BOTSWANA POPULATION & HOUSING CENSUS 2022 : ANALYTICAL REPORT

VOLUME 5

FERTILITY, MORTALITY AND HOUSEHOLD ENERGY USE

STATISTICS BOTSWANA

UNFPA

Republic of Botswana

PALO BATHO • CENSUS 2021 • STATISTICS BOTSWANA •

Mpala, Ke Botlhokwa

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PREFACE

The 2022 Population and Housing Census (PHC) represents a significant milestone in the conduct of Botswana's decennial Population and Housing Censuses. Its undertaking provides a comprehensive snapshot of the nation's demographic, social, and economic landscape. The data collected through this census offers invaluable insights into the country's evolving population dynamics, household characteristics and socio-economic trends.

These thematic volume follows a series of reports earmarked as products of the 2022 Population and Housing Census. Due to the rich resource of the census data, there is need to further delve into deeper analysis. This report presents a detailed thematic analysis of the 2022 PHC data. The analysis presented in this report is based on rigorous data processing and statistical techniques. Every effort has been made to ensure the accuracy and reliability of the findings.

The analysis of the 2022 PHC has been organized into six thematic volumes:

- **Volume 1**: Demographic and Social Characteristics, Registration, Youth and Elderly, Education
- **Volume 2**: Household Characteristics, Economic Activity
- **Volume 3:** Gender, Disability, Nuptiality, Migration, and Urbanization
- **Volume 4:** Transport and ICT, Agriculture and Land Ownership
- **Volume 5:** Fertility, Mortality and Household Energy Use
- **Volume 6:** Employment (Occupation and Industry)

I express my sincere gratitude to the dedicated team of professionals/analysts who contributed to the successful implementation and analysis of the 2022 PHC. Their hard work and commitment have made this comprehensive analysis possible. Statistics Botswana also acknowledge the support of our development partners, particularly the United Nations Fund for Population Activities (UNFPA) and United Nations Development Programme (UNDP), whose technical assistance was instrumental in the conduct of the census. I trust that these thematic volumes report will serve as a valuable resource for understanding Botswana's demographic and socio-economic landscape.

Dr. Lucky Mokgatlhe
Acting Statistician General
February 2025

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Botswana Demographic Indicators PHC, 1971, 1981, 1991, 2001, 2011 and 2022

Population Characteristics	1971	1981	1991	2001	2011	2022
Sex Ratio (Males per 100 Females)	84	89	92	93.8	95.5	95
Percentage Urban	9	17.7	45.7	54.2	64.1	66.5
Population Density (per km)	1	1.6	2.3	2.9	3.5	4.1
Crude Birth Rate (per 1000)	45.3	47.7	39.3	28.9	25.7	24.5
Crude Death Rate (per 1000)	13.7	13.9	11.5	12.4	6.25	6.7
Natural Rate of Increase (% per annum)	3.1	3.4	2.7	1.7	1.9	1.44
General Fertility Rate (per 1000 women aged 15-49)	189	210	161	106.9	92.2	90.0
Mean age at childbearing	30.5	30.6	30	30.3	20	30.4
Total Fertility Rate(births per woman)	6.5	6.6	4.2	3.27	2.7	2.9
Infant Mortality Rate	97	71	48	56	17	27.9
Child Mortality Rate	56	35	16	19		
Under 5 Mortality	152	105	63	74	28	22.4
Life Expectancy at Birth (years)	**55.5**	**56.5**	**65.3**	**55.6**	**68**	**69**
Males	52.5	52.3	63.3	52.0	66	66
Females	58.6	59.7	67.1	57.4	70	71
Mean Age (years)	**23.4**	**22.7**	**23**	**24.8**	**26.2**	**28.1**
Males	22.6	22.0	22.4	24.2	25.2	27.2
Females	24.1	23.4	23.5	25.3	26.8	28.9
Median Age (Years)	**15.0**	**15.3**	**16.8**	**20.1**	**23**	**26**
Males	13.5	15.0	16.0	19.4	22	25
Females	16.7	16.5	17.4	20.8	24	26
Population Growth Rate		**4.7**	**3.5**	**2.4**	**1.9**	**1.9**


PALO BATHO • CENSUS 2021

ANALYSIS OF PATTERNS, LEVELS AND TRENDS OF FERTILITY IN BOTSWANA

By: Gobopamang Letamo and Tiro Theodore Monamo

EXECUTIVE SUMMARY

A population census provides crucial information about the people in each geographic location: their spatial distribution, age, and sex composition, size, and change. One of the key determinants of population is fertility. The fertility component is the most amenable component of population change to manipulate and therefore most governments find it easy to manipulate it to achieve the desired demographic and development objectives of the country. As such, fertility estimates are imperative inputs into the socioeconomic development of a country.

The objective of this study is to investigate fertility levels, trends, and patterns to guide the socioeconomic and demographic policies and programmes of Botswana. Using the Botswana 2022 Population and Housing Census and previous census data, the specific objectives of this chapter are to assess the quality of fertility data derived from the census; estimate fertility levels and trends; describe the emerging fertility patterns by socio-economic and demographic variables; and suggest policy recommendations.

The current study is based on data collected cross-sectionally through a population census, which is a complete count of all the people in Botswana. The 2022 Population and Housing Census data were collected using three face-to-face questionnaires: household, institutional, and hotel institutional questionnaires. Fertility data were evaluated before being used for analysis and the Whipple's Index, Meyers' index, Bachi's index and the UN age-sex accuracy index all showed that the data were highly accurate. Various indirect estimation techniques (P/F Ratio, the Gompertz Relational, and the Arriaga Method) were used to check if they can produce similar results to the direct methods.

The fertility level in Botswana was estimated to be 2.7 in 2022 using the Arriaga adjusted estimate. The TFR based on observed age-specific fertility rates was estimated to be 2.9 children per woman in 2022. Because of the high quality of Botswana's 2022 PHC data, this study relied on the direct estimates of fertility and settled for a TFR of 2.9 children per woman. This estimate is also consistent with those found in Southern African countries and the World Bank estimate.

Fertility trends in Botswana show that fertility has been declining consistently since the 1980s, dropping from a high TFR of 6.5 children per woman in 1981 to 2.8 in 2011 and increased to 2.9 in 2022. This consistent drop is also evident from the data obtained from the mean number of children ever born among the 45–49-year-olds where completed family size dropped from 6.5 in 1981 to 4.0 in 2011 and 2.9 in 2022.

Fertility patterns show that fertility varies by place of residence, employment status, educational level and marital status. The lowest fertility levels were observed among residents of cities/towns compared to rural residents (2.4 compared to 3.5 children), the employed compared to the unemployed (2.8 compared to 3.3 children), those with tertiary or higher educational attainment compared to those with primary or less education (2.2 compared to 3.8 children), and those never married compared to those living together (2.8 compared to 3.8 children).

