrant, following a clockwise direction for each EA. We chose manual digitization over automatic algorithms because of the non-uniform shapes and irregular spacing of various structures in the different terrains; for example, satellite imagery could not clearly delineate thatched roofs which was used in many buildings in the rural areas.

There were two levels of quality control: each mapper's work was first reviewed by an expert GIS supervisor, and a second team of GIS experts comprised of INSD, ISSP and JHU did a detailed plenary review of every EA to confirm its alignment with the census base maps. They also verified that the potential residential structures were reasonably selected and correctly enumerated. Digitization and quality control started in October 2019 and was completed in January 2020.

3.3.6. Construction of the sampling frame using the digitized structures as a proxy for households and systematic random selection of structures

The merged attribute table in QGIS® containing the geographic coordinates of all enumerated structures and the shapefiles of digitized EAs formed the main sampling frame, was exported to Stata 14[45] for systematic sampling of potentially residential structures per EA using a study-generated do-file.

3.3.7. Pilot

A pilot exercise was conducted using 4 EAs that were not sampled for the main survey to represent urban, peri-urban, and rural areas. Two urban EAs were selected in Ouagadougou and two EAs in Saaba town (one rural and one peri-urban) using the same two-stage cluster sampling as the main study. For the GIS method, twenty potentially residential structures were selected in each EA using systematic sampling.

The pilot aimed to assess the feasibility of identifying and locating the structures in the three different terrains using an offline navigation app and printouts of satellite images. All 80 sampled structures were found: 74% were occupied residential structures, while 10 structures (12.5%) were vacant, and 11 structures were non-residential. Our pilot showed the need to account for non-residential structures, otherwise in some EAs, we would not complete 20 household interviews. Based on these results, for the main survey, the sample size for the GIS method was adjusted upwards in each stratum: in the rural EAs, we increased to 22 structures per EA while in the urban areas, we increased to 23 structures per EA.

3.3.8. Field implementation of the survey using navigation application and satellite images

For the fieldwork preparation, we imported the list of sampled structures to Google MyMaps to create digital satellite images of the assigned structures for each interviewer. The excel lists and satellite images of individual assignments were uploaded onto the tablets and also printed on paper as a backup in case of battery power loss. Corresponding KML files derived from Google MyMaps were exported toMaps.me, an offline navigation application that was used to provide directions to the selected structures in the field. We selected Maps.me because Open Street Map was its base map, it was stable on the Android platform and its offline version was reliable so it worked regardless of internet connectivity.

We used Samsung tablets (SM-T561, Android 4.4.4) for data collection using Open Data Kit Collect[49] (ODK) forms, which included up to 3 revisits when eligible respondents were not present during the initial visit. The interviewers located assigned structures, using the combination of Maps.me app and the satellite images. Team leaders and field supervisors used same navigation application and satellite images to supervise data collectors.

Multi-residential buildings (*célibaterium*) were commonly found in the urban EAs. Interviewers were trained to randomly select one household in a multi-residential structure using a random subsampling procedure which was modified from the classical Kish grid method.[48] We incorporated a random number generator within the ODK[49] household survey questionnaire tool for those implementing the GIS method. Upon arrival at a multi-residential structure, interviewers rapidly enumerated all households within the structure, and the random number generator tool randomly selected one of the listed households that the interviewer would proceed to interview.

If a structure was vacant, the interviewer documented this result and proceeded to the next location on their list. If a structure was occupied but household members were temporarily absent, interviewers made up to two return visits to attempt to interview the household. No replacement was allowed in the field.

3.3.9. Measures of feasibility

Using an embedded mixed methods approach, we assessed technical and logistical feasibility by focusing on the appropriateness of the GIS method across a range of terrains and the procedures that were implemented. The quantitative measures of feasibility were the time and personnel requirements for creating the sampling frame, the proportion of residential and non-residential structures sampled, survey response rates and costs. The comparative analysis of costs of the GIS and conventional sampling methods are detailed in another paper. The qualitative assessment aimed to understand study staff experiences with preparatory work such as digital mapping and enumeration, quality of satellite images used, and advantages and challenges of the GIS methodology during field implementation.

We conducted 14 key informant interviews with selected study staff. Key informants included data collectors, team leaders, digital mapping team, and their respective supervisors. A purposive sampling approach was chosen to capture a wide breadth of skills and experiences. A list of potential participants was drawn, and they were contacted via email and WhatsApp to request their participation using a recruitment script that explained the purpose of the interviews. Participants were recruited in March 2020, within two weeks after fieldwork was completed.

Interview guides were developed based on a review of the literature on assessing feasibility of implementation for health services delivery. [33,63] All questions were open-ended and included questions about participants' experience, the advantages and disadvantages of the method, the difficulties they encountered during implementation, areas of improvement and their likelihood to use the GIS method for future surveys. (Appendix D) Interviews were conducted virtually using Skype and WhatsApp due to covid-19 travel restrictions and they were audio recorded. Oral consent was obtained prior to the start of each interview. Interviews ranged from 30 minutes to 1 hour.

Interviews were transcribed verbatim and de-identified. Two members of the JHSPH team independently reviewed the transcripts and developed an initial coding framework based on themes that emerged from the data. Using the draft framework, we performed blind coding on the same set of interviews, followed by a detailed review of differences to ensure internal coding consistency. We then coded all interviews, continuously reviewing and refining the coding framework in consultation with the research team. We used Dedoose software for coding and analysis.[64]

3.3.10. Data analysis

Quantitative data analysis was done using Stata version 14.[45] For the GIS method, we described the survey response rates by type of geographic cluster and by sampling method. We calculated survey response rate by type of sampling method used, and by the occupancy status of residential structures. We compared the survey response rate in the two sampling methods using Pearson's chi-square test.

To assess the performance of the method and account for the differences in geographic cluster types, we divided the urban and rural strata into sub-strata. In the urban area, we categorized clusters as urban blocks (loti), urban informal settlements (non-loti), and loti or non-loti areas under construction. Urban loti were the city neighborhood blocks arranged in a grid layout, urban non-loti were the unorganized, informal, and often crowded neighborhoods, and the areas undergoing construction were new neighborhoods that were springing up either due to government planning of new city blocks or the continuing spread of the city's non-loti. In the rural area, we categorized clusters as rural villages or rural towns. The rural villages followed the classical pattern of concessions, while the rural towns were larger, more populated and situated landmarks such as the mayor's office, police station, or the community health center.

3.3.11. Ethical approval

Ethical approval for the survey was received from the Johns Hopkins Bloomberg School of Public Health Institutional Review Board (IRB 00009713) and the Centre De Recherche de Nouna Ethics Committee (determination 2019·018·/MS/SGIINSP/ CRSN /CIE) in Burkina Faso. The key informant interviews were determined to be non-human subjects research by the JHSPH IRB.

3.4. Results

3.4.1. Survey sample and response rates

Of the 75 urban clusters, 36 were urban loti, 14 urban non-loti, 14 were urban loti located in new development and 11 were urban non-loti in new development. The clusters located in new development neighborhoods were characterized by ongoing construction. Among the 75 rural clusters, 66 were rural villages while 9 were rural towns. Figure 3.1 showed the satellite images of clusters selected from the different topographies that were included in the study.

For the GIS sampling method, 58,120 potentially residential structures were digitized in both urban and rural areas, of which 3,371 structures were sampled (Table 3.1). During data collection, 2,968 (88.1%) sampled structures were found to be residential structures, 105 (3.1%) were non-residential structures and 297 (8.8%) were vacant or destroyed structures. Residential structures were defined as structures where the household members were present and consented to participate, were absent for a short or long period, or refused to participate. Non-residential structures were defined as buildings that were used for other purposes such as hostel, workshop venue, or neighborhood corner store. Vacant or destroyed structures were completely roofed buildings that had no inhabitants. The rural towns, non-loti, and the urban loti under construction had the highest proportion of vacant structures (Table 3.1).

Table 3.1. Types of structures found by the GIS sampling method, by geographic cluster type

Geographic cluster type	Number of EAs	Total number of potential residential structures digitized in the EAs	Number of sampled structures	Number (%) of occupied residential structures*	Number (%) of non-residential structures	Number (%) of Vacant / destroyed structures
Urban blocks *(loti)*	36	8,925	825	732 (88.7%)	43 (5.2%)	50 (6.1%)
Urban *non-loti*	14	7,274	321	277 (86.3%)	7 (2.2%)	37 (11.5%)
Urban *loti* under construction	14	8,121	276	193 (69.9%)	24 (8.7%)	59 (21.4%)
Urban *non-loti* under construction	11	5,059	299	248 (82.9%)	11 (3.7%)	40 (13.4%)
Rural villages	66	25,969	1452	1376 (94.8%)	13 (1%)	63 (4.3%)
Rural towns	9	2,772	198	143 (72.2%)	7 (3.5%)	48 (24.2%)
Total	150	58,120	3,371	2,969 (88.1%)	105 (3.1%)	297 (8.8%)

**Occupied residential structures include those with household members present, absent, refused, or the same household had more than one structure selected.*

In the standard method, 14,610 households were enumerated, and 3,021 households sampled. 505 households were selected by both methods. Table 3.2 compares the survey responses among all structures that were visited by the GIS method to the conventional method. 83% of the sample were present in the household and consented to interview compared to the conventional method where 93% of the households were present and participated in the study. The difference between survey response in the two methods was mostly attributed to the higher proportions of vacant and non-residential structures in the GIS method.

Table 3.2: Survey response by sampling method

	Sampling method	
Survey response	Conventional	GIS
	N (%)	N (%)
Member Present	2,820 (93.35%)	2,791 (82.79%)
Absent	133 (4.4%)	137 (4.06%)
Refused	22 (0.73%)	38 (1.13%)
Vacant	42 (1.39%)	270 (8.01%)
Destroyed	1 (0.03%)	27 (0.8%)
Not found	1 (0.03%)	0 (0%)
Non-residential	0 (0%)	105 (3.11%)
Other	2 (0.07%)	3 (0.09%)
Total	3,021	3,371

Figure 3.1. Satellite images of enumerated clusters in Google maps® satellite view

Rural township (top left), rural village (top right), urban planned (bottom left), urban spontaneous (bottom middle), urban planned under construction (bottom right). Cluster limits are represented by the blue lines.

Table 3.3: Survey response by sampling method in occupied residential structures

	Sampling method	
Survey response	Conventional (n=2,975)	GIS (n=2,917)
Present	2,820 (94.8%)	2,742 (94.0%)
Absent	133 (4.5%)	137 (4.7%)
Refused	22 (0.7%)	38 (1.3%)
Pearson chi2(2)	4.85 (p=0.089)	

In Table 3.3, we focused on only structures that were occupied in the two methods in order to discard any differences due to field data collectors' skills, implying that any differences would be due to the inherent bias in the sampling methods. An occupied household is one where the household members are present, absent, or refused to participate. The GIS method had about 1.5 times the refusal rate (1.3%) compared to the conventional method's refusal rate (0.7%). Using a p-value of 0.05, Pearson's chi-square was not statistically significantly different in the survey responses for the two sampling methods. The refusal rate for both methods was largely driven by refusals in the urban areas. (See Appendix B)

3.4.2. Feasibility of implementing GIS sampling method

3.4.2.1. Quantitative assessment: Time and personnel requirements

For the GIS method, the process of creating the sampling frame, from delineating clusters, digitizing structures to quality control lasted 42 days, accruing 276 person-days. This consisted of three days of training six people by two trainers, 21 days of digital mapping, (14 days to delineate clusters, seven days to enumerate potentially residential structures), 12 days of quality control by four persons (four days for first-level, eight days for second level) and six days of preparation. (Table 3.4)

Clusters located in the urban blocks were the quickest to complete, with each team member delineating three EAs daily. In the rural areas, clusters were delineated on an average of two EAs daily, while the urban unplanned neighborhoods were the slowest to delineate at one EA per day per team member. They were slowest because the absence of landmarks and poor road networks made it difficult to delineate cluster boundaries. Field preparation team consisted of seven people who spent one week to upload the assigned structures, satellite images, and individual itineraries to interviewers' tablets.

Table 3.4. Person-time of mapping activities (prior to survey implementation) by method

Activities	GIS method		Conventional method	
	Days	Persons	Days	Persons
Training	3	6	6	28
Mapping and supervision[a]	21	8	28	22
Quality control	12	4	6	3
Field preparations[b]	6	7	3	2
Total person-days for mapping activities[c]	276		918	

[a] *Mapping: Digital delineation of clusters and enumeration of buildings by 6 people with 2 supervisors in the GIS method. Detailed sketching of clusters and field enumeration of all households in the conventional method.*
[b] *Field preparations consisted all activities prior to field deployment such as printing of sketched maps (standard method), digital maps (GIS method), uploading satellite images, assigning teams to clusters and preparing other materials ahead of fieldwork.*
[c] *Person-time computed as days spent training, mapping, quality control and field preparations x number of persons. Assumed 8 working hours/day.*

In the conventional method, field-based mapping and enumeration lasted 48 days, accruing 918 person-days. This included six days of training 28 cartographers and enumerators by three trainers, 28 days of fieldwork, six days of quality control and three days of preparation. (Table 3.4) 20 field agents created detailed maps of clusters and listed all households within the cluster in teams of two (one cartographer, one enumerator), supervised by two supervisors. Cartographers started from the urban block clusters, then urban unplanned clusters and finally the rural clusters. Teams spent two days per cluster. Two people implemented the field preparation activities which included printing and organizing sketch maps.

For survey implementation, the workforce comprised 24 data collectors, 8 team leaders and 3 supervisors for each method. Less than 10% of the GIS field staff had prior GIS sampling survey experience. After a week of plenary training, there was one day of method-specific training and 2 days of field practice at urban and peri-urban locations that were not included in the survey sample.

During data collection, teams spent two days per cluster. Although we did not maintain time logs, we observed that the GIS method data collectors tended to finish data collection earlier in the day than the standard method data collectors. While we could not eliminate the possibility of locating the wrong structures in the GIS method, this was negligible in our study (less than 1%) because the GPS coordinates for every sampled structure visited were collected and matched to the coordinates of the satellite image for all sampled buildings.

3.4.2.2. **Qualitative assessment of field implementation**

3.4.2.2.1. Preparatory work

Respondents highlighted having a multi-disciplinary team comprised of members who were familiar with household survey methodology, geography, GIS techniques, and with the realities of the field as a key facilitator for carrying out this work efficiently. One respondent said *"there were moments of difficulty linked to the delimitation of the enumeration areas and of numbering residential structures. Maybe our luck was that we were a complementary team where we exchanged together to be able to quickly overcome areas of difficulty."* The quality of the hand-drawn sketches of the census enumeration areas had a direct effect on the ease of delineation of the cluster borders on the satellite images. In rural areas where thatched roofs are common, it was difficult to identify differences between residential structures and other structures within the compound such as granaries, toilets, and animal coops. Several respondents described *"the major difficulties […] due to the absence of reflections of the roofs of the residential structures in rural environment since thatch roofs are generally used. Inside the concessions, it is difficult to distinguish the animal enclosures from the structures where people sleep."*

The two-part delay between when the base maps were drawn and when the satellite images were taken, and also between when the satellite images were taken and when data collection occurred meant that the images did not always correspond to what data collectors saw in the field, particularly in the urban *non-loti* where structures were often built up quickly*. "Another element, the dates of the satellite images were not in line with the sketches [base maps] that we had. The sketches were made on an earlier date than the images. So, there was a phase difference between the terrain [fieldwork] and what we had on the sketches."*

3.4.2.2.2. Quality of satellite images and time to find structures

In urban blocks, the image resolution was clear up to 6.1 meters (20 feet) and made it easier to identify structures. In urban slums and rural areas, the satellite images were often good, though they became blurred when zoomed at high resolutions beyond 15 meters (50 feet). According to respondents, *"in urban blocks, buildings follow a certain layout plan, so one can easily distinguish the different streets, lanes, compounds and even the structures inside…. let's say the resolution of the image is better. In reality, on the satellite maps, you can even see the alleys, the small lanes. […] if you look closely […] you can see the trees, the small walls, even the small roads in the concessions, which often help us make a difference. The urban non-loti, the images are often taken months before we leave for the field…things move much faster there so the images you took two months ago may be out of date at the time of [data] collection."*

In some rural areas, when the satellite images were taken in the rainy season with a lot of foliage, and data collection was done in the dry season, aligning the satellite images with the field reality could be challenging. A respondent described the experience *"in rural areas, I have the impression that the satellite images were taken in the rainy season. So, in terms of the images, there was a lot of green. In the beginning when we arrived in a rural environment, we took a little more time to be able to identify the pointed structure and then since there are the huts, often it is complicated, as we weren't used to it."*

Respondents reported that the time taken to locate the sampled structures in the field depended on the geographic location (urban, peri-urban or rural), and the distance between structures. Upon arrival to the neighborhood of the selected structure, the key informants reported a range of 2 to 10 minutes to identify the structure. The urban blocks were the quickest to identify, followed by the rural concessions, and identifying a structure in the very dense urban *non-loti* could take up to 10 minutes using the combination of maps.me™ navigation application and print-outs of the satellite image.

3.4.2.2.3. Advantages of using GIS methodology in field implementation

Key informants reported that it was easy to identify the structures in the urban areas, in both neighborhood blocks and slum areas. Respondents said that the GIS method could be used in difficult-to-reach locations and was potentially cost-saving. Being able to go directly to households without having to do an initial field enumeration of the cluster allowed data collectors to save time, vehicle and motorcycle rental costs and gas costs. A respondent said: *"the GIS method can be an alternative method for areas that are not fully accessible, areas of insecurity, areas that are quite remote. […] it allows us to save a little, […], compared to the standard method where we have to deploy the teams twice: a first time for the enumeration and a second time for the interviews[…]. With the GIS method, it allows us to save the first deployment to do the enumeration.*"

In rural areas, respondents reported that they found the method generally easy to use because the structures were distanced from each other – leaving little room for confusion about selected structures. They also reported that the GIS method allowed them to find structures independently, without the use of local guides and without creating tensions with neighbors about why one household was selected over another. As a field agent put it: *"we don't come with a name. We just identify the structure using the method. When we arrive, no one can say that we chose someone and intentionally left someone else out."* Another respondent described *"using the GIS method made us confident that we were interviewing the right people because it was more accurate in* *locating the selected structures, and we did not need to ask anyone for directions.”* A third data collector noted *“I will say it is for the precision, here we cannot go to wrong structures […] the margin of error there is very small”*

Supervisors also reported that their workload was lighter and the overall process more streamlined because they were able to meet their data collectors quicker. According to a supervisor: *“if the agent has to go to a given location, has difficulty finding […] he calls me on the phone […] gives me the structure number only. He doesn't have to tell me where the structure is […] and I run maps.me (navigation app). In less than 5 minutes, I am already in the structure […]. Compared to other methods, to other studies that I have had to participate in, ah, that's complicated! The agent will call, give explanations of the points of the structures: you have to go to such and such a place, you have to turn left and we communicate for a long time to be able to find the structure to be investigated. So I think that in any case to identify a structure, the GIS I think is the best method.”*

3.4.2.2.4. Challenges of using GIS methodology in field implementation

The most common challenges encountered were related to the navigation application used by data collectors, which included recommendations of long itineraries and the inability to use the *‘trace an itinerary route’* function in remote areas. It was difficult to tell if these challenges were a result of the method or due to the reality of the context. In areas where there were few formal roads (i.e. in urban *non-loti* and remote rural areas), participants reported that the navigation application was not always able to trace an itinerary. A data collector said: *"the urban non-lotis [unplanned areas], this is a problem…there are no roads because people have built anarchically…it [navigation app] is telling you the structure is there but there's no way to reach there […] to find the structure, often you have to go around […], do a lot of turns to be able to find the structure."* Data collectors therefore had to use a combination of printed satellite images and the movement of the location marker in the app to orient themselves. One field agent elaborated: *"When you move, it [blue location marker in the app] moves with you. That's what made it easy for us. Because when you know that, […] when you move, the blue point there moves with you […], but when you choose the itinerary, it says there is no route to get there."* However, once this workaround was established, participants found this method to be easy to use.

3.5. Discussion

This paper described and assessed the feasibility of a GIS satellite imagery-based method for sampling households for large-scale, population-based surveys to estimate coverage of health interventions. We found that implementing this GIS-based household survey method is feasible in rural areas, and in urban planned and unplanned settlements in Burkina Faso to create a relatively accurate sampling frame. Our overall survey yield of 82% occupied residential structures across a variety of geographic landscapes was similar to other studies conducted in Cameroon, Sudan, Tanzania and Malawi, where survey yield ranged from 72% to 97% for GIS and Google satellite imagery survey sampling methods across urban and rural areas. [30,65–67]

In this study, we used the census enumeration areas (EAs) as the primary sampling unit, similar to Escamilla and colleagues in a malaria transmission study in Malawi. [30] Other studies have used satellite images to create primary sampling units (PSUs). In Niger and Mozambique, sampling grids were placed over a scanned street map or over a satellite image of the study areas to create PSUs independent of census EAs.[21,46] In Iraq, Galway and colleagues used pre-made gridded population data masked to the country's spatial extent. [33] While these are relatively faster methods to develop PSUs, sampling grids are more feasible in urban or peri-urban areas where buildings are more likely to be dense, than in rural areas where residential buildings are more dispersed. [21] We used the census EAs in this study to have a consistent approach across the variety of geographic landscapes, focus on testing a novel probability method for selecting secondary sampling units while keeping the PSUs constant, and facilitate comparison to the conventional method.

There are numerous ways that potentially residential structures can be digitally enumerated using free or paid GIS software. In Mozambique, the polygons of individual buildings within the study area were delineated using Open Street Map®; in Malawi, Digipoint 2 was used to digitize individual structures; and in Zambia and Pakistan, buildings were manually enumerated using ArcGIS. [29–31,46] In this study, we used QGIS[43] to manually enumerate and sequentially count the potentially residential structures. We approximated the probability of selecting a household as the probability of selecting an enumerated potentially residential structure in the GIS method. This approach was similar to studies done in Mozambique, Lebanon and Pakistan where the probability of selecting a residential structure was a proxy for the probability of household selection.[31,32,46] One of our underlying assumptions was that only one household will be interviewed in a residential building to preserve statistical efficiency.[48] Our approach resulted in a digital sampling frame that could be used for variety of purposes including planning targeted interventions, repeated cross-sectional surveys, longitudinal population-based studies, disease and demographic surveillance, in humanitarian settings where limited field exposure is pertinent, and could be regularly updated in low-resource settings where population census is not regularly conducted.[21,30,31,33,34]

Various approaches have also been used to locate sampled structures. These include using paper printouts of satellite images with teams assigned to locations based on their familiarity with the community; [29] using Garmin eTrex Global Positioning Systems devices, though this can be expensive; [30] using an offline navigation application to identify the geographic center of the cluster and a random-walk technique to identify structures as a function of proximity to the center; [46] or a combination of satellite imagery and GPS devices. [31] We used a combination of free satellite images and offline navigation app. While Google satellite imagery now covers 98% of the habited earth, effective use of this method depends on accuracy, quality and recency of satellite images.[68] Settings where free, high-quality, recent images are available facilitate the identification of structures so this method will not be useful where satellite images are of poor quality or outdated.

Our GIS sampling method had some limitations. First, we digitized hand-drawn sketches of base maps of EAs from the national census bureau that were of varying quality, were not always accurate or drawn to scale. For example, a landmark placed in the north on the base map sketch might truly be in the east on the satellite image. Similar to Tanzania and Iraq, in our study, having a multi-disciplinary team that included those familiar with the terrain was indispensable to ensure correct interpretation and digitization.[33,66] Another limitation occurred in some rural villages where the quality of the satellite images was poor. However, combining two or more sources helped to identify the features.

Second, delineating cluster boundaries and enumerating potentially residential structures was done manually. Though guidelines were established to standardize selection across the digital mapping team, team members sometimes made judgement calls on what could be potentially residential based on their knowledge of the terrain. Satellite images provide aerial views, so it was not always possible to identify non-residential structures or to predict a building's use. While the proportion of non-residential structures (3%) was similar to a study in Zambia, in our study, almost 9% of sampled buildings were vacant or destroyed, which was lower than what researchers in Cameroon found.[29,65] Since we implemented only one round of field visits, households were visited and interviewed the same day without prior information on what structures were non-residential or vacant in the clusters. We mitigated this by inflating the sample size by 10-15% to account for potentially vacant and non-residential structures. To mitigate sample selection bias, a navigation app was used to direct field interviewers to the pre-selected locations and they were not permitted to replace structures if they ended up at a non-residential or vacant structure. [69]

The main limitation of the feasibility assessment is that standardized methods and indicators to measure feasibility of new sampling or data collection methods do not exist. Feasibility studies generally focus on the implementation process to demonstrate whether a new intervention works, for what contexts it works, and whether others can adopt and implement if it meets their technical and financial capability. As a result, studies of the feasibility of new sampling methods are limited in literature, and generally focused on time spent on implementation with varying metrics, capability requirements and financial implications. Studies have used various time measures such as days of training, days of interviews, and time to locate assigned structures or travel time to the selected clusters.[20,21,31]

We selected measures that would aid comparability between the two methods and included days of training, person-time requirements for the different stages of implementation by method, key informant interviews to capture field experiences, and a cost-benefit analysis that will be detailed in a future publication. We did not collect data on individual interviewers' time to locate assigned structures in the field. However, field observations and qualitative interviews suggested that the interviewers implementing the GIS method were quicker to locate the assigned structures and often completed their daily quota earlier in the day than those in the standard method who relied on the mapping supports, local guides and neighbors to assist them in locating the assigned households. In Pakistan, researchers noted novel alternatives required more time; in our study, while the GIS method had overall three times lower person-time requirement, field preparation required seven times higher person-time compared to the standard method. [31]

The GIS method had several strengths. First, we prioritized developing a comprehensive sampling frame where we identified all potentially residential structures, including some structures located in commercial areas and along the highways. This resulted in digitizing more structures, allowing us to capture wider variability of respondents, including vulnerable populations such as those fleeing violence, living in incomplete buildings, in their shops, or in unplanned neighborhoods who are more likely to be missed in traditional surveys because of reliance on outdated census, field workers overlooking buildings or skipping neighborhoods that appear unhabitable.

Second, to our best knowledge, this was the first real-time comparison of satellite imagery probability method to the standard probability method in terms of the person-time required for each method. Third, substituting highly expensive technology such as commercial satellite images, ArcGIS software[53] and GPS navigation devices and maximizing the range of freely available tools such as free satellite images with high global coverage, free offline navigation app, and free GIS software increases the generalizability of this method, and we found that the response rate among occupied residential dwellings was similar to the standard probability method. A comparison of coverage indicators estimated from the two samples is published in Chapter 4.

Fourth, we highlighted the limitations of dichotomizing areas as rural or urban. By disaggregating urban and rural clusters into sub-categories such as rural townships, rural villages, urban planned and unplanned neighborhoods, our study found significant differences in the survey yield by type of geographic area. (Appendix Table A.1) Lastly, we used an embedded mixed method design to assess feasibility. To our best knowledge, this was the first qualitative description of field experiences from the perspective of implementers of GIS-based survey sampling method. Articulating the realities on ground helped to contextualize the results and could benefit future adoption of the method across a variety of geographic landscapes within resource-constrained settings.

3.6. Conclusion

Based on the feasibility of this method (quicker implementation, lower person-time requirement, and similar response rates), and the increasing availability of free technologic resources, the GIS probability sampling method can be considered a valid alternative to the current standard second stage sampling method for large-scale surveys. In areas with security concerns, humanitarian disasters, or in the current Covid-19 pandemic where it is important to limit exposure and time spent in the field, the GIS approach may be a better option than multiple field visits.[32,33]

New technologies could further increase the feasibility of this method, for example by integrating satellite images and itineraries with data collection applications; instead of navigating multiple applications, a one-stop approach could improve method uptake.

Although our mapping and quality control process lasted a month, the emergence of artificial intelligence and machine learning could improve image quality in rural areas, and automate the process of delineating clusters and enumerating residential structures. [70] Probability cluster sampling remains the most efficient way to generate a representative survey, and the adaptability of this approach for a variety of terrains calls for it to be replicated in settings where it is imperative to collect timely, high quality, and representative population-based data.

Chapter 4. Comparing GIS and conventional household survey sampling methods for estimating family planning coverage and determinants of modern contraceptive use in Burkina Faso

4.1. Abstract

Background

Universal access to family planning is a global priority under the Sustainable Development Goal on health. The coverage of contraceptive need and use is generally measured through household surveys in low and middle-income countries using conventional multi-stage probability cluster sampling design which often involves two field operations. The first, called mapping & enumeration creates the sampling frame, and the second entails data collection from eligible respondents. We implemented a novel probability sampling approach using satellite images and geographic information system (GIS) techniques to replace the first field operation. We compared estimates of selected family planning (FP) coverage indicators in the two sampling approaches using pre-determined equivalence thresholds and identified determinants of these coverage indicators in the population.

Methods

Concurrent cross-sectional studies were implemented using both the conventional and GIS sampling methods from February to March 2020 in the same 150 census enumeration areas in two provinces in Burkina Faso. Selected FP coverage indicators

were modern contraceptive prevalence rate (mCPR), unmet need for FP and demand for FP satisfied using modern methods. Equivalence threshold of ± 5% was defined a priori using confidence interval approach. Multivariable logistic regression identified associations between determinants and selected indicators.

Results

9,907 eligible women were selected, composed of 4,370 in the conventional method, 3,913 in the GIS method and 1,624 who were selected by both methods. The rural and urban samples between the two methods had overlapping confidence intervals in terms of sociodemographic, fertility, employment status and participation in healthcare decision-making. Across the coverage indicators, the difference in point estimates between the two methods ranged from -2.6% to 1.2% in the urban stratum and -2.3% to 1.4% in the rural stratum. The confidence intervals for the difference in mCPR and unmet need estimates fell within the preset equivalence margin of ± 5 percentage points in both strata. Completing at least a primary education and having gainful employment were significantly associated with being a modern contraceptive user, and having demand for family planning satisfied, compared to their respective references, holding other variables constant.

Conclusion

GIS satellite image sampling method is equivalent to the conventional sampling method when estimating family planning coverage. Probability sampling is fundamental to achieve representative surveys and implementing it using satellite images could potentially balance the need for high-quality data with the high resources demanded by the conventional sampling method, thereby increasing its adoption by organizations operating in low-resource settings.

4.2. Introduction

4.2.1. Relevance of HH surveys in family planning programs

The use of and access to family planning methods is foundational to achieve gender equity, women's empowerment, child survival, poverty reduction and sustainable development. In the Sustainable Development Goals (SDGs), the family planning goal is: "b*y 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes*."[71] Studies show that prioritizing family planning can reduce poverty and foster human capital development. [3,4]

The coverage of contraceptive need and use is generally measured through household surveys in low and middle-income countries (LMICs). Routine health administrative records may be inaccurate or incomplete.[72] Some modern contraceptive methods can be obtained through local vendors and pharmacies, therefore reliance on even accurate routine health records would provide an incomplete picture of use of contraceptives in the communities. Household surveys fill the information gap, monitor progress in communities against predetermined global and national targets, provide information on the determinants of intervention coverage in the target population and identify areas for improvement during program implementation.[10] Having annual household surveys can signal trends in population health early so that research, policies, and interventions can be designed to address them.

4.2.2. Probability-based survey sampling

Probability survey sampling is the standard for household surveys because it generates valid estimates for the reference population, quantifies sampling errors and makes inferences bounded by confidence limits.[15] Most of the national surveys conducted in LMICs for demography and coverage of health interventions implement the USAID/Demographic and Health Survey (DHS) or UNICEF/Multiple Indicator Cluster Survey (MICS); these surveys use a multi-stage probability cluster sampling design. After stratification, in the first stage the primary sampling units, usually national census enumeration areas (EAs) are selected with probability proportional to size.[16] In the second stage, sampled EAs are mapped by field cartographers and the households enumerated by interviewers who go from house to house within the EAs to create or update household lists, a process that could last several months. Households (secondary sampling units) are then sampled from the updated household listing using systematic random sampling.[16]

While this approach to sampling remains the standard, the main drawbacks of costs and high technical expertise requirement have contributed to the infrequent implementation of these surveys, resulting lack of current data for policy making and program implementation. In sub-Saharan Africa, Senegal is the only country to have repeated annual DHS since 2013, while in most other countries, DHS or MICS surveys are once in 3-5 years or up to 10 years in some countries.[73]

The use of GIS and satellite imagery for household surveys in public health is an emerging field, and has been tested more in urban and peri-urban than rural areas. [13,29,30,32–35] While this field is growing, there is a need to present evidence of the comparability of using satellite imagery for household survey sampling vis-à-vis the conventional household survey sampling method.

In this paper, we compare the point estimates of the coverage of family planning indicators between two probability survey sampling methods in Burkina Faso: a relatively new GIS sampling method using satellite images and the conventional survey sampling method. We also explore the determinants of modern contraceptive use and other selected coverage indicators for family planning in this setting.

4.3. Methods

4.3.1. Study setting

We implemented the coverage surveys in Kadiogo and Boulkiemde provinces of Burkina Faso. Our objective was to compare the sampling methods across a variety of geographies (urban, peri-urban and rural areas), and indicators. Kadiogo province, which contains the national capital city of Ouagadougou, was selected for the urban, planned and peri-urban, spontaneous settlements EAs. Boulkiemde province comprised several rural towns and villages which served as the rural EAs.