Conclusion and Recommendations

In conclusion, the following policy actions are recommended for harnessing the economic benefits of the demographic dividend: family planning and sexual reproductive health services for all, providing school-based sexual education, expanding girls' secondary school enrolment and retention, and a larger quantity of education opportunities to match economic opportunities is required; investing in the creation of new jobs in growing economic sectors and the development of an adaptive labour market; and reinforcing laws to discourage adolescent childbearing.

1 INTRODUCTION

1.1 Overview

Fertility statistics are imperative for the provision of reproductive and child health services, including antenatal care, postnatal care, and child immunization (Republic of the Union of Myanmar, 2016). These fertility statistics are important to indicate the demand for reproductive and child health services. Fertility statistics provide a crucial input for making population projections.

The number of people in a country that allows societies to sustain a decent standard of living without compromising the quality of life for future generations is referred to as an optimum population. An optimum population can be achieved by balancing the three components of population change, which are fertility, migration, and mortality. Therefore, population policies are designed to achieve the necessary changes in the three components to achieve the set demographic and developmental targets. The fertility component is the most amenable to manipulation and therefore most governments find it easy to manipulate it to achieve the desired demographic and development objectives of the country. However, interventions for mortality are usually designed to reduce it and never to increase it. Migration can be manipulated by controlling the number of people who enter the country but cannot force people to leave their country of origin.

There are various reasons why the census collection of fertility data is critical for the development of a country. First, fertility is the main driver of population change. The other two factors are mortality and migration. Secondly, complete and accurate data on the birth and deaths of children are used to generate various fertility and child survival indicators which support the implementation of population and development programmes. Third, fertility data are important for determining the distribution of social services such as education and health facilities. Fourth, census data provides an opportunity to disaggregate fertility data at lower levels of administration such as districts where registration of births is low or does not exist. Lastly, census data on fertility and child survival will complement available administrative data in computing key fertility and child survival indicators (Ghana Statistical Service, 2021).

1.2 Botswana context with regard to fertility

Botswana experienced a high fertility regime in the 1970s and early 1980s. However, by the mid-1980s and beyond fertility started to decline and continued until the early 2000s (Republic of Botswana, 2010). Fertility declined from 7.1 children per woman in 1981 to 3.2 in 2006 and down to 2.9 in 2011. Some of the factors attributed for the fertility decline are higher age at first birth, lower infant mortality, prolonged breastfeeding duration, higher education levels, use of modern contraceptives, urbanization, and women's participation in the labour force (Ngom and Zulu, 1994: Thomas and Muvandi, 1994; Langeni-Mndebele, 1997; Letamo and Letamo, 2002; Letamo and Oucho, 2002; Republic of Botswana, 2009).

The Revised National Population Policy of Botswana has the goal of improving the quality of life and standard of living (Republic of Botswana, 2010).

1.3 Objectives of this fertility chapter

The objective of this chapter is to further investigate fertility levels, trends, and patterns to guide the socio-economic and demographic policies and programmes of Botswana. Using the Botswana 2022 Population and Housing Census and previous census data, the specific objectives of this chapter are to:

- Assess the quality of fertility data derived from the census;
- Estimate fertility levels and trends; and
- Describe the emerging fertility patterns by socio-economic and demographic variables
- Suggest policy recommendations

1.4 Definition of fertility terms

Age-Specific Fertility Rates (ASFRs): are obtained by dividing the number of births by women in a particular age group, x to x+n, in a specific calendar year, to the mid-year population of women in the same age group. It measures the average number of children a woman of a particular age group would have under the current fertility conditions of the year.

Childbearing Age: is generally for women in the reproductive age range, 15–49 years.
Child-Woman Ratio: the ratio of children to women aged 15-49 years.
General Fertility Rate: the number of live births per 1,000 women aged 15-49 years in a population per year.
Total Fertility Rate: the average number of children that will be born to a woman by the time she ends her childbearing if she were to experience all her childbearing years conforming to the age-specific fertility rates of a given year.
Parity: the number of children born alive to a woman.
Children Ever Born: the mean number of children born alive to women in a given age group.
Live birth: The complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of pregnancy, which after separation, breathes or shows any other signs of life such as the beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles, whether or not the umbilical cord has been cut or the placenta is attached.

2 LITERATURE REVIEW

Population numbers are critical for national programmes and policies on education, health care provision, labour, social welfare, economic development, and many others. Any discussion about the social and economic development of a country is about people. A population census provides crucial information about the people in each geographic location: their spatial distribution, age, and sex composition, size, and change. One of the key determinants of population is fertility.

The reproductive behaviour in Asia, Africa and Latin America are said to be regulated by a wide range of forces such as taboos on sexual intercourse at certain periods, terminal abstinence from intercourse after becoming a grandparent, changes in marriage patterns or spousal separation and breastfeeding patterns (Hirschman, 2001; Bulatao, 2001). Coale (1973) cited in Cleland and Wilson (1987) identify three conditions for the decline in marital fertility in Europe; (i) fertility must be the calculus of conscious choice; (ii) effective techniques of fertility reduction must be known and available; and (iii) reduced fertility must be perceived to be advantageous. These summarize the key explanations for fertility transitions and the next section is an attempt to briefly highlight these explanations.

Mortality reduction

The Demographic Transition Theory links a reduction in fertility to a reduction in mortality. The theory argues that fertility can only decline after the decline in mortality. Bongaarts (2006) argues that changes in the cost/benefit ratio lead parents to want fewer children, and mortality decline raises child survival so that families need fewer births to achieve their desired number of surviving children. Doepke (2005) also argues that declines in child mortality lower total fertility rates but do not cause decreases in net fertility. Yairiada (1984) has also demonstrated that a decline •in infant mortality that is due to an increase in per capita real income triggers a subsequent decline in fertility. As such where mortality levels are low, one would expect to see declining fertility rates.

Reduced economic contributions from children

Socioeconomic development is taken as the main cause of fertility decline over some time in the benefits of children and the rise in their costs (Bongaarts, 2006). Bulatao (2001) argues that children contribute less if they cannot work while young, have to spend many hours and years in school and are less committed to supporting aging parents. In addition, Cain (1983) noted that several sources of change would make children even more costly: such as; (1) an increase in female wages, (2) labour force participation that raises the time costs of children, (3) technological change that erodes the market for child labour, all reducing the potential contributions of children. This changing socio-economic landscape may explain why couples might want fewer children in the course of socio-economic development.

Opportunity costs of childbearing

Childrearing interferes with adult activities. It can make it difficult for the mother to work and her income is a cost to the family (Bulatao, 2001). It is argued that mothers have an incentive to earn their own cash and protect their own earning power by increasing employment and reducing their fertility (Joshi, 1997).

Family formation

The change to fewer births is accompanied by a transformation in the institution of the family from a multigenerational concern with clear lines of authority to a small, conjugal unit focused on the individual needs of the members (Bulatao, 2001). As couples' aspirations, preferences, tastes and choices change with the changing socio-economic and cultural landscape, their childbearing decisions also change.

Vanishing cultural props for childbearing

Traditional societies maintained high fertility because it was fully supported by religious and cultural values and norms of the time. As these normative support systems weaken as societies modernize, individuals gain the power to make their own choices, often in preference for smaller families. It is this change that facilitates fertility transitions in many developing countries. Bongaarts (2006) stipulates that the decline in demand for children in turn raises the demand for birth control (i.e. contraception and induced abortion) and to the extent this demand is satisfied, lower fertility results. Africa's low level of economic development and heavy reliance on agriculture has been cited as one of the reasons for high fertility (Goliber, 1997). Another important factor for high fertility regime has been identified as religious and cultural traditions of old age security and insurance against family mortality (Goliber, 1997).

Improved access to effective fertility regulation

The availability and accessibility of family planning programmes facilitate fertility transition by reducing the cost of birth control, thus raising the level of implementation of the demand for contraception and reducing the unmet need for contraception (Bongaarts, 2006). The 1997 National Population Policy of Botswana promoted the use of modern contraceptives as a way of averting unwanted and unplanned births and attaining the desired family size by couples.

Marriage delay

The delayed age at first marriage and age at first birth has a bearing on the eventual fertility. Marriage delay has often added to overall fertility decline (Bulatao, 2001). Where most of the childbearing occurs outside the institution of marriage, age at first birth may be used as an indicator for delayed childbearing.

Diffusion

The spread of ideas and practices that lower fertility has often facilitated the adoption of the strategies discussed above. The idea is that individuals do not act alone: they interact and influence each other, giving the process of fertility change its particular dynamics (Bulatao, 2001). The adoption of small family size norms may be a result of interaction with the West and other cultures where small family size is the norm.

Based on this framework, it is evident that the existing literature on fertility change falls far short for us to have a deeper understanding of fertility dynamics in Botswana. The objective of this study, therefore, is to examine the fertility levels, trends, and differentials and to try to explain the causes of the observed fertility change. An attempt to speculate on prospects for fertility is also undertaken.

The fertility transition in the developing countries was accompanied by many important socio-economic changes such as increasing urbanization, increasing life expectancy, the decline in infant and childhood mortality rates, increased levels of education, the decline in agricultural employment rate, increasing gross national income, availability of induced abortion services, and increasing contraceptive uptake (Bongaarts and Hodgson, 2022). Bongaarts and Hodgson (2022) argue that although a definitive answer as to why fertility declined in the developing world is difficult to offer because of a large number of concurrent changes taking place, an analytical framework for determinants of fertility that summarizes the multiple factors can assist to elucidate these factors.

2.1 Theoretical Framework

Over time several theories and their variants have been developed and offered as explanations providing insights that are crucial for understanding reproductive change and the design of policies aimed at lowering fertility and slowing down population growth (Bongaarts and Hodgson, 2022). The analytical framework discussed below is a summary of explanations provided by Bongaarts and Hodgson (2022) (see Figure 1 below). It should be noted that fertility is directly determined by behaviours such as contraceptive use and induced abortion. These behaviours are in turn determined by a set of intermediate factors such as desired family size, demand for contraception and the implementation of preferences. The background or underlying variables consist of variables such as socio-economic change, voluntary family planning programmes, and coercive anti-natalist policies (Bongaarts and Hodgson, 2022). In Figure 1, the three pathways represent the three different drivers of fertility change.

Path 1. Conventional Theories

Path 1 deals with conventional theories. One such theory is the demographic transition theory which argues that in traditional agricultural societies, high fertility was needed to offset high mortality and ensure population survival. Conscious contraceptive practices did not exist at the time. However, as societies modernized as a result of economic and social changes such as industrialization, urbanization, increase in education, growing incomes, and declining mortality led to fertility transition (Bongaarts and Hodgson, 2022). The rising costs of children and their declining economic value were key drivers of a decline in family size, which in turn increased the demand for and adoption of birth control to implement changing preferences (Bongaarts and Hodgson, 2022).

Other scholars such as demographers, economists, and sociologists further elaborated on this conventional framework. Economists assumed parents to be rational actors who would maximize the utility derived from the various choices that they make. As such, economists argue that parents in choosing family size have preferences not only in the number of children they want but also the quality of children they want. Therefore, as countries develop and incomes rise, parents increasingly want high-quality children which raises their cost, thus driving parents to want smaller family sizes (demand theory of fertility) (Bongaarts and Hodgson, 2022).

Path 2. Revisionist Theories and Family Planning Programmes

Path 2 raises questions and concerns regarding the adequacy of the demand theory of fertility in explaining fertility transition. One assumption of the early demand theories of fertility was that the costs of contraception is so low that it can be ignored. This assumption was challenged in the late 1960s and early 1970s when it became evident that there was frequent use of induced abortion in both the developed and developing countries, implying that unintended pregnancies were common (Rochat et al., 1980; Tietzi, 1981: cited in Bongaarts and Hodgson, 2022). These findings influenced the economic theories of fertility developed by Easterlin (1975, 1978) and Easterlin and Crimmins (1985). His theory recognizes that the cost of birth control (broadly defined to include economic, health, psychological, and social obstacles) could be substantial, leading to significant number of unplanned pregnancies. The theory also acknowledges that without efforts to control conception, women who are sexually active will bear many children because their reproductive years last decades. Therefore, parent must practice birth control to avoid unplanned births (Bongaarts and Hodgson, 2022).