4.3.2. Survey sampling

Two-stage stratified cluster survey sampling design was used for both sampling methods where selection of EAs was the first stage, and selection of households or potentially residential buildings was second stage. The same primary sampling units (EAs) were used for both the GIS and conventional sampling methods. The list of EAs in the two provinces was provided by the Burkina National Institute for Statistics and Demography (INSD). To explore the GIS methodology in different geographies and to reduce sampling error, we stratified by geography into urban and rural areas. Within each stratum, 75 EAs were selected from each of the two provinces using probability proportional to (estimated) size. The methods differed in the creation of the sampling frame used for the selection of households in the second stage of sampling. (Appendix C). We described the creation of the sampling frames for both methods in Chapter 3. INSD also provided the hand-drawn sketches of selected EAs.

For the conventional method, study cartographers re-mapped the EAs while enumerators listed the households within each EA. For the GIS method, our team recreated the boundaries of each EA digitally on the satellite image and enumerated potentially residential structures using polygon functions and point functions respectively in QGIS software.[43] We assumed only one household would be interviewed within a building since conducting interviews within multiple households in the same building was statistically inefficient.[48] In multi-unit structures, interviewers enumerated all households and used a random number generator built into the survey data collection software to randomly select one dwelling to interview.[48]

4.3.3. Data collection

Prior to training, interviewers were randomly assigned to the conventional or GIS sampling methods teams. During data collection, for the conventional method, interviewers were assigned by their team leader to the sampled households to be interviewed, and they relied on their local knowledge, phone numbers of heads of households, asked neighbors or used local guides to locate the sampled households. For the GIS method, the daily itinerary of each interviewer, satellite images of sampled structures, and an offline navigation application called Maps.me® to guide interviewers to the selected households were preloaded to the tablets used for data collection. The details of the field implementation and feasibility of a GIS-based probability sampling method have been discussed in another paper. (Chapter 3)

Eligible women were identified from the household listing roster as those aged 15-49 years residing in or who spent the previous night in a sampled household. All eligible women in the selected households were interviewed. Oral informed consent was obtained from the head of the household and each eligible woman before conducting the interviews. The women's questionnaire (Appendix A) administered to all eligible respondents was adapted from the RADAR project coverage survey questionnaires, modified for Burkina Faso setting. (https://www.radar-project.org/coverage-survey) The women's questionnaire included sociodemographic characteristics, family planning, pregnancy, childbirth, and women's decision-making autonomy modules.[74]

Data were collected on Samsung tablets using Open Data Kit (ODK) survey software.[49] At the end of every working day, or as often as internet connection was available, the team leaders verified all entries were correct and uploaded the data to the study's server. The two surveys were conducted concurrently within the same EAs in two provinces in Burkina Faso to ensure comparability.

4.3.4. Definitions of family planning coverage indicators

The family planning coverage indicators we examined are shown in Table 4.1.

Table 4.1. Selected coverage indicators for family planning

Family Planning coverage indicators	Definition[75]
Modern contraceptive prevalence rate (mCPR)	Percentage of currently married women who currently use any modern method of contraception. Modern methods include: female sterilization, male sterilization, oral contraceptive pills, intrauterine devices (IUD), injectables, implant, female or male condom, diaphragm, contraceptive jelly, lactational amenorrhea method
Unmet need for family planning	Percentage of women who want to delay or stop pregnancy and are not using any contraception.
Demand for family planning satisfied with modern methods	Number of women who are using any modern contraceptive method that have a met or unmet need for family planning

Definitions published in Guide to DHS statistics (DHS-7).

To test whether the main family planning coverage indicators: modern contraceptive prevalence rate (mCPR), unmet need for family planning and demand for family planning satisfied were comparable among the two sampling methods, we adopted the confidence interval approach recommended for equivalence studies.[52] The null hypothesis, H_o to imply nonequivalence was expressed as: $|P_R – P_{GIS}| \geq \Delta$ and alternative hypothesis, H_A to imply equivalence was expressed as: $- \Delta < |P_R – P_{GIS}| < \Delta$, where P_R is the outcome (indicator point estimate) in the conventional sampling method and P_{GIS} is the outcome in the GIS sampling method. To test the alternative hypothesis of equivalence among the sampling methods, the sample size was estimated using twosided confidence interval (1-2α)*100% of the observed difference between the two means using binary outcomes, significance level (α) of 5%, 80% power (1-β) and a threshold margin (Δ) of ± 5 percentage points for equivalence.

One of the methods to select equivalence margin is to consider the lower bound of the confidence interval (CI) of the difference between two population means as the conservative estimate of the true difference.[76–78] The most recent population-based survey on family planning coverage in Burkina Faso is the Performance, Measurement and Accountability 2020 (PMA2020) surveys.[28] These are repeated cross-sectional surveys with multistage stratified cluster sampling method and have been collecting data on family planning coverage annually since 2015 in Burkina Faso.[28] We calculated the difference between mCPR prevalence for the two most recent years where sampling errors were published.[79,80] The difference was 4.5 percentage points (95% CI: 3.7-5.6), so we chose Δ of 5% with symmetric margins from -5% to 5% as a ≤ 5% difference would be practically insignificant to influence policy decisions, and feasible to attain the sample size needed to implement our study.[81] Based on this definition of equivalence, if the 90% CI of the observed difference lies entirely within - Δ and + Δ, equivalence is demonstrated, if not, we cannot assert that the methods are not equivalent, and if the CI lies entirely outside these margins, we will infer non-equivalence. [52,77,82]

We sampled 150 EAs (clusters) and 20 households per cluster for the conventional method, accounting for 10% non-response rate. In the GIS method, the number of potentially residential structures selected per cluster was increased to 22 in urban and

23 in rural clusters to account for vacant and non-residential structures. This 10-15% increase in the sample size was based on the results of the pilot. (detailed in Chapter 3)

4.3.5. Statistical analysis

Indicators were estimated separately for each sampling method, stratified by geographic area. The weighted point estimates and standard errors of coverage indicators were analyzed using the survey analysis commands in Stata 14 (StataCorp LP, College Park, TX, USA).[45] Standard errors (SE) were estimated using Taylor linearization method to account for the survey design. Coverage estimates were compared between the two sampling methods using ‘partially overlapping package’ in R [83,84] to account for any potential covariance among respondents that were selected by both sampling methods, although we assumed independence of sample selection in each method.

The difference between the two population means from the sampling methods was generated, and the 90% CI derived to test equivalence at $\alpha = 5\%$.[77] As a sensitivity analysis, we compared coverage estimates in the two methods using simple logistic regression and adjusted Wald tests in Stata to derive the difference between the two sampling methods.

We used multivariable logistic regression models to explore potential determinants of family planning indicators such as age (continuous, years), education (none, primary, secondary/higher), geography (urban, rural), marital status (currently married or living with a partner, or not in union), employment status (employed or unemployed in the last

12 months preceding the survey), birth experience (ever given birth or not) and the participation of the respondent in decision making regarding her healthcare (yes or no) using data from the conventional sampling method. Covariate selection for model building was based on literature review and a conceptual framework (see Appendix F) on the determinants of modern contraception.[85–87]

Bivariate and multivariate logistic regression analyses were performed to assess factors associated with the selected family planning coverage indicators, accounting for the two-stage cluster survey design and nonresponse rates. Models were fit under specifications of design-based analysis with weighting to account for unequal probabilities or selection and non-response. Goodness-of-fit tests were performed on all multivariate logistic regression models to assess the model fit to the data. The adjusted odds ratios and corresponding 95% confidence intervals were estimated to determine the magnitude and significance of associations with family planning coverage.

4.3.6. Ethical approval

Study procedures received ethical approval from the institutional review boards of the Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA, (IRB00009713) and the Centre de Recherche en Sante de Nouna in Burkina Faso (2019-018-/MS/SG/INSP/CRSN/CIE). All respondents provided oral consent prior to interviews.

4.4. Results

4.4.1. Survey response rates

There were 9,907 eligible women (aged 15-49 years) within the interviewed households, including 1,624 women who were selected in the households sampled by the two methods, 4,370 in the conventional method only and 3,913 women in the GIS method only. (Table 4.2)

Table 4.2. Response rates of household and women interviews, by sampling method and geography

	Conventional Method Only			GIS Method Only			Sampled By Both Methods		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Households									
Sampled households / potentially residential structures [a]	1273	1412	2685	1418	1617	3035	232	104	336
Occupied households [b]	1257	1382	2639	1239	1342	2581	232	104	336
Interviewed households	1215	1269	2484	1194	1212	2406	232	104	336
Absent	41	92	133	43	94	137	0	0	0
Refused	1	21	22	2	36	38	0	0	0
Household response rate [c]	95.4%	89.9%	92.5%	84.2%	75.0%	79.3%			
Women aged 15-49									
Eligible women sampled	2506	1864	4370	2089	1824	3913	609	203	812
Eligible women interviewed	2223	1644	3867	1962	1686	3648	552	178	730
Eligible women response rate[d]	88.7%	88.2%	88.5%	93.9%	92.4%	93.2%	90.6%	87.7%	89.9%

[a] In conventional method, households were sampled while under GIS method, potentially residential structures were sampled.
[b] Occupied households were defined as households where members were present and consented, absent household members and households that refused.
[c] interviewed households / sampled households
[d] eligible women interviewed / eligible women sampled

The household response rate was higher in the conventional method compared to the GIS method in both geographic locations. Conversely, the GIS method had higher response rates among eligible women in both rural and urban areas.

4.4.2. Study population and sociodemographic characteristics of respondents

The rural and urban samples were similar between the two methods with respect to age, educational attainment, marital status, religion, employment status with overlapping confidence intervals (Tables 4.3 and 4.4). Remarkably, about two-thirds of the respondents in the rural areas under both methods reported having no education.

Table 4.3. Sociodemographic characteristics of conventional sampling method's study population by geography (weighted, accounting for survey design)

	Conventional Method						
	Rural		Urban		N		
	Percent	95% CI	Percent	95% CI	Rural	Urban	Total
Mean age	29.8	[29.2,30.3]	27.6	[27.2,27.9]	2,775	1,822	4,597
Highest education level attained							
None	63.4	[58.6,68.0]	24.5	[22.1,27.2]	1,795	463	2,258
Primary	14.9	[12.6,17.5]	23.1	[21.0,25.4]	389	433	822
Secondary+	21.6	[18.6,25.0]	52.4	[49.2,55.6]	591	926	1,517
Matrimonial status							
not in union	29.6	[26.9,32.5]	43.2	[40.7,45.7]	820	788	1,608
in union	70.4	[67.5,73.1]	56.8	[54.3,59.3]	1,955	1,034	2,989
Religion							
Christian	60.1	[52.7,67.0]	39.9	[36.2,43.6]	1,642	749	2,391
Muslim	37.1	[30.1,44.6]	60	[56.2,63.6]	1,038	1,070	2,108
Traditional	2.4	[1.5,3.9]	0.1	[0.0,0.4]	83	2	85
Employment status							
Unemployed	39.8	[34.8,45.0]	29.8	[27.6,32.1]	1,118	552	1,670
Employed	60.2	[55.0,65.2]	70.2	[67.9,72.4]	1,657	1,270	2,927
Wealth quintile							
Poorest	18.6	[15.4,22.3]	18	[12.7,24.8]	532	343	875
Poor	18.4	[15.8,21.3]	18.8	[15.7,22.3]	509	347	856
Middle	20	[17.0,23.4]	20.6	[17.6,23.9]	561	379	940
Wealthy	19.6	[16.2,23.6]	19.6	[16.3,23.4]	540	341	881
Wealthiest	23.4	[19.3,28.0]	23	[18.5,28.2]	633	412	1,045
Participation in healthcare decision-making							
Alone	17.7	[14.7,21.2]	20.9	[18.2,23.9]	474	378	852
With someone else (partner, family)	12.4	[10.0,15.1]	19.1	[15.7,22.9]	342	358	700
Someone else alone	70	[66.2,73.5]	60	[56.3,63.6]	1,959	1,086	3,045

95% CI: 95% confidence interval

Table 4.4. Sociodemographic characteristics of GIS sampling method's study population by geography (weighted, accounting for survey design)

	GIS Method						
	Rural		Urban		N		
	Percent	95% CI	Percent	95% CI	Rural	Urban	Total
Mean age	29.5	[28.9, 30.0]	27.6	[27.1, 28.1]	2,514	1,864	4,378
Highest education level attained							
None	64.2	[57.3,70.6]	32.6	[28.8,36.7]	1,644	535	2,179
Primary	13.5	[9.8,18.2]	20.6	[18.4,23.0]	308	400	708
Secondary+	22.3	[19.4,25.6]	46.8	[42.9,50.7]	562	929	1,491
Matrimonial status							
not in union	27.4	[25.3,29.6]	43.5	[39.7,47.4]	716	846	1,562
in union	72.6	[70.4,74.7]	56.5	[52.6,60.3]	1,798	1,018	2,816
Religion							
Christian	60.1	[49.0,70.3]	38.6	[34.4,43.0]	1,512	775	2,287
Muslim	37.4	[27.6,48.4]	61	[56.7,65.1]	929	1,084	2,013
Traditional	2.1	[1.3,3.3]	0.3	[0.1,0.8]	65	4	69
Employment status							
Unemployed	45.6	[35.8,55.9]	28.9	[26.0,32.0]	1,042	567	1,609
Employed	54.4	[44.1,64.2]	71.1	[68.0,74.0]	1,472	1,297	2,769
Wealth quintile							
Poorest	20	[16.4,24.0]	17.9	[13.4,23.7]	554	257	811
Poor	20.2	[17.4,23.3]	17.6	[14.0,21.8]	531	302	833
Middle	20.1	[16.6,24.2]	20.2	[15.9,25.4]	471	321	792
Wealthy	19.8	[16.1,24.1]	20.8	[16.9,25.3]	496	444	940
Wealthiest	20	[15.7,25.0]	23.5	[17.0,31.6]	462	540	1,002
Participation in healthcare decision-making							
Alone	11.3	[9.3,13.6]	15.5	[12.5,19.0]	280	304	584
With someone else (partner, family)	14.2	[11.3,17.7]	19.2	[15.9,22.9]	387	351	738
Someone else alone	74.6	[70.1,78.6]	65.3	[61.5,69.0]	1,847	1,209	3,056

95% CI: 95% confidence interval

4.4.3. Family Planning coverage indicators

4.4.3.1. Modern contraceptive prevalence rate and method mix

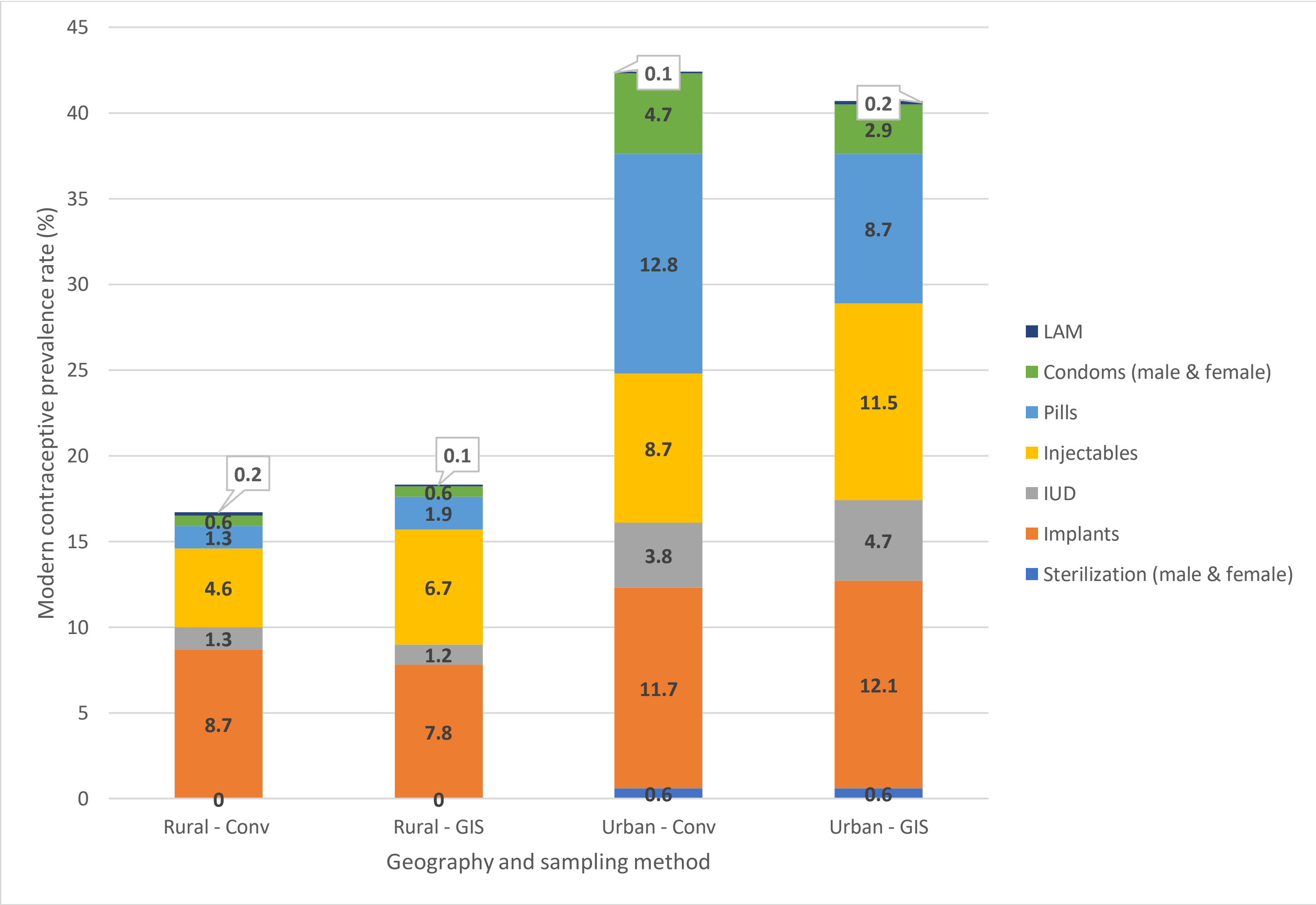
The modern contraceptive prevalence rate (mCPR) among married women categorized by sampling method and geography is shown in Table 4.5. Overall, mCPR in the rural areas under the conventional sampling method was 18.0% (95% CI: 15.5-20.8) while under the GIS sampling method, it was 20.4% (95% CI: 17.8-23.2). In urban areas, under the conventional method, mCPR was 42.6% (95% CI: 39.5-45.7) while under the GIS method, it was 42.3% (95% CI: 36.2-48.6). For some sub-groups such as those aged 15-19 years in the rural areas, there were larger magnitudes of the difference between conventional and GIS method estimates, but their wide confidence intervals suggest small sample sizes, and our study might have been underpowered to detect such sub-group differences, so it should be cautiously interpreted. The two sampling methods showed that implants were the most used contraceptive method in both rural and urban areas. (Figure 4.1) GIS method indicated injectables were the second most used method in both rural and urban areas, while the conventional method showed injectables were the second most used method in the rural area and oral contraceptive pills were the second most frequently used method in the urban areas. Appendix E details the method mix for modern methods by sampling method and geography.

Table 4.5. Modern contraceptive prevalence rate (mCPR) among married women only, by sampling method and region (weighted, accounting for sampling design)

	Conventional method				GIS method			
	Rural		**Urban**		**Rural**		**Urban**	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Aggregate	18.0	[15.5,20.8]	42.6	[39.5,45.7]	20.4	[17.8,23.2]	42.3	[36.2,48.6]
Age (years)								
15-19	8.5	[4.0,17.4]	23.9	[12.3,41.2]	21.1	[9.9,39.6]	17.4	[6.9,37.3]
20-29	17.4	[14.1,21.2]	48.9	[43.8,54.0]	18.8	[16.0,22.0]	43.3	[33.4,53.7]
30-29	19.9	[16.4,24.0]	44.1	[39.6,48.6]	23.2	[18.8,28.1]	46.6	[38.0,55.4]
40-49	17.6	[13.8,22.2]	32.5	[26.2,39.6]	18.1	[13.9,23.3]	36.5	[29.8,43.7]
Highest education level attained								
None	15.8	[13.3,18.7]	36.9	[31.6,42.7]	17.6	[15.1,20.5]	38.6	[31.6,46.2]
Primary	21.3	[16.0,27.8]	44	[37.9,50.3]	30.2	[24.7,36.4]	44.1	[34.0,54.6]
Secondary+	33.7	[24.9,43.8]	46.7	[40.5,53.0]	32.4	[26.9,38.4]	46.1	[36.6,55.9]
Religion								
Christian	17.6	[14.3,21.4]	44.9	[39.7,50.2]	19.1	[16.3,22.3]	40.8	[31.6,50.7]
Muslim	19.4	[16.8,22.3]	41.4	[37.3,45.6]	22.6	[18.4,27.4]	42.6	[36.7,48.7]
Traditional	10.9	[4.2,25.4]	0	0	16.1	[8.4,28.6]	0	0
Employment status (past 12 months)								
Unemployed	12.6	[9.8,16.0]	41.8	[35.0,48.9]	21.4	[17.1,26.4]	41.2	[31.8,51.3]
Employed	21	[17.9,24.4]	42.8	[39.2,46.5]	19.7	[17.0,22.7]	42.6	[36.6,48.8]
Wealth quintile								
Poorest	13.7	[10.0,18.5]	38.6	[30.6,47.2]	19.2	[12.0,29.3]	37.1	[25.3,50.5]
Poor	13.8	[10.3,18.3]	46.8	[38.8,55.1]	20	[15.8,24.9]	36.9	[27.1,47.8]
Middle	15.7	[11.6,20.8]	39.3	[32.5,46.5]	15.1	[10.4,21.3]	49.5	[38.9,60.2]
Wealthy	18.1	[13.3,24.3]	44.1	[37.7,50.8]	25.4	[19.0,33.0]	46.9	[36.4,57.6]
Wealthiest	27.6	[22.9,33.0]	44.7	[36.8,53.0]	22.3	[15.5,30.9]	41	[34.4,48.0]
Ever given birth								
Yes	18.4	[15.9,21.2]	44.1	[41.0,47.3]	21	[18.3,24.0]	44.1	[37.9,50.6]
No	7.3	[1.6,28.2]	10.9	[4.2,25.3]	4.1	[0.9,16.1]	12.8	[3.5,37.5]
Participation in healthcare decision-making								
Alone	13.9	[10.0,18.9]	41.5	[33.9,49.4]	25.3	[18.2,34.0]	52	[42.2,61.6]
With someone else (partner, family)	23.3	[17.8,29.9]	46.7	[40.7,52.7]	22.3	[17.0,28.8]	45.6	[36.9,54.6]
Someone else alone	18.1	[15.5,21.0]	40.8	[35.8,46.1]	19	[15.7,22.8]	38.3	[31.3,45.9]

95% CI: 95% confidence interval

Figure 4.1. Method mix for modern contraceptive method use among women in union, by geography and sampling method



Conv – conventional sampling method; GIS: GIS sampling method; IUD: Intrauterine device; LAM: Lactational amenorrhea

4.4.3.2. Unmet need and demand for family planning satisfied using modern methods

Compared to the rural areas, the total unmet need for family planning was lower in urban areas. The total unmet need for family planning was 3.6 percentage points (pp) higher in the conventional sampling compared to the GIS sampling in rural areas while in the urban areas, the conventional method was 3.1pp higher relative to the GIS method. (Tables 4.6 and 4.7)

Table 4.6. Demand satisfied and unmet need for family planning among married women in the conventional sampling method, by geography (weighted, accounting for sampling design)

	CONVENTIONAL METHOD					
	RURAL			URBAN		
	Unmet need for family planning % [95% CI]		Demand satisfied using modern methods % [95% CI]	Unmet need for family planning % [95% CI]		Demand satisfied using modern methods % [95% CI]
	Spacing	limiting		spacing	limiting	
Aggregate	21.2 [18.7,23.8]	10.4 [9.0,12.0]	34.4 [30.3,38.7]	16.3 [13.7,19.3]	6.5 [4.8,8.6]	62.3 [58.1,66.3]
Age group						
15-19	50.1 [39.3,60.8]	0	13.1 [6.0,26.2]	34.3 [21.0,50.7]	0	36.7 [18.4,59.8]
20-29	30.2 [26.2,34.4]	2.1 [1.1,3.9]	33 [27.1,39.4]	20.4 [16.2,25.3]	0.9 [0.3,2.6]	66.3 [59.9,72.2]
30-39	19.9 [16.5,23.8]	11.1 [9.4,12.9]	37.4 [31.9,43.2]	16.6 [13.0,21.0]	6.1 [3.4,10.6]	64.3 [58.2,70.0]
40-49	8.8 [6.6,11.7]	19.9 [16.3,24.0]	35.7 [28.8,43.3]	4.6 [2.4,8.5]	18.5 [13.7,24.7]	54.5 [45.6,63.0]
Highest education level attained						
None	20.6 [18.0,23.4]	11.4 [9.7,13.4]	31.1 [26.7,35.8]	13.8 [10.6,17.9]	8.7 [5.6,13.2]	57.5 [49.6,65.1]
Primary	25.1 [18.6,32.9]	7.7 [4.5,12.9]	38.2 [29.4,47.8]	17.8 [13.4,23.3]	7.1 [4.1,12.2]	64.4 [56.6,71.5]
Secondary+	20.8 [14.6,28.8]	4.9 [1.9,12.2]	54.6 [40.2,68.2]	17.4 [13.7,21.8]	4.1 [2.6,6.5]	64.7 [57.6,71.1]
Employment status (in the past 12 months)						
Unemployed	24.2 [20.2,28.8]	7.7 [5.9,10.1]	26.3 [20.6,33.0]	23.6 [18.3,29.9]	3.4 [1.7,6.7]	57.7 [50.2,64.8]
Employed	19.5 [16.8,22.5]	11.9 [9.9,14.2]	38.2 [33.4,43.3]	14.1 [11.6,17.1]	7.4 [5.3,10.2]	63.7 [58.6,68.4]

Wealth quintile						
Poorest	21.3 [17.0,26.4]	8.7 [6.1,12.4]	29.2 [22.3,37.3]	17.2 [11.9,24.1]	8.3 [4.9,13.7]	57.6 [46.6,68.0]
Poor	22.5 [17.6,28.3]	12.6 [9.5,16.7]	26.2 [20.2,33.1]	15.0 [10.6,20.9]	5.6 [2.9,10.5]	68.8 [58.4,77.6]
Middle	20.8 [16.4,25.9]	11 [7.8,15.3]	31.5 [23.8,40.3]	19.6 [14.2,26.4]	4.1 [2.0,8.0]	59.6 [49.1,69.3]
Wealthy	22.3 [17.7,27.7]	8.2 [5.8,11.6]	34.8 [26.7,43.9]	15.1 [10.4,21.4]	6.5 [3.5,12.0]	61.8 [53.1,69.8]
Wealthiest	19.1 [18.7,23.8]	11.3 [8.2,15.6]	46.2 [39.2,53.4]	14.3 [10.3,19.3]	7.8 [4.7,12.7]	63.8 [54.3,72.7]
Ever given birth						
Yes	21.6 [19.1,24.3]	10.9 [9.4,12.6]	34.3 [30.3,38.6]	17.1 [14.3,20.3]	6.9 [5.2,9.2]	62.4 [58.3,66.3]
No	12.3 [7.2,20.2]	0	39.3 [9.9,79.3]	4.4 [1.2,15.3]	0	52.7 [19.7,83.5]

95% CI: 95% confidence interval

Table 4.7. Demand satisfied and unmet need for family planning among married women in GIS sampling method, by geography (weighted, accounting for sampling design)

	GIS METHOD					
	RURAL			URBAN		
	Unmet need for family planning % [95% CI]		Demand satisfied using modern methods % [95% CI]	Unmet need for family planning % [95% CI]		Demand satisfied using modern methods % [95% CI]
	Spacing	limiting		spacing	limiting	
Aggregate	20.4 [18.0,23.0]	7.6 [6.4,9.0]	38.7 [34.4,43.3]	14.0 [11.6,16.8]	5.7 [3.8,8.4]	64.8 [58.2,70.9]
Age group						
15-19	24.6 [14.8,38.0]	0	42.7 [23.9,63.8]	18.7 [7.9,38.1]	1.3 [0.2,9.5]	37.2 [15.8,65.1]
20-29	28.2 [25.5,31.0]	1.2 [0.5,2.7]	35.4 [30.7,40.3]	20.5 [15.5,26.7]	0	65 [54.4,74.3]
30-39	22.8 [17.7,28.9]	8.5 [5.3,13.3]	39.9 [33.0,47.2]	13.1 [9.8,17.4]	3.8 [2.2,6.5]	71.3 [61.9,79.1]
40-49	6.9 [4.7,10.3]	15.6 [13.3,18.3]	40.4 [32.5,43.3]	4.6 [2.3,8.8]	18.6 [12.0,27.5]	55.6 [46.5,64.4]
Highest education level attained						
None	19.6 [17.0,22.4]	8.8 [6.8,11.2]	35 [30.6,39.6]	14.0 [10.8,17.8]	7.0 [4.3,11.1]	62.5 [54.2,70.2]
Primary	16.7 [7.6,32.9]	4.7 [1.8,11.4]	56.2 [35.8,74.8]	14.3 [9.0,22.0]	5.9 [3.2,10.7]	66.4 [53.9,77.0]
Secondary+	32.8 [24.8,42.0]	1.1 [0.3,4.1]	44.9 [36.7,53.4]	13.9 [9.3,20.2]	3.9 [1.6,9.0]	66.6 [55.9,75.8]
Employment status (in the past 12 months)						
Unemployed	23.9 [19.6,28.8]	5.1 [3.5,7.3]	39.4 [33.3,45.8]	15.1 [11.2,20.1]	1.8 [0.7,4.4]	66.7 [57.3,74.9]
Employed	18 [15.2,21.2]	9.3 [7.7,11.2]	38.3 [33.5,43.3]	13.7 [10.8,17.2]	6.8 [4.5,10.3]	64.4 [56.7,71.4]
Wealth quintile						
Poorest	20.8 [19.6,28.8]	5.5 [3.3,8.9]	37.4 [24.6,52.3]	14.9 [9.1,23.6]	4.1 [1.8,9.2]	65.0 [50.1,77.4]
Poor	22.7 [19.6,26.1]	8.6 [6.2,11.9]	34.8 [26.8,43.7]	15.3 [10.4,21.9]	7.4 [4.4,12.0]	57.7 [47.4,67.4]

Middle	23.1 [16.9,30.7]	4.5 [2.2,8.7]	32.5 [25.3,40.7]	16.8 [10.0,26.8]	3.4 [1.4,7.9]	68.0 [54.7,78.9]
Wealthy	16.5 [12.7,21.2]	9.7 [6.4,14.5]	46.7 [38.5,55.1]	7.6 [4.8,11.8]	6.7 [3.5,12.4]	73.3 [62.3,82.0]
Wealthiest	18.6 [13.9,24.4]	9.8 [6.8,14.1]	41.6 [31.4,52.5]	15.3 [10.9,21.1]	7.0 [2.3,19.4]	59.7 [49.5,69.2]
Ever given birth						
Yes	21 [18.6,23.7]	8.0 [6.7,9.4]	38.7 [34.3,43.3]	14.7 [12.2,17.5]	6.1 [4.1,9.1]	65.1 [58.5,71.1]
No	5.9 [2.4,13.8]	0	39.9 [15.9,69.9]	6.8 [2.8,15.6]	0.7 [0.1,5.1]	53.8 [19.9,84.5]

95% CI: 95% confidence interval

Conversely, regarding the demand for family planning satisfied using modern contraceptives, the GIS method was consistently higher (Rural: 4.3pp higher, urban: 2.5 pp higher) relative to conventional sampling method in both strata. (Tables 4.6 and 4.7) These patterns for unmet need and demand satisfied were generally consistent across the categorical and binary variables examined.

4.4.4.3. Equivalence tests of family planning indicators across the sampling methods, by geography

Across the three indicators, the difference in point estimates between the two methods ranged from -2.6% to 1.2% in the urban stratum and -2.3% to 1.4% in the rural stratum. (Table 4.8) Across the sociodemographic characteristics and family planning coverage indicators, the confidence intervals (CIs) of the estimates in the GIS sampling method generally overlapped the conventional sampling method, with the exception of those aged 15-19 years old due to very small sample sizes in both samples.

Table 4.8. Equivalence test for the selected family planning coverage indicators

Indicators (prevalence)	Difference	90% Conf. Int.	p-value	N (CONV)	N (GIS)	N (overlap)
Rural						
mCPR	-0.7%	[-2.0%, 0.6%]	0.350	2223	1963	1103
Unmet need for FP	1.4%	[0%, 2.8%]	0.099	2223	1963	1103
Demand for FP satisfied (modern)	-2.3%	[-5.0%, 0.5%]	0.174	2223	1963	1103

Urban						
	Difference	90% Conf. Int.	p-value	N (CONV)	N (GIS)	N (overlap)
mCPR	-0.1%	[-1.9%, 2.7%]	0.763	1643	1690	353
Unmet need for FP	1.2%	[-0.3%, 2.8%]	0.190	1643	1690	353
Demand for FP satisfied (modern)	-2.6%	[-5.7%, 1.3%]	0.301	1643	1690	353

Difference: difference in prevalence of unweighted estimates; CONV: conventional sampling method; GIS: GIS sampling method; 90% Conf. Int: 90% confidence interval of the difference; Overlap: Both methods selected the same respondents.
N = number of observations; mCPR: modern contraceptive prevalence rate; FP: family planning

Our study was powered to accept equivalence margins from -5% to 5%. The CI of the difference between the two sampling methods for modern contraceptive use and unmet need for family planning indicators in urban and rural areas fell within the predetermined equivalence margins. However, the lower bound of the CI of the difference between the demand satisfied for family planning using modern methods fell outside the equivalence margin in the urban stratum. We could not conclusively determine that they were not equivalent for demand satisfied for family planning using modern methods in urban areas because the upper bound of the CI was within the equivalence margin. If the entire CI was outside the margin, we would have concluded they were non-equivalent. Thus, we can say that the two sampling methods were equivalent in terms of the mCPR and unmet need for family planning indicators. The sensitivity analysis removing respondents that overlapped across both methods yielded similar results.