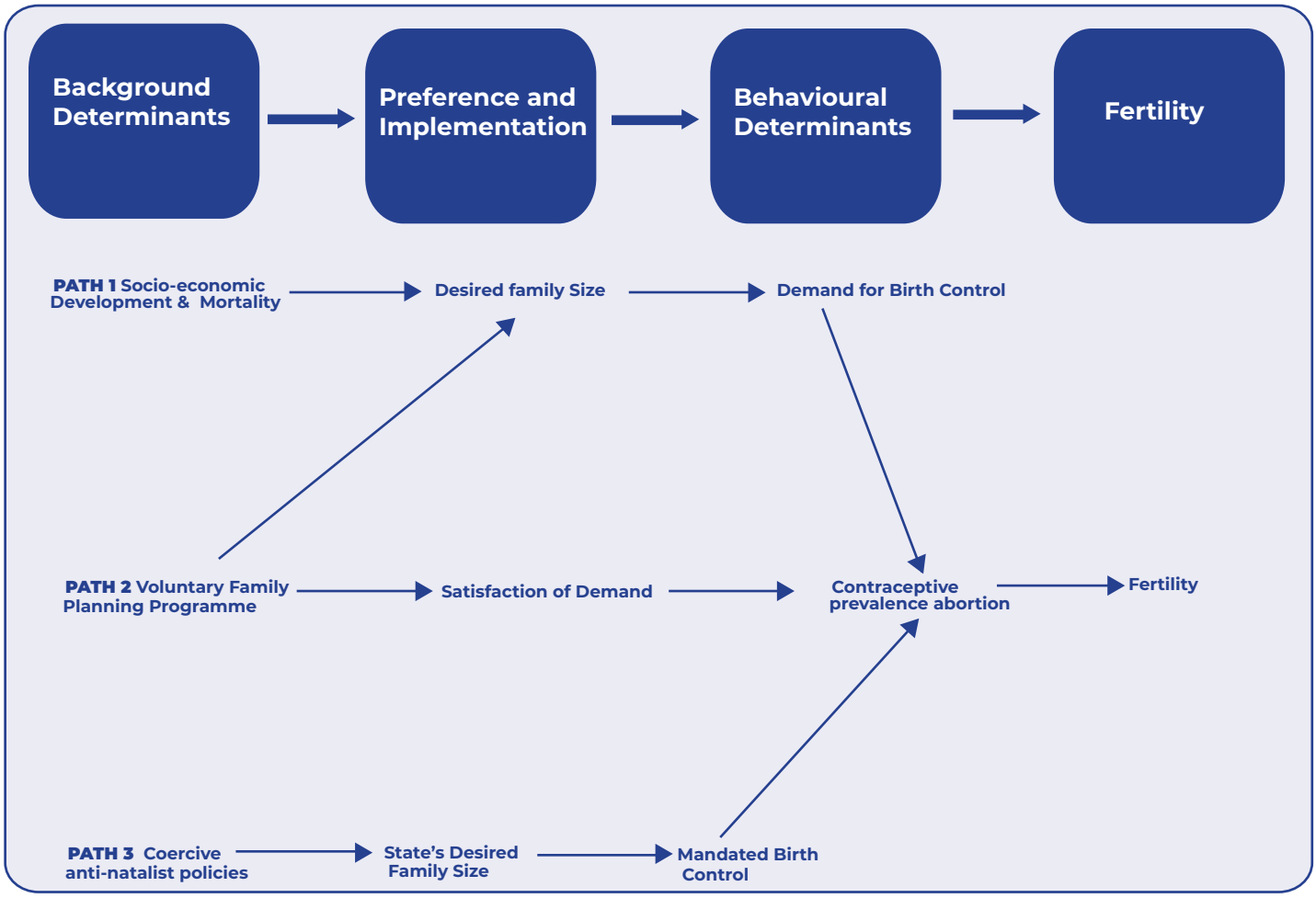
Another challenge found with the early demand theories was failure to observe a link between development indicators and fertility as expected from conventional theories. Data from European countries yielded two surprising results: (i) socio-economic conditions were only weakly associated with fertility declines; and (ii) once a region in a country had begun fertility decline, neighbouring regions sharing the same language or culture followed after short delays, even when they are less developed (Bongaarts and Hodgson, 2022). In addition, levels and trends in fertility in the developing countries since the 1950s deviated widely from the expectations (Bongaarts and Watkins, 1996).

Another crucial component that was unexplored by early demand theories was the role of social norms in influencing reproductive behaviour. Such normative structures can be important obstacles to the introduction of new behaviours such as contraceptive use, in societies where it has been absent. Traditional norms, including those promoting high fertility, tend to become less influential as societies develop and education levels rise (Bongaarts and Hodgson, 2022). These findings provide a strong rationale for family planning programmes that can accelerate fertility transitions by providing information that can alter parents' evaluations of the costs and benefits of children and more directly reduce the costs of contraception to those who want to plan or limit childbearing.

Path 3. Coercive Policies

A third path to lower fertility is for governments to implement coercive birth control policies, An example of this approach is China's one-child policy which sets a limit on the number of children women can have and mandates birth control to reach the set objective (Bongaarts and Hodgson, 2022). Another example is India's sterilization programme in the 1970s. Coercion of any kind is universally rejected as an abuse of human rights. Many governments interested in accelerating fertility decline opt for voluntary family planning programmes rather than coercive policies.

FIGURE 1: ANALYTICAL FRAMEWORK FOR THE DETERMINANTS OF FERTILITY



Source: Bongaarts and Hodgson, 2022

3 METHODOLOGY

This section discusses the research design used, data collection methods adopted, data analysis methods used and ethical considerations adopted

3.1 Research design

The current study is based on data collected cross-sectionally through a population census, which is a complete count of all the people in Botswana.

3.2 Data collection methods

The 2022 Population and Housing Census data were collected using three face-to-face questionnaires. One of the questionnaires was the household questionnaire which was designed to collect data from households. Another questionnaire was the institutional questionnaire which consisted of two types – (i) institutional questionnaire designed for tertiary students living away from their parental homes while attending college or university; the homeless, army staying in army barracks; and mine workers staying in mine hostels, and (ii) hotel institutional questionnaire which covered patients in hospitals, persons staying in hotels, lodges, safari camps, and prisoners. It should be noted that the institutional questionnaire was a shorter version of the household questionnaire. After data collection, the data were merged by Statistics Botswana to create a single data file which was used for data analysis.

3.3 Evaluation of fertility data

Some of the problems with age reporting accuracy can be related to several causes. Johnson et al. (2022) have summarised how age misreporting may come about in the following section. First, respondents round the ages (or year of birth) to end with a digit 0 or 5 (or even numbers). Second, age may be overstated their ages, for example, to gain prestige or pensions. Third, respondents may understate their ages, for example, to avoid military service. Fourth, women may under- or overstate their ages depending on social norms about childbearing, for example, childless women may understate their ages, or women with higher-than-normal numbers of children may overstate their ages. Fifth, using relatives or neighbours to report the age of a respondent may lead to inaccurate age reporting. Lastly, problems with the census questionnaire or procedures for collecting age may result in the incorrect recording of age (Johnson et al. 2022). Because of the above-mentioned problems, it is imperative that before analysing data, age misreporting has to be checked and corrected if it exists. This section discusses the different methods used to check for age misreporting and its correction if it exists.

3.3.1 Assessment of age data

3.3.1.1 Whipple's index

The Whipple's index was developed to reflect a preference for or avoidance of a terminal digit. The original Whipple's index measures age heaping for ages ending 0 and 5 in the age range of 23 to 62 years. It assumes a linear distribution of ages in each 5-year age range. The choice of the range 23 to 62 is standard, but largely arbitrary. In computing indexes of heaping, ages during childhood and old age are often excluded because they are strongly affected by other types of errors of reporting than preference for specific terminal digits.

Whipple's Index Interpretation (Ranges between 100 and 500)

Less than 105 = Highly accurate
105 – 109.9 = Fairly accurate
110 – 124.9 = Approximate
125 – 174.9 = Rough
175 or more = Very rough

TABLE 1: Whipple's index, Botswana's 2022 Population and Housing Census

	MALE	FEMALE	BOTH SEXES
2022	100	99	99

The results in **Table 1** above show that the 2022 population and housing census was highly accurate for males, females and both sexes.

3.3.1.2 Meyers' index

Meyers' index is conceptually like Whipple's index, except that the index considers preference (or avoidance) of age ending in each of the digits 0 to 9 in deriving overall age accuracy score. It is based on the principle that in the absence of age heaping, the aggregate population of each age ending in one of the digits 0 and 9 should represent 10% of population. The theoretical range of Myers' Blended index is from 0 to 90, where 0 indicates no age heaping and 90 indicates the extreme case where all recorded ages end in the same digit.

The summary of the index can be done through the following categories.

Good <10
Satisfactory 10-20
Poor <20

TABLE 2: Meyers's index, Botswana's 2022 Population and Housing Census

MALE	FEMALE	BOTH SEXES
2.4	2.2	2.3

The Myers' index for Botswana's 2022 PHC data was 2.3 for both sexes, 2.4 for males and 2.2 for females. In ranking, the indices state that any score less than 10 indicates good data, hence the 2022 PHC had good data.

3.3.1.3 Bachi's index

The Bachi index involves applying Whipple's index method repeatedly to determine the extent of preference for each final digit. It equals the sum of the positive deviations from 10%. The Bachi's index has a theoretical range from 0 to 180 and 10 is the expected value for each digit. 0 indicates no age heaping and 180 indicates that a terminal digit was reported for all ages. It considers the population between 23 and 72 years.

TABLE 3: Bachi's index, Botswana's 2022 Population and Housing Census

MALE	FEMALE	BOTH SEXES
1.4	1.3	1.4

Bachi's index of 1.4 for males, 1.3 for females and 1.4 for both sexes were reported for Botswana's 2022 census data. The indices were closer to zero, hence the data for Botswana's 2022 PHC was good.

3.3.1.4 National UN Age-sex Accuracy Index

The United Nations age-sex accuracy index is used to evaluate the quality of enumerated sex and age data in 5-year age groups. It combines measures of the accuracy of age group data for both sexes with the accuracy of sex ratio scores of various age groups. The United Nations age-sex accuracy index classifies population age-sex structures into three categories:

1. Accurate if the score is < 20
2. Inaccurate if the score is 20 - 40
3. Highly inaccurate if the score is > 40

Table 4 below shows the results of the age-sex accuracy index for males and females for Botswana's 2022 PHC data.

TABLE 4: UN Age-sex Accuracy Index, Botswana's 2022 Population and Housing Census

INDICATOR	SCORE
Males' Age Ratio Score	3.9
Females' Age Ratio Score	3.4
Sex Ratio Score	3.0
Un Age-Sex Accuracy Index	16.3

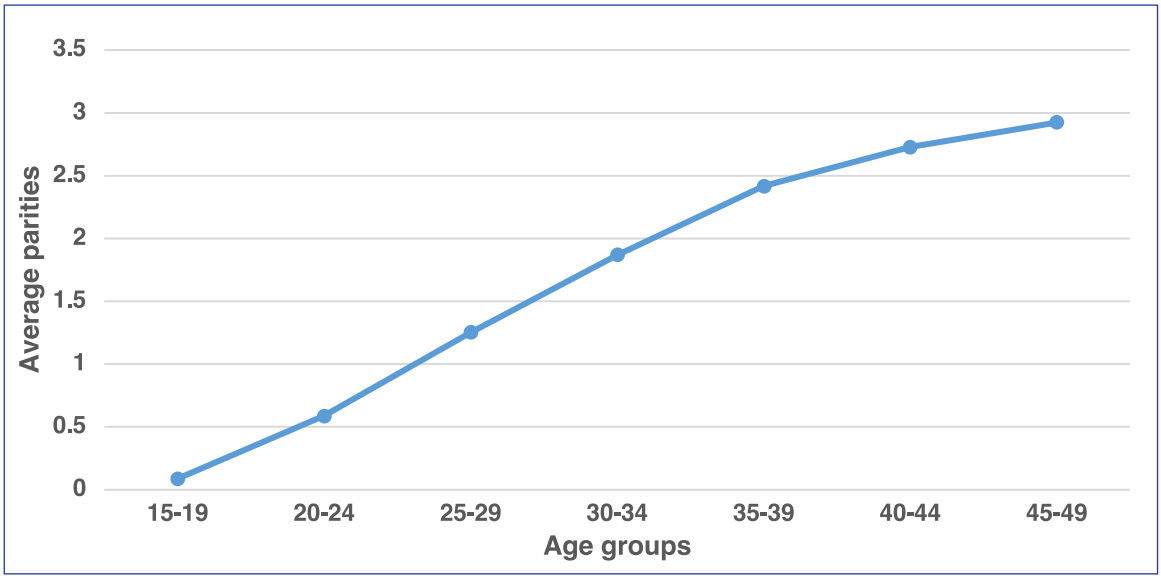
The UN age-sex accuracy score is 16.3, which, according to the classification, shows accurate data. The accuracy is slightly higher in female age data than in males. It is recommended that data is subjected to smoothing if the accuracy index is above 20. Therefore, this data was not subjected to any smoothing. The data is more accurate and can be analyzed to produce reliable results.

3.3.2 Assessment of the quality of data on fertility

3.3.2.1 Assessment of parity data

The first question on fertility asked in censuses concerns women's lifetime fertility (Moultrie, 2013a). Data on fertility is subject to reporting errors. First, there is recall bias with increasing age which is likely to result in the omission of some births. Second, fertility data are best reported by the mother. However, in some instances, data on children ever born are reported by proxy respondents where the mother is absent. The proxy respondent is likely to be less knowledgeable about the children in the household, especially children who reside elsewhere and those who have died. These two possible sources of error lead to under-enumeration of parities (Republic of Zimbabwe, 2015). Figure 2 below depicts that there is a positive relationship between average parities and the age of women (average parities, increase with age of women). As expected, the number of children ever born should be higher among women who are in their late ages of childbearing.