4.4.4. Determinants of family planning coverage indicators

The results for the bivariate and multivariate regression models of the three selected family planning coverage indicators are shown in tables 4.9-4.11 for the conventional sampling method. All covariates were statistically significantly associated with the use of modern contraceptives in the bivariate analysis, and they were all included in the multivariate analysis. Women living in urban areas had 2.35 times higher odds of using modern contraceptives compared to those in the rural areas [95% CI: [1.903, 2.905], after adjusting for other sociodemographic, fertility, employment status and the respondents' participation in household healthcare decision making pertaining to her health. (Table 4.9)

Completing at least a primary education or higher, being married or in a union, being employed and having ever given birth all had significantly higher odds of modern contraceptive use compared to their respective references. (Table 4.9) The woman's participation in decision-making regarding her healthcare were significant in the bivariate analysis but not in the multivariate analysis. Only in the highest wealth quintile was there a significant association between socioeconomic status and contraceptive use.

Table 4.9. Determinants of modern contraceptive prevalence rate in the conventional sampling method among all eligible women (15-49 years)

	Bivariate model		**Multivariate model**	
Variables	Odds Ratio	95% CI	Adjusted Odds Ratio	95% CI
Place of residence				
Rural (reference)	1.000		1.000	
Urban	2.53***	[2.097, 3.056]	2.351***	[1.903, 2.905]
Age group (reference)				
15-19	1.000		1.000	
20-29	3.846***	[2.966, 4.986]	1.814***	[1.348, 2.441]
30-39	3.77***	[2.861, 4.968]	1.597***	[1.156, 2.208]
40-49	2.473***	[1.872, 3.266]	1.155	[0.833, 1.600]
Highest education level attained				
None (reference)	1.000		1.000	
Primary	1.554***	[1.265, 1.91]	1.525***	[1.229, 1.893]
Secondary+	1.462***	[1.212, 1.764]	1.940***	[1.570, 2.397]

Matrimonial status				
not in union (reference)	1.000		1.000	
in union	2.478***	[2.076,2.957]	1.726***	[1.322, 2.254]
Wealth quintile				
Poorest (reference)	1.000		1.000	
Poor	1.151	[0.857, 1.547]	1.111	[0.837, 1.474]
Middle	1.073	[0.806, 1.43]	1.017	[0.774, 1.337]
Wealthy	1.2	[0.892, 1.615]	1.208	[0.904, 1.613]
Wealthiest	1.4**	[1.074, 1.823]	1.432***	[1.095, 1.874]
Employment status				
Unemployed (reference)	1.000		1.000	
Employed	1.864***	[1.529, 2.272]	1.466***	[1.198, 1.794]
Participation in healthcare decision-making				
Does not participate (reference)	1.000		1.000	
Participates	1.527***	[1.275, 1.83]	1.030	[0.846, 1.253]
Ever given birth				
No (reference)	1.000		1.000	
Yes	2.842***	[2.321,3.481]	2.344***	[1.716, 3.203]

*95% CI: 95% confidence interval. *** p<.01, ** p<.05, * p<.1; Number of observations: 4,171. Goodness of fit F-test=1.226 (p-value: 0.284).*

Table 4.10. Determinants of unmet need for family planning in the conventional sampling method among all eligible women (15-49 years)

	Bivariate model		Multivariate model	
Variables	Odds Ratio	95% CI	Odds Ratio	95% CI
Place of residence				
Rural (reference)	1.000		1.000	
Urban	0.498***	[0.418, 0.594]	0.636***	[0.523, 0.773]
Age group				
15-19 (reference)	1.000		1.000	
20-29	4.206***	[3.235,5.47]	3.865***	[2.928, 5.104]
30-39	5.898***	[4.478,7.767]	4.498***	[3.286, 6.158]
40-49	5.217***	[3.917,6.948]	3.706***	[2.624, 5.235]
Highest education level attained				
None (reference)	1.000		1.000	
Primary	0.555***	[0.452,0.683]	0.811*	[0.652, 1.009]
Secondary+	0.265***	[0.216,0.324]	0.469***	[0.369, 0.596]
Wealth quintile				
Poorest (reference)	1.000		1.000	
Poor	0.971	[0.748, 1.26]	0.998	[0.763, 1.304]
Middle	0.946	[0.735,1.219]	1.000	[0.771, 1.298]
Wealthy	0.863	[0.66,1.127]	0.943	[0.717, 1.240]
Wealthiest	0.74**	[0.567, 0.964]	0.943	[0.721, 1.234]
Employment status				

Unemployed (reference)	1.000		1.000	
Employed	1.09	[0.912,1.302]	0.934	[0.771, 1.130]
Autonomy in healthcare decision-making				
Does not participate (ref)	1.000		1.000	
Participates	1.102	[0.931, 1.304]	0.905	[0.752, 1.090]

*95% CI: 95% confidence interval. *** p<.01, ** p<.05, * p<.1; Number of observations: 4,597. Goodness of fit F-test=1.422 (p-value: 0.184)*

Each age group had four to five times significantly higher odds of having an unmet need for family planning compared to those 15-19 years old, after adjusting for other variables in the model. (Table 4.10) Women who completed at least primary education or higher had lower odds of having an unmet need for family planning compared to those no education. This remained highly statistically significant only among women who completed secondary education or higher (p<0.01), after controlling for other variables.

Being employed in the last 12 months, socioeconomic status and participating in decisions regarding her own healthcare were not significantly associated with having an unmet need for family planning in the adjusted model.

Table 4.11. Determinants of demand satisfied for family planning using modern methods in the conventional sampling method among all eligible women (15-49 years)

	Bivariate model		**Multivariate model**	
Variables	Odds Ratio	95% CI	Adjusted Odds Ratio	95% CI
Area of residence				
Rural (reference)	1.000		1.000	
Urban	3.60***	[2.834, 4.571]	2.726***	[2.069, 3.592]
Age group				
15-19 (reference)	1.000		1.000	
20-29	0.933	[0.654, 1.332]	2.410***	[1.456, 3.990]
30-39	0.718*	[0.501, 1.029	2.500***	[1.500, 4.169]
40-49	0.557***	[0.395, 0.786	2.198***	[1.321, 3.656]
Highest education level attained				
None (reference)	1.000		1.000	
Primary	2.324***	[1.771, 3.049]	1.438**	[1.069, 1.935]

Secondary+	3.723***	[2.89, 4.796]	1.583***	[1.177, 2.130]
Matrimonial status				
not in union (reference)	1.000		1.000	
in union	0.086***	[0.052, 0.142]	0.051***	[0.020, 0.129]
Wealth quintile				
Poorest (reference)	1.000		1.000	
Poor	1.181	[0.813, 1.717]	1.118	[0.781, 1.600]
Middle	1.103	[0.763, 1.595]	1.030	[0.722, 1.470]
Wealthy	1.224	[0.835, 1.795]	1.159	[0.787, 1.706]
Wealthiest	1.631***	[1.139, 2.336]	1.415**	[1.006, 1.991]
Employment status				
Unemployed (reference)	1.000		1.000	
Employed	1.535***	[1.19, 1.98]	1.442***	[1.099, 1.893]
Autonomy in healthcare decision-making				
Does not participate (reference)	1.000		1.000	
Participates	1.321**	[1.052, 1.658]	1.018	[0.801, 1.293]
Ever given birth				
No (reference)	1.000		1.000	
Yes	0.1768***	[0.111, 0.255]	1.597	[0.704, 3.619]

*95% CI: 95% confidence interval; *** p<.01, ** p<.05, * p<.1; Number of observations: 1,742.*
Goodness of fit F-test=0.763 (p-value: 0.651)

Completing at least a primary education or higher, being in a higher age group, and being employed were factors that had significantly higher adjusted odds of demand for family planning being satisfied using a modern contraceptive method compared to their respective references, holding other variables constant. (Table 4.11) Women in union had significantly lower odds of having their demand for family planning met, relative to women not in union. Participating in decisions regarding her own healthcare was not significant in the adjusted model. The association between socioeconomic status and demand satisfied was significant only in the wealthiest quintile after adjusting for other variables.

The goodness of fit results for the three models were not significant, indicating good model fit. The unadjusted and adjusted regression models fitted using the GIS sample also yielded similar findings across the coverage indicators and can be found in Appendix G.

4.5. Discussion

To our knowledge, this is the first study that empirically compared GIS-based satellite imagery sampling method to the conventional cluster survey sampling method for household health surveys within the same set of clusters to estimate the coverage of family planning. We found the two methods to be equivalent in terms of the family planning coverage indicators of modern contraceptive prevalence rate, unmet need for family planning, and only in the rural areas for demand for family planning satisfied using modern methods. A study in Pakistan compared GIS grid sampling, the World Health Organization's original Expanded Program on Immunization (EPI), and compact segment sampling methods to measure vaccination coverage indicators.[31] They found there were no statistically significant differences among the vaccination coverage estimates. In Ecuador, a rapid survey method similar to the original EPI method was compared to the conventional method to estimate modern contraceptive prevalence rate (mCPR) among married women aged 15-49 years.[88] Researchers found similar mCPR for the two methods on average but found differences when disaggregated by rural vs urban areas of residence when they combined a set of independent variables of age, education, and other sociodemographic variables in multinomial regression analyses.

In our study, the selection of primary sampling units was the same for the two methods. The selection of secondary sampling units (households) was where the methods differed. For the conventional method, the probability of selecting a household was directly calculated based on the number of households within the cluster.[16] For the GIS method, the probability of selection of households was approximated using the number of potentially residential structures identified within clusters as a proxy, similar to what was done in Mozambique where satellite images were used to develop a representative sample for an evaluation of health system interventions.[46] In Pakistan where GIS grid methodology was used, researchers also used approximate selection probabilities based on number of residential buildings.[31]

The previous studies in Pakistan and Mozambique did not use census enumeration areas as clusters in their GIS-based survey sampling due to outdated population maps;[31,46] however, we used the EAs in our study because the population maps were recently updated due to the ongoing national census that coincided with our survey. Moreover, selecting census EAs with PPS is one of the components of the conventional method, so applying familiar principles could facilitate the adoption of the GIS satellite image method for researchers who would want to implement it in the future.

Equivalence

Showing that there is no difference between two methods in terms of the estimated proportions does not imply that they are equivalent, and the aim of equivalence testing is to determine whether a new method or intervention is of similar effectiveness as the existing method or intervention. [77,89] When comparing a new method to an existing method, equivalence testing is more appropriate than classical tests of differences between means such as t-tests because when a test result is statistically insignificant at $p>0.05$, we fail to reject the null but cannot conclude that there is no difference.[77,90]

Failure to reject the null hypothesis of zero difference could also be influenced by sample sizes (large samples are prone to find statistical significance and vice versa), and cannot reasonably conclude about the alternative hypothesis of interest because the result does not directly translate to evidence of equivalence.[77,91,92] Equivalence testing allows us to conclude that the effects are within or outside the equivalence margin by setting the threshold in a way that takes into account the intended use of the data.

Though several methods for equivalence testing exist,[90,93] we used the confidence interval approach because we were examining differences in population means using complex survey design.[77] Based on the finding that the confidence intervals of the difference between the conventional and GIS sampling methods fell within the preset equivalence margin regarding modern contraceptive use and unmet need for family planning, we could conclude the two methods were equivalent for these indicators.

Regression analyses

Logistic regression was used because our dependent variables were binary variables. In our study, completing primary or higher education, residing in urban areas and being married or in a union were significantly associated with higher odds of using contraceptives. Demand satisfied for family planning with modern methods was positively associated with residence in urban areas, employment in the last 12 months, and at least primary education. Moreover, women who completed at least primary education, had been employed during the last 12 months or lived in the urban areas were less likely to have an unmet need for family planning. The directionality of the estimates was the same in both sampling methods. These findings reinforce the importance of girls' education in communities in Burkina Faso. Education among girls has been increasing since 2012, according to UNESCO, but there is still a high dropout rate of about 25% among girls transitioning between primary school and junior secondary school.[94] When women are educated, they are more likely to understand their contraceptive choices, empowered to find avenues to meet those needs and have more opportunities for gainful employment. Our findings are similar to studies in Burkina Faso, Ecuador, and Mali that showed education is a major determinant of contraceptive use.[87,88,95]

Being gainfully employed during the last 12 months prior to the survey was also significantly associated with having demand satisfied with modern methods and use of modern contraceptives, after adjusting for education and all other covariates. Our findings were similar to studies in Kenya where they found employed women had a higher likelihood of using contraceptives, and in Turkey where employed women were 36 percentage points more likely to choose modern contraceptive methods compared to unemployed women.[96,97]

The relationship between paid employment and contraceptive use can be described as bi-directional. When women are gainfully employed, they become empowered to make choices for their health, including contraceptive choices. Moreover, contraceptive use helps women to adequately plan, space and limit their family size which could increase their ability to participate meaningfully in the labor force.[98,99] In our study, most contraceptive users used it for spacing their children, few used it for limiting their family size. There is also evidence that contraceptive use is a significant determinant of workforce participation.[98] Although family planning is free in government-owned health facilities in Burkina Faso, external factors like costs of clinic registration, women's preference for private clinics or pharmacies which do not provide free services, transportation and childcare could impede women's ability to access family planning services. The ability to afford some of these expenses independently when in paid employment could influence contraceptive choices, although we did not look at these distal factors in this study.

Our findings on education and employment are important for policy makers as these modifiable risk factors could guide resource allocation decisions to improve coverage of family planning interventions in the country. We had similar findings when using data collected using the GIS satellite imagery sampling method, which implies either sampling method would be valid in informing decisions of policy makers.

Limitations

For the GIS satellite image method, our main source of free images was through the satellite view in Google maps. However, in the crowded peri-urban areas and sparsely distributed rural areas, the image quality was sometimes poor and blurred. We supplemented with Bing Maps, and Open Street Maps in these locations, so although Google satellite imagery now covers 98% of the habited earth[68], replicating this method successfully relies on updated, high quality satellite images and using a combination of sources.

Satellite images in many low-income countries are limited to only provide aerial views, unlike in the United States and other high-income countries where Google street views are available. Thus, it was impossible to accurately identify non-residential structures or predict building's function 100% of the time. We only found the true function of the building (truly residential, non-residential, or vacant) during the single data collection field visit. Almost 9% of sampled buildings were vacant and 3% were non-residential, which was lower than what was found in a study using similar methods in Cameroon.[65] By inflating the sample size by 10-15%, we accounted for potentially vacant and non-residential structures a priori which ensured the GIS method had comparable sample size with the conventional method. A free navigation app directed interviewers to the selected buildings; however, if the selected structure was non-residential or vacant, they were not permitted to replace structures to mitigate selection bias.

There are no clear guidelines regarding the choice of equivalence margins (delta) for cluster survey studies. This is not particular to the field of public health, but also in clinical and biopharmaceutical research and the larger scientific community.[77,100] A systematic review of the choice of delta showed only about a third of studies had a rationale for the choice of equivalence margins in non-inferiority or equivalence trials.[100,101] In the absence of specified guidelines, clinical and pharmaceutical researchers use what they would consider 'clinically irrelevant' or 'smallest effect size' or the 'minimum clinically acceptable difference' which is conventionally defined as the difference between a placebo and the reference intervention. [76,89,100,102,103] Our choice of delta was guided by statistical and practical significance like feasibility of implementation and the importance of the difference to influence policy decisions. Future studies might explore using different thresholds for delta to see at what threshold the comparators are no longer equivalent or could interview decision makers to determine what values they would consider practically significant differences.

Across the two sampling methods, our survey data were self-reported and could contain some degree of reporting error or social desirability bias. We mitigated social desirability bias by ensuring that at least (70%) of the interviewers were of the same gender and age range as the respondents, however, this was not possible for all respondents. Furthermore, by using cross-sectional data, we cannot establish causation or temporality of our findings.

Strengths

This study was the first to compare the satellite image sampling method to the conventional sampling method in the same clusters which reduces the likelihood of chance differences between the areas implementing each method if completely different clusters were used. By predetermining the structures to be visited, preloading the locations and itinerary map on both satellite images and navigation app used by interviewers and their supervisors, we achieved two things. We reduced the possibility of selection bias that could be introduced by interviewers in the field inadvertently. If an interviewer made an error in locating the assigned household, the supervisors were able to quickly correct the interviewer because they used the app to locate the selected structures and interviewers within their teams. This advantage also facilitated the supervision, which was a positive unintended consequence, based on qualitative interviews of data collectors and their supervisors. (The findings of qualitative interviews are detailed in Chapter 3). These benefits of the GIS sampling method were not documented in previous studies.

Another strength of the study was that we tested the GIS sampling method across a range of geographic terrains in urban and rural clusters, demonstrating the equivalence of the sampling methods in these different settings. The equivalence of the GIS method to the conventional sampling method; the ubiquity of freely available satellite images and GIS software; and relative ease of implementation are additional strengths of the GIS approach over the conventional method. In a future publication, we examine the cost comparisons of the two sampling methods.

4.6. Conclusion

We showed the GIS satellite image sampling method is equivalent to the conventional method when comparing family planning coverage, specifically the modern contraceptive prevalence rate and unmet need for family planning estimates. This satellite imagery method has been used to measure vaccination coverage and family planning coverage and could be replicated by researchers working in other fields of public health.

Future research could replicate our findings in other contexts, and also use the GIS data to conduct spatial analysis such as hotspot detection at the sub-province levels (like communes in the case of Burkina) to identify specific communities with low contraceptive use that could help policy makers direct resources and interventions. Probability sampling remains the bedrock of survey sampling and implementing it using satellite images for household surveys could provide the balance between producing high-quality data needed to monitor progress of effective public health interventions in communities and the high resources demanded by the conventional sampling method, thereby increasing its adoption by organizations operating in resource-constrained settings.

Chapter 5. Costing analysis of conventional and GIS sampling methods for household surveys in Burkina Faso

5.1. Abstract

Background

Household survey data are used to monitor progress of public health interventions and evaluate the population level impact of health policies and programs in low- and middle-income countries. The high costs associated with conducting probability surveys is a major concern that drives the search for alternative survey sampling methods. Moreover, the cost implication of an alternative sampling method is also an important component when considering its feasibility. This study compared implementation costs of two probability household survey sampling methods: the conventional sampling method and a relatively novel GIS & satellite imagery sampling method across 150 clusters in Burkina Faso.

Methods

Micro-costing approach was used to estimate costs, taking the perspective of an international donor organization. The cost input categories included personnel, logistics, communication, equipment, supplies, coordination, and dissemination. Total costs were expressed as cost-per-sampling method stratified by geography (rural/urban). We estimated the differences in costs per various input categories, survey phases, and fixed vs variable costs to identify the biggest cost differences between the two sampling methods. Average and incremental costs per cluster and costs per

completed interview were calculated. One-way sensitivity analysis was done to determine the main drivers of the costs of survey implementation.

Results

Total survey costs were $302,169 for the conventional method and $258,640 for the GIS method, resulting in a difference of $43,529. Relative to the conventional method, the GIS method was about 15% less expensive in urban and rural areas, and it reduced the costs of mapping by 81%. Compared to conventional sampling, GIS sampling cost $266 and $314 less per cluster, and $13 and $4 less per completed interview, in the urban and rural areas, respectively. Incremental costs for an additional cluster were approximately equal ($243) in the urban area in both sampling methods, while in the rural area, the GIS method ($286) was about $4 less expensive compared to the conventional method. One-way sensitivity analyses showed that varying the number of days for data collection during the main survey data collection phase had the highest impact on total direct survey costs in the two methods.

Conclusion

The lower costs of the GIS sampling method compared to the more expensive conventional method make it a valid option for household surveys that should be considered by survey implementers, policy makers and donors operating in resource-constrained contexts.

5.1. Introduction

Household surveys are a major method of collecting data to assess the need for, and evaluate the impact of, policies and interventions at the population level in low- and middle-income countries (LMICs). Nationwide household surveys conducted in LMICs are mostly based on the conventional survey methodology (examples include Demographic and Health Surveys, UNICEF's Multiple Indicator Cluster Survey), although countries have varying levels of expertise, infrastructure, and experience in conducting household surveys.[104]

Probability cluster sampling is the most cost-effective sampling method among the probability sampling methods because it requires less time, human and financial resources to implement when the clusters are geographically defined.[105] Although this is the standard way most LMICs conduct large-scale in-person surveys,[10,104] the success of the survey design depends on the availability, quality, and accuracy of the sampling frame.[106,107] Considering the limited financial resources in which countries operate, there is need to continue to improve on survey methodologies in order to improve efficiency and minimize the costs of conducting surveys.[47,108]

The high costs associated with conducting probability surveys[17] has been identified as the most important factor that drives the search for alternative survey sampling methods, while the technologic advancement in recent decades have made it essential for survey methodology to find ways to improve and evolve.[109] To determine the feasibility of a sampling method, it is important to understand its cost implications. [110]

Evidence on the costs of conducting probability cluster sampling for a household survey in LMICs is scarce. Few studies have estimated the costs of conducting a large-scale household survey in LMICs; most were related to infectious disease surveillance.[110,111] In Burkina Faso, one study compared costs of different household survey sampling methods for neglected tropical diseases.[112] The PMA2020 initiative conducts surveys on family planning need, use and service availability in several LMICs, and recently compared the costs of two modes of remote data collection in Burkina Faso.[113] Another study compared the costs of stand-alone vs integrated surveys for vital events and morbidity at one of the demographic surveillance sites in the country. [114]

We conducted a study to compare two methods of household survey sampling: the conventional probability sampling method and a relatively novel method using satellite images and geographic information system (GIS) technology to develop sampling frames within census enumeration areas. We assessed the feasibility of the GIS method on four dimensions of personnel, time, implementation[1] and cost. Our hypothesis was that the GIS sampling method will be a potentially cost-minimizing alternative to the conventional household survey method. Given that the GIS sampling method is relatively novel, there is a need to assess its costs and compare it with the conventional survey sampling method in order to inform decision-making regarding the feasibility of adopting and implementing it. This paper provides a detailed description of the financial

[1] Implementation included uploading images to tablets, using navigation software to locate selected buildings.

costs of conducting a large-scale household survey and compares the costs of conventional and GIS survey sampling approaches.

5.2. *Methods*

5.2.1. Survey design and location

We conducted coverage surveys in Kadiogo (predominantly urban) and Boulkiemde (predominantly rural) provinces of Burkina Faso. The main objective was to compare two probability sampling methods: the conventional sampling method used for large-scale surveys and a relatively novel GIS-based sampling method using satellite images across the same 150 census enumeration areas (clusters), evenly divided across the rural and urban provinces. The two surveys were conducted in the same clusters during the same 6-week period using a two-stage stratified cluster survey design. The sampling methods are described in detail in Chapters 3 and 4.

Probability sampling involves the creation of a sampling frame that includes all sampling units in the population, and a known probability of selection of sampling units within the frame. We referred to the creation of the sampling frame and drawing the survey sample as the first phase of the study, piloting both sampling methods was the second phase, data collection from eligible respondents was the third phase, and data analysis and dissemination the fourth phase. (Figure 5.1) We obtained the hand-drawn sketch maps of the selected clusters from Burkina National Institute for Statistics and Demography (INSD).

The methods differed in the second stage of sampling which is the selection of households within selected clusters that entails mapping & enumeration of all buildings and households by a team of cartographers and enumerators to create the sampling frame. In the conventional sampling method, as a first field operation, cartographers identified cluster boundaries, confirmed locations, corrected sketch map errors, and included all residential, non-residential buildings and landmarks in a detailed cluster map used by data collectors in the second field operation to locate selected households and conduct interviews.[16] (Phases 2 & 3)

In the GIS sampling method, this first field operation was conducted digitally using free satellite images of the study areas predominantly in Google Maps®, imported into QGIS software[43] installed on laptop computers. Using the same INSD sketch maps, the cluster boundaries were digitally delineated to confirm locations, correct errors, potentially residential buildings were identified and counted, potentially non-residential and landmark buildings were identified and labeled using QGIS software.[43] The list of potentially residential structures across all the clusters was the sampling frame that was used to systematically select potential structures to visit. During the interview phase (Phase 3), if a multi-household residence was selected, interviewers did a modified household listing and randomly selected one household within the building to interview. An average of 20 households were sampled per cluster using the conventional method while an average of 22 potentially residential structures were sampled per cluster for the GIS method. We sampled more households in the GIS method because we expected a higher non-response rate, due to potential misclassification of non-residential or vacant buildings as residential during the GIS mapping. We calculated sample size of 3,000 households per method as sufficient to compare the equivalence of the estimates generated by these methods. Using the confidence interval approach,[77] we set equivalence threshold of ± 5% with 80% power and alpha of 0.05. All eligible women found in the households were interviewed. The same questionnaires were used in both arms to ensure comparability of the two sampling methods. Each survey team spent two days per cluster to locate households and interview eligible respondents. The detailed field implementation of the two sampling methods is in Chapter 3.

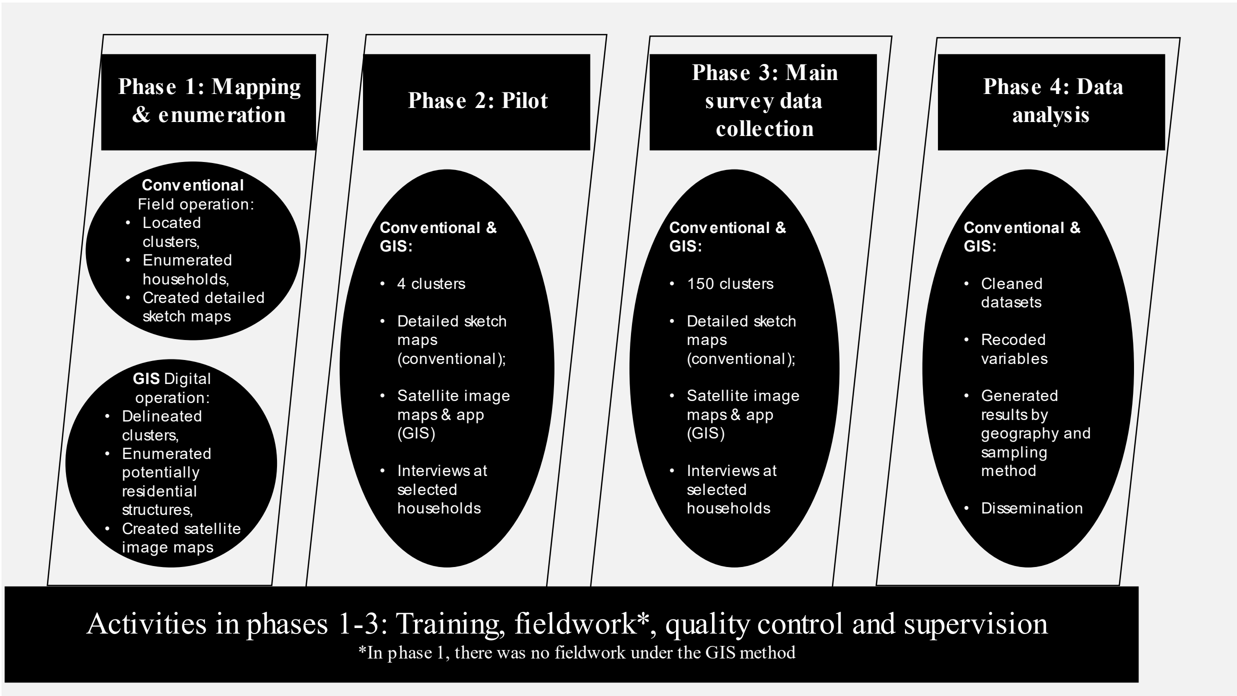
5.2.2. Survey cost data and estimation of direct survey costs

We reported costs from a donor's perspective since most of the standard large-scale surveys in sub-Saharan Africa are currently donor-funded. Specifically, we wanted to understand the total costs of conducting a large-scale population-based survey, including personnel, equipment, transportation, trainings, field work and supervision, using each of these sampling methods. We used a micro-costing approach to estimate direct survey costs. In the context of this study, micro-costing is a cost estimation method that involves collection of itemized data on the input consumed in terms of quantities and prices of resources used to implement a household survey.[115] It is necessary when estimating the costs of new interventions or cost variations between similar procedures.[108,115]

We used reported expenditures instead of the study budget because expenditures accurately portrayed the reality of implementation. Reported expenditure was sourced from receipts, purchase orders and sub-contracts procured in local currency, West African CFA Franc (CFA). It included data on the number of units procured, number of days of activities, and the unit prices of goods and services. We converted from CFA to US dollars using the annual exchange rate of 2019 (USD $1 = 550 CFA), the start year of implementation.[116] Due to the short time horizon of about 5 months of field work, there was no need for discounting. Analysis was done from the perspective of donor organizations and did not capture the costs of respondents' participation.

Direct costs were broadly categorized according to the three survey implementation phases and input categories. The survey implementation phases were mapping & enumeration, pilot, the main surveys where households were visited and eligible respondents interviewed, and data analysis (Figure 5.1). The cost input categories included personnel, logistics, communication, equipment, supplies, coordination, and dissemination. Costs were proportionally allocated by sampling method. Cross-cutting expenses such as coordination, administrative oversight and data analysis were fixed for each method since these were costs that would be incurred irrespective of the survey study design. Other costs were specific to a sampling method such as the mapping and enumeration of clusters and use of local guides in the conventional sampling method, and digitizing cluster maps in the GIS sampling method.

Figure 5.1. Survey phases and activities by sampling method



5.2.3. Input Categories

5.2.3.1. Personnel

There were three categories of personnel: survey-specific personnel, temporary personnel, and permanent institutional employees. The survey-specific personnel were recruited on short-term contracts to conduct survey activities such as mapping and enumeration of survey clusters, interviewing the eligible respondents at their homes. The number of days they spent on the study was their allotted contract time and 100% of their time was included in the analysis. Personnel time included training days, field practice days, field work while their costs included per diems, salaries, and health insurance coverage. For the household survey, a survey team comprised three field workers, one team leader, a permanent supervisor overseeing four teams. Temporary personnel included local language experts and local guides within the communities. Language experts were recruited during trainings to ensure the survey questionnaires were correctly translated. Their costs accrued as the number of days they participated in the training. Local guides assisted teams that implemented the conventional sampling method to locate addresses of sampled households in the rural communities during the household surveys.

Permanent employees served as central supervisors, data quality control and coordination teams. This included the in-country principal investigators, research assistants, and institutional directors of the two collaborating institutions (ISSP and INSD) who allocated pre-specified proportions of their time to the study. Their costs were calculated as proportional salary attribution. Central coordinators oversaw multiple field teams, implemented survey preparation activities, data quality and tracked the progress of the study's implementation according to the approved plan.

5.2.3.2. Logistics

Logistics included transportation to and within the study clusters, lodging in rural areas and catering during trainings. Motorcycles were rented daily for the survey teams for fieldwork during the mapping and enumeration exercise conducted under the conventional sampling method, and during the fieldwork conducted for the main surveys under the two sampling methods. Vehicles were rented for each permanent supervisor who covered four survey teams daily. Rental costs were fixed per day and covered the duration of days of field work. Since most of the personnel lived in Ouagadougou, the study covered lodging costs for the implementation in Boulkiemde as it was impractical to require personnel return to Ouagadougou at the end of each day's activities.

5.2.3.3. Equipment

We procured tablets and its accessories for electronic data entry for the interviewers and their supervisors to facilitate electronic data entry and upload of data directly to the study servers. Laptops were provided for the permanent supervisors whose role included daily data quality checks using the study's data dashboard. Other equipment included power banks which are pre-charged batteries that could be used to power tablets when the battery strength is low, and phone SIM cards to facilitate communication.

5.2.3.4. Supplies and communication

Consumables mainly consisted of copies of survey administrative forms, informed consent forms, stationery, copies of training manuals, phone airtime for communication. Specifically, for the GIS sampling method, we printed the satellite images that contained the selected potentially residential structures to aid identification in the field, in addition to the maps uploaded to the tablets and the navigation application. For the conventional method, the cluster maps provided by INSD were also printed to help locate sampled respondents in the clusters. Other supplies included interviewers' bags to hold documents, battery-operated torches, first aid kits and mosquito nets. All survey-specific and permanent employees were provided with sim cards and airtime to facilitate communication within teams and across data collection and supervision teams.

5.2.3.5. Administration, data analysis and dissemination

Administrative costs included the payments for ethical review forms from the Institutional Review Board in the country. A data analysis workshop was held to generate study results, and a dissemination workshop was organized to share the findings of the study among the country partners, donors, and government officials. Indirect and overhead costs were included in computing the total survey costs.

5.2.4. Data analysis

Data were compiled and analyzed using Microsoft Excel.[44] Total costs were expressed as cost-per-sampling method which was stratified by area of residence (rural/urban). Cost per cluster was calculated based on the number of clusters per method and cost per completed interview was calculated based on the numbers of eligible women that were interviewed by method, stratified by area of residence. We estimated the differences in costs per various categories and survey phases to identify the biggest cost differences between the two sampling methods.