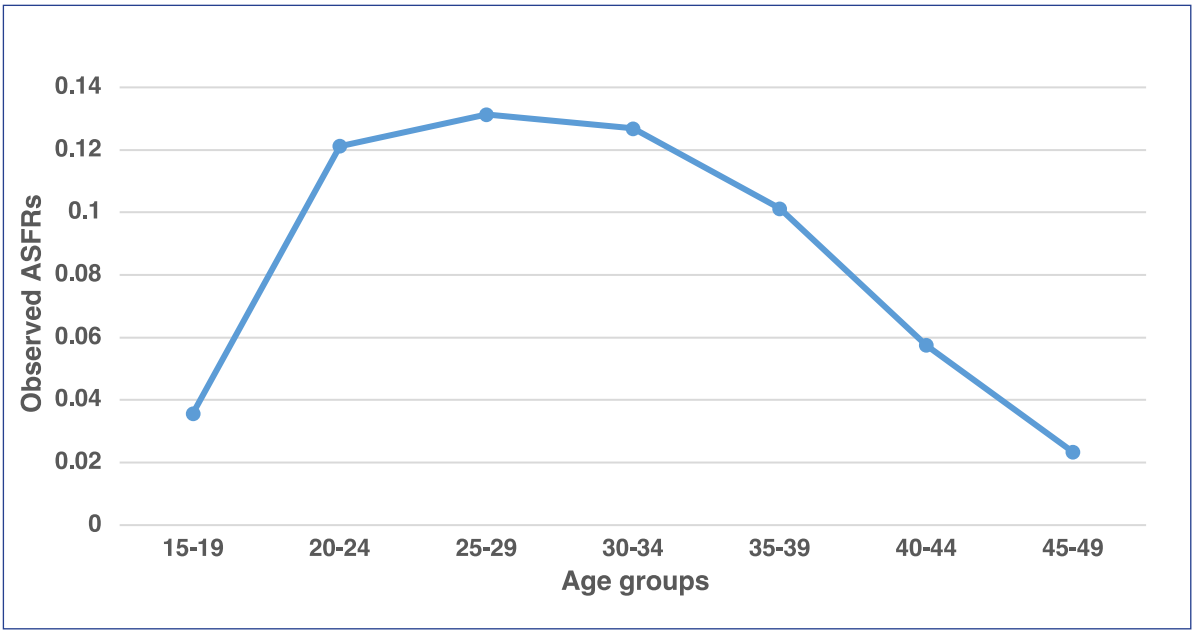
FIGURE 2: DISTRIBUTION OF WOMEN BY AGE AND PARITY



3.3.2.2 Quality of data on births in the past 12 months before the census

This section discusses some of the possible errors associated with recent births. First, the uncertainty of the exact date of birth relative to the reference period may introduce errors by either excluding or excluding some births. Second, incorrectly moving births in or out of the reference period. The above reference period errors could lead to the inclusion or exclusion of births that were not supposed to. Third, women who had a birth recently but died or migrated out before the census will lead to under-reporting of recent births. Fourth, a household that had a birth recently, but the household dissolved before the census will lead to the omission of recent births. **Figure 3** below displays that fertility increases from age 15 years up to 29 years, afterwards it decreases from 30 years up to 49 years. This is consistent with the estimates by the American Society for Reproductive Medicine, which states that women under 30 have about 25% chance of getting pregnant naturally each cycle and that chance drops to 20% for women over 30 whereas, by 40, the chance of getting pregnant naturally each month is just 5%.

FIGURE 3: DISTRIBUTION OF WOMEN BY AGE AND OBSERVED ASFRS



3.3.3 Conclusion on the assessment of the quality of fertility data

The assessment of the quality of the data on fertility from the 2022 population and housing census showed that the quality of the fertility data was highly accurate. Therefore, data adjustments were not applied for the data because it was highly accurate. If applied in such a situation, smoothing formulas could introduce more errors when they eliminate minor irregularities that truly reflect the population composition. Consequently, this study settled for the use of direct methods of estimating fertility to investigate the levels, patterns, and differentials fertility in Botswana.

3.4 Methods used in the indirect estimation of fertility levels

This study also explored the use of indirect estimation techniques of fertility to see what results they would yield compared to the direct estimates. However, this study settled on using the direct methods to investigate levels and trends of fertility because of the high quality of Botswana's 2022 PHC data.

3.4.1 The P/F Ratio Method

The P/F ratio method is based on the following assumptions: 1) fertility has been constant in the recent past; 2) the level of underreporting of births in the year before the census/survey does not vary by age; 3) data on CEB for younger women (up to 35 years of age) are more completely reported than births in the previous

year (Moultrie et al. 2013); and 4) age misreporting among women of childbearing ages is negligible. The assumptions do not quite hold in the current Botswana situation. For instance, the crucial assumption of constancy of fertility in the period immediately before a census/survey data collection is not true for the country's population. A study by Bainame and Letamo (2014) has shown that fertility has been declining in the country since the 1980s.

Some refinements to the method have been proposed. These include the Feeney (1998) approach and the Synthetic cohort P/F ratio method. The calculated P/F ratios indicate that the P/F ratio method cannot be used to adjust ASFRs as the ratios are three times above unity which could indicate declining fertility. Some of the indirect techniques require certain assumptions regarding the past course of fertility. For example, the Brass P/F Ratio method requires fertility to have remained unchanged. If this method is applied to data when fertility has been declining, as is currently the case in Botswana, it overestimates current fertility. The estimated TFR from P/F Ratio method was 3.2 based on the adjustment factor of averages of P3 /F3 and P4 /F4 which is highly likely to be an overestimate. Therefore, it was decided that because one of the key assumptions of the P/F ratio method has been violated, it cannot be used to provide reliable fertility estimates in the context of Botswana.

3.4.2 The Gompertz Relational Method

The relational Gompertz model evolved from the Brass P/F ratio method. It works with the same input data and makes use of the parity data from younger women to set the level of fertility, while the shape of the fertility distribution is determined by women's reports on recent births. The advantage of the method is that it provides estimates of TFR based on each 5-year age group in childbearing ages which allows for inferences about trends in the level of fertility (Arriaga 1994). Another attractive characteristic of the Relational Gompertz method is that it is flexible enough to fit good data well but bad data badly (Udjo 2009). The major limitations of the method include: 1) the results obtained by applying the method are highly sensitive to errors in the reported numbers of children ever born by women; 2) estimates based on data for women aged 15–19 years are not reliable because data for these ages are sensitive to information errors; 3) the method is only well suited for populations with medium to high fertility (Paget and Timæus, 1994). Estimates derived from the Gompertz relational method are rather higher **(see Table 5 below)**. As such this method cannot be used to estimate fertility in the context of Botswana.

TABLE 5: Calculation of corrected fertility rates using Gompertz Relational Method, Botswana 2022

AGE	ASFR *	P2/F2 - 1.108	P3/F3 - 1.064	P3/F3 1.021	Avg (P3/F3, P4/F4) 1.043
15-19	0.0434	0.0481	0.0462	0.0443	0.0453
20-24	0.1264	0.1401	0.1345	0.1292	0.1319
25-29	0.1319	0.1461	0.1403	0.1347	0.1375
30-34	0.1252	0.1388	0.1333	0.1279	0.1306
35-39	0.0982	0.1088	0.1044	0.1003	0.1024
40-44	0.0528	0.0585	0.0562	0.0539	0.0550
45-49	0.0195	0.0216	0.0207	0.0199	0.0203
TFR	2.9870	3.3096	3.1783	3.0510	3.1146

3.4.3 The Arriaga Method

Based on a simulation model, Arriaga (1994) shows that under conditions of declining fertility, the number of children ever born by the age of the mother changes linearly for mothers under 35 years of age. This observation and the fact that parity reports for women under 35 years of age are usually of good quality allow for linear interpolation of the data on children ever born per woman by age of mother from two or more censuses/surveys to derive estimates of children ever born for one year prior (or posterior) to the date of the census/survey (Arriaga 1994). Therefore, having information on the average number of children ever born per woman by age of mother for two consecutive years, the cohort differences between them for each single year of age of the female population represent ASFRs by single year of age.