Survey costs were also characterized as fixed or variable. In this study, fixed costs were the costs of the survey that were irrespective of the number of women interviewed or clusters covered, while variable costs were the costs that changed depending on the number of clusters or the number of women interviewed.[115] Fixed costs included remuneration of permanent employees, local language experts, study equipment, administrative and dissemination costs while variable costs were related to training and field implementation activities. Fixed and variable costs were computed according to the phases of the survey, by sampling method and geography. Incremental costs per cluster (and per completed interview) were computed as total variable costs for an additional cluster divided by number of clusters (interviews). We did a one-way sensitivity analysis limited to survey-specific personnel and duration of training and field work activities in each survey method to determine the main drivers of the costs of survey implementation.

5.2.5. Ethical approval

The survey sampling study received ethical approval from the institutional review boards of the Centre de Recherche en Sante de Nouna in Burkina Faso (2019-018-/MS/SG/INSP/CRSN/CIE) and the Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA (IRB00009713).

5.3. Results

The conventional method interviewed 4,597 women in both areas of residence and the GIS method concurrently interviewed 4,378 women in the same clusters. (Table 5.1) For the conventional method, the first field operation for mapping and enumeration was conducted by 11 teams, each comprising one cartographer and enumerator, lasting for 28 days. For the GIS method, the digital mapping and enumeration was conducted in an office by 6 research assistants & GIS specialists, lasting 21 days. Pilot activities lasted about three weeks. The main survey comprised trainings, field practice and data collection, and lasted about 3 months.

Total survey costs per method was $302,169 for the conventional method and $258,640 for the GIS method, resulting in a difference of $43,529. (Table 5.1) For the same number of clusters covered by the two sampling methods, the GIS method was about 15% less expensive compared to the conventional method in urban and rural areas. The average cost per cluster under the conventional method was $2,014, while under the GIS method was $1,724. Compared to conventional sampling, GIS sampling cost $266 and $314 less per cluster, and $13 and $4 less per completed interview, in the urban and rural areas, respectively. The average cost per completed interview was higher in the urban compared to the rural areas in both methods because of the higher response rate and more eligible women per household in the rural areas. (Table 5.1)

Table 5.1. Total and average survey costs by clusters and completed interviews, disaggregated by geography

	Urban			Rural		
	Conventional	GIS	Difference	Conventional	GIS	Difference
Number of clusters	75	75	0	75	75	0
Number of completed women interviews	1,822	1,864	-42	2,775	2,514	261
Total survey costs	$145,660	$125,688	$19,972	$156,509	$132,952	$23,557
Average cost per cluster	$1,942	$1,676	$266	$2,087	$1,773	$314
Average cost per completed women interview	$80	$67	$13	$56	$53	$4

Difference = conventional – GIS sampling method costs. All costs in 2019 USD.

In both sampling methods, the costs of conducting surveys were higher in the rural areas than in the urban areas because of additional lodging costs incurred in the rural areas. In terms of the phases of the study, 88% of the difference in costs between the conventional and GIS sampling methods was in the mapping and enumeration of clusters in the field which is integral to the conventional method. (Table 5.2) This first field visit was substituted with digitally delineating the cluster boundaries and enumerating potential residential buildings in the GIS method which accrued lower costs.

The GIS pilot was slightly more expensive than the conventional method pilot due to higher printing supplies. The remaining difference between methods in the main survey data collection phase was attributable to mapping supplies and the use of local guides in rural areas in the conventional method which the GIS method did not incur. We substituted the use of local guides by uploading the geographic coordinates of sampled potentially residential structures to a freely available navigation app called Maps.me® on the tablets used by data collection teams and their supervisors to locate the respondents in the GIS method.

Table 5.2. Difference in survey costs by survey phases and areas of residence

	Urban			Rural			Total difference	Percentage of total difference
Survey phases	Conventional	GIS	Difference	Conventional	GIS	Difference		
Phase 1: Mapping and enumeration	$20,115	$4,136	$15,978	$22,878	$4,136	$18,742	$34,720	88%
Phase 2: Pilot	$4,690	$4,818	$-128	$4,701	$4,818	$-117	$-244	-1%
Phase 3: Survey data collection	$60,524	$58,218	$2,305	$67,612	$64,822	$2,790	$5,096	13%
Phase 4: Data analysis and dissemination	$2,645	$2,645	0	$2,645	$2,645	0	0	0

Difference = conventional – GIS sampling method costs. Percentages sum up to 100%. All costs in 2019 USD.

Coordination personnel costs accounted for about one-third of the total direct costs of the survey, followed closely by the costs of the survey personnel which was 25% on average. (Table 5.3) The differences in sampling method costs were mostly contributed by the logistics, survey personnel and supplies categories, which were driven by expenses incurred during the mapping and enumeration phase in the conventional method. (Table 5.3)

Table 5.3. Survey costs, disaggregated by input categories, geography and sampling method

	Urban			Rural		
Input Categories	Conventional (%)	GIS (%)	Difference (%)	Conventional (%)	GIS (%)	Difference (%)
Coordination Personnel (permanent employees)	$43,808 (33%)	43,808 (38%)	0	$43,808 (31%)	43,808 (36%)	0
Survey-specific and temporary Personnel	$ 34,629 (26%)	$ 28,716 (25%)	$ 5,913 (33%)	$ 34,629 (24%)	$ 28,716 (24%)	$ 5,913 (28%)
Logistics	$ 27,648 (21%)	$ 21,406 (19%)	$ 6,243 (34%)	$ 35,652 (25%)	$ 28,009 (23%)	$ 7,643 (36%)
Equipment	$ 12,688 (10%)	$ 10,724 (9%)	$1,964 (11%)	$ 12,688 (9%)	$ 10,724 (9%)	$1,964 (9%)
Supplies	$ 8,830 (7%)	$ 5,003 (4%)	$ 3,828 (21%)	$ 8,830 (6%)	$ 5,003 (4%)	$ 3,828 (18%)
Communication	$ 1,533 (1%)	$ 1,324 (1.2%)	$ 209 (1%)	$ 3,392 (2.4%)	$ 1,324 (1%)	$ 2,068 (10%)
Administrative	$ 636 (0.5%)	$ 636 (0.6%)	0	$ 636 (0.4%)	$ 636 (0.5%)	0

Data analysis and Dissemination	$2,645 (2%)	$2,645 (2%)	0	$2,645 (1.9%)	$2,645 (2%)	0
Total Direct Cost	**$ 132,418**	**$ 114,262**	**$ 18,156**	**$ 142,281**	**$ 120,866**	**$ 21,416**

Coordination personnel were the permanent employees of the partner institutions who contributed allocated proportions of their time to implement the study. Survey-specific personnel were trained and implemented field activities such as mapping& enumeration, survey data collection. Temporary personnel included local guides and local language experts. Logistics included transportation, lodging, and feeding. All percentages add up to 100. Costs expressed in 2019 USD.

Total fixed costs were the same in urban and rural areas for each sampling method, but different when comparing the two sampling methods. The main driver of this difference in fixed costs was the purchase of GPS devices used during mapping and enumeration phase in the conventional method. The variable costs were different by geography and sampling method, ranging from 50% to 58% of total direct costs. In the urban area under the GIS method, variable costs were $56,221 (50% of total) while in the rural area under the conventional method, it was $82,277 (58% of total) (Table 5.4).

Table 5.4: Fixed and variable costs, by sampling method and geography

	Conventional sampling		GIS sampling	
Variable Costs	Urban	Rural	Urban	Rural
Phase 1: Mapping & Enumeration				
Training (Staffing, logistics, supplies)	$3,494	$3,494	0	0
Fieldwork (Logistics, Communication & Supplies)	$16,621	$19,385	0	0
Mapping (digitizing) of satellite pictures [a] (Training & production)	0	0	$4,136	$4,136
Phase 2: Pilot				
Training (Staffing)	$634	$634	$634	$634
Training (Logistics & Supplies)	$1,461	$1,461	$1,461	$1,461
Method-specific training	$110	$110	$110	$110
Fieldwork (Staffing)	$1,091	$1,091	$1,091	$1,091
Fieldwork (Logistics, Communication & Supplies)	$1,296	$1,306	$1,298	$1,298
Method-specific supplies	$54	$54	$178	$178
Phase 3: Survey Data Collection				
Training (Staffing)	$3,205	$3,205	$3,205	$3,205
Training (Logistics & Supplies)	$4,421	$4,421	$4,421	$4,421
Method-specific training	$464	$464	$461	$461

Fieldwork (Staffing)	$19,390	$19,390	$19,390	$19,390
Fieldwork (Logistics, Communication & Supplies)	$17,374	$24,463	$17,139	$23,742
Method-specific supplies	$2,800	$2,800	$2,697	$2,697
Fixed Costs				
Local language expert(s) during trainings (phases 2 & 3)	$227	$227	$227	$227
Equipment (phases 1-3) [b]	$12,688	$12,688	$10,724	$10,724
Coordination Personnel [c]	$43,808	$43,808	$43,808	$43,808
Administrative	$636	$636	$636	$636
Analysis and Dissemination	$2,645	$2,645	$2,645	$2,645
Total				
Total Variable Cost	$72,414	$82,277	$56,221	$62,825
Total Fixed Cost	$60,005	$60,005	$58,041	$58,041

[a] Freely available satellite images were taken from satellite view on Google Maps for the two study provinces.
[b] Difference in equipment costs by method was due to the GPS devices used during mapping phase in conventional method which was not needed in the GIS method.
[c] Coordination personnel were the permanent employees of the partner institutions who contributed allocated proportions of their time to implement the study. Logistics included transportation, lodging, and feeding during trainings. Costs expressed in 2019 USD.

Incremental costs for an additional cluster were approximately equal ($243) in the urban area in both sampling methods, while in the rural area, the GIS method ($286) was about $4 less expensive compared to the conventional method. (Table 5.5) Relative to the conventional method, incremental costs for an additional interview with GIS sampling was $1.15 less in the urban area, and $2.08 less in the rural area.

Table 5.5: Incremental costs per cluster and completed interview, by sampling method and geography

	Conventional		GIS	
Additional supplies per cluster	Urban	Rural	Urban	Rural
General supplies (Pens, binders, batteries for lamps and for GPS devices) [a]	$ 0.42	$ 0.42	$ 0.27	$ 0.27
Method-specific supplies	$ 19	$ 19	$ 18	$ 18

Total VC for additional supplies	$ 20	$ 20	$ 19	$ 19
Additional staffing per cluster	$ 120	$ 120	$ 120	$ 120
Additional costs for transportation per cluster	$ 96	$ 103	$ 96	$ 103
Additional costs for lodging per cluster	$ 0	$ 36	$ 0	$ 36
Additional costs for communication per cluster [b]	$ 8	$ 11	$ 8	$ 8
Total VC for additional logistics	$ 103	$ 150	$ 103	$ 147
Total VC per additional cluster	$ 243.16	$ 290.42	$ 242.18	$ 286.20
VC per additional completed interview	$ 12.16	$ 14.52	$ 11.01	$ 12.44

[a] GIS method did not use GPS devices, so no battery costs were incurred.
[b] Local guides used in rural areas under conventional method incur extra costs.
VC: variable costs. Costs expressed in 2019 USD.

Sensitivity analyses limited to survey-specific personnel and duration of training and field work showed that in the two methods, varying the number of days for data collection during the main survey (phase 3) had the highest impact on total direct survey costs. (Figures 5.2 & 5.3) The second most impactful variable was varying the number of fieldworkers involved in the same phase in survey data collection.

From the base case of $181,424 in the conventional method, increasing the number of days for fieldwork by 20% while holding all other variables constant resulted in higher survey costs of $204,317. In the GIS method, from the base case of $140,963, increasing the number of days for fieldwork by 20% while holding all other variables constant resulted in higher survey costs of $162,750. Varying the number of days spent on mapping or the number of mappers by 20% had minimal impact on survey costs in GIS method compared to the conventional method.

Figure 5.2. One-way sensitivity analysis for GIS sampling method

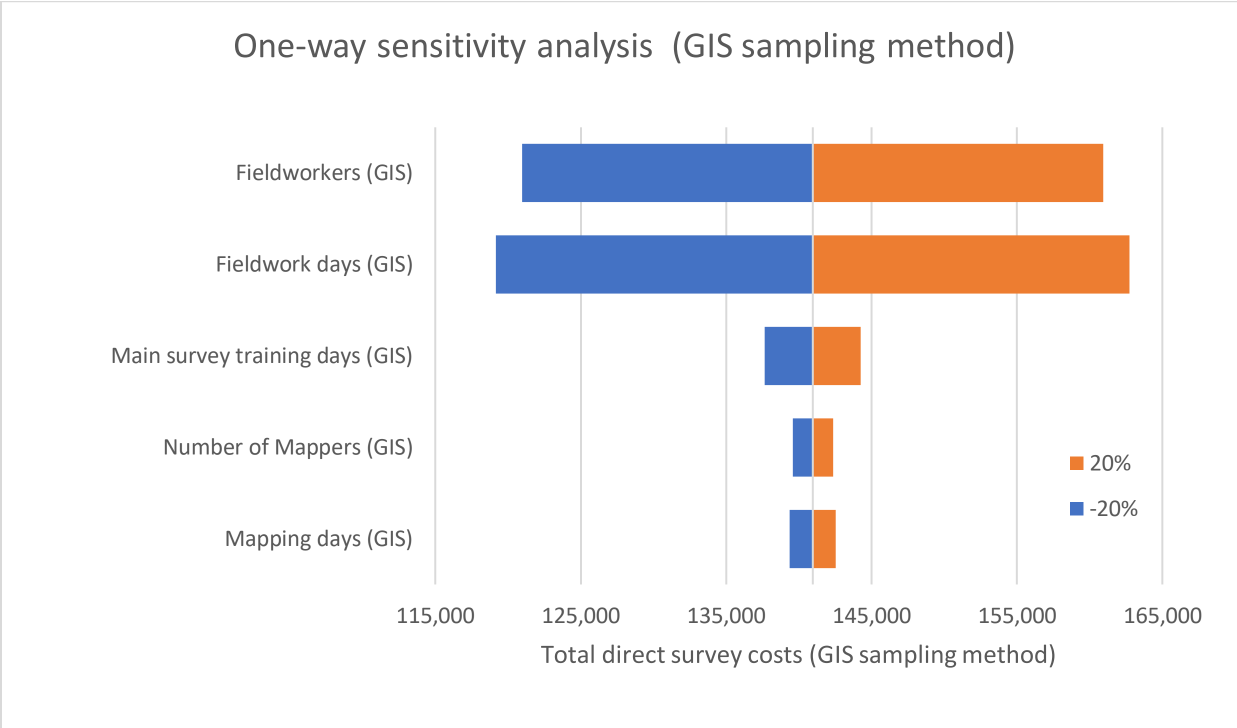
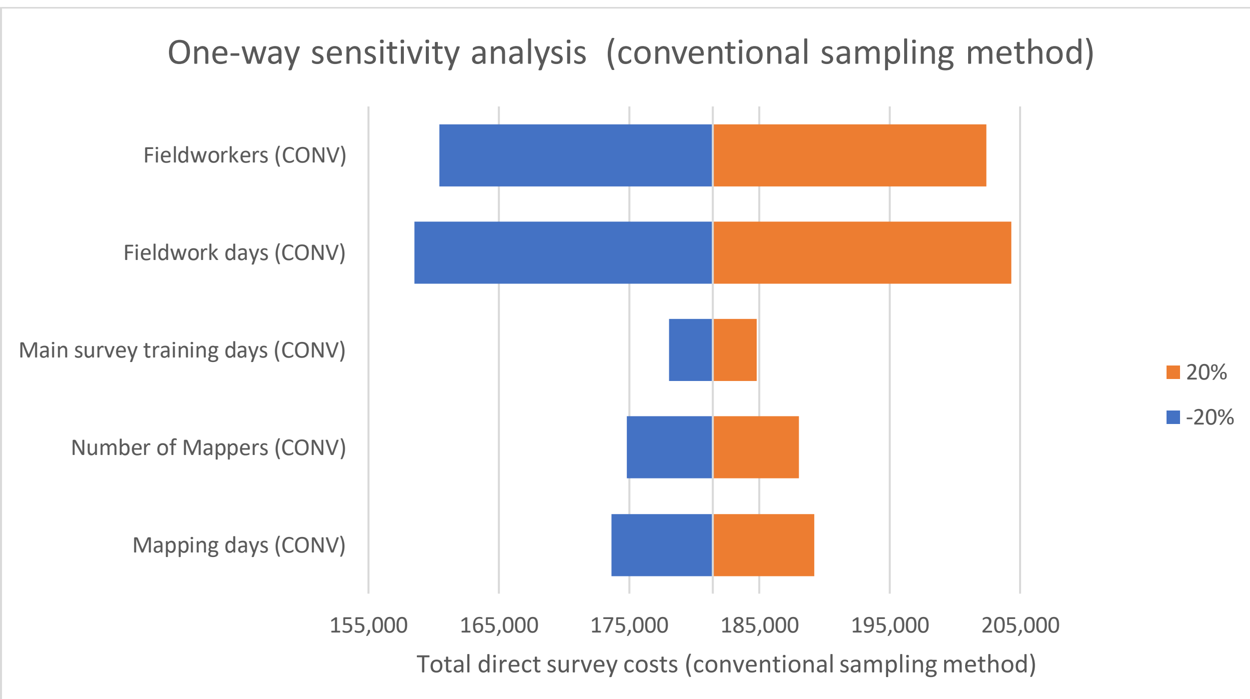


Figure 5.3. One-way sensitivity analysis for conventional sampling method



5.4. Discussion

This study had two main objectives: to provide a detailed description of the financial costs of conducting large-scale household surveys; and to compare the costs of conventional and GIS survey sampling approaches. This information can assist organizations, governments, and donors to make informed decisions regarding the choice and feasibility of implementation while balancing rigorous sampling and resource constraints. We found that the GIS sampling method was overall 15% less expensive to implement compared to the conventional method. The difference in implementation costs was driven by the differences in the mapping and enumeration phase of the two methods.

Despite having interviewed more women than the GIS method which could have reduced the cost per respondent, the conventional method incurred higher cost per women interviewed because of the first field operation of mapping and enumeration in the selected study clusters, an integral component of the sampling method.[16,56] In the GIS method, this phase was replaced by using freely available tools such as Google Maps® satellite images, and QGIS software[43] that reduced the costs of mapping by 81%. Taking advantage of technology also contributed to the vast reduction in personnel involved in the mapping phase which reduced the direct costs of implementation. To our best knowledge, this is the first study that has described the actual costs of implementing a large-scale household survey using the conventional sampling method in Burkina Faso. This study is also the first to compare the costs of a relatively novel GIS sampling method to the conventional method.

Survey costs are driven by multiple factors, including the research question, sample size, study design, personnel qualifications, and whether it is a one-time study vs repeated cross-sectional or longitudinal study. Depending on the type of survey, reported costs are varied. The 2003 DHS in Burkina Faso, a large-scale, cross-sectional national survey that covered 9,097 households was reported to cost $900,000 (about $100 per surveyed household), higher than the costs per completed interview in either sampling methods in our study.[117] A multi-country comparison of three different survey sampling methodologies (EPI, LQAS and PSS) that included three districts in Burkina Faso estimated survey costs of training and implementation ranging from $4385 to $4816 per sampling method, which is much lower than our results, but this study did not account for some of the cost input categories that we included. The study tested survey sampling methods that were completely different from our study, highlighting the difficulty of generalizing survey costs without accounting for methodological differences.

Although few studies that have reported the costs of implementing household surveys in other LMICs, cost comparisons across countries should be done cautiously because of differences in country contexts such as availability of human resources and purchasing power. A serosurvey study in Zambia to measure measles and rubella immunity in the community estimated an average cost per participant of $104 and average cost per cluster of $4,285 which were higher than the average costs estimated in this study. [110] The serosurvey included biospecimen collection, laboratory testing and a smaller sample size which contributed to the higher costs. The sample size of surveys is the main driver of costs as all other expenses such as personnel for field work, training, travel, and the duration of data collection depend on it.[109] Because our sample size was 13 times larger relative to the Zambia study, we could distribute costs over a bigger sample and achieve lower costs due to economies of scale.[108]

In lieu of real survey implementation costs, survey budgets could provide an inkling of what to expect when planning for large-scale household surveys. A recent publication estimated a typical DHS survey budgeted $1.6M per country to implement[17] which is higher than our study; however, personnel costs accounted for at least half of the survey budget, consistent with our findings in both sampling methods.[118] Moreover, a budget framework by the UN Statistics Division that estimated the proportional allocations of survey costs across 12 LMICs in Africa found on average the personnel costs were 63% of the budget, similar to our survey implementation costs reported for the GIS sampling method. [119] Our findings were also consistent with preliminary results from an analysis of country-level budgets of over 20 conventional household surveys across 13 LMICs. This analysis estimated a mean survey cost of $331,649, and cost per household of $73, within the range of our results in the conventional method in this study. (Personal communication with George Mwinnyaa). It should be noted that while these were budgets for surveys implementing conventional sampling methods, our results represent the reality of implementation since we reported expenditures.

The lower costs of implementing the GIS method highlights the importance of leveraging technology in the evolution of survey research methodology. [47,109] When countries, implementing organizations and donors weigh options for probability-based household surveys, assessing the evidence on feasibility metrics (such as number and technical qualifications of personnel, equipment, implementation time, and survey implementation costs) could influence decisions between methods of equivalent scientific rigor. We compared selected indicators of family planning coverage such as modern contraceptive prevalence rate (mCPR) and the unmet need for family planning among married women aged 15-49 years and found that the two sampling methods were equivalent (Chapter 4).

Limitations

Although we adopted the perspective of an international donor organization, our costs did not include the expenditures from setting up the study server in the cloud, the costs associated with the research team at Johns Hopkins University (the international collaborator) that comprised their proportionally allocated time on the project, international flights, and hotel bookings for their travels to Burkina Faso during the study implementation. This could suggest an underestimation of the results presented. However, our intent was to present the costs accrued in implementing of household surveys within the country so that our findings could be extrapolated to similar LMICs that are transitioning to fund their surveys.

Some of the coordination personnel were involved in implementing the mapping and enumeration phase in the two sampling methods. However, we could not disaggregate how many hours they worked on each method since they were concurrently implemented and our accounting software was not set up to provide such level of detail. However, we expect the costs would even out leaving little difference between sampling methods.

Other costs that may be incurred for other surveys include the costs of developing the questionnaires, and the data collection software. We adapted the RADAR project's coverage surveys generic questionnaire to Burkina Faso's setting, because they are standardized questionnaires designed to cover key coverage indicators designed for household surveys and freely available. (https://www.radar-project.org/coverage-survey) Moreover, we took advantage of free data collection software (Open Data Kit) which was installed in all the tablets used for the two studies. In settings where the quality of satellite images is poor, survey teams may need to procure commercial satellite images to replicate the GIS survey method. This is becoming rarer as Google continues to update satellite imagery globally. [68]

We did not include the time-related opportunity costs of respondents resulting from interruptions in their daily activities to respond to survey questions. Since we took the perspective of survey research donors, capturing respondents' opportunity costs was not relevant to this analysis, but these opportunity costs are important for survey implementers to consider. Moreover, the main cost savings in the GIS method was driven by substituting the first field visit with digital technology tools.

It is recommended that when using micro-costing approach, personnel costs should include other benefits in addition to salary contributions.[115] Our study included salary and health insurance costs of all in-country survey personnel for the duration of the fieldwork, however we did not cover other accrued benefits that are associated with full-time employment such as pension contributions since our study was short-term. Employees working full-time on survey implementation should have their personnel costs include pension contributions, health insurance coverage and any other accrued benefits included when calculating personnel costs.

Generalizability of the findings will be limited to low resource settings with similar or stronger internet penetration, purchasing power similar to Burkina Faso, and study design similar to this study. For instance, it will be necessary to adjust for labor inputs to account for standard salary structures and the qualifications of the various classes of personnel in a new context. We have presented our findings in terms of implementation phases so that other studies can adjust as relevant for their settings.

5.5. Conclusion

We compared two survey sampling methodologies, while ensuring adherence to fundamental principles of standard probability survey implementation, including constructing household sampling frames in every cluster, conducting pilots and lengthy training for data collectors, including field practice, and keeping data collecting teams to supervision ratios small to ensure adequate supervision, which may not be possible for every survey.[16,56] Our findings could guide donors and policy makers as they consider the financial costs, cost drivers, and options for household surveys for program planning and evaluation.

The high costs associated with conventional survey sampling has been of concern to in-country implementers in LMICs. We have tested an alternative approach to doing mapping and enumeration in the field and found it to be less costly than the conventional sampling method, despite having the same costs in terms of coordination personnel, household visits and approximately similar number of women interviewed. The lower costs of the GIS sampling method, coupled with the opportunities to leverage freely available technology, relative ease of implementation (Chapter 3), with equivalent results (Chapter 4) as the more expensive conventional method make it a valid alternative for consideration by survey implementers, donors, and countries.

Chapter 6. Conclusions

6.1. Summary of results

6.1.1. Paper 1

This study compared two probability sampling methods for conducting household surveys: a relatively novel sampling method based on geographic information system (GIS) techniques and the conventional sampling method. We highlighted the field implementation experience using free GIS software and tools, assessed feasibility of GIS sampling method for large-scale household surveys and compared the survey response rates between the two methods. We found the GIS method was feasible to implement in terms of number and technical qualifications of personnel, equipment, and implementation time across diverse geographic landscapes in Burkina Faso.

For the GIS sampling method, 58,120 potentially residential structures were digitized in both urban and rural areas, of which 3,371 structures were sampled. 88.1% were found to be truly residential. Comparing the survey responses in truly occupied dwellings in the rural and urban areas, we found the two sampling methods were not statistically significantly different (p=0.089).

While the GIS method had three times lower person-time requirement during mapping & enumeration activites, field preparation required seven times higher person-time compared to the standard method. During data collection, all teams spent two days per cluster irrespective of the sampling method. Although we did not maintain time logs, we noted that it was relatively easier to locate structures under the GIS method, and data collectors tended to finish their assignments earlier in the day than those implementing the conventional method.

Qualitative data revealed the advantages experienced during implementation of the GIS method including independence from local guides, less risk of error in locating assigned structures and ease of supervision. Challenges described were initial difficulties using the navigation app in non-loti and rural areas. Once a workaround was established within the app, it became easy to use the method. Our findings support the hypothesis that the GIS method is feasible to implement in large-scale household surveys in low-resource settings.

6.1.2. Paper 2

In this paper, we compared estimates of selected family planning (FP) coverage indicators in the two sampling approaches using pre-determined equivalence thresholds and identified determinants of these coverage indicators in the population. In comparing the selected FP coverage indicators, the confidence intervals of the difference in the estimates of the two methods fell within the equivalence margin of $\pm$ 5% for modern contraceptive prevalence rate and the unmet need for FP, except for the estimates for the demand satisfied for FP using modern methods. We concluded the sampling methods were equivalent in terms of modern contraceptive prevalence and unmet need for FP but could not conclude they were not equivalent regarding demand satisfied using modern contraceptive methods.

Completing at least a primary education and having gainful employment were both significantly associated with being a modern contraceptive user, and having demand for family planning satisfied, compared to their respective references, after adjusting for other variables in multivariable logistic regression models in both the conventional and GIS sampling methods. This indicated that the results of either of the methods could be used to inform decision making.

6.1.3. Paper 3

This paper presented a detailed description of the financial costs of conducting a large-scale, conventional sampling household survey, and compared the costs of conventional and GIS survey sampling approaches. Total survey costs were $302,169 for the conventional method and $258,640 for the GIS method, resulting in a difference of $43,529. Relative to the conventional method, the GIS method was about 15% less expensive to implement in both urban and rural areas. The main survey phase that contributed most of the difference in implementation costs was mapping and enumeration. Mapping and enumeration costs accounted for 16% of the total survey costs in the conventional method, in the GIS method, these costs reduced by 81%.

The average cost per cluster under the conventional method was $2,014, while under the GIS method was $1,724. Total fixed costs were equal by geography for each sampling method, but different when comparing the two sampling methods. Total variable costs were different across geography and sampling method, ranging from 50% to 58% of total direct costs. Incremental costs per cluster were approximately equal in the urban area in both sampling methods, while in the rural area, the GIS method was about $4 less expensive compared to the conventional method.

One-way sensitivity analyses showed that varying the number of days for data collection and the number of fieldworkers involved during the main survey data collection phase were the two variables that had the highest impact on total direct survey costs in the two methods.

6.2. Overall conclusions

In conclusion, this research showed that a GIS survey sampling approach using freely available technology generated a representative population sample, equivalent family planning results compared to conventional sampling, and at lower survey implementation costs. The main takeaways aligned with the thesis aims are:

1. Satellite image survey sampling is feasible to implement for large-scale population or household surveys for large (n=3,000 households) sample sizes in urban (planned and spontaneous settlements) and rural areas in low-income settings provided high-resolution satellite images are available.
2. Using spatial sampling yielded statistically equivalent results as a conventional household survey when comparing socio-demographic characteristics and family planning indicators. Exploring the determinants of modern contraceptive use, demand satisfied for family planning and unmet need for family planning yielded similar associations in logistic regression models.

3. GIS sampling method was approximately 15% cheaper than conventional methods when comparing costs.

This study contibutes several firsts to household survey methodology research. It is the first comparison of GIS-based probability survey sampling method to the conventional survey sampling method. It is the first documented use of GIS survey sampling across urban and rural communities in Francophone West Africa. We clearly defined specific feasibility measures to be considered when comparing household survey methods, namely: implementation costs, technical qualifications and number of personnel, time, equipment, software, and other logistical requirements. The costing analysis of the survey methods presented real-world implementation evidence that can assist decision-makers considering options for household survey methods which had not been previously documented.

Spatial sampling method using satellite images is promising, as it is improving rapidly and becoming increasingly accessible with free, recent, high-resolution images.[68,120] Challenges remain in its adoption into national and sub-national decision making and sustainability. Nevertheless, the cost and implementation feasibility advantages over conventional surveys that this research showed could unlock its potential in monitoring and evaluating progress of several SDG-3 indicators as countries strive to fulfill their commitment to the universal goal of leaving no one behind.

6.3. Strengths and limitations

6.3.1. Limitations of the Study

There were some limitations of the GIS method we used. Digitizing hand-drawn sketches of base maps of EAs that had varying quality, were not always accurate or drawn to scale meant mappers had to sometimes use their best judgement. Having a multi-disciplinary digital mapping team including Burkinabès familiar with the terrain was vital to ensure correct interpretation and digitization.[33,66] In some of the crowded peri-urban and sparsely populated rural villages, the structures on the Google Maps satellite images became blurred when zoomed in; combining additional sources helped to identify the structures. Satellite images in Burkina Faso provide only aerial views, which brings the potential for misclassification of building's function. Increasing the sample size by 10-15% a priori to account for potentially vacant and non-residential structures based on findings from the pilot mitigated this error.

We did not find clearly defined indicators to measure feasibility of new survey sampling in published literature prior to this study. We defined measures to compare the two methods such as personnel, time, equipment, software and logistical requirements and implementation costs. Moreover, there are no clear guidelines regarding the choice of equivalence margins (delta) for cluster survey studies. Our choice of delta was guided by statistical significance like the impact of the magnitude of the difference on decision-making, and practical significance like feasibility of implementation.

The household survey data were self-reported in both methods which could contain reporting and social desirability biases. However, any biases would be similar in the two methods and would cancel out in the equivalence analysis. Reporting errors were minimized by using shorter recall periods and visual aids to cue respondents' responses as needed. About 70% of the field data collectors were of the same gender and age range as the respondents which facilitated communication and mitigated social desirability bias. As an overall limitation of cross-sectional study designs, we cannot establish causality or temporality regarding the associations of the determinants of the coverage estimates.

Costing analysis excluded costs accrued by the international research team at Johns Hopkins University such as their proportional salaries and international travel costs to Burkina Faso during the study implementation which could connote an underestimation of survey costs. Presenting country-level survey implementation costs would improve external validity of results as more LMICs transition to fund their own surveys.

We could not disaggregate the costs of coordination personnel who also implemented the mapping and enumeration activities by method due to limitations in our accounting software capacity. Nonetheless, we expect no meaningful difference in these costs since both methods were concurrently implemented and would have accrued similar time costs. External validity of survey implementation costs will be limited to contexts with similar or stronger internet capacity and purchasing power similar to Burkina Faso.

6.3.2. Strengths of the Study

This was the first study that compared GIS sampling to the conventional sampling method using the same clusters over diverse geographic landscapes, across survey response rates, sociodemographic characteristics, family planning coverage indicators, and survey implementation costs. The sampling frame of the GIS method included all potentially residential structures, including those located in commercial areas and along the highways. This resulted in a comprehensive sampling frame that could capture wider variability of respondents, including vulnerable populations living in incomplete buildings, shops, and spontaneous settlements who were more likely to be missed in traditional surveys.

Substituting the expensive GIS technology like commercial satellite images, and ArcGIS software[53] with freely available alternatives improves the potential adoption and generalizability of the GIS sampling method in low-resource settings. Under the GIS method, assigning all the structures to be visited by individual field interviewers before starting data collection, preloading geographic coordinates of assigned structures on the navigation app in each interviewer's tablet, complemented by printouts of the satellite images, we achieved several things that prior studies did not document. First, compared to the conventional method, it was relatively easier and quicker for interviewers and supervisors to locate assigned structures. Second, potential for interviewer-related selection bias and margin of error in locating assigned structures was reduced because when interviewers went to the wrong structures, supervisors could assist or make corrections in real-time.

Assessing feasibility with an embedded mixed method design resulted in the first qualitative documentation of the experiences of implementers of the GIS survey sampling method. Enunciating these experiences contextualized the quantitative results and could inform future adoption of the method. To our best knowledge, this is the first documentation of survey implementation costs of the conventional sampling method for large-scale household surveys in Burkina Faso. The comparative analysis of detailed survey implementation costs of the two methods presented additional evidence supporting the feasibility of the GIS sampling method.

6.4. Recommendations for future research

1. Additional analysis for women and child health indicators in the RADAR surveys: We compared socio-demographic and selected indicators of contraceptive coverage in this study. A further study could compare other key maternal health indicators on pregnancy and fertility, autonomy, and economic empowerment, as well as indicators of child health such as immunization coverage and prevalence of childhood diseases. Since these data were already collected in the main RADAR sampling study, a next step is to complete the analyses and build up the evidence base of equivalence of the spatial sampling method to the conventional method.

2. Being the first study to compare the GIS sampling method to the conventional method in a large-scale household survey, this work calls for replication studies to test the internal and external validity of our results in similar implementation

contexts. Replicating this in other contexts will further contribute to the body of evidence regarding the GIS method.

3. Longitudinal studies: Satellite imagery holds promise for longitudinal studies and repeated cross-sectional surveys. For example, demographic and surveillance sites in LMICs could adopt it to update their sampling frames more frequently without geographic bias[121] and potentially reduce spending resources on repeated mapping & enumeration field visits and time used in locating households during data collection.[30] By measuring changes over time, longitudinal studies would also contribute to the reliability of the method over time. [120]

4. Integration of GIS with conventional surveys: We have shown that satellite images and navigation can replace the use of local guides, reduce time and costs of mapping and enumeration is a major cost driver of conventional surveys. Integrating satellite imagery with high quality training and data collection from conventional approach as we implemented, could yield significant improvement in data quality, paired with reduction in survey costs while maintaining high quality implementation rigor.

Chapter 7. Policy recommendations

Based on the findings of this research that provide evidence in support of the feasibility of GIS survey sampling for household surveys, the following are main recommendations that are applicable to policy makers in LMICs, international development donors, household survey method researchers and implementers.

The role of household surveys in policy making in low- and middle-income countries cannot be substituted.

Household surveys remain a major channel to understand and evaluate how investments in health programs and health systems directly affect the intended beneficiaries and end-users. They can represent the whole population, include both users and non-users of health services, and fill the information gaps in routine administrative data that usually includes only those who have sought specific services. In addition, household surveys systematically capture the decision-making process and the determinants of use or non-use of health services at the household level. Furthermore, services provided by private health facilities, pharmacies, patent drug stores, community health providers and volunteers are often left out of reported routine administrative data which tend to capture data at built government-owned facilities only.

Household surveys help policy makers to target, allocate or re-route resources to sections of the population with greatest need or possibility of highest impact. Our study contributes the data needed on not only family planning coverage indicators, but also the determinants of contraceptive use and decision-making at the household level among users in Burkina Faso. This research offers insights to policy makers on decision-making at household levels and will serve as a baseline in evaluating the effectiveness of government policy on family planning [6] on the demand-side component of the health system.

Despite these important uses of household surveys, in many low- and middle-income countries (LMICs), they are done infrequently because of inadequate funding and weak technical capacity. Conventional surveys are expensive, recent data suggests estimates of $1.6M for each Demographic and Health Survey (DHS) per country[17] and it takes up to 2 years to plan, implement, analyze, and disseminate results.[16] This lag means these surveys are not ideal for rapidly evolving conditions and cannot reflect recent changes in populations grappling with security challenges, rapid fertility, or humanitarian emergencies (wars, natural disasters or pandemics) where data is needed quickly for decision making. Because of the implicit design that features two rounds of field deployment of survey staff, there is higher risk of staff safety when placed in areas experiencing insecurity or insurgency, or those populations risk exclusion from national information.[122,123]

A review of DHS and MICS surveys conducted in the 41 African countries ranked as low-or lower-middle income by the World Bank[124] showed 18 of them have not had either survey since 2015. For example, Burkina Faso's most recent DHS was conducted in 2010 (plans are underway for 2021 DHS survey) thus, data are not being generated where they are most needed making it impossible to drive evidence-based decision making when evidence is not being generated. Our study demonstrated the possibility of replacing the first field deployment (mapping & enumeration) which is a major cost driver of surveys with digital mapping using satellite images. Our results showed mapping and enumeration personnel and field deployment accounted for 16% of total direct survey costs which GIS sampling method offset by 81%.

In this setting, spatial survey sampling methods is an equivalent alternative to conventional household surveys for conducting large-scale household surveys, incurs lower costs, and could potentially become an important contributor to achieving the Sustainable Development Goal on health.

Exploring feasibility of adopting a valid alternative sampling approach involves considerations of costs, technical requirements, time, personnel, quality of data generated and replicability. Our results generated evidence for the study hypothesis that the deployment of freely available satellite imagery and GIS tools is a valid alternative for conducting large-scale household surveys that yielded representative samples and valid population estimates while saving costs. It is both a contribution and advancement in the field of survey sampling methodology by answering questions about what is possible, who can do it and how much it cost. We presented evidence regarding technical requirements, time, personnel, costs, quality of data generated, and not only replicated what prior researchers have done in spatial sampling [13,29,30,32] but also extended to large sample size of over 3,000 households and to rural areas. In addition, we showed that the satellite imagery sampling-derived estimates of sociodemographic characteristics and family planning indicators were equivalent to the standard method within a 5% equivalence threshold.

Therefore, considering the enormous need to collect data on progress towards the United Nations Sustainable Development Goal on health (SDG3) which has 28 key indicators[125] that countries are expected to report on annually, satellite imagery could serve as a substitute or enhancer to conventional surveys in low-resource contexts where high data needs are coupled with scarcity of data generation. This study demonstrated practical ways to increase generation and availability of survey data. Moreover, the global health financing landscape is shifting as traditional Western donors are contributing less to international funding support, exacerbated by COVID-19. As LMICs take ownership of their health sector and determine their priorities instead of being subject to donor preferences, they intentionally or unintentionally signal their willingness to invest in creating homegrown financial and human resource solutions to bridge their data gaps.[126] More LMICs are expected to wholly take up or contribute substantially to fund their own national statistics development strategies.[17] In light of limited resources in these countries, our research shows that satellite-based household sampling methods can generate cost savings that could be directed to strengthen and build capacity within the context of health system strengthening, while the equivalence with estimates from conventional sampling method implies the integrity of high-quality data is maintained.

Spatial sampling can generate valid sub-national estimates to facilitate decision-making.

The growing recognition of diversities in economic, security, health, education status coupled with income inequality within low-income countries makes it difficult to assume national averages for all provinces and districts. This dissertation provided province-level data for two provinces in Burkina Faso and fills a gap in research, policy and governance that require granular data that are sufficiently powered to assess the coverage of targeted government investments.

In our study, the Ministry of Health specifically selected the two provinces because they were interested in assessing the extent of family planning coverage in the population as a result of several recent years of donor and government investments in family planning. Presenting this data to the government within a year of survey commission could help them hasten resource allocation decisions in planning. Moreover, research and donor-funded projects often select provinces within countries to work in, so using national-level data could over- or underestimate the true coverage of interventions within selected sub-national levels. Satellite imagery could offer enhanced rapidity in data collection from intended beneficiaries in settings where the cluster boundaries and residential structures are already digitized and could increase confidence that the right populations are being reached.

Adoption and sustainability of new technology requires building trust and in-country human resources capacity.

It is human nature to learn about what is unknown in relation to existing knowledge, hence a new approach should not be implemented in isolation because it becomes difficult for new adopters to contextualize it. Adopting new technology takes time and requires building trust and transparency particularly with those who are intended implementers and beneficiaries. Given that satellite imagery is emerging technology, decision makers are reluctant and our in-country research collaborators were understandably initially hesitant and curious about whether it will be "as good as" the conventional method.

The need to foster adoption and sustainability of spatial sampling was one of the reasons we compared the spatial sampling to the conventional method to assess if it was "good enough" by evaluating the equivalence of key indicators and feasibility of implementation in real-world settings. By collaborating directly with key local institutions in Burkina Faso, namely the University of Ouagadougou's ISSP, INSD, the national statistics office of Burkina Faso, and IGB, the national geographic bureau (which was involved in spatial sampling only), we created the opportunity for institutional survey researchers and implementers to actively participate in and learn about satellite imagery sampling, which contributed to building and strengthening local capability in using GIS survey sampling techniques.

This dissertation provides evidence that spatial sampling can be implemented with existing equipment, internet technology and trained personnel, while yielding valid and comparable estimates as the conventional sampling method, at lower costs in Burkina Faso and similar low-income settings. To scale-up adoption and sustainability, public and private sectors and donors can form public-private partnerships to support these approaches in resource-limited settings. [127] These institutions should consider allocating funding for satellite imagery research to improve the method and support more countries to develop digital repositories of national map inventories that can be easily updated, preserved from degradation and securely stored, as has been done for Ghana, Mexico and Tanzania.[128]

References

Appendices

Appendix A. Data collection instruments

Household and Women’s Survey Questionnaire

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Institut Supérieur des Sciences de la Population	Institut National de la Statistique et de la Démographie	Johns Hopkins Bloomberg School of Public Health

Institute for International Programs – Johns Hopkins University

Real Accountability: Data Analysis for Results (RADAR)

Enquête de comparaison des méthodes d'échantillonnage

QUESTIONNAIRE DE L'ENQUETE

DE COUVERTURE

November22th, 2019

RADAR Coverage Survey Generic questionnaires August 2018

CONTENTS

QUESTIONNAIRE MÉNAGE

TABLEAU D'INFORMATION DU MENAGE (HH)

HH1.	Nom et numéro de la région de résidence Centre .... Centre-Ouest.. 2	HH2.	Nom et numéro de la province de résidence: Kadiogo... Boulkiemdé ....
HH2a.	Nom et numéro du village/secteur de résidence ………………………………….. ____ ____	HH2b.	Nom et numéro de la commune/arrondissement de résidence ………………………………….. ____ ____
HH2c1 et HH2c2.	Enregistrez le numéro de la grappe et de la structure marquée sur le portail/la porte EE / ___ ___ ___ / ___ ___ ___ NUMERO NON-LISIBLE 99999 POUR GRAPPE NUMERO NON-LISIBLE 999 POUR STRUCTRURE PAS DE NUMERO 88888 POUR GRAPPE PAS DE NUMERO 888 POUR STRUCTRURE		
HH2d.	Type de méthode d'échantillonnage	Standard .... 1 SIG/GIS .... 2 EPI...3	

Vérifiez la question HH2d.

HH2d = 1→HH3
HH2d = 2 →HH3
HH2d =3 ET HH2=1 →HH3
HH2d =3ET HH2=2 →HH4

HH3.	Nom et numéro de la grappe: ………………………………….. _____ ___	

Vérifiez la question HH2d.

HH2d = 1 → HH3c
HH2d = 2 → HH3a
HH2d = 3 → HH4

HH3ax.	Combien de ménages y a-t-il dans la structure ? __ __ ___ ____	**Vérifiez la question HH3ax.** **HH3a = 1 → HH4** **HH3a > 1 → HH3b**		
		HH3b	Enregistrez les noms des chefs de ménage dans la structure : 1. ________________________ 2. ________________________ n. ________________________ ________________________	**→ HH4**

<table>
<tr><td>HH3c</td><td>Numéro de la structure: ___ ___ ___</td><td></td><td colspan="2"></td></tr>
<tr><td>HH4</td><td>Numéro du ménage: ____ ____</td><td></td><td colspan="2"></td></tr>
<tr><td>HH4a.</td><td>Nom et prénom du chef de ménage :
___________________________________</td><td></td><td colspan="2"></td></tr>
<tr><td>HH4b.</td><td>Coordonnées GPS de la concession/le bâtiment dans laquelle se trouve le ménage

Précision …………………………………………..</td><td colspan="3">Latitude ....

Longitude ....</td></tr>
<tr><td>HH6.</td><td>Nom et numéro de l'enquêteur/trice:

Nom ____________________ ____ ____</td><td>HH7.</td><td colspan="2">Nom et numéro du superviseur:

Nom ____________________ ____ ____</td></tr>
<tr><td>HH8.</td><td>Jour / Mois / Année de l'enquête:</td><td colspan="3">____ ____ /____ ____ / 2 0 ___ ___</td></tr>
<tr><td>HH9.</td><td>Résultat de l'enquête de ménage:</td><td colspan="2">Completé 01
Pas de membre du ménage à la maison ou pas d'enquêté compétent à la maison au moment de la visite...02
Ménage entier absent pour une longue période03
Refusé 04
Logement vide ou pas de logement à l'adresse 05
Logement détruit...06
Logement non trouvé..07
Ménage déjà enquêté 08
Autre (préciser)...96</td><td>HH9a

OH3 (02–07)

HH9a
OH3</td></tr>
<tr><td>HH9a</td><td>Le ménage a-t-il une carte de passage donnée lors de la cartographie ?
Insistez pour voir la carte</td><td colspan="2">Oui 1
Non ....2</td><td>
→HH9c</td></tr>
<tr><td>HH9b</td><td>Identifiant sur la carte de passage</td><td colspan="2">Numero de grappe : __ __ __
Numéro de concession : __ __
Numéro du ménage : __ __</td><td></td></tr>
<tr><td colspan="5">HH9c
Filtre : Vérifiez la question HH9.
HH9=08 →HH9d
HH9=01→HH10</td></tr>
<tr><td>HH9d.</td><td>Nom et numéro de l'enquêteur/trice ayant déjà enquêté le ménage :</td><td colspan="2">Nom ____________________
Numéro ____ ____</td><td>→OH3</td></tr>
</table>

HH9y	Votre ménage a-t-il été interviewé par un agent lors du recensement général de la population au cours du mois de Novembre, Décembre 2019 ou janvier 2020	Oui, carte vue……………………………………1 Oui, carte pas vue…………………………………2 Non…………………………………………………3 Ne sait………………………………………………4	
HH10.	Quelle est la religion du chef de ce ménage?	Catholique ....1 Protestante ....2 Musulmane ....3 Traditionnelle/animiste.......................................4 Sans religion/aucune ....5 Autre religion (préciser) 6	
HH11.	Quelle est la langue maternelle / locale du chef de ce ménage?	Bobo ....01 Dioula ....02 Fulfulde/Peulh..03 Gourmantche ....04 Gourounsi ....05 Lobi..06 Mossi ....07 Senoufo ....08 Touareg/Bella ....09 Dagara...10 Bissa..11 Français...21 Anglais...22 Autre langue (préciser) 96	
HH12.	Quel est le groupe ethnique du chef de ce ménage ?	Bobo ....01 Dioula ....02 Fulfulde/Peulh ....03 Gourmantche ....04 Gourounsi ....05 Lobi..06 Mossi ....07 Senoufo ....08 Touareg/Bella ....09 Dagara...10 Bissa..11	

		Autre CEDEAO ....21 Autre pays africain ....22 Autre nationalité..23 Autre ethnie (préciser) ....96 Ne sait pas..98

											Pour l'ensemble des membres du ménage âgé de 3 ans ou plus				Pour les femmes de 15-49 ans	Pour les enfants de 0-4 ans			
HL1. N° de ligne.	**HL2**. NOM	**HL3**. Quelest le lien deparenté de (NOM)avec le chefde ménage ? *VOIR CODES CI-DESSOUS*	**HL4**. (NOM) est-ilde sexe masculin ou féminin? *1 Masculin 2 Féminin*		**HL5**. Quelle est la date de naissance de(NOM) ? *98 DK 9998 DK*		**HL6**. Que lâge a (NOM)? *Enregistrer en années révolues* *SI 95OU PLUS, INSCRIVEZ '95'.*	**HL6A**. (NOM)vit-il/elleici habituellement?	**HL6B**. (NOM)A T-IL/ELLE PASSELA NUIT DERNIERE ICI?	**HL6C**. (NOM) Fréquente ou a-t-il/elle déjà fréquenté l'école?	**HL6D**. SI (NOM) fréquente actuellement l'école, demandez le type d'école	**HL6DX**. SI (NOM) fréquente actuellement l'école, demandez Est-ce en cours du jours ou en cours du soir	**HL6E**. Quelestle plus haut niveau d'études que (NOM) a atteint?	**HL6F**. Quelle est la dernière classe que(NOM)a achevée à ce niveau? N°	**HL7A**. *ENCERCLEZ LE N°DELIGNEDE TOUTES LES FEMMES DE 15-49ANS.*	**HL7B**. *ENCERCLEZ LE N°DELIGNEDE TOUS LES ENFANTS DE0-4ANS.*	**HL8**. Lamère biologique de(NOM)est-elle envie? 1 Oui 2 Non 8 Ne sait pas	**HL9**. Lamère biologiquede (NOM)vit-ellehabituelle mentdans ceménage ? *SIOUI: INSCRIVEZLE N°DE LIGNE DE LA MERE. SI NON, INSCRIVEZ '00'.*	**HL1(** *INSCRI LE N°DEL DE LA M INSCRITE LA COLONNE* Si le nur de ligne colonne est vide '00' Demand personn qui pre habituelle t soin (NOM) inscrive numéro ligne cettepers
Li	Nom	Lien*	M	F	Mois	Année	Age	O N	O N	1. Fréquente actuellement 2. A fréquenté (Allez HL6E) 3. Non (Allez HL7A)	Type d'école **	1 cours du jour 2 cours du soir 3 cours du jour et cours du soir 4 NSP	Niveau atteint***	Classe achevée ****	15-49	0-4	O N NSP	Mère	Mèr
0		0 1	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 23					01	01	1 2 8	__ __	__ _
0		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					02	02	1 2 8	__ __	__ _

												Pour l'ensemble des membres du ménage âgé de 3 ans ou plus				Pour les femmes de 15-49 ans	Pour les enfants de 0-4 ans			
HL1. N° de ligne	**HL2**. NOM	**HL3**. Quelest le lien deparenté de (NOM)avec le chefde ménage ? *VOIR CODES CI-DESSOUS*	**HL4**. (NOM) est-ilde sexe masculin ou féminin? *1 Masculin 2 Féminin*		**HL5**. Quelle est la date de naissance de(NOM) ? *98 DK 9998 DK*		**HL6**. Que lâge a (NOM)? *Enregistrer en années révolues* *SI 95OU PLUS, INSCRIVEZ '95'.*	**HL6A**. (NOM)vit-il/elleici habituellement?	**HL6B**. (NOM)A T-IL/ELLE PASSELA NUIT DERNIERE ICI?	**HL6C**. (NOM) Fréquente ou a-t-il/elle déjà fréquenté l'école?	**HL6D**. SI (NOM) fréquente actuellement l'école, demandez le type d'école	**HL6DX**. SI (NOM) fréquente actuellement l'école, demandez Est-ce en cours du jours ou en cours du soir	**HL6E**. Quelestle plus haut niveau d'études que (NOM) a atteint?	**HL6F**. Quelle est la dernière classe que(NOM)a achevée à ce niveau? N°	**HL7A**. *ENCERCLEZ LE N°DELIGNEDE TOUTES LES FEMMES DE 15-49ANS.*	**HL7B**. *ENCERCLEZ LE N°DELIGNEDE TOUS LES ENFANTS DE0-4ANS.*	**HL8**. Lamère biologique de(NOM)est-elle envie? 1 Oui 2 Non 8 Ne sait pas	**HL9**. Lamère biologiquede (NOM)vit-ellehabituellement dans ceménage ? *SIOUI: INSCRIVEZLE N°DE LIGNE DE LA MERE.* *SI NON, INSCRIVEZ '00'.*	**HL1**[...] *INSCRI[...] LE N°DEL[...] DE LA M[...] INSCRITE [...] LA COLONNE* *Si le nu[...] de ligne [...] colonne [...] est vide [...] '00' Demand[...] personn[...] qui pre[...] habituell[...] t soin [...] (NOM)? inscrive[...] numéro[...] ligne [...] cettepers[...]*
Li	Nom	Lien*	M	F	Mois	Année	Age	O N	O N	1. Fréquente actuellement 2. A fréquenté (Allez HL6E) 3. Non (Allez HL7A)	Type d'école **	1 cours du jour 2 cours du soir 3 cours du jour et cours du soir 4 NSP	Niveau atteint***	Classe achevée ****	15-49	0-4	O N NSP	Mère	Mèr[...]
2																			
03		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					03	03	1 2 8	__ __	__ _
04		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					04	04	1 2 8	__ __	__ _
05		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					05	05	1 2 8	__ __	__ _

											Pour l'ensemble des membres du ménage âgé de 3 ans ou plus				Pour les femmes de 15-49 ans	Pour les enfants de 0-4 ans			
HL1. N° de ligne	**HL2**. NOM	**HL3**. Quelest le lien deparenté de (NOM)avec le chefde ménage ? *VOIR CODES CI-DESSOUS*	**HL4**. (NOM) est-ilde sexe masculin ou féminin? *1 Masculin 2 Féminin*		**HL5**. Quelle est la date de naissance de(NOM) ? *98 DK 9998 DK*		**HL6**. Que lâge a (NOM)? *Enregistrer en années révolues* *SI 95OU PLUS, INSCRIVEZ '95'.*	**HL6A**. (NOM)vit-il/elleici habituellement?	**HL6B**. (NOM)A T-IL/ELLE PASSELA NUIT DERNIERE ICI?	**HL6C**. (NOM) Fréquente ou a-t-il/elle déjà fréquenté l'école?	**HL6D**. SI (NOM) fréquente actuellement l'école, demandez le type d'école	**HL6DX**. SI (NOM) fréquente actuellement l'école, demandez Est-ce en cours du jours ou en cours du soir	**HL6E**. Quelestle plus haut niveau d'études que (NOM) a atteint?	**HL6F**. Quelle est la dernière classe que(NOM)a achevée à ce niveau? N°	**HL7A**. *ENCERCLEZ LE N°DELIGNE DE TOUTES LES FEMMES DE 15-49ANS.*	**HL7B**. *ENCERCLEZ LE N°DELIGNE DE TOUS LES ENFANTS DE0-4ANS.*	**HL8**. Lamère biologique de(NOM)est-elle envie? 1 Oui 2 Non 8 Ne sait pas	**HL9**. Lamère biologiquede (NOM)vit-ellehabituellement dans ceménage ? *SIOUI: INSCRIVEZLE N°DE LIGNE DE LA MERE.* *SI NON, INSCRIVEZ '00'.*	**HL1(** *INSCRI LE N°DEL DE LA M INSCRITE LA COLONNE* *Si le nur de ligne colonne est vide '00' Demand personn qui pre habituelle t soin (NOM)? inscrive numéro ligne cettepers*
Li	Nom	Lien*	M	F	Mois	Année	Age	O N	O N	1. Fréquente actuellement 2. A fréquenté (Allez HL6E) 3. Non (Allez HL7A)	Type d'école **	1 cours du jour 2 cours du soir 3 cours du jour et cours du soir 4 NSP	Niveau atteint***	Classe achevée ****	15-49	0-4	O N NSP	Mère	Mèr
06		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					06	06	1 2 8	__ __	__ _
07		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					07	07	1 2 8	__ __	__ _
08		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					08	08	1 2 8	__ __	__ _
0		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					11	11	1 2 8	__ __	__ _

												Pour l'ensemble des membres du ménage âgé de 3 ans ou plus				Pour les femmes de 15-49 ans	Pour les enfants de 0-4 ans			
HL1. N° de ligne	**HL2**. NOM	**HL3**. Quelest le lien deparenté de (NOM)avec le chefde ménage ? *VOIR CODES CI-DESSOUS*	**HL4**. (NOM) est-ilde sexe masculin ou féminin? *1 Masculin 2 Féminin*		**HL5**. Quelle est la date de naissance de(NOM) ? *98 DK 9998 DK*		**HL6**. Que lâge a (NOM)? *Enregistrer en années révolues* *SI 95OU PLUS, INSCRIVEZ '95'.*	**HL6A**. (NOM)vit-il/elleici habituellement?	**HL6B**. (NOM)A T-IL/ELLE PASSELA NUIT DERNIERE ICI?	**HL6C**. (NOM) Fréquente ou a-t-il/elle déjà fréquenté l'école?	**HL6D**. SI (NOM) fréquente actuellement l'école, demandez le type d'école	**HL6DX**. SI (NOM) fréquente actuellement l'école, demandez Est-ce en cours du jours ou en cours du soir	**HL6E**. Quelestle plus haut niveau d'études que (NOM) a atteint?	**HL6F**. Quelle est la dernière classe que(NOM)a achevée à ce niveau? N°	**HL7A**. *ENCERCLEZ LE N°DELIGNED E TOUTES LES FEMMES DE 15-49ANS.*	**HL7B**. *ENCERCLEZ LE N°DELIGNED E TOUS LES ENFANTS DE0-4ANS.*	**HL8**. Lamère biologique de(NOM)est-elle envie? 1 Oui 2 Non 8 Ne sait pas	**HL9**. Lamère biologiquede (NOM)vit-ellehabituellement dans ceménage ? *SIOUI: INSCRIVEZLE N°DE LIGNE DE LA MERE.* *SI NON, INSCRIVEZ '00'.*	**HL1(** *INSCRI LE N°DEL DE LA M INSCRITE LA COLONNE* Si le nur de ligne colonne est vide '00' Demand personn qui pre habituelle t soin (NOM) inscrive numéro ligne cettepers
Li	Nom	Lien*	M	F	Mois	Année	Age	O N	O N	1. Fréquente actuellement 2. A fréquenté (Allez HL6E) 3. Non (Allez HL7A)	Type d'école **	1 cours du jour 2 cours du soir 3 cours du jour et cours du soir 4 NSP	Niveau atteint***	Classe achevée ****	15-49	0-4	O N NSP	Mère	Mèr
1		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					12	12	1 2 8	__ __	__ __
1		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					11	11	1 2 8	__ __	__ __
1		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					12	12	1 2 8	__ __	__ __

										Pour l'ensemble des membres du ménage âgé de 3 ans ou plus					Pour les femmes de 15-49 ans	Pour les enfants de 0-4 ans			
HL1. N° de ligne	**HL2**. NOM	**HL3**. Quelest le lien deparenté de (NOM)avec le chefde ménage ? *VOIR CODES CI-DESSOUS*	**HL4**. (NOM) est-ilde sexe masculin ou féminin? *1 Masculin 2 Féminin*		**HL5**. Quelle est la date de naissance de(NOM) ? *98 DK 9998 DK*		**HL6**. Que lâge a (NOM)? *Enregistrer en années révolues* *SI 95OU PLUS, INSCRIVEZ '95'.*	**HL6A**. (NOM)vit-il/elleici habituellement?	**HL6B**. (NOM)A T-IL/ELLE PASSELA NUIT DERNIERE ICI?	**HL6C**. (NOM) Fréquente ou a-t-il/elle déjà fréquenté l'école?	**HL6D**. SI (NOM) fréquente actuellement l'école, demandez le type d'école	**HL6DX**. SI (NOM) fréquente actuellement l'école, demandez Est-ce en cours du jours ou en cours du soir	**HL6E**. Quelestle plus haut niveau d'études que (NOM) a atteint?	**HL6F**. Quelle est la dernière classe que(NOM)a achevée à ce niveau? N°	**HL7A**. *ENCERCLEZ LE N°DELIGNEDE TOUTES LES FEMMES DE 15-49ANS.*	**HL7B**. *ENCERCLEZ LE N°DELIGNEDE TOUS LES ENFANTS DE0-4ANS.*	**HL8**. Lamère biologique de(NOM)est-elle envie? 1 Oui 2 Non 8 Ne sait pas	**HL9**. Lamère biologiquede (NOM)vit-ellehabituellement dans ceménage ? *SIOUI: INSCRIVEZLE N°DE LIGNE DE LA MERE.* *SI NON, INSCRIVEZ '00'.*	**HL1(** *INSCRI LE N°DEL DE LA M INSCRITE LA COLONNE* *Si le nur de ligne colonne est vide '00' Demand personn qui pre habituelle t soin (NOM)? inscrive numéro ligne cettepers*
Li	Nom	Lien*	M	F	Mois	Année	Age	O N	O N	1. Fréquente actuellement 2. A fréquenté (Allez HL6E) 3. Non (Allez HL7A)	Type d'école **	1 cours du jour 2 cours du soir 3 cours du jour et cours du soir 4 NSP	Niveau atteint***	Classe achevée ****	15-49	0-4	O N NSP	Mère	Mèr
13		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					13	13	1 2 8	__ __	__ __
14		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					14	14	1 2 8	__ __	__ __
15		__ __	1	2	__ __	__ __ __ __	__ __	1 2	1 2	1 2 3					15	15	1 2 8	__ __	__ __

										Pour l'ensemble des membres du ménage âgé de 3 ans ou plus				Pour les femmes de 15-49 ans	Pour les enfants de 0-4 ans			
HL1. N° de ligne.	**HL2**. NOM	**HL3**. Quelest le lien deparenté de (NOM)avec le chefde ménage ? *VOIR CODES CI-DESSOUS*	**HL4**. (NOM) est-ilde sexe masculin ou féminin? *1 Masculin 2 Féminin*	**HL5**. Quelle est la date de naissance de(NOM) ? *98 DK 9998 DK*	**HL6**. Que lâge a (NOM)? *Enregistrer en années révolues* *SI 95OU PLUS, INSCRIVEZ '95'.*	**HL6A**. (NOM)vit-il/elleici habituellement?	**HL6B**. (NOM)A T-IL/ELLE PASSELA NUIT DERNIERE ICI?	**HL6C**. (NOM) Fréquente ou a-t-il/elle déjà fréquenté l'école?	**HL6D**. SI (NOM) fréquente actuellement l'école, demandez le type d'école	**HL6DX**. SI (NOM) fréquente actuellement l'école, demandez Est-ce en cours du jours ou en cours du soir	**HL6E**. Quelestle plus haut niveau d'études que (NOM) a atteint?	**HL6F**. Quelle est la dernière classe que(NOM)a achevée à ce niveau? N°	**HL7A**. *ENCERCLEZ LE N°DELIGNE E TOUTES LES FEMMES DE 15-49ANS.*	**HL7B**. *ENCERCLEZ LE N°DELIGNE E TOUS LES ENFANTS DE0-4ANS.*	**HL8**. Lamère biologique de(NOM)est-elle envie? 1 Oui 2 Non 8 Ne sait pas	**HL9**. Lamère biologiquede (NOM)vit-ellehabituellement dans ceménage ? *SIOUI: INSCRIVEZLE N°DE LIGNE DE LA MERE.* *SI NON, INSCRIVEZ '00'.*	**HL1(** *INSCRI LE N°DEL DE LA M INSCRITE LA COLONNE* *Si le nur de ligne colonne est vide '00' Demand personn qui pre habituelle t soin (NOM) inscrive numéro ligne cettepers*
Li	Nom	Lien*	M F	Mois	Année	Age	O N	O N	1. Fréquente actuellement 2. A fréquenté (Allez HL6E) 3. Non (Allez HL7A)	Type d'école **	1 cours du jour 2 cours du soir 3 cours du jour et cours du soir 4 NSP	Niveau atteint***	Classe achevée ****	15-49	0-4	O N NSP	Mère	Mère

Cochez ici si un questionnaire supplémentaire est utilisé	☐

Insistez pour d'éventuelsautres membres du ménage.
Insistez particulièrement pour les nourrissons et les enfants en bas âge ne figurant pas sur la liste, ainsi que ceux qui ne font pas partie de la famille (tels que les employé(s) de maison, les amis) mais qui vivent généralement dans le ménage.
Insérez les noms des membres supplémentaires dans la liste des ménages et remplissez le formulaire en conséquence.

Maintenant, pour chaque femme de 15 à 49 ans, écrivez son nom, son numéro de ligne et d'autres informations d'identification dans le panneau d'information d'un questionnaire individuel séparépour les femmes.
Pour chaque enfant de moins de 5 ans, écrivez son nom et son numéro de ligne ainsi quele numéro de ligne de sa mère ou de son responsable dans le panneau d'informations d'un questionnaire séparé pour les moins de 5 ans.
Vous devriez maintenant avoir un questionnaire séparé pour chaque femme, et pour chaque enfant éligible du ménage.