The Arriaga method is affected by the misreporting of children in older ages. However, as with the P/F ratio method, if an age pattern of fertility is available such a pattern can be adjusted to the fertility level implied by the fertility rates derived from the information on children ever born. This study uses the Arriaga technique to indirectly estimate TFR for the year 2022, alongside the direct TFR estimate on the basis that it serves to be a superior method to the P/F Ratio method on the account that it does not conform to the assumption that fertility must have been constant in the recent past.

4 FINDINGS AND DISCUSSION

The findings of this study start by presenting the levels, trends and differentials of fertility derived from the Arriaga method and the direct method of estimating fertility. All other methods of estimating fertility were considered inadequate especially where the method assumptions were violated.

Fertility levels

The results in **Table 6** below show estimates of fertility based on the Arriaga method with adjusted ASFRs based on different age groups. According to the estimates of fertility based on the Arriaga method, the total fertility rate for Botswana in 2022 was estimated to range from 2.7 to 3.0 depending on the age group used to adjust the ASFRs data. However, the estimated TFR for Botswana is 2.74 derived from the adjusted ASFR and TFR based on women 25-34 because the technique recommends the adjustment factor close to the mean age at childbearing which is 30.1 years. If the adjustment factor used to adjust ASFRs is for women aged between 20 and 29 years then the estimated TFR would be almost the same as the reported TFR, which are 2.926 and 2.987, respectively.

The direct estimate of 2.98 children per woman is reasonable and it is consistent with fertility trends in sub-Saharan Africa. For instance, South Africa's national TFR was estimated to be 2.6 in the year 2016 (Tesfa, et al., 2023). Eswatini's TFR was estimated to be 2.8, South Africa 2.4, Lesotho 3.0, and Botswana 2.8 in 2021 (World Bank, 2022). However, Botswana's TFR of 2.7 in 2022 using indirect estimation techniques is lower compared to the direct estimate of fertility, which in this case is more reliable because of the high quality of the data, henceforth we cannot rely on indirect estimation methods to estimate fertility levels from Botswana's 2022 PHC data.

TABLE 6: Age-Specific Fertility Rates and Total Fertility Rates, by Maternal Age, Botswana 2022

AGE	REPORTED ASFR	ADJUSTED 20-29	ADJUSTED 25-29	ADJUSTED 25-34	ADJUSTED 30-34
15-19	0.0434	0.0426	0.0409	0.0398	0.0388
20-24	0.1264	0.1239	0.1188	0.1158	0.1127
25-29	0.1319	0.1292	0.1239	0.1207	0.1175
30-34	0.1252	0.1227	0.1176	0.1146	0.1116
35-39	0.0982	0.0962	0.0922	0.0899	0.0875
40-44	0.0528	0.0517	0.0496	0.0483	0.0470
45-49	0.0195	0.0191	0.0184	0.0179	0.0174
TFR	2.987	2.926	2.807	2.735	2.663
Mean Age	30.38				

Fertility trends

Data from the previous censuses show that fertility has been declining since the 1980s. The total fertility rate (TFR) was 6.6 children per woman in 1981 and decreased to 4.2 in 1991, 3.3 in 2001, 2.8 in 2011 and increased to 2.98 in 2022 **(see Table 7 below)**. Thus, fertility decline has been sustained since the 1980s. An analysis of the age-specific fertility rates (ASFRs) shows a substantial decrease in 20–24-year-olds specifically between 2011 and 2022. However, age-specific fertility rates for the 15–19-year-olds show a rise, implying rising adolescent birth rates. All the other age-groups (25-29, 30-34, 35-39, 40-44 and 45-49) also showed an increase in the age-specific fertility rates from the years 2011 to 2022.

TABLE 7: Reported Age Specific Fertility Rates and Total Fertility Rates: 1981-2022

AGE	1981	1991	2001	2011	2022
15-19	0.1015	0.0536	0.0533	0.0375	0.0434
20-24	0.2599	0.1340	0.1713	0.1323	0.1264
25-29	0.2504	0.1338	0.2021	0.1316	0.1319
30-34	0.2336	0.1191	0.1296	0.1121	0.1252
35-39	0.1902	0.1023	0.0686	0.0863	0.0982
40-44	0.1341	0.0641	0.0258	0.0429	0.0528
45-49	0.837	0.0358	0.0031	0.0139	0.0195
TFR	6.5	4.2	3.3	2.8	2.9

The completed family size is the number of children ever born by the end of the reproductive period of a woman's life. It tends to exhibit much more stability than age-specific fertility rates from year to year. Usually, the average parity of women aged between 45 and 49 is taken to represent the completed family size with the assumption that the fertility of older cohorts is equal to the current fertility experience of women in childbearing ages. **Table 8** below supports the consistent fertility decline from the 1980s to the year 2022. It is certain from **Table 8** that both the completed family size and the TFR show a sustained decline since 1981. The completed family size shows that fertility declined from 6.5 children per woman in 1981 to 2.9 in 2022. TFR shows fertility declined from 6.6 in 1981 to 2.8 in 2011 and suddenly increased to 2.98 births per woman in 2022.

Table 8: Comparison of Completed Family Size and Total Fertility Rates by Age of Women: 1981-2022

	AGE-GROUP							
YEAR OF CENSUS	15-19	20-24	25-29	30-34	35-39	40-44	45-49	TFR
1981	0.26	1.33	2.76	4.16	5.24	6.15	6.5	6.5
1991	1.12	1.12	2.27	3.49	4.60	5.56	6.1	4.2
2001	0.13	0.85	1.68	2.65	3.60	4.56	5.3	3.3
2011	0.10	0.73	1.44	2.12	2.75	3.38	4.0	2.8
2022	0.09	0.59	1.25	1.87	2.42	2.73	2.9	2.9

4.3 Fertility differentials

Fertility differentials in this study are presented for the type of localities, employment status and level of education because these characteristics are the most important structural stratifiers or societal hierarchies. Table 9 shows the TFRs and the mean number of children ever born to women aged from 45 to 49 years by type of locality, employment status, level of education and marital status. As expected, the fertility of women living in cities and towns was much smaller than that of women residing in urban villages and rural areas, for both the TFR and mean children ever born. Most of the difference between rural and urban fertility rates was a result of higher ASFRs among rural residents aged from 20 to 39.