** Codes pour **HL3**: Lien de parenté avec le chef de ménage:*	01 Chef de Ménage 02 Epouse ou époux / Partenaire 03 Fils / Fille	04 Gendre/ Belle-Fille 05 Petit Fils/fille 06 père,mère	07 Beau Père/Belle mère 08 Frère / Soeur 09 Beau-Frère /Belle-Soeur	10 Oncle / Tante 11 Nièce / Neveu 12 Autre parent	13 Adopté / Confié/ Enfant du conjoint/conjointe 14 Employé(e) de maison (vivant dans) 15 co-épouse	96 Autre (Sans Parenté) 98 NSP
***Codes pour **HL6D**:*	01 Ecole publique formelle	02ecole publique non-formelle 03Ecole privée catholique	04Ecole privée protestante 05Ecole privée musulmane	06Autre école privée	96. Autres à préciser	
****Codes pour **HL6E***	1 Maternelle 2 Primaire	3 Post-primaire 4 Post-pirmaire professionnel	5 Secondaire 6 Secondaire professionel	6 Supérieur		
***** Codes pour **HL6F**:*	00 Aucun 01 Maternelle 02 CP1 03 CP2	04 CE1 05 CE2 06 CM1 07 CM2	08 6è 09 5è 10 4è 11 3è	12 2nde 13 1è 14 Tle 15 1ière année d'université	16 2è année d'université 17 3è année d'université 18 4è année d'université. 19 5èannéed'université	20 6è année d'université 21 7è année d'université

MODULE MIGRATION

MI1.	Depuis combien de temps votre ménage habite de façon continue dans la province (Kadiogo, Boulkiemdé) ?	Il y a des mois……………………………….1 Il y a des années……………………………..2 Depuis toujours……………………………...3 NSP…………………………………………..98	→ MI3
MI2.	Où est-ce que votre ménage a vécu dernièrement avant de s'installer dans cette province ?	Choisir code de la province ou localité (voir fiche des provinces)	
MI3.	Votre ménage a-t-il acceuilli/reçu de nouveau membres en provenance d'autres provinces au cours des 3 dernières années (2017, 2018, 2019)	Oui…………………………………………...1 Non…………………………………………...2	→ MI6
	Filtre: **Si MI1=3 & MI3=2 →prochain module (HA1)** **Si MI1=1,2,98 & MI3=2 →MI6** **Si MI3=1 →MI4**		
MI4A.	Combien de personnes en provenace d'autres provinces ou pays au cours des 3 dernières années (2017, 2018, 2019) sont toujours de votre ménage ? enfants de moins de 5ans	--	
MI4B.	Combien de personnes en provenace d'autres provinces ou pays au cours des 3 dernières années (2017, 2018, 2019) sont toujours de votre ménage ?hommes âgés de 15 ans et plus	--	
MI4C.	Combien de personnes en provenace d'autres provinces ou pays au cours des 3 dernières années (2017, 2018, 2019) sont toujours de votre ménage ? femmes âgées de 15 ans et plus	---	
MI4D.	Combien de personnes en provenace d'autres provinces ou pays au cours des 3 dernières années (2017, 2018, 2019) sont toujours de votre ménage ? nombre total de nouvelles personnes		
MI5.	De quelle province ou pays ces nouveaux membres sont –ils en majorité venues ?	Choisir code de la province et pays (voir fiche des provinces et pays)	

MI6.	Quelle était la principale raison de la venue de votre ménage/des nouveaux membres au cours des 3 dernières années ?	Insécurité/conflits……………………………….1 Famines/ insécurités alimentaire……………...2 Sécheresse/Inondation………………………...3 Travail/emploi………………………………….4 Pauvrété………………………………………..5 Scolarisation……………………………………6 Raisons Familiales…………………………….7 Autres raisons…………………………………..8	
MI7.	Quelles étaitent les raisons secondaire de la venue de votre ménage/des nouveaux membres au cours des 3 dernières années ?	Insécurité/conflits……………………………….1 Famines/ insécurités alimentaire……………...2 Sécheresse/Inondation………………………...3 Travail/emploi………………………………….4 Pauvrété………………………………………..5 Scolarisation……………………………………6 Raisons Familiales…………………………….7 Autres raison……………………………………8 Pas de raisons secondaires……………………9	

MODULE DES BIENS DU MENAGE (HA)

HA1.	Quel type de combustible votre ménage utilise-t-il principalement pour cuisiner ?	Electricité.. 01 Gaz en bouteille .... 02 Biogaz .... 04 Paraffine/Pétrole.. 05 Charbon de bois .... 06 Charbon, lignite .... 07 Bois .... 08 Résidus agricoles, paille/branchages/ herbes .. 09 Bouse d'animaux... 11 Pas de repas préparé dans le ménage .... 95 Autre (préciser).. 96	
HA2.	Dans ce ménage, combien de pièces utilisez-vous pour dormir ?	Nombre de pièces ___ ___	
HA3.	Est-ce que votre ménage possède du bétail, des troupeaux, d'autres animaux de ferme ou de la volaille ?	Oui .... 1 Non... 2	 **→HA5**

HA4.	Parmi les animaux suivants, combien votre ménage en possède-t-il ? LISEZ CHAQUE ÉLÉMENT. SI AUCUN, NOTEZ '00'. SI 95 OU PLUS, NOTEZ '95'. SINESAITPAS,INSCRIVEZ'98'. Vaches laitières ou taureaux? Autre bétail? Chevaux, ânes ou mules ? Chèvres? Moutons? Cochons? Poulets ou autres volaille ?	Vaches laitières / taureaux? ___ ___ Autre bétail ___ ___ Chevaux, ânes ou mules ? ___ ___ Chèvres ___ ___ Moutons ___ ___ Cochons ___ ___ Poulets ou autres volaille ? ___ ___	
HA5.	Est-ce qu'un membre de votre ménagepossède des terres cultivables ?	Oui ..... **1** Non..... 2	 →HA7
HA6.	Combien d'hectares de terres cultivables les membres du ménagepossèdent-ils ? **SI 95 OU PLUS, ENCERCLEZ '95.0'.**	Hectares __ __. __ 95 Hectares ou plus ..... 95.0 Ne sait pas 99.8	
HA7.	Dans ce ménage, avez-vous : L'électricité connectée au réseau? Un poste radio en état de fonctionnement ? Une télévision en état de fonctionnement ? Un téléphone fixe en état de fonctionnement? Un réfrigérateur/ congélateur en état de fonctionnement ? Un ordinateur en état de fonctionnement ? Energie solaire, batterie, ou groupe électrogène ?	Oui Non Électricité..... 1 2 Radio..... 1 2 Télévision ..... 1 2 Téléphone fixe..... 1 2 Réfrigérateur/Congélateur..... 1 2 Ordinateur ..... 1 2 Batterie..... 1 2	

HA8.	Est-ce qu'un membre de votre ménage possède : Une montre ? Une bicyclette ? Un téléphone portable ? Une motocyclette ou tricycle ou un scooter ? Une voiture ou une camionnette ? Une charrette tirée par un animal ? Un bateau à moteur ?	Oui Non Montre .... 1 2 Bicyclette .... 1 2 Téléphone portable .... 1 2 Motocyclette/tricycle/scooter .... 1 2 Voiture/camionnette .... 1 2 Charette .... 1 2 Bateau à moteur 1 2	
HA9.	Est-ce qu'un membre de votre ménage a un compte en banque ?	Oui .... 1 Non .... 2 Ne sait pas 8	
HA10.	Un membre de ce ménage a-t-il un compte mobile ([OrangeMoney; MobiCash, CorisMoney,etc])?	Oui .... 1 Non .... 2 Ne sait pas 8	
HA11.	OBSERVEZ LE MATÉRIAU PRINCIPAL DU TOIT DU LOGEMENT. ENREGISTREZL'OBSERVATION.	Toîture en matériau naturel Pas de toît .... 11 Chaume/feuilles de palmes/feuilles .... 12 Herbes .... 13 Toîture en matériau rudimentaire Nattes .... 21 Palmier/bambou .... 22 Planches en bois .... 23 Carton .... 24 Toîture en matériau fini Métal/tôle .... 31 Bois .... 32 CalamineFibre de ciment .... 33 Tuiles en céramique .... 34 Ciment .... 35 Toît de bardeaux (shingles) .... 36 Autres (*specifier*) 96	

HA12.	OBSERVEZ LE MATÉRIAU PRINCIPAL DES MURS EXTÈRIEURS DU LOGEMENT. ENREGISTREZL'OBSERVATION.	Murs en matériau naturel Pas de mur .... 11 Bambou/palme/tronc .... 12 Boue/terre .... 13 Murs en matériau rudimentaire Bambou avec boue .... 21 Pierre avec boue .... 22 Adobe non couvert .... 23 Contre-plaqué .... 24 Carton .... 25 Bois de récupération .... 26 Murs en matériau fini Ciment .... 31 Pierre avec chaux/ciment .... 32 Briques cuites .... 37 Blocs de ciment .... 34 Adobe recouvert .... 35 Planches en bois/bardeaux .... 36 Autres (*spécifier*) 96	

MODULE EAU ET ASSAINISSEMENT (WS)

WS1.	D'où provient principalement l'eau que boivent les membres de votre ménage ?	Eau du robinet Robinet dans le logement.......... 11 Robinet dans la cour ou parcelle.......... 12 Robinet Public/Borne Fontaine.......... 13 Puits à pompe/Forage.......... 21 Puit creusé Puit protégé.......... 31 Puit non protégé.......... 32 Eau de source Source protégée.......... 41 Source non protégée.......... 42 Eau de pluie.......... 51 Camion-citerne.......... 61 Charrette avec petite citerne/tonneau.......... 71 Eau de surface (rivière, ruisseau, barrage, lac, mare, canal,canal d'irrigation).......... 81 Eau en bouteille.......... 91 Eau en sachet.......... 92 Autre (*préciser*) ______ 96	11–81 → WS3

WS2.	D'où provient principalement l'eau utilisée par votre ménage à d'autres fins comme pour faire la cuisine et se laver les mains ?	Eau du robinet Robinet dans le logement............................ 11 Robinet dans la cour ou parcelle................. 12 Robinet Public/Borne Fontaine.................... 13 Puits à pompe/Forage...................................... 21 Puit creusé Puit protégé .... 31 Puit non protégé.. 32 Eau de source Source protégée .... 41 Source non protégée .... 42 Eau de pluie .... 51 Camion-citerne... 61 Charrette avec petite citerne/tonneau .... 71 Eau de surface (rivière, ruisseau, barrage, lac, mare, canal,canal d'irrigation) .... 81 Eau en bouteille……………………………….91 Eau en sachet .... 92 Autre (*préciser*) 96	
WS3.	Quel type de toilettes les membres de votre ménage utilisent-ils habituellement ? **Si c'est "chasse d'eau" ou "Chasse d'eau manuelle", demander:** Où est elle connectée? **S'il n'est pas possible de déterminer le type de toilettes, demandez la permission de voir l'installation.**	Chasse d'eau / Chasse d'eau Manuelle Chasse d'eau connectée à un système d'égout.................................. 11 à une fosse septique.................................... 12 à une fosse d'aisance .... 13 à quelque chose d'autre.............................. 14 à un lieu inconnu / pas sûr / ne sait pas où.. 15 Fosse d'aisances Fosse d'aisances améliorée ventilée........... 21 Fosse d'aisances avec dalle......................... 22 Fosse d'aisances sans dalle /trou ouvert...... 23 Toilettes à compostage .... 31 Seau/Tinette... 41 Toilettes/latrines suspendues........................... 51 Pas de toilettes ou nature ou champs .... 61 Autre (*préciser*) ________________________ 96	 → OH1
WS4.	Partagez-vous ces toilettes avec d'autres ménages ?	Oui.. 1 Non... 2	

OBSERVATIONS SUR LE QUESTIONNAIRE MENAGE (OH)

OH1	LANGUE DE L'ENTRETIEN	Français .... 1 Mooré .... 2 Dioula .... 3 Peulh/Fulfuldé .... 4 Gourounsi............ 5 Autre langue (préciser)............ 6
OH2	UN TRADUCTEUR A-T-IL ÉTÉ UTILISÉ POUR TOUTE OU UNE PARTIE QUELCONQUE DE CE QUESTIONNAIRE?	Oui, questionnaire complet … .... 1 Oui, une partie du questionnaire … .... 2 Non, pas utilisé … 3
OH3	POUR ENQUETEUR/TRICE : Enregistrez tous les commentaires ou observations concernant cet entretien:	
OH4	POUR LE SUPERVISEUR / L'EDITEUR: Notez tous les commentaires ou observations pour cet entretien :	

REMERCIER L'ENQUETE(E)
FIN DU QUESTIONNAIRE MENAGE

QUESTIONNAIRE DE LA FEMME

PANEL D'INFORMATION SUR LES FEMMES (WM)

Ce questionnaire doit être administré à toutes les femmes âgées de 15 à 49 ans (voir HL7A).
Remplissez un questionnaire pour chaque femme éligible.

WM1. Nom et numéro de la région: Centre...... Centre-Ouest......2	WM2. Nom et numéro de la province : Kadiogo......1 Boulkiemdé......2
WM2a. Nom et numéro de la commune/arrondissement de résidence .... ___ ___ ___	WM2b. Nom et numéro du secteur/village de résidence .... ___ ___ ___
WM3. Numéro de la grappe : .... ___ ___ ___	WM4. Numéro du ménage : ___ ___
WM5. Nom de la femme : ______________________	WM6. Numéro de ligne de la femme : ___ ___

WM7. Quel âge a NOM en années : ___ ___
(posez la question)

WM8. La femme est-elle mariée ?
Oui......1
Non......2

Si la femme a entre 15 et 17 ans et est célibataire, lisez le texte de la permission adressé à la mère, au père ou au tuteur de la femme, ainsi que le texte d'assentiment à la femme. Vous DEVEZ obtenir la permission du parent / tuteur ETl'assentiment de la femme avant de poursuivre

Si la femme est mariée ou est célibataire et âgée de plus de 17 ans, lisez-lui le script de consentement de la femme. Vous DEVEZ obtenir le consentement de la femme avant de poursuivre

OUI, AUTORISATION ACCORDÉE → Module d'information sur les femmes

NON, PERMISSION NON DONNÉE → Codes des résultats

Visite 1	Visite 2	Visite 3	Visite Final
Date : __ __/__ __/__ __ Nom de l'intervieweur : ____________ N° de l'Intervieweur __ __ Résultat : ___	**Date :** __ __/__ __/__ __ Nom de l'intervieweur : ____________ N° de l'Intervieweur __ __ Résultat : ___	**Date :** __ __/__ __/__ __ Nom de l'intervieweur : ____________ N° de l'Intervieweur __ __ Résultat : ___	**Date :** __ __/__ __/__ __ Nom de l'intervieweur : ____________ N° de l'Intervieweur __ __ Résultat : ___
Prochainevisite Date : __ __ /__ __/__ __ **Heure :** ____________	**Prochainevisite Date :** __ __ /__ __/__ __ **Heure :** ____________		Nombre total de visites : ____

WM9. Codes de résultat : 1 = Complété 2 = Pas à la maison 3 = Non compétente	4 = Différé 5 = Refusé 6 = Pas à la maison pendant une période prolongée 7 = Partiellementterminé 9 = Autre (précisez): ______________________

WM10. Heure au début de l'entretien	__ __ hr __ __ min
WM11. Heure à la fin de l'entretien	__ __ hr __ __ min

MODULE D'INFORMATION DE LA FEMME (WI)

WI1.	En quel mois et en quelle année êtes-vous née ?	Mois.......... __ __ Ne sait pas le mois.......... 98 Année .... __ __ __ __ Ne sait pas l'année..........9998	
WI2.	Quel âge aviez-vous à votre dernier anniversaire ? **<u>Comparez et corrigez WI1 et WI2 si incohérentes</u>**	Années révolues .... ____ ____	
WI3.	Êtes-vous présentement ou avez-vous déjà fréquenté une école ?	Oui, je fréquente actuellement .... 1 Oui, j'ai déjà fréquenté .... 2 Non, jamais fréquenté 3	→WI5c
WI4.	Quel est le plus haut niveau de scolarité que vous avez atteint ?	Primaire.......... 1 Post-primaire/Secondaire (1st cycle) .... 2 Secondaire (2nd cycle).......... 3 Supérieur / Université.......... 4	
WI5.	Combien d'années avez-vous réussi à teminer à ce niveau ?	Année(s).......... __ __ Ne sait pas 98	
WI5c. Pour l'interviewer : Vérifiez WI4 : **Fréquente actuellement au niveau secondaire ou au supérieur →WI7** **Jamais allé à l'école ou à fréquenté l'école primaire →WI6**			
WI6.	J'aimerais maintenant que vous me lisez cette phrase. Lisez autant que vous le pouvez. **Montrer la carte avec la phrase au répondant. Si la répondante ne peut pas lire la phrase entière, demandez :** Pouvez-vous me lire une partie de la phrase ?	Ne peut pas lire du tout.......... 1 Capable de ne lire que des parties de la phrase .... 2 Capable de lire la phrase entière .... 3 Aucune phrase dans la langue..........4 Aveugle ou malvoyante.......... 6	
WI7.	Quelle est votre religion ?	Catholique.......... 1 Protestant.......... 2 Musulmane.......... 3 Traditionnelle/Animiste.......... 4 Autre religion (Préciser).......... 5	

		Sans religion/Aucune 6	
WI8.	A quel groupe ethnique appartenez-vous ?	Bobo .... 01 Dioula .... 02 Fulfulde/Peulh .... 03 Gourmantche .... 04 Gourounsi.. 05 Lobi .... 06 Mossi.. 07 Senoufo.. 08 Touareg/Bella.. 09 Dagara .... 10 Bissa .... 11 Autre CEDEAO .... 21 Autre pays africain .... 22 Autre nationalité .... 23 Autre ethnie (préciser).. 96 Ne sait pas 98	

MODULE DE FERTILITÉ (FE)

FE1.	Avez-vous déjà donné naissance ? **Si «non», demandez :** Je parle d'un enfant qui a déjà respiré, pleuré ou montré d'autres signes de vie, même s'il n'a vécu que quelques minutes ou quelques heures ? *Ce module ne devrait inclure que les enfants nés vivants. Les morts nés ne doivent pas être inclus en réponse à une question.*	Oui ....1 Non 2	 →FP1
FE2.	Quels sont le mois et l'année de votre première naissance ? Je veux dire la première fois que vous avez accouché, même si l'enfant n'est plus en vie, ne vit plus avec vous ou si son père n'est pas votre conjoint / partenaire actuel. **Si la répondante ne connaît pas la date exacte, demandez-luid'estimer le mois et l'année**	Date de la première naissance vivante Mois .... __ __ Année ....__ __ __ __	

FE3.	Quels ont été le mois et l'année de votre naissance la plus récente ? Je veux dire la dernière fois que vous avez accouché, même si l'enfant n'est plus en vie, ne vit plus avec vous ou dont le père n'est pas votre partenaire actuel. **Si la répondante ne connaît pas la date exacte, demandez-lui d'estimer le mois et l'année**	Date de la dernière naissance vivante Mois .... __ __ Année .... __ __ __ __	
FE4.	Quel est le nom de cet enfant ? **Enregistrer le nom. Si l'enfant est décédé avant d'avoir été nommé, écrivez «BÉBÉ».**	______________________	
FE5.	Est-ce que (NOM) est un garçon ou une fille ?	Garçon .... 1 Fille 2	

Ces questions doivent être posées à toutes les femmes ayant eu une naissance vivante au cours des deux années précédant la date de l'entretien. Pour les femmes ayant plus d'une naissance vivante au cours des deux années précédant l'enquête, les questions se rapportent uniquement à la naissance vivante la plus récente.

Pour l'intervieweur : Vérifiez FE3. La naissance vivante est-elle survenue après le [JJ / MM / AAAA-2 DE L'INTERVIEW] ?

Oui .... 1→Continuez jusqu'à CB1. Toutes les questions se rapportent à (NOM) à partir de FE4. Utilisez le nom de cet enfant dans les questions suivantes, le cas échéant. Si l'enfant est décédé avant d'être bâptisé, utilisez 'VOTRE BÉBÉ' à la place de (NOM)

Non .... 2→FP1

MODULE ANTENATAL ET ENFANT (CB)

Maintenant, je veux vous demander votre expérience pendant que vous étiez enceinte de (NOM)

CB1.	Pendant que vous étiez enceinte de (NOM), avez-vous vu quelqu'un pour des soins prénatals ?	Oui .... 1 Non .... 2 Ne sait pas 8	**→CB1b**
CB1a	Diriez-vous que le fait de ne pas aller aux soins prénatals était principalement votre décision, principalement celle de votre (mari / partenaire), ou avez-vous décidé tous les deux ensemble ?	Répondant .... 1 Mari / partenaire .... 2 Répondant et mari / partenaire conjointement .... 3 Famille / parent .... 4 Répondant et famille / parent conjointement .... 5 Quelqu'un d'autre .... 6 Répondant et quelqu'un d'autre conjointement 7	**→CB4** **→CB4** **→CB4** **→CB4** **→CB4** **→CB4** **→CB4**

CB1b.	Qui avez-vous vu ? **Demandez : "Quelqu'un d'autre ?»** **Notez toutes les réponses. Explorer pour déterminer le type de personne.**	**PERSONNEL DE SANTÉ** Médecin....A Attaché de santé....B Infirmier/ère....C Sage-femme....D Accoucheuse auxiliaire....E Matrone/accouheuse formée....F Agent auxiliaire de santé....G Autre (préciser) ________W **AUTRES PERSONNES** Accoucheuse traditionnelle....K Agent de Santé Communautaire/Village....L Autre (préciser) ________X Ne sait pas....Z	
CB2a.	Votre mari / partenaire vous a-t-il accompagné lors de visites de soins prénatals au cours de cette grossesse ?	Oui....1 Non....2 Répondant n'avait pas de mari / partenaire....3	 **→CB2ba** **→CB2c**
CB2ab	Votre mari / partenaire a-t-il été autorisé dans la chambre / l'espace pendant les visites de soins prénatals au cours de cette grossesse ?	Oui....1 Non....2 Ne sait pas....8	 **→CB2ba** **→CB2ba**
CB2b.	Votre mari / partenaire était-il présent dans la pièce ou dans un autre espace lors de votre consultation de soins prénatals ?	Oui....1 Non....2 Ne sait pas....8	**→CB2c**
CB2ba	Auriez-vous souhaité que votre mari / partenaire soit présent dans la pièce ou dans un autre espace lors de votre consultation de soins prénatals ?	Oui....1 Non....2 Ne sait pas....8	
CB2c	Diriez-vous que les soins prénatals ont été principalement votre décision, principalement celle de votre (mari/partenaire), ou avez-vous décidé tous les deux ensemble ?	Répondant....1 Mari/Partenaire....2 Répondant et mari / partenaire conjointement....3 Famille / parent....4 Répondant et famille / parent conjointement....5 Quelqu'un d'autre....6 Répondent et quelqu'un d'autre conjointement....7	
CB3.	Combien de fois avez-vous reçu des soins prénatals lorsque vous étiez enceinte de (NOM) ?	Nombre de fois : __ __ Ne sait pas....98	

CB4.	Pendant votre grossesse de (NOM), avez-vous pris un médicament pour vous empêcher d'avoir le paludisme ?	Oui ... 1 Non ... 2 Ne sait pas ... 8	 **→CB13** **→CB13**
CB5.	Quels médicaments avez-vous pris pour prévenir le paludisme ? **Noter tous les médicaments pris. Si le type de médicament n'est pas déterminé, montrez l'antipaludéen typique au répondant.**	SP / Fansidar ... A Chloroquine ... B Amodiaquine/flavoquine ... C Quinine ... D Artenusate-amodiaquine ... E Artemeter-lumefantrine ... F Médicament traditionnelle ... G Autre (*préciser*) ... X Ne sait pas ... Z	
Pour l'intervieweur : Vérifiez CB5 pour le médicament pris. A-t-elle pris SP / Fansidar (A) ? **Oui→ CB6** **Non → CB13**			
CB6.	Pendant votre grossesse avec (NOM), combien de fois avez-vous pris SP / Fansidar au total ?	Nombre de fois ... __ __ Ne sait pas ... 98	
CB6a.	Avez-vous reçu le SP / Fansidar lors d'une visite de soins prénatals, d'une autre visite dans un établissement de santé ou d'une autre source ? **NOTEZ TOUTES LES REPONSES.**	Visite prénatale ... A Une autre visite au centre de santé ... B Autre source (préciser) ... C	
CB13.	Pendant que vous étiez enceinte de (NOM), vous a-t-on donné ou avez-vous acheté des comprimés de fer ou du fer en sirop ? **Montrer les comprimés de fer ou le sirop au répondant**	Oui ... 1 Non ... 2 Ne sait pas ... 8	 →CB15 →CB15
CB14	Durant toute la grossesse, pendant combien de jours avez-vous pris des comprimés ou du sirop contenant du fer? **Si la réponse n'est pas numérique, insistez pour obtenir un nombre de jours**	Jours:__ __ __ __ Ne sait pas……998	
J'aimerais maintenant vous poser une question sur le moment où vous avez donné naissance à (NOM)			

CB15.	Où avez-vous donné naissance à (NOM) ? **Une seule réponse autorisée. Sondez pour identifier le type de source.** **Si un hôpital, un centre de santé ou une clinique, inscrivez le nom du lieu ci-dessous :** ____________________ (Nom du lieu)	**DOMICILE** Son domicile....................11 Autre domicile ....12 En route pour l'hôpital ....13 **SECTEUR PUBLIC** Centre hospitalier /CHU/CHR....................21 Centre médical (avec antenne chirurgicale) /CMA/CM public ....22 Centre de santé et de promotion sociale /CSPS ....23 Dispensaire/Maternité publique....................24 Poste d'agent de terrain/d'agent de santé communautaire25 Autre secteur public (préciser) ....26 **SECTEUR PRIVE** Centre médical (avec antenne chirurgicale) /CMA/CM privé ....31 Dispensaire/Maternité privée....................32 Clinique/Polyclinique ....33 Poste d'agent de terrain/d'agent de santé communautaire ....34 Autre secteur médical privé *(préciser)*....................36 Autre (préciser) 96	
CB16.	Qui vous a assisté à la naissance de (NOM) ? **Demandez :** "Quelqu'un d'autre ?" **Notez toutes les réponses. Explorer pour déterminer le type de personne. Si le répondant dit que personne ne l'a aidé, demandez-lui si un adulte était présent.**	**PERSONNEL DE SANTÉ** Médecin....................A Attaché de santé....................B Infirmier/ère ....C Sage-femme....................D Accoucheuse auxiliaire....................E Matrone/accouheuse formée ....F Agent auxiliaire de santé ....G Autre (préciser)....................W **AUTRES PERSONNES** Accoucheuse traditionnelle....................K Agent de Santé Communautaire/Village....................L Parent/ami ....M Autre (préciser) ....X Personne n'a assisté....................Y Ne sait pas....................Z	

Pour l'interviewer : Vérifiez CB15. La naissance a-t-elle eu lieu en route pour ou dans un établissement de santé (CB15 est 13, 21-36) ?

OUI, dans un établissement de santé (CB15 est 21-36)-> Passer à CB17

OUI, en route (CB15 est 13) -> Continuer à CB17a

Non - > Passer à CB17d

CB17.	Est-ce que (NOM) a été accouché par césarienne ? C'est-à-dire, vous ont-ils ouvert le ventre pour sortir le bébé ?	Oui .... 1 Non 2	
CB17a.	Votre mari / partenaire était-il avec vous lorsque vous avez accouché (NOM) ?	Oui .... 1 Non .... 2 Répondant n'avait pas de mari / partenaire 3	 **→CB17ba** **→CB17c**
CB17ab	Votre mari / partenaire était-il autorisé dans la chambre lors de l'accouchement de (NOM) ?	Oui .... 1 Non .... 2 Ne sait pas 8	 **→CB17ba** **→CB17ba**
CB17b.	Votre mari / partenaire était-il présent dans la salle d'accouchement pendant le travail ou l'accouchement ?	Oui .... 1 Non .... 2 Ne sait pas 8	**→CB17c**
CB17ba	Auriez-vous souhaité que votre mari / partenaire soit présent dans la salle d'accouchement pendant le travail ou l'accouchement ?	Oui .... 1 Non .... 2 Ne sait pas 8	
CB17c.	Diriez-vous que l'accouchement dans un établissement de santé a été principalement votre décision, principalement celle de votre (mari / partenaire), ou avez-vous décidé tous les deux ensemble ?	Répondante .... 1 Mari/partenaire .... 2 Répondante et mari / partenaire conjointement .... 3 Famille / parent .... 4 Répondant et famille / parent conjointement .... 5 Quelqu'un d'autre .... 6 Répondante et quelqu'un d'autre conjointement 7	**→CB18** **→CB18** **→CB18** **→CB18** **→CB18** **→CB18** **→CB18**
CB17d	Diriez-vous que ne pas accoucher dans un établissement de santé était principalement votre décision, principalement la décision de votre (mari / partenaire), ou avez-vous décidé tous les deux ensemble ?	Répondante .... 1 Mari/partenaire .... 2 Répondante et mari / partenaire conjointement .... 3 Famille / parent .... 4 Répondant et famille / parent conjointement .... 5 Quelqu'un d'autre .... 6 Répondante et quelqu'un d'autre conjointement 7	

CB18.	Est-ce que (NOM) a déjà été allaité ?	Oui .... 1 Non 2	
CB22.	Est-ce que quelque chose a été appliquée sur le cordon ombilical après sa coupure ? **Demandez :** «Quelque chose a-t-il été appliqué sur le moignon du cordon ombilical avant sa séparation?»	Oui .... 1 Non .... 2 Ne sait pas 8	 **→FP1** **→FP1**
CB23.	Qu'est-ce qui a été appliqué ? **Demandez :** « Quelque chose d'autre ?» **Noter toutes les réponses**	Beurre .... A Huile .... B Cendre .... D Boue .... E Bouse .... F Lait maternel .... G Salive .... H Herbes/Epices .... I Alcool .... J Antiseptique .... K Chlorhexidine (Hibitane) .... L Indéterminé .... X Autre (*préciser*) .... Z	

MODULE DE PLANIFICATION FAMILIALE (PF)

FP1.	Êtes-vous actuellement mariée ou vivez-vous avec un homme comme si vous étiez marié ?	Oui, actuellement marié ....1 Oui, vit avec un homme ....2 Non, pas en union..3	
FP2.	Avez-vous été mariée ou vécu avec un homme seulement une fois ou plus d'une fois ?	Juste une fois .... 1 Plus d'une fois.. 2 Jamais marié ou vécu avec un homme 3	→FP4
FP3.	J'aimerais maintenant poser des questions sur votre (premier) (mari / partenaire). En quel mois et en quelle année avez-vous commencé à vivre avec lui ?	Mois .... ___ ___ Ne connait pas le mois..98 Année .... ___ ___ ___ ___ Ne connait pas l'année 9998	
FP4.	VÉRIFIEZ LA PRÉSENCE D'AUTRES PERSONNES. AVANT DE CONTINUER, FAITES TOUT EFFORT POUR ASSURER LA CONFIDENTIALITÉ.		
FP12.	Êtes-vous actuellement enceinte?	Oui .... 1 Non ....2 Ne sait pas 8	→FP15 →FP15
FP13.	Quand vous êtes tombée enceinte, vouliez-vous êtes enceinte à ce moment-là?	Oui..1 Non 2	→FP15
FP14.	Vouliez-vous avoir un enfant plus tard ou vous ne vouliez pas (plus) d'enfants?	Plus tard..1 Non plus//Aucun..2	→Module suivant →Module suivant
FP15.	Quand est-ce que vos dernières règles ont-elles commencé? **(Noter la date, si donnée)** **Mois** __ __ **Année** __ __ __ __	Il y a des jours ....1 .___ ___ Il y a des semaines ....2 .___ ___ Il y a des mois ....3 .___ ___ Il y a des années ....4 .___ ___ En ménopause / a eu une hystérectomie..................994 Avant la dernière naissance..995 Jamais eu de régles.. 996	→Module suivant →Module suivant
FP16.	Est-ce que vous ou votre partenaire faites actuellement quelque chose ou utilisez une méthode quelconque pour retarder ou éviter une grossesse ?	Oui..1 Non 2	→FP18

FP17.	Avez-vous déjà fait quelque chose ou utilisé une méthode quelconque pour retarder ou éviter de devenir enceinte ?	Oui .... 1 Non 2	**→FP20** **→FP20**
FP18.	Que faites-vous pour retarder ou éviter une grossesse ? **Ne pas demander. Notez toutes les réponses**.	Stérilisation féminine .... A Stérilisation masculine .... B DIU .... C Injectables .... D Implants .... E Pilule .... F Préservatif masculin .... G Préservatif féminin .... H Diaphragme .... I Mousse / Gelée .... J Aménorrhée Lactationnelle méthode (ALM) .... K Abstinence périodique / rythme .... L Retrait .... M Autre (préciser) X	
FP19.	Diriez-vous que l'utilisation de la contraception est principalement votre décision, principalement la décision de votre (mari / partenaire), ou avez-vous décidé tous les deux ensemble ?	Principalement le répondant .... 1 Principalement mari / partenaire .... 2 Décision commune .... 3 Autre (préciser) 6	**→FP21** **→FP21** **→FP21** **→FP21**
FP20.	Diriez-vous que le choix de ne pas utiliser la contraception est principalement votre décision, principalement la décision de votre (mari / partenaire), ou avez-vous décidé tous les deux ensemble ?	Principalement le répondant .... 1 Principalement mari / partenaire .... 2 Décision commune .... 3 Autre (préciser) 6	
FP21. Ces questions doivent être posées aux femmes non enceintes ayant une naissance vivante au cours des deux années précédant la date de l'entretien. **Pour l'interviewer : Vérifiez FE3. La naissance vivante la plus récente est-elle survenue après le [JJ / MM / AAAA-2 DE L'INTERVIEW] ?** **Oui..........................1 → Passer à FP22. Toutes les questions se rapportent à (NOM) à partir de FE4. Utilisez le nom de cet enfant dans les questions suivantes, le cas échéant. Si l'enfant est décédé avant son nom, utilisez 'VOTRE BÉBÉ' à la place de (NOM)** **Non.................................2 → Passer à FP25.**			
FP22.	Quand vous êtes tombée enceinte de (NOM), vouliez-vous être enceinte à ce moment-là?	Oui .... 1 Non 2	**→ FP24**
FP23.	Vouliez-vous avoir un enfant au plus tard ou vous ne vouliez pas (plus) d'enfantà ce moment-là?	Plus tard .... 1 Pas d'autre/aucun 2	

FP24.	Vos règles sont-elles revenues depuis la naissance de (NOM)?	Oui ....1 Non 2	 **→Module suivant**
FP25.	Je voudrais maintenant poser des questions sur l'avenir. Voudriez-vous avoir (un/un autre) enfant ou préféreriez-vous ne pas (plus) avoir d'enfant?	Avoir un (ou plus) enfant ....1 Pas d'autre/aucun ....2 Dit qu'elle ne peut pas tomber enceinte ....3 Indécise/Ne sait pas 8	 **→Module suivant** **→Module suivant** **→Module suivant**
FP26.	Combien de temps voudriez-vous attendre à partir de maitenant avant la naissance d'un (autre) enfant ?	Mois ....1 .___ ___ Années ....2 .___ ___ Bientôt / Maintenant ....993 Dit qu'elle ne peut pas tomber enceinte ....994 Après le marriage ....995 Autre (Précisez) ______________________ ......996 Ne sait pas 998	

TRAVAIL ET PRISE DE DECISION (DM)

DM1.	Maintenant, je veux vous poser des questions sur votre activité au cours des sept derniers jours. Mis à part vos tâches ménagères, avez-vous effectué des travaux au cours des sept derniers jours ?	Oui……………………1 Non……………………2	**→DM4**
DM2.	Comme vous le savez, certaines femmes occupent des emplois pour lesquels elles sont rémunérées en espèces ou en nature. D'autres vendent des choses, ont une petite entreprise ou travaillent dans la ferme familiale ou dans l'entreprise familiale. Au cours des sept derniers jours, avez-vous fait l'une de ces choses ou un autre travail ?	Oui……………………1 Non……………………2	**→DM4**
DM3.	Avez-vous effectué des travaux au cours des 12 derniers mois ?	Oui……………………1 Non……………………2	 **→DM5**
DM4.	Êtes-vous payé en espèces ou en nature pour ce travail ou n'êtes-vous pas payé du tout ?	Argent comptant seulement……………1 Argent et nature……………2 En nature seulement……………3 Non payé……………4	

DM5.	Avez-vous de l'argent dont vous seul pouvez décider de l'utilisation ?	Oui………………………………………………1 Non………………………………………………2	→DM7
DM6.	Qui décide comment votre propre argent sera utilisé ? *Notez que cette question inclut toutes les formes de revenu que le répondant peut avoir, y compris l'argent gagné du travail rémunéré et / ou d'autres sources de revenu.* **Notez toutes les réponses.**	Répondante .... A Mari/partenaire.................................... B Mère .... C Père .... D Belle-mère .... E Beau-père .... .F Soeur .... G Frère .... H Fille ....I Fils ....J Ancien mari / partenaire..................... K Copain actuel......................................L Ancien petit ami ....M Belle-mère .... N Beau-père ....O Autre membre feminin de la famille / belle-famille .... P Autre membre masculin de la famille / belle-famille ....Q Amie / Connaissance féminine .... R Ami / Connaissancemasculine......................... S Employeur.. T Autre (préciser) ...... ____________________ X Le répondant n'a pas d'argent .... Z	
DM7.	Avez-vous un compte bancaire ou un compte dans une autre institution d'épargne en votre nom ou conjointement avec quelqu'un d'autre ? **ENREGISTRER TOUT CE QUI EST MENTIONNE.**	Oui, en nom propre ....A Oui, compte commun...........................B Non C	 →DM10
DM8.	Est-ce que vous gerer vous-même le compte, c'est-à-dire signez des chèques ou déposez et retirez de l'argent ?	Oui………………………………………………1 Non ………………………………………………2	
DM10.	Avez-vous un compte mobile (comme OrangeMoney ; MobiCash ; CorisMoney, etc) ?	Oui………………………………………………1 Non ………………………………………………2	
DM11.	**Pour l'intervieweur : Vérifiez FP1. La femme est-elle actuellement mariée ou vit-elle avec un homme ?** **Oui .... 1→ Passez à DM12** **Non .... 2→ Passez à DM15**		

DM12.	Votre (mari / partenaire) a-t-il effectué un travail au cours des 7 derniers jours ?	Oui ……………………………………………….1 Non ………………………………………………..2 Ne sait pas ……………………………………..8	
DM14.	Qui décide habituellement de la manière dont les revenus de votre (mari / partenaire) seront utilisés : vous, votre (mari / partenaire), ou vous et votre (mari / partenaire) conjointement ?	Répondante ……………………………………1 Mari/partenaire ………………………………..2 Répondant et mari / partenaire conjointement …3 Le mari / partenaire n'a aucun revenu …………..4 Autre (préciser) _______________________6	
DM15.	Qui prend habituellement des décisions concernant les soins de santé pour vous-même : vous (votre mari / partenaire), vous et votre (mari / partenaire) conjointement, votre famille / parent, vous et votre famille / parent conjointement, une autre personne, ou vous et une autre personne conjointement ?	Répondante ………………………………………1 Mari/partenaire ………………………………..2 Répondant et mari / partenaire conjointement….3 Famille/parent ……………………………………..4 Répondante et famille/parent conjointement…….5 Quelqu'un d'autre …………………………………6 Répondante et quelqu'un autre conjointement …7	
DM16.	Êtes-vous généralement autorisée à vous rendre seule aux endroits suivants, uniquement si quelqu'un vous accompagne ou pas du tout ?		

			Seule	Jamais Seule	Non pas du tout
	Au marché local pour acheter des choses ?	Marché	1	2	3
	À un centre de santé local ou chezun médecin ?	Cenre de santé	1	2	3
	Au centre communautaire ou àun autre lieu de rencontre à proximité ?	Centre communautaire	1	2	3
	Aux domicilesd'ami(e)s dans le quartier ?	Domiciles ami(e)s	1	2	3
	À un lieu de culte / mosquée / temple / église proche ?	Lieu de culte	1	2	3
	Juste à l'extérieur de votre maison ou de votre propriété?	En dehors de la maison	1	2	3

			OUI	NON
DM20.	**Pour l'intervieweur : PRÉSENCE D'AUTRES SUR CE POINT**	Femmes adultes	1	2
		Mari/partenaire	1	2
		Autres hommes adultes	1	2
		Enfants <10 ans	1	2

OBSERVATIONS SUR LE QUESTIONNAIRE FEMME (OW)

OW1.	Langue de l'entretien ?	Français ……… 1 Mooré……… 2 Dioula ……… 3 Peulh/Fulfuldé……… 4 Gourounsi ……… 5 Autre langue (préciser)……… 6

OW2.	Un traducteur at-il été utilisé pour une partie de ce questionnaire ?	Oui, tout le questionnaire .... 1 Oui, une partie du questionnaire .... 2 Non, pas utilisé 3
OW3.	POUR INTERVIEWEUR : Enregistrez tous les commentaires ou observations concernant cet entretien :	
OW4.	POUR LE/LA SUPERVISEUR : Notez tous les commentaires ou observations pour cet entretien :	

JE VOUS REMERCIE

FIN DU QUESTIONNAIRE FEMME

Appendix B. Guidance used for identifying potentially residential structures under GIS sampling method

The general guidance to identify a potentially residential structure varied by geography. In the urban EAs, structures that had regular polygon shapes such as rectangles, of an adequate size (larger than vehicles) were considered potentially residential. In the rural EAs, many residential structures do not have regular polygon shapes such as rectangles, but generations of families cluster together in compounds (concessions) which have wide fields separating one group of families from their neighbors. Irregularly shaped or unusually sized structures were landmarks such as marketplaces, places of worship, schools, football fields and served as reference points. The irregular shapes and varied spacing of structures across the three different geographies made manual digitization preferable than automated digitization to ensure that the methodology used was similar in both urban and rural areas. Supplementary Table S1 shows the survey response categorized by the geographic sub-strata classifications by the survey sampling methods.

Supplementary Table S1. Survey response by conventional and GIS sampling methods and geographic types of the clusters

Geography	**Sampling methods**							
Urban blocks	STANDARD		GIS		TOTAL			
Survey response	N	%	N	%	N	%	Pearson chi2	p-value
present	652	90.7	657	90	1,309	90.3	5.26	0.07
absent	53	7.4	45	6.2	98	6.8		
refused	14	2.0	28	3.8	42	2.9		
Total	719	100	730	100	1,449	100		
Urban slums								
present	262	94.9	255	92.1	517	93.5	4.22	0.12

absent	11	4.0	21	7.6	32	5.8		
refused	3	1.1	1	0.4	4	0.7		
Total	276	100	277	100	553	100		
Urban slums under construction								
present	200	94.3	157	92.9	357	93.7	0.33	0.848
absent	11	5.2	11	6.5	22	5.8		
refused	1	0.5	1	0.6	2	0.5		
Total	212	100	169	100	381	100		
Urban blocks under construction								
present	259	92.8	248	91.5	507	92.2	1.12	0.57
absent	17	6.1	17	6.3	34	6.2		
refused	3	1.1	6	2.2	9	1.6		
Total	279	100	271	100	550	100		
Rural villages								
present	1,281	97.6	1,304	97.4	2,585	97.4	0.40	0.82
absent	31	2.4	34	2.5	65	2.5		
refused	1	0.1	2	0.2	3	0.1		
Total	1,313	100	1,340	100	2,653	100		
Rural towns								
present	166	94.3	131	93.6	297	94.0	0.08	0.781
absent	10	5.7	9	6.4	19	6.0		
refused	0	0	0	0	0	0		
Total	176	100	140	100	316	100		
Present comprised those who accepted to participate, absent were those who were not living at their residences during the period of the survey and refused were those who did not consent to participate.								

Comparing the standard sampling method and the GIS sampling method yielded similar survey responses across the different cluster types after accounting for clustering. In the urban blocks, 90.7% of the survey respondents were present and gave consent in the standard method while 90% were present and accepted the survey in the GIS method. In the urban slums, survey participation was 94.9% in the standard method and 92.1% in the GIS method. In the rural villages, survey participation was 97.6% in the standard method and 97.3% in the GIS method. In urban slums, the GIS method had twice higher absent responses (7.6%), and it had twice the refusals compared to the standard method in the urban blocks (3.8%). At a p-value of 0.05, Pearson chi-square tests indicated there were no statistically significant differences in the two methods.

Appendix C. Sample size calculation

Survey cluster and household estimation using probability proportional to (estimated) size method.

Within each stratum, 75 EAs were selected from each of the two provinces with a known probability of selection using probability proportional to (estimated) size (PPES), *Pjs*. The same primary sampling units (EAs) were used for both the GIS and conventional sampling methods. The probability of selecting a cluster *j* within a stratum *s* in the conventional method is shown in Equation 1.

Equation 1. Probability of selecting a cluster within a stratum under conventional sampling

$$P_{js} = \frac{number\ of\ households\ in\ cluster\ j\ in\ sampling\ frame * number\ of\ clusters\ to\ be\ selected\ in\ stratum}{total\ number\ of\ households\ \ in\ the\ sampling\ frame}$$

for GIS method, P_{js} =

Equation 2. Probability of selecting a cluster within a stratum under GIS sampling

$$\frac{number\ of\ buildings\ in\ cluster\ j\ in\ sampling\ frame *\ number\ of\ clusters\ to\ be\ selected\ in\ stratum}{total\ number\ of\ buildings\ \ in\ the\ sampling\ frame}$$

In the second stage of sampling, for the conventional method, systematic sampling of households was done by calculating the sampling interval, ***k***, by dividing the total number of households to be sampled by the total number of households listed in the sampling frame that was created during the field mapping and enumeration phase. The probability of selecting households in cluster *j*, P_{hhj}:

Equation 3. Probability of selecting households within a cluster under conventional sampling

$$P_{hhj} = \frac{number\ of\ households\ to\ sample\ in\ cluster\ j}{total\ number\ of\ households\ listed\ in\ cluster\ j\ during\ the\ mapping\ and\ enumeration}$$

The probability of selecting a household, $P_{hh} = P_{js} * P_{hhj}$

In the second stage of sampling, for the GIS method, an approximate probability of selection was estimated using the number of potentially residential buildings enumerated during the digital mapping and enumeration of satellite images as a proxy for households. This was logical because for both methods one of the main assumptions of the survey was that only one household would be interviewed in a building. The probability of selecting households in cluster *j*, P_{hhj}:

Equation 4. Probability of selecting households within a cluster under conventional sampling

$$P_{hhj} = \frac{number\ of\ buildings\ to\ sample\ in\ cluster\ j}{total\ number\ of\ buildings\ listed\ in\ cluster\ j\ during\ the\ mapping\ and\ enumeration}$$

The probability of selecting a household, $P_{hh} = P_{js} * P_{hhj}$

For both methods, all eligible women in the household were interviewed.

Equation 5. Formula to determine the sample size for the target population size was modified to account for design effect and non-response:

$$n = deff * Z_{\left(\frac{\alpha}{2}\right)}^{2} * \frac{p\,(1-p)}{d^2} * \frac{1}{1-r}$$

Equation 6: Calculating household conversion factor, ***h***
$h = \frac{number\ of\ women\ 15-49\ in\ the\ last\ BFDHS}{total\ number\ of\ households\ interviewed\ in\ the\ last\ BFDHS}$

Equation 7: Converting target population to the number of households
$N = \frac{n}{h}$
Where: n = number of individuals in the denominator of the coverage rate h = average number of target population per household N = number of households

Appendix D: Key Informant Interview Guide

Entretien avec des informateurs clés pour évaluer la faisabilité de l'utilisation de la méthode SIG pour une enquête auprès des ménages
Guide d'entretien

Introduction

Merci de participer à cet entretien.

Nous aimerions comprendre votre point de vue et vos pensées sur la nouvelle méthode SIG que vous avez mise en œuvre dans le cadre de l'étude d'échantillonnage RADAR, car nous voulons tirer parti de vos expériences. SVP, Soyez aussi franc que possible en répondant aux questions. Il n'y a pas de bonnes ou de mauvaises réponses. L' entrevue durera 30 à 45 minutes . Je vais utiliser un appareil d'enregistrement pour enregistrer l'entrevue afin qu'il puisse être transcrit et traduit par la suite.

Vous n'êtes soumis à aucune obligation de participer; vous arrêter l'entretien à tout moment si vous vous sentez mal à l'aise avec les questions sans conséquences pour votre participation continue à l'enquête. Vous pouvez contacter le Dr Idrissa Ouili , le PI local, pour toute question ou préoccupation que vous pourriez avoir.

Est-ce qu'on a votre consentement pour commencer ?

Pour commencer, je vais poser certaines questions et attendre votre reponse.

Des questions

1. Pour quelle structure travaillez-vous? (Pour les superviseurs uniquement)
2. Quel est votre rôle dans cette étude? (Collecteur de données sur le terrain, chef d'équipe, assistant de recherche, assistant de saisi, superviseur)
3. Quelle étape de la méthode SIG avez-vous mise en œuvre ?
    a. Étape 1 - création des limites des zones de dénombrement (ZD) et numérisation des structures résidentielles potentielles utilisées pour l'étude
    b. Étape 2 - Collecte des données sur le terrain: identification des structures sélectionnées sur le terrain avant de commencer l' entretien
4. Décrivez votre expérience. (Sondes: par cela, je veux dire quelles tâches spécifiques avez-vous effectuées qui étaient directement liées à la méthode SIG? Est-ce la première fois que vous avez été impliqué dans l'utilisation d' une méthode SIG dans une enquête ? Avez-vous trouvé cela difficile ou avez-vous trouvé facile à apprendre les tâches spécifiques? Combien de temps vous a-t-il fallu pour comprendre et pratiquer les tâches? Avez-vous ressenti que cela devenait progressivement plus facile ou difficile à mesure que vous vous engagiez dans la méthode? Est-ce que certaines tâches étaient plus faciles que d'autre ? Il y avait-il une différence dans la difficulté des tâches entre la zone urbaine et rurale ? Selon vous, qu'est ce qui aurait rendu le travail plus simple ?
    a. Comment vous avez gerer les SR non-residentielle dans votre equipe ?
5. Comment avez - vous trouvé la méthode SIG ? Comment la methode a ameliorer votre travail en tant que chef d'equipe ou superviseur?
6. Quels avantages avez-vous observés dans la mise en œuvre de la méthode?

7. Qu'est -ce qui n'a pas bien fonctionné ou pourrait être amélioré?
8. Question de temps
   a. En moyenne, combien de temps vous a-t-il fallu (ou à votre équipe, s'il s'agit d'un chef d'équipe) pour identifier une structure attribuée? (pour les agents de terrain et les chefs d'équipe uniquement). En moyenne, combien de temps a-t-il pris à votre équipe pour identifier une structure assignée
   b. En moyenne, combien de temps vous a-t-il fallu pour delimiter une ZD et pour saisir les structures dans les ZD? (pour les assistants de recherche)
9. Comment vous avez effectué la partie contrôle de la qualité du travail?
10. Formation : Si vous aviez la chance d'enseigner à quelqu'un d'autre comment exécuter les tâches , le feriez-vous de la même manière qu'on vous a formé ou que changeriez-vous? PILOT ??
11. Sur une échelle de 1 à 10 où 10 est le plus probable et 1 le moins probable, quelle est la probabilité que vous utilisiez cette méthode dans une future enquête?
12. Autre choses a dire ?

Merci pour votre temps.

Appendix E. Supplementary Tables for family planning indicators

Supplementary Table S2. Contraceptive prevalence and method mix among married women only in the conventional sampling method, in rural area (unweighted, accounting for survey design)

			Type of modern method							Number of women
	Modern method		Sterilization (male & female)	Implants	IUD	Injectables	Pills	Condoms (male & female)	LAM	
	%	95% CI	%	%	%	%	%	%	%	
Aggregate	17.5	[15.2,20.0]	0	8.7	1.3	4.6	1.3	0.6	0.2	1,740
5-year age group										
15-19	7.9	[3.7,16.2]	0	3.2	0	2.6	0	1.1	0	76
20-24	14	[9.9,19.5]	0	6.1	1.3	3.5	1.3	1.5	0	228
25-29	20.7	[15.9,26.4]	0	9	0.4	7.4	1.4	1.2	0.7	285
30-34	21.6	[17.1,26.9]	0	12	0.3	6	1.3	0.3	0	301
35-39	16.4	[12.6,21.2]	0	7.8	1.8	3.8	2.1	0	0.3	341
40-44	16.4	[12.2,21.6]	0	9.7	1.7	3.3	1	0	0	299
45-49	17.6	[13.2,23.1]	0	8.7	3.3	3.8	0.5	0.4	0	210
Highest education level attained										
None	15.1	[12.8,17.9]	0	8	0.9	4.1	0.9	0.2	0.1	1,400
Primary	22.7	[17.2,29.2]	0	11.4	2	6.4	2	0	0.5	203
Secondary+	33.6	[26.2,41.9]	0	11.9	5.1	6.6	3.6	5	0	137
Religion										
Christian	16.6	[13.8,19.9]	0	7.9	1.5	4	1.3	0.7	0.3	979
Muslim	19.4	[16.7,22.4]	0	10.3	1.2	5.6	1	0.4	0	691
Traditional	11.1	[4.3,25.7]	0	4.2	0	3.2	3.2	0	0	63
No religion/Pagan	0		0	0	0	0	0	0	0	7
Employment status										
Unemployed	12.7	[9.9,16.1]	0	6.4	0.2	4.2	0.5	0.4	0	615
Employed	20.1	[17.2,23.3]	0	10	2	4.8	1.7	0.6	0.3	1,125
Wealth quintile										
Poorest	12.9	[9.4,17.3]	0	6.3	0.9	3.2	0.9	0.3	0.6	342
Poor	13.3	[10.4,16.8]	0	7.7	0.6	2.5	0.6	0.5	0.3	316
Middle	15.2	[11.3,20.1]	0	8.7	1.4	3	0.8	0.5	0	362
Wealthy	18.6	[14.0,24.1]	0	8.3	0.9	6.6	2.6	0	0	350
Wealthiest	26.5	[21.8,31.8]	0	12.4	2.7	7.3	1.4	1.5	0	370

Ever given birth										
Yes	17.9	[15.5,20.5]	0	9.1	1.3	4.7	1.3	0.5	0.2	1,689
No	3.9	[0.9,15.0]	0	0	2	0	0	1.2	0	51
Participation in healthcare decision-making										
Alone	14.8	[11.1,19.4]	0	8.3	1.7	3.5	1.7	0.3	0	345
With someone else (partner, family)	20.6	[15.9,26.3]	0	9.8	1.1	7.1	0.7	0.3	0	267
Someone else only	17.6	[15.0,20.4]	0	8.5	1.2	4.3	1.2	0.7	0.3	1,128

Supplementary Table S3. Contraceptive prevalence and method mix among married women only in the conventional sampling method, in urban area (unweighted, accounting for survey design)

			Type of modern method							Number of women
	Modern method		Sterilization (male & female)	Implants	IUD	Injectables	Pills	Condoms (male & female)	LAM	
	%	95% CI	%	%	%	%	%	%	%	N
Aggregate	42.9	[40.0,45.8]	0.6	11.7	3.8	8.7	12.8	4.7	0.1	903
5-year age group										
15-19	28.1	[15.7,45.1]	0	6.5	0	3.1	6.3	8.7	0	32
20-24	45.9	[39.4,52.5]	0.1	9.4	1.4	11	12.3	7.7	0.7	146
25-29	49.5	[42.6,56.3]	0.1	14.3	2.1	13.7	14.7	3.6	0	190
30-34	50.3	[43.4,57.1]	0.1	16.2	6	7.5	16.1	4.2	0	199
35-39	37.5	[29.7,46.0]	0.1	10.1	5.9	6.6	14.7	2.7	0	136
40-44	37.8	[29.9,46.5]	0	11.1	4.5	8.1	9.9	3.4	0	111
45-49	27	[18.1,38.1]	0.2	5.8	3.4	3.4	5.6	5.8	0	89
Highest education level attained										
None	38.3	[33.5,43.4]	0.2	11	2.8	8.9	13.8	1.1	0	326
Primary	44.9	[38.8,51.1]	0.2	16	3.8	10.7	10.3	4.6	0.4	234
Secondary+	45.8	[40.3,51.3]	0.2	9.6	4.7	7.3	13.7	8.1	0	343
Religion										
Christian	46	[40.7,51.4]	0.3	13.6	4.4	9.7	12.1	6.6	0	339
Muslim	41	[37.1,45.0]	0.3	10.5	3.4	8.2	13.4	3.7	0.2	561
Traditional	50	[5.5,94.5]	0	50	0	0	0	0	0	2
No religion/Pagan	0		0	0	0	0	0	0	0	1
Employment status										
Unemployed	40.3	[33.4,47.7]	0	11.7	1.5	11.4	11.9	2.1	0	201
Employed	43.6	[40.0,47.2]	0.6	11.7	4.4	8	13.1	5.5	0.1	702
Wealth quintile										
Poorest	40.4	[33.0,48.3]	0.1	12.6	4	7.6	10.1	3.1	0	198
Poor	46.2	[38.9,53.5]	0.1	13.6	4.4	11	15.4	1.9	0	182
Middle	38	[31.6,44.8]	0	10.4	2.1	9.1	11.2	4.2	0	187
Wealthy	45.6	[39.1,52.4]	0	12.7	1.9	10	16.3	6.9	0	160
Wealthiest	44.9	[37.5,52.5]	0.3	9.2	6.3	6.3	11.9	8.2	0.6	176
Ever given birth										
Yes	44.3	[41.4,47.3]	0.6	12.5	3.9	9.1	13.2	4.9	0.1	864
No	10.3	[3.9,24.2]	0	0	0	0	5.1	3	0	39

Participation in healthcare decision-making										
Alone	41.8	[34.7,49.3]	0.2	12.7	5.6	5.6	10.7	5.1	0	177
With someone else (partner, family)	46.2	[40.6,51.8]	0.3	14.9	2.7	8.1	15	7.3	0	260
Someone else only	41.4	[36.6,46.4]	0.1	9.7	3.6	10.3	12.4	3.3	0.2	466

Supplementary table S4. Contraceptive prevalence and method mix among married women only in the GIS sampling method, in rural area (unweighted, accounting for survey design)

			Type of modern method							
	Modern method		Sterilization (male & female)	Implants	IUD	Injectables	Pills	Condoms (male & female)	LAM	Number of women
	%	95% CI	%	%	%	%	%	%	%	N
Aggregate	19	[16.7,21.5]	0	7.8	1.2	6.7	1.9	0.6	0.1	1,561
5-year age group										
15-19	17.9	[10.9,28.1]	0	6.5	0	7.7	1.3	1.1	0	78
20-24	17.6	[12.9,23.7]	0	6.9	1	5.4	2	0.8	0	204
25-29	17.8	[13.2,23.4]	0	6.7	0	6.2	1.7	2.1	0.4	242
30-34	27.4	[21.9,33.6]	0	12.9	0.4	10.5	2.5	0.3	0	285
35-39	18.2	[14.0,23.2]	0	5.9	1.9	7.3	2.5	0.3	0.3	314
40-44	17.7	[13.4,23.1]	0	9.6	1.9	5.3	1.1	0	0	265
45-49	12.1	[7.8,18.4]	0	4.1	2.3	3.5	1.2	0	0	173
Highest education level attained										
None	17.2	[14.9,19.7]	0	7.4	0.9	6.6	1.2	0.4	0.2	1,282
Primary	24.4	[17.7,32.6]	0	8.6	1.8	7.9	4.3	0.5	0	164
Secondary+	31.3	[24.4,39.1]	0	11.2	2.6	7	6.1	2.8	0	115
Religion										
Christian	17.7	[15.3,20.5]	0	7.2	1.1	5.8	2	1	0.1	896
Muslim	21.3	[17.5,25.7]	0	9.1	1.3	8.2	1.8	0.1	0	609
Traditional	13.7	[7.1,24.8]	0	5.2	0	5.9	0	0	2	51
No religion/Pagan	0		0	0	0	0	0	0	0	5
Employment status										
Unemployed	18.1	[14.8,21.9]	0	7.4	0.2	8.4	0.9	0.5	0	548
Employed	19.4	[16.8,22.4]	0	8.1	1.7	5.8	2.4	0.7	0.2	1,013
Wealth quintile										
Poorest	14.9	[11.3,19.3]	0	4.8	0.9	7.9	0.9	0	0	343
Poor	18.9	[14.9,23.6]	0	8.4	1.5	5.1	2.7	0.5	0.3	334
Middle	13.8	[10.0,18.8]	0	7.3	0.3	4.1	1	0.3	0.3	290
Wealthy	23.5	[19.3,28.2]	0	10.3	0.6	8.4	1.3	0.8	0	311
Wealthiest	24.4	[18.5,31.5]	0	8.7	2.5	8.1	3.5	1.6	0	283
Ever given birth										
Yes	19.5	[17.2,22.1]	0	8.2	1.2	6.9	1.9	0.6	0.1	1,504
No	3.5	[0.9,13.4]	0	0	0	1.8	0	1.2	0	57

Participation in healthcare decision-making										
Alone	22	[16.7,28.3]	0	12.7	0.5	6.5	3	0.5	0	200
With someone else (partner, family)	22.6	[17.6,28.6]	0	7.7	1	10.5	2.9	0.5	0	314
Someone else only	17.3	[14.8,20.1]	0	7	1.3	5.6	1.3	0.7	0.2	1,047

Supplementary table S5. Contraceptive prevalence and method mix among married women only in the GIS sampling method, in urban area (unweighted, accounting for survey design)

			Type of modern method							Number of women
	Modern method		Sterilization (male & female)	Implants	IUD	Injectables	Pills	Condoms (male & female)	LAM	Number of women
	%	95% CI	%	%	%	%	%	%	%	N
Aggregate	41	[37.1,45.1]	0.6	12.1	4.7	11.5	8.7	2.9	0.2	877
5-year age group										
15-19	23.1	[10.7,42.9]	0	8.6	0	3.8	0	5.7	0	26
20-24	45	[36.4,53.8]	0	11.3	3.9	14	10.1	5.7	0	129
25-29	40.9	[33.2,48.9]	0.2	11	3.7	12.8	8.5	3.7	0	164
30-34	46.2	[38.6,54.0]	0	16	4.9	10.9	9.8	1.9	1.1	184
35-39	42.1	[34.0,50.7]	0	15.3	5.7	11.3	8.8	1.7	0	159
40-44	43.4	[34.8,52.5]	0.1	9.8	4.9	13.1	11.5	3.8	0	122
45-49	25.8	[18.5,34.7]	0.3	6.3	6.5	7.5	3.2	0	0	93
Highest education level attained										
None	37.5	[32.1,43.2]	0.2	12.3	2.6	11.6	8.2	1.5	0.6	352
Primary	42.6	[35.2,50.2]	0	14.5	5	11.4	8.4	1.7	0	202
Secondary+	44	[37.4,50.7]	0.4	10.4	6.8	11.5	9.3	5.2	0	323
Religion										
Christian	41.1	[35.0,47.4]	0.3	14.2	3.8	12.6	6.7	2.8	0	341
Muslim	40.8	[36.2,45.6]	0.3	10.6	5.2	10.9	9.7	3	0.4	534
Traditional	100		0	100	0	0	0	0	0	1
No religion/Pagan	100		0	0	0	0	100	0	0	1
Employment status										
Unemployed	40.3	[33.2,47.9]	0	10.3	2	12.8	9.2	2.9	0.5	196
Employed	41.3	[37.2,45.4]	0.6	12.6	5.4	11.2	8.5	3	0.1	681
Wealth quintile										
Poorest	39.2	[30.6,48.5]	0	13.6	1.4	12.6	7	3.1	0	143
Poor	34.3	[25.6,44.2]	0.1	11.3	3	11.8	7.7	0.5	0.6	169
Middle	44.2	[35.9,52.9]	0.1	12	3.2	12.8	11.5	2.2	0.6	156
Wealthy	45.1	[37.8,52.6]	0.1	15.2	5.9	11.3	7.4	3.8	0	204
Wealthiest	41.5	[34.0,49.3]	0.3	8.7	8.3	9.8	9.8	4.6	0	205
Ever given birth										
Yes	42.5	[38.5,46.6]	0.5	12.9	4.9	12.1	9	2.8	0.2	835
No	11.9	[4.8,26.5]	0.1	1.4	0	0	2.4	4.3	0	42

Participation in healthcare decision-making										
Alone	48.8	[39.4,58.2]	0.1	10.4	7.4	17.4	8.3	5.2	0	121
With someone else (partner, family)	41	[34.1,48.4]	0.3	12.9	4.1	10.1	10.8	4.1	0.4	268
Someone else only	39.1	[34.6,43.8]	0.2	12	4.3	10.9	7.6	1.8	0.2	488

Supplementary table S6. Unmet need for family planning (FP) and demand satisfied using modern methods among married women in the conventional sampling method in rural area (unweighted, accounting for survey design)

	Conventional Sampling Method (Rural)								
	Unmet need for FP								
	Spacing		Limiting		Total		N	%demand satisfied (modern methods)	
	%	95% CI	%	95% CI	%	95% CI		%	95% CI
Aggregate	21.7	[19.5,24.2]	10.4	[9.0,12.0]	32.1	[29.8,34.7]	1,955	33.3	[29.3,37.5]
Age group									
15-19	51.6	[41.1,62.0]	0	0	51.6	[41.1,62.0]	93	11.8	[5.4,23.8]
20-29	30.9	[27.3,34.9]	1.7	[0.9,3.1]	32.6	[29.0,36.5]	585	33.5	[27.6,39.9]
30-39	20.2	[17.5,23.1]	11.6	[9.9,13.6]	31.8	[28.5,35.2]	714	35.3	[30.0,40.9]
40-49	9.2	[7.1,11.9]	19.7	[16.1,23.9]	28.9	[24.8,33.5]	563	34.7	[28.2,41.8]
Highest education level attained									
None	21.3	[18.9,23.9]	11.4	[9.8,13.3]	32.7	[30.2,35.4]	1,577	29.8	[25.6,34.4]
Primary	23.7	[18.5,29.9]	8.2	[5.1,12.9]	31.9	[25.6,39.1]	219	40	[30.7,50.1]
Secondary+	23.3	[16.9,31.2]	3.8	[1.6,8.8]	27.1	[20.0,35.5]	159	52.9	[41.2,64.3]
Religion									
Christian	20.3	[17.4,23.5]	10.7	[9.0,12.7]	31	[28.0,34.2]	1,100	32.7	[27.7,38.1]
Muslim	22.7	[19.4,26.4]	10.2	[7.9,13.0]	32.9	[29.8,36.1]	776	35.4	[30.6,40.6]
Traditional	31.9	[22.9,42.6]	8.3	[3.6,18.1]	40.2	[28.0,53.9]	72	21.2	[9.7,40.4]
No religion/Pagan	42.9	[13.9,77.6]	14.3	[1.9,59.3]	57.2	[22.4,86.1]	7	0	
Employment status									
Unemployed	25	[21.3,29.1]	8.4	[6.5,10.8]	33.4	[29.4,37.7]	704	25.7	[20.3,32.1]
Employed	19.9	[17.4,22.7]	11.6	[9.8,13.7]	31.5	[28.6,34.5]	1,251	37	[32.2,42.1]
Wealth quintile									
Poorest	23	[18.8,27.9]	9.2	[6.3,13.1]	32.2	[27.2,37.6]	382	26.8	[20.0,35.0]
Poor	23	[18.2,28.5]	11.7	[8.8,15.5]	34.7	[30.0,39.7]	366	25.9	[20.3,32.5]

Middle	21.2	[16.7,26.4]	11.1	[7.8,15.5]	32.3	[27.2,37.6]	416	30.4	[22.9,39.0]
Wealthy	22.2	[18.0,27.1]	8.8	[6.1,12.5]	31	[26.4,36.0]	387	34.8	[27.1,43.3]
Wealthiest	19.6	[15.8,24.0]	11.4	[8.4,15.2]	31	[26.5,35.7]	404	44.5	[37.9,51.4]
Ever given birth									
Yes	22.1	[19.8,24.7]	10.9	[9.4,12.5]	33	[30.5,35.6]	1,874	33.3	[29.4,37.5]
No	12.3	[7.3,20.2]	0		12.3	[7.3,20.2]	81	25	[6.1,63.2]

N = Number of eligible women demanding contraception

Supplementary table S7. Unmet need for family planning (FP) and demand satisfied using modern methods among married women in the conventional sampling method in urban area (unweighted, accounting for survey design)

	Conventional Sampling Method (Urban)								
	Unmet need for FP						N	%demand satisfied (modern methods)	
	Spacing		Limiting		Total				
	%	95% CI	%	95% CI	%	95% CI		%	95% CI
Aggregate	16.3	[14.1,18.8]	6.1	[4.6,8.0]	22.4	[19.9,25.2]	1,034	62.7	[59.0,66.3]
Age group									
15-19	32.6	[20.7,47.3]	0		32.6	[20.7,47.3]	46	40.9	[22.7,62.0]
20-29	20.8	[16.9,25.3]	1	[0.4,2.6]	21.8	[17.7,26.5]	404	65.4	[59.2,71.2]
30-39	16.5	[13.0,20.6]	5.2	[3.1,8.6]	21.7	[17.7,26.4]	364	65.4	[59.6,70.7]
40-49	4.5	[2.5,8.2]	18.2	[13.5,24.0]	22.7	[17.5,29.0]	220	55.9	[47.0,64.5]
Highest education level attained									
None	14	[10.9,17.8]	7.4	[4.8,11.2]	21.4	[17.2,26.2]	365	60.7	[53.7,67.3]
Primary	18.3	[14.2,23.4]	6.9	[4.1,11.3]	25.2	[20.6,30.4]	262	64	[56.8,70.6]
Secondary+	17.2	[13.8,21.3]	4.4	[2.8,6.9]	21.6	[17.8,26.0]	407	63.6	[57.3,69.4]
Religion									
Christian	13.8	[10.7,17.6]	6.4	[4.2,9.7]	20.2	[16.4,24.7]	376	66.4	[59.8,72.4]
Muslim	17.9	[14.9,21.3]	5.8	[4.1,8.1]	23.7	[20.2,27.5]	655	60.5	[55.4,65.4]
Traditional	0		0		0		2	100	
No religion/Pagan	0		100		0		1	0	
Employment status									
Unemployed	23.3	[18.8,28.6]	3.3	[1.7,6.3]	26.6	[22.0,32.0]	240	56.3	[48.9,63.4]
Employed	14.2	[11.9,17.0]	6.9	[5.1,9.4]	21.1	[18.1,24.6]	794	64.7	[59.8,69.3]
Wealth quintile									
Poorest	17.5	[12.8,23.5]	7.6	[4.2,13.4]	25.1	[19.1,32.3]	223	59.7	[49.2,69.4]

Poor	15.9	[11.5,21.5]	4.7	[2.5,8.5]	20.6	[15.1,27.3]	214	68.3	[58.7,76.5]
Middle	19.3	[14.2,25.7]	4.2	[2.2,8.1]	23.5	[17.8,30.6]	212	58.7	[48.9,67.8]
Wealthy	15.3	[11.1,20.9]	5.8	[3.3,10.2]	21.1	[16.1,27.3]	189	62.9	[54.5,70.7]
Wealthiest	13.3	[9.7,17.9]	8.2	[4.9,13.3]	21.5	[16.5,27.4]	196	64.2	[55.9,71.8]
Ever given birth									
Yes	17.2	[14.9,19.8]	6.5	[4.9,8.6]	23.7	[21.0,26.6]	967	62.9	[59.2,66.4]
No	4.5	[1.4,13.6]	0		4.5	[1.4,13.6]	67	50	[19.5,80.5]

N = Number of eligible women demanding contraception

Supplementary table S8. Unmet and met need for family planning (FP), and demand satisfied using modern methods among married women in the GIS sampling method in rural area (unweighted, accounting for survey design)

	GIS Sampling Method (Rural)								
	Unmet need for FP						N	%demand satisfied (modern methods)	
	Spacing		Limiting		Total				
	%	95% CI	%	95% CI	%	95% CI		%	95% CI
Aggregate	21.1	[19.2,23.1]	8.2	[6.9,9.7]	29.3	[27.2,31.5]	1,798	36.3	[32.5,40.3]
Age group									
15-19	31.5	[21.8,43.2]	0		31.5	[21.8,43.2]	92	32.6	[20.1,48.1]
20-29	28.8	[25.6,32.3]	2.1	[1.1,3.7]	30.9	[27.6,34.4]	531	33.5	[27.5,40.1]
30-39	23.6	[19.9,27.7]	8.1	[6.1,10.6]	31.7	[27.8,35.8]	666	39.4	[33.6,45.4]
40-49	7.9	[5.8,10.6]	16.3	[13.5,19.5]	24.2	[21.0,27.6]	509	35.2	[29.0,42.0]
Highest education level attained									
None	20.2	[18.2,22.4]	9	[7.5,10.9]	29.2	[26.9,31.7]	1,470	34.1	[30.1,38.3]
Primary	23.8	[17.0,32.2]	6.5	[3.5,11.8]	30.3	[22.5,39.3]	185	42.1	[31.4,53.6]
Secondary+	26.6	[19.6,34.9]	2.1	[0.7,6.3]	28.7	[21.6,37.0]	143	48	[37.2,59.0]
Religion									
Christian	19.6	[17.2,22.1]	9	[7.3,11.1]	28.6	[26.0,31.3]	1,033	35.3	[31.0,40.0]
Muslim	22.8	[19.0,27.0]	6.7	[5.0,8.9]	29.5	[25.8,33.5]	702	39.2	[32.7,46.0]
Traditional	24.1	[14.9,36.7]	13.8	[7.1,25.0]	37.9	[26.4,51.0]	58	24.1	[13.5,39.4]
No religion/Pagan	60	[19.4,90.3]	0		60	[19.4,90.3]	5	0	
Employment status									
Unemployed	24.4	[20.9,28.3]	5.3	[3.8,7.3]	29.7	[26.2,33.5]	639	35.6	[30.2,41.5]
Employed	19.2	[17.1,21.6]	9.8	[8.1,11.9]	29	[26.5,31.8]	1,159	36.7	[32.1,41.5]
Wealth quintile									
Poorest	20.2	[16.3,24.6]	7.3	[4.8,11.0]	27.5	[22.9,32.5]	397	30.9	[23.3,39.7]
Poor	23	[19.8,26.6]	8.4	[5.7,12.4]	31.4	[26.9,36.3]	391	34.8	[28.5,41.7]

Middle	24.5	[20.1,29.5]	6.9	[4.6,10.5]	31.4	[27.2,36.0]	331	28.2	[21.9,35.4]
Wealthy	17.9	[14.2,22.2]	9.2	[6.6,12.7]	27.1	[22.7,32.0]	358	44	[36.8,51.4]
Wealthiest	19.9	[15.5,25.2]	9.3	[6.3,13.7]	29.2	[25.2,33.7]	321	42.9	[34.0,52.2]
Ever given birth									
Yes	21.7	[19.7,23.8]	8.6	[7.3,10.2]	30.3	[28.2,32.6]	1,714	36.4	[32.6,40.4]
No	8.3	[4.0,16.7]	0		8.3	[4.0,16.7]	84	28.6	[8.8,62.3]

N = Number of eligible women demanding contraception

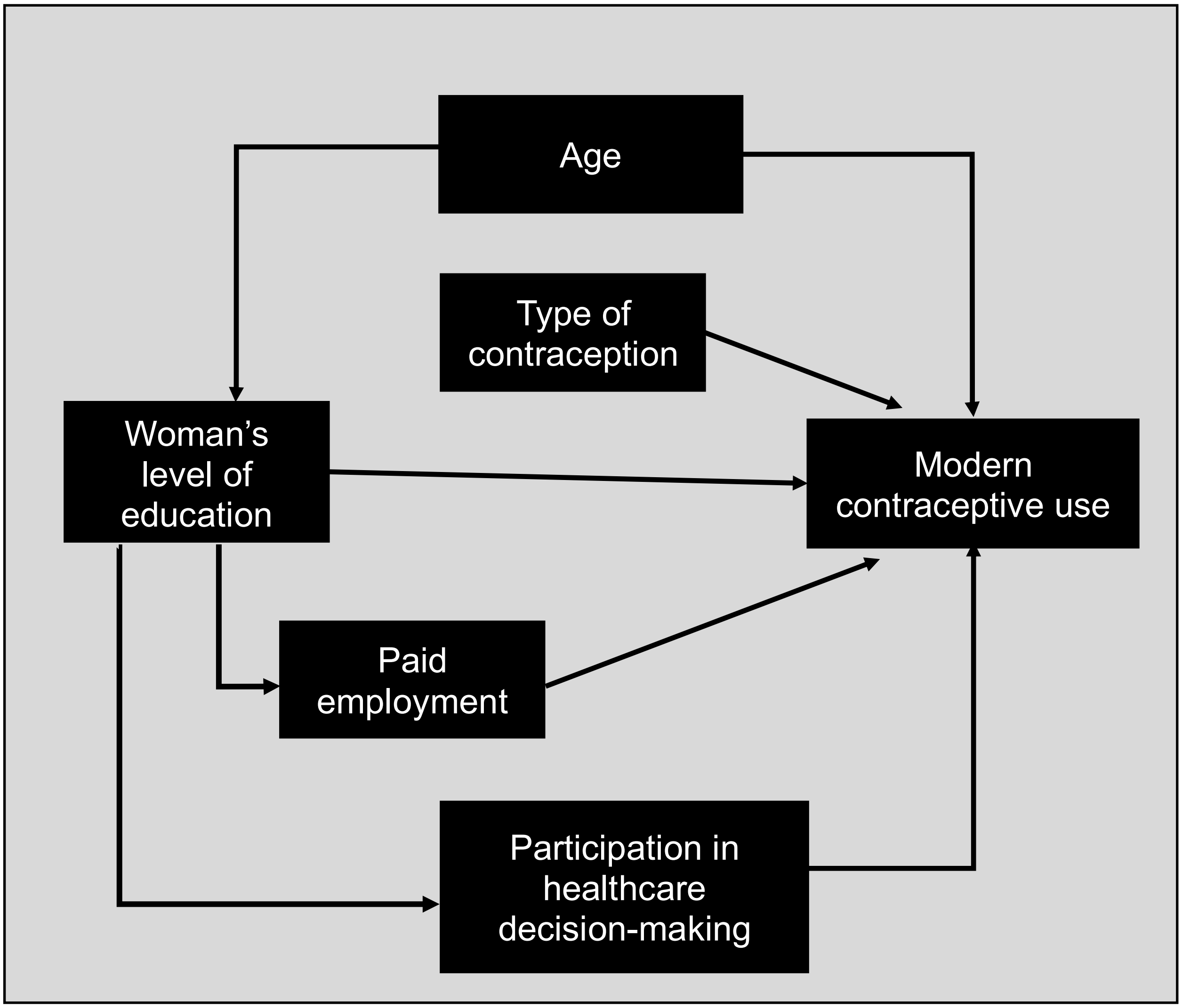
Supplementary table S9. Unmet and met need for family planning (FP), and demand satisfied using modern methods among married women in the GIS sampling method in urban area (unweighted, accounting for survey design)

	GIS Sampling Method (Urban)								
	Unmet need for FP						N	%demand satisfied (modern methods)	
	Spacing		Limiting		Total				
	%	95% CI	%	95% CI	%	95% CI		%	95% CI
Aggregate	15	[12.9,17.4]	6.1	[4.6,8.0]	21.1	[18.7,23.8]	1,018	62.7	[58.2,67.0]
Age group									
15-19	28.6	[15.5,46.6]	2.9	[0.4,17.7]	31.5	[18.0,48.9]	35	37.5	[18.5,61.3]
20-29	20.6	[16.7,25.0]	0		20.6	[16.7,25.0]	350	63.8	[56.3,70.6]
30-39	14.4	[11.1,18.5]	4.1	[2.6,6.5]	18.5	[14.9,22.9]	388	68.5	[61.8,74.4]
40-49	6.1	[3.4,10.7]	18.4	[13.7,24.2]	24.5	[19.2,30.6]	245	55	[47.4,62.4]
Highest education level attained									
None	14.8	[11.4,18.8]	7.2	[5.0,10.5]	22	[18.0,26.5]	400	60.3	[53.2,67.0]
Primary	15.4	[11.0,21.1]	8.1	[4.9,13.1]	23.5	[17.9,30.3]	234	61.9	[52.3,70.6]
Secondary+	15.1	[12.0,18.9]	3.6	[2.2,6.1]	18.7	[15.3,22.8]	384	65.7	[58.6,72.2]
Religion									
Christian	12.7	[9.9,16.2]	8.4	[5.9,11.8]	21.1	[17.6,25.1]	393	61.7	[55.6,67.4]
Muslim	16.5	[13.9,19.6]	4.7	[3.1,6.9]	21.2	[18.1,24.6]	623	63.2	[57.5,68.5]
Traditional	0		0		0		1	100	
No religion/Pagan	0		0		0		1	100	
Employment status									
Unemployed	17.4	[13.6,21.9]	2.1	[0.9,4.7]	19.5	[15.4,24.1]	242	63.2	[54.9,70.7]
Employed	14.3	[11.9,17.2]	7.3	[5.5,9.8]	21.6	[18.5,25.1]	776	62.6	[57.3,67.6]
Wealth quintile									

Poorest	16.7	[10.8,24.9]	4.3	[2.0,8.9]	21	[14.4,29.5]	162	64.4	[51.7,75.3]
Poor	16.4	[11.5,22.8]	9.2	[5.8,14.4]	25.6	[19.9,32.3]	195	53.2	[42.2,63.9]
Middle	16.9	[11.9,23.5]	3.8	[1.9,7.6]	20.7	[14.8,28.4]	183	65.7	[54.6,75.4]
Wealthy	11	[7.6,15.6]	5.9	[3.5,9.8]	16.9	[13.1,21.5]	237	69.2	[61.1,76.2]
Wealthiest	15.4	[11.1,20.8]	6.6	[3.8,11.3]	22	[16.9,28.2]	241	60.7	[51.3,69.4]
Ever given birth									
Yes	15.4	[13.3,17.8]	6.4	[4.9,8.5]	21.8	[19.3,24.6]	948	63.2	[58.6,67.5]
No	10	[4.8,19.8]	1.4	[0.2,10.0]	11.4	[5.7,21.5]	70	41.7	[18.1,69.8]

N = Number of eligible women demanding contraception

Appendix F. Conceptual Framework for determinants of modern contraceptive use



Appendix G. Bivariable and Multivariable Logistic Regression analysis using the GIS sampling method

Supplementary table S10. Determinants of modern contraceptive prevalence rate in the GIS sampling method among eligible women (15-49 years)

	Bivariate model		Multivariate model	
Variables	Odds Ratio	95% CI	Adjusted Odds Ratio	95% CI
Place of residence				
Rural (reference)	1.000		1.000	
Urban	2.306***	[1.893, 2.809]	2.181***	[1.723, 2.761]
Age group (reference)				
15-19	1.000		1.000	
20-29	4.062***	[2.989, 5.52]	2.368***	[1.677, 3.344]
30-39	4.617***	[3.335, 6.392]	2.588***	[1.751, 3.825]
40-49	2.947***	[2.134, 4.07]	1.665**	[1.120, 2.474]
Highest education level attained				
None (reference)	1.000		1.000	
Primary	1.357***	[1.083, 1.7]	1.419***	[1.104, 1.824]
Secondary+	1.28**	[1.054, 1.555]	1.812***	[1.400, 2.345]
Matrimonial status				
not in union (reference)	1.000		1.000	
in union	2.287***	[1.869, 2.799]	1.503***	[1.174, 1.925]
Wealth quintile				
Poorest (reference)	1.000		1.000	
Poor	1.114	[0.394, 3.15]	1.120	[0.828, 1.515]
Middle	0.557	[0.168, 1.849]	1.118	[0.829, 1.507]
Wealthy	1.639	[0.61, 4.4]	1.457***	[1.116, 1.902]
Wealthiest	1.375	[0.435, 4.349]	1.215	[0.889, 1.661]
Employment status				
Unemployed (reference)	1.000		1.000	
Employed	1.491	[1.282, 1.732]	1.033	[0.878, 1.217]
Participation in healthcare decision-making				
Does not participate (reference)	1.000		1.000	
Participates	1.76***	[1.488, 2.081]	1.238**	[1.040, 1.473]
Ever given birth				
No (reference)	1.000		1.000	
Yes	2.769***	[2.154, 3.56]	1.946***	[1.336, 2.835]

*95% CI: 95% confidence interval. *** p<.01, ** p<.05, * p<.1; Number of observations: 3,924. Goodness of fit F-test=1.445 (p-value: 0.174)*

Supplementary table S11. Determinants of unmet need for family planning in the GIS sampling method among eligible women (15-49 years)

	Bivariate model		Multivariate model	
Variables	Odds Ratio	95% CI	Adjusted Odds Ratio	95% CI
Place of residence				
Rural (reference)	1.000		1.000	
Urban	0.492***	[0.415, 0.582]	0.595***	[0.488, 0.725]
Age group				
15-19 (reference)	1.000		1.000	
20-29	5.777***	[4.008, 8.327]	5.260***	[3.640, 7.602]
30-39	8.415***	[5.726, 12.368]	6.305***	[4.148, 9.584]
40-49	7.064***	[4.942, 10.097]	4.940***	[3.313, 7.365]
Highest education level attained				
None (reference)	1.000		1.000	
Primary	0.596***	[0.459, 0.775]	0.928	[0.695, 1.239]
Secondary+	0.263***	[0.212, 0.326]	0.504***	[0.385, 0.658]
Wealth quintile				
Poorest (reference)	1.000		1.000	
Poor	1.224	[0.918, 1.633]	1.310*	[0.973, 1.764]
Middle	1.021	[0.77, 1.352]	1.153	[0.865, 1.537]
Wealthy	0.797*	[0.621, 1.023]	0.972	[0.750, 1.258]
Wealthiest	0.803*	[0.627, 1.029]	1.150	[0.886, 1.492]
Employment status				
Unemployed (reference)	1.000		1.000	
Employed	1.291**	[1.059, 1.574]	1.043	[0.856, 1.271]
Autonomy in healthcare decision-making				
Does not participate (ref)	1.000		1.000	
Participates	1.242**	[1.03,1.498]	0.949	[0.773, 1.166]

*95% CI: 95% confidence interval. *** p<.01, ** p<.05, * p<.1; Number of observations: 4,378.*
Goodness of fit F-test=0.787 (p-value: 0.629)

Supplementary table S12. Determinants of demand satisfied for family planning using modern methods in the GIS sampling method among eligible women (15-49 years)

	Bivariate model		Multivariate model	
Variables	Odds Ratio	95% CI	Adjusted Odds Ratio	95% CI
Area of residence				
Rural (reference)	1.000		1.000	
Urban	3.562***	[2.805, 4.523]	2.579***	[1.968, 3.381]
Age group				
15-19 (reference)	1.000		1.000	
20-29	0.644*	[0.393, 1.056]	1.371	[0.704, 2.671]
30-39	0.529**	[0.323, 0.869]	1.775*	[0.925, 3.408]
40-49	0.4***	[0.246, 0.651]	1.184	[0.610, 2.297]
Highest education level attained				
None (reference)	1.000		1.000	
Primary	1.969***	[1.469, 2.639]	1.248	[0.889, 1.751]
Secondary+	3.818***	[2.944, 4.953]	1.446**	[1.048, 1.994]
Matrimonial status				
not in union (reference)	1.000		1.000	
in union	0.013***	[0.004, 0.042]	0.009***	[0.002, 0.034]
Wealth quintile				
Poorest (reference)	1.000		1.000	
Poor	0.991	[0.668, 1.47]	0.975	[0.651, 1.459]
Middle	1.197	[0.818, 1.752]	0.989	[0.662, 1.477]
Wealthy	1.857***	[1.296, 2.659]	1.507**	[1.057, 2.147]
Wealthiest	1.614**	[1.106, 2.357]	1.164	[0.783, 1.731]
Employment status				
Unemployed (reference)	1.000		1.000	
Employed	1.061	[0.852, 1.321]	0.979	[0.771, 1.242]
Autonomy in healthcare decision-making				
Does not participate (ref)	1.000		1.000	
Participates	1.226*	[0.978, 1.536]	1.358**	[1.06, 1.734]
Ever given birth				
No (reference)	1.000		1.000	
Yes	0.093	[0.053, 0.164]	1.947	[0.713, 5.318]

*95% CI: 95% confidence interval; *** p<.01, ** p<.05, * p<.1; Number of observations: 1,598. Goodness of fit F-test=0.454 (p-value: 0.903)*

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122. Higgins J, Adamu U, Adewara K, et al. Finding inhabited settlements and tracking vaccination progress: the application of satellite imagery analysis to guide the immunization response to confirmation of previously-undetected, ongoing endemic wild poliovirus transmission in Borno State, Nigeria. *International Journal of Health Geographics*. 2019;18(1):11. doi:10.1186/s12942-019-0175-y

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Curriculum Vitae

Adetoun Olateju MD, MPH

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www.linkedin.com/in/adetoun-olateju

EDUCATION

Johns Hopkins Bloomberg School of Public Health Baltimore, MD
Ph.D. in Global Disease Epidemiology and Control 2017-expected 2021
Concurrent Masters in Global Health Economics 2018-expected 2021
Certificate in Evaluation of International Health Programs 2018-expected 2021
Department of International Health
Recipient: Robert D. & Helen S. Wright Scholarship

Harvard University T.H. Chan School of Public Health Cambridge, MA
Master of Public Health (MPH) May 2014

- Concentration: Global Health and Population
- Recipient: Harvard University scholarship, International Peace Scholarship

Igbinedion University Benin-City | Nigeria
Bachelor of Medicine; Bachelor of Surgery (M.B;B.S) June 2007
(U.S. equivalent: Doctor of Medicine, MD)

RESEARCH AND PROGRAM IMPLEMENTATION EXPERIENCE

JHSPH Institute for International Programs
Research Assistant
Project: Real Accountability: Data for Results (RADAR) January 2019 – present

- Develop and implement the use of innovative GIS methods to improve the quality of data generated in household surveys for reproductive, maternal, child and adolescent health.

Project: Improving Coverage Measurement January 2018 – Feb 2019

- Map and analyze global indicators to measure adolescent health interventions. Developed a readiness index to measure the availability and quality adolescent health programs in population-based surveys and health facility assessments.

JHSPH International Health Department (Health Systems) April 2018 – 2020
Research Assistant
Project: Implementation Science for Global Health: Synthesis and Translation of Research and Innovation from the Global Polio Eradication Initiative (GPEI)

- Conducted comprehensive systematic reviews used to develop global learning resources based on the lessons learned from GPEI implementation.
- Analyzed online survey results and applied implementation science strategies to improve health systems.

JHSPH International Vaccine Access Center Jan – Dec 2018
Research Assistant and co-Investigator
Project: Formative research to design HPV vaccination program for out-of-school girls in India (Proposal won a $25,000 grant from JHSPH Alliance for a Healthier World)

- Developed focus group discussion guides, adolescent co-creation guides incorporating human-centered design, informed consent forms and assisted with IRB application.

Jhpiego, Baltimore MD June – Sep 2018
Student Research Assistant, Monitoring, Evaluation and Research Department
Project: Analysis of the maternal and child health indicators in health management information systems of countries under USAID's flagship Maternal and Child Health Survival.

- Analyzed routine health facility data collection forms for the availability of maternal and newborn health indicators across 24 USAID-supported low and middle-income countries.
- Conducted a comprehensive literature review of health management information systems.

Bush Global Health Initiative, Washington D.C. 2015 - 2017
Programs Manager and M&E Lead
George W. Bush Presidential Center & Institute, Dallas, TX 2014-2015
Programs and M&E Coordinator
Worked on the Pink Ribbon Red Ribbon (PRRR) initiative, a $50m global public-private partnership focused on cervical and breast cancer prevention programs in HIV and general populations in ***Botswana, Ethiopia, Tanzania, and Zambia.***

- Headed technical assistance teams to leadership of Ministries of Health (MOH) to develop, support and implement contextually-appropriate, costed strategic plans focused on transition from pilots to nationwide-scale programs.
    - Catalyzed PRRR from screening 16,000 women per year to screening over 160,000 women annually. Over 400,000 women were screened, and those positive were treated for cervical and breast cancers. Approximately 120,000 girls completed HPV vaccinations.
    - Cultivated several public-private partnerships that culminated to the

implementation of new cancer prevention programs in Tanzania ($5.5m) and Ethiopia ($7.8m).
    - Supported countries to secure additional $5m from The Global Fund to scale-up national cervical cancer screening programs by re-directing unspent HIV support funds.
- Analyzed quarterly data reports from portfolio countries, generated and disseminated quarterly progress reports to various stakeholders and audiences, with 10-25% improvements in monitoring of cervical cancer and breast cancer prevention programs in partner countries.
- Designed studies on technologic innovations to improve cervical cancer screening: adaptability of mobile colposcopy devices in Ethiopia, and feasibility of HPV-DNA self-sampling in Botswana.

Equal Health*, *Boston, MA 2014

Graduate consultant, Curriculum Development Unit

- Created 5 problem-based learning modules to facilitate postgraduate continuing medical education for public health professionals in Haiti. Conducted quality assurance of French translations.

United Nations Population Fund (UNFPA)*, *NY 2014

Sexual and Reproductive Health (SRH) Technical Division
Graduate Intern

- Conducted literature review of national and community health insurance programs in 24 low and middle-income countries to assess the coverage of sexual and reproductive health services within universal health coverage programs.

Harvard *Project Antares,* Cambridge, MA 2014

Graduate Consultant, Pro bono consulting

- Developed a phased market entry strategy for an online healthcare services company to expand to low-income communities in San Francisco, CA and the United States.

College of Medicine, University of Ibadan, Nigeria 2013

Pioneer Research Project Coordinator (THRIVES PROJECT)

- Developed the project management protocols to establish the implementation processes of a $700,000 NIH-funded randomized trial on neurologic outcomes after stroke management.
- Trained 7 medical officers and research assistants on the data collection instruments, conducted data quality audits to ensure compliance with study protocols.

West African Health Organization, ECOWAS, Burkina Faso 2012
Monitoring & Evaluation (M&E) Analyst
Represented Nigeria on the highly selective Young Professionals Programme. Implemented an urban reproductive health initiative pilot in ***Senegal*** *at IntraHealth International.*

- Trained about 500 nurses and midwives to offer long-acting contraceptives (LACs).
- Conducted monthly analysis of program data and presented results to inform program improvement. Installed quality assurance systems in MS Excel for tracking progress on project indicators which improved the data quality and completeness from 75% to 99%.

Yakubu Gowon Presidential Centre, Abuja, Nigeria 2009 - 2011
Project: The Global Fund Malaria grants, Principal Recipient Rounds 4 & 8
Zonal Program Manager / M&E Coordinator

- Led the implementation of the Global Fund Malaria grants in the North-Central zone of Nigeria. Managed the pooled procurement and mass distribution of over 6 million Long Lasting Insecticide-treated mosquito Nets (LLINs).
- Facilitated the training of over 2,000 health workers. Led data quality audits with federal and state Ministry of Health officials to verify malaria case management data across 870 facilities.

Kwara State Ministry of Health, Ilorin, Nigeria 2008– 2009
District Medical Officer & Field HIV Project Officer

- Led the implementation of community-based approaches that increased immunization coverage from 60% to 92%, and facility-based deliveries increased by 25 percentage points.
- Pioneered the HIV treatment center in the hospital with a focus on prevention of mother-to-child transmission.

University College Hospital, Ibadan, Nigeria 2007 –2008
House Officer

- Provided clinical management to patients in rotations in pediatrics, surgery, internal medicine, and obstetrics& gynecology. Conducted literature reviews and data collection activities for departmental research activities.

TEACHING EXPERIENCE

Teaching Assistantships

- JHSPH Health Systems Summer Institute May – June 2018
- Fundamentals of Global Health Practice Aug 2018 – Dec 2019
- Social & Behavioral Foundations in Primary Health Care Jan 2019 – July 2020
- Spatial Analysis I Aug 2019 – Oct 2020
- Methods for Planning & Implementing Evaluations in LMICs Mar-May 2020
- Essential medicines, commodities, and supplies for PHC Aug – Oct 2020
- Spatial Analysis II Oct – Dec 2020
- Urban Primary Health Care in LMIC Oct – Dec 2020
- Planning Training and Learning Programs for CHWs Jan – Mar 2021

PROFESSIONAL DEVELOPMENT

- Languages: French (Working proficiency); Yoruba (Native speaker).
- Software: Stata®; Tree Age®, ArcGIS®, R.

SELECTED CONFERENCE PRESENTATIONS

- 11th International Conference on Cancer in Africa Kigali, Rwanda| 2017
    - **Olateju A**, Wieland J, Bottecchia M, et al. *'Using smart phones and imaging of an enhanced visual-assessment device to detect cervical cancer in low-resource settings: a pilot program in the Federal Democratic Republic of Ethiopia.'* http://aorticconference.org/2017/wp-content/uploads/2017/10/2017-AORTIC-Abstracts.pdf
- National Cancer Institute Bethesda, MD| 2017
    - Panelist: '*Bridging the gap between cervical cancer screening outcomes and pathology results: Experiences from selected Pink Ribbon Red Ribbon-partner countries'*
    - **Olateju A**: '*Mass outreach campaigns to hard-to-reach female populations for cancer screening in Tanzania' (oral and poster)*
- World Cancer Congress Paris, France| 2016
    - **Olateju A**: '*Partnerships for Comprehensive Cervical and Breast Cancer Control in Resource-Limited Countries: Experiences from Botswana, Ethiopia, Tanzania and Zambia.*' https://b-com.mci-group.com/Abstract/Statistics/AbstractStatisticsViewPage.aspx?AbstractID=325322
    - **Olateju A**., Chalambo D: '*Providing transportation support to increase access*

to cancer treatment in Tanzania.' https://b-com.mci-group.com/Abstract/Statistics/AbstractStatisticsViewPage.aspx?AbstractID=325334

- Univ. of Texas 5th Global Health Symposium Dallas, TX | 2016
  - Invited Faculty Presentation: *'Cervical Cancer Prevention and Control: Utilizing Public-Private Partnerships to Strengthen Health Systems in sub-Saharan Africa'*
- 10th International Conference on Cancer in Africa Morocco | 2015
  - Rositch A., Oluwole D., Ramin C., Steiger W., **Olateju A**: '*Use of Health Outcomes Modeling to Estimate the Short-Term Impact of Cervical Cancer Screening Programs in sub-Saharan Africa.'*
  - Oluwole D., Steiger W., Asante E., **Olateju A**.: '*Partnerships in International Development: The Pink Ribbon Red Ribbon model.'*
  - Ndakidemi E, Masika P, Luvanda B., Oluwole D., Asante E., **Olateju A**: '*Increasing Access to Information and Demand for Cervical Cancer Screening Services in Mwanza, Tanzania by Utilizing Mobile Technology*.'
- Univ. of Minnesota Symposium on Cancer in Tanzania Minneapolis| 2015
  - Speaker: *'Innovative solutions to combating cervical and breast cancer in Tanzania'*

SELECTED BLOGS AND PUBLICATIONS

- Schleiff, M., **Olateju, A.**, Decker, E. et al. A multi-pronged scoping review approach to understanding the evolving implementation of the Smallpox and Polio eradication programs: what can other Global Health initiatives learn? BMC Public Health 20, 1698 (2020).
- **Olateju A**., Sarathy M, Wieland J, Schocken C. Pink Ribbon Red Ribbon and the possibility to end cervical cancer in our lifetime. http://www.cancercontrol.info/2017/Olateju.pdf
- **Olateju A.** An innovative approach to screening for cervical cancer in Ethiopia. http://pinkribbonredribbon.org/an-innovative-approach-to-screening-for-cervical-cancer-in-ethiopia/
- **Olateju A**., Dialwa R. *Accessing Women Living in Hard-to-Reach communities of Botswana with Cervical Cancer Screening.* http://pinkribbonredribbon.org/accessing-women-living-in-hard-to-reach-communities-of-botswana-with-cervical-cancer-screening-mahalapye-district-hospitals-see-and-treat-clinic-outreach-services/

- Bertram M., **Olateju A**. January is cervical cancer awareness month. https://www.cancer.gov/about-nci/organization/cgh/blog/2016/cervical-cancer
- **Olateju A.** Africa's Hopeful Future: A look at tomorrow's opportunities and challenges. Contributing author to George W. Bush Institute's quarterly publication. https://www.bushcenter.org/catalyst/africa/rising-leaders.html

CONTRIBUTIONS TO NATIONAL AND INTERNATIONAL GUIDELINES

- Improving data for decision-making: a toolkit for cervical cancer prevention and control programmes. World Health Organization.(2019) https://www.who.int/ncds/surveillance/data-toolkit-for-cervical-cancer-prevention-control/en/
- National Guidelines for the Early Diagnosis of Breast Cancer and Referral for Treatment. United Republic of Tanzania. (2018) https://ww5.komen.org/International_Grants/2017_Tanzania.pdf
- National Quality Improvement Guidelines for Cervical Cancer Screening. United Republic of Tanzania. (2016)
- National Cancer Control Plan. First Edition. Federal Democratic Republic of Ethiopia. (2015-2020). https://www.iccp-portal.org/plans/NCCPEthiopia.pdf