Data in **Table 9** also shows that TFR and the mean number of children ever born to women aged 45-49 years were lower among women who reported that they were employed at the time of the census compared to those who were not employed. The analysis also revealed that fertility rates were lower among women who had tertiary education compared to those who had secondary education and primary or less education. The findings of this analysis are consistent with that of other studies in sub-Saharan Africa. These results are consistent with the previous studies that have reached a similar conclusion. Urbanisation, employment, and high educational attainment are known to be negatively associated with fertility.

TABLE 9: Total fertility rates and mean number of children ever born by women's types of localities, women's employment status, women's level of education, and women's marital status Botswana 2022

CHARACTERISTIC	15-19	20-24	25-29	30-34	35-39	40-44	45-49	TFR	Mean No. of CEB (45-49)
TYPE OF LOCALITY									
Cities/ towns	0.013	0.064	0.091	0.099	0.074	0.038	0.014	2.0	2.4
Urban villages	0.028	0.111	0.124	0.121	0.097	0.056	0.020	2.8	2.8
Rural areas	0.065	0.190	0.173	0.149	0.120	0.066	0.024	3.9	3.5
EMPLOYMENT STATUS									
Employed	0.059	0.090	0.099	0.103	0.079	0.045	0.018	2.5	2.8
Not employed	0.036	0.141	0.168	0.159	0.131	0.072	0.025	3.7	3.3
LEVEL OF EDUCATION									
Primary/ less	0.093	0.183	0.179	0.161	0.128	0.072	0.021	4.2	3.8
Secondary	0.035	0.153	0.149	0.131	0.102	0.055	0.020	3.2	2.9
Tertiary/ higher	0.010	0.056	0.109	0.123	0.093	0.049	0.021	2.3	2.2
MARITAL STATUS									
Married	0.222	0.244	0.223	0.179	0.116	0.057	0.026	5.3	3.1
Never married	0.032	0.114	0.123	0.118	0.097	0.058	0.023	2.8	2.8
Living together	0.310	0.226	0.178	0.155	0.125	0.076	0.026	5.5	3.8
Previously married	0.556	0.110	0.101	0.077	0.070	0.040	0.020	2.1	3.0

5 POLICY IMPLICATIONS

This section presents key findings from the 2022 PHC and their implications in terms of the development of policies and programmes that will address the fertility issues identified. The section identifies policy implications for achieving the overall objective of the Sustainable Development Goals, to leave no one behind, by ensuring full participation of women and men, girls, and boys, in the country.

Government support to family planning

Access to family planning and reproductive health services is critical to the health of women and children worldwide. Improving such access can help to prevent maternal deaths and reduce unwanted pregnancies. Target 3.7 of the Sustainable Development Goal (SDG) 3 on "Good health and well-being: Ensure healthy lives and promote well-being for all at all ages" calls on Botswana "to 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 by 2030". The decline in fertility levels shows that Botswana's support for family planning is becoming successful. Investing in family planning and reproductive health services is therefore important in reducing the level of fertility in Botswana. In addition, the fertility rate of 2.9 children per woman in 2022 is closely in line with the Government policy of maintaining fertility at 3 children per woman as per the Revised National Population Policy of 2010.

Measures to Improve Adolescent Sexual and Reproductive Health

The analysis of this study showed that age-specific fertility rates among 15–19-year-olds increased from 37.5 births in 2011 to 43.4 births per 1,000 women aged 15-19 years in 2022. Adolescent pregnancies and births are closely associated with negative outcomes in sexual and reproductive health and the social and economic well-being of adolescents. Achieving SDG target 3.7, which calls for universal access to sexual and reproductive healthcare services, including family planning, information, and education, is critical for improving adolescent sexual and reproductive health. Botswana should adopt policies to improve the sexual and reproductive health of adolescents. The government should provide school-based sexual education and adopt measures to expand girls' secondary school enrolment and retention.

Policies to discourage adolescent childbearing

Population policies in the country should be placed within the larger context of major socio-political changes. In the 1900s, women were mostly restricted to family roles in Botswana. In the late 1900s, women were granted some liberties and civil rights, were allowed into the labour force, and were given certain protections in the workplace: their employment could not be terminated because of marriage, and they were also granted maternity protection. Currently, Botswana has increased the age of defilement from 16 years to 18 years, however, adolescent pregnancies still exist in the country as depicted in the analysis of this study. Therefore, Botswana should reinforce its laws and policies to eliminate adolescent childbearing.

Economic policies

Economics research on individual fertility decisions has naturally focused on the universal trends associated with this demographic transition, primarily negative relationships between fertility and income and between female labour force participation and income. Economists have proposed two main explanations.

The first is known as the quantity-quality trade-off. It suggests that as parents get richer, they invest more in the "quality" (for example, education) of their children. This investment is costly, so parents choose to have fewer children as incomes rise. Historically fertility and GDP per capita are strongly negatively related, both across countries and over time.

The second explanation acknowledges how time-consuming it is to raise children. As wages increase, devoting time to childcare (time that could otherwise be spent working) becomes more costly for parents, and especially for mothers. The result is a decline in fertility and greater female labour force participation. There is historically a strong negative association between female labour force participation and fertility over time and across countries. Therefore, it is crucial to promote gender-neutral hiring practices to target the growing number of females seeking participation in the workforce.

6 CONCLUSION AND RECOMMENDATIONS

The findings of the study showed that the indirect estimation techniques of fertility should not be used to estimate fertility levels in Botswana's 2022 PHC data since the methods give lower estimates compared to other sources. The study indicates that fertility levels have been declining since the 1980s in Botswana, from as high as 6.6 children per woman in 1981 to 2.98 children per woman in 2022. The analysis from the study also revealed that fertility rates vary by type of locality, employment status, level of education and marital status with the worst-off groups experiencing higher fertility rates compared to their respective counterparts. These changing fertility rates combined with changing mortality rates have socioeconomic implications expressed above. In conclusion, the following policy actions are recommended for harnessing the economic benefits of the demographic dividend: family planning and sexual reproductive health services for all, providing

school-based sexual education, expanding girls' secondary school enrolment and retention, and a larger quantity of education opportunities to match economic opportunities is required; investing in the creation of new jobs in growing economic sectors and the development of an adaptive labour market; and re-enforcing laws to discourage adolescent childbearing.

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AGE AT FIRST BIRTH AND SUBSEQUENT FERTILITY: DOES EDUCATION DELAY CHILDBIRTH IN BOTSWANA?

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EXECUTIVE SUMMARY

The purpose of this paper is to analyse the impact of female education on the age at which a woman gives birth to her first child using the 2022 Population and Housing census data. The analysis was done based on the variables that have a great impact in influencing women's timing of first birth. These are area of residence, highest level of education and school attendance. This analysis is based on females who were aged between 15 and 49 years during the time of the census.

Fertility refers to the reproductive performance of males and females in a population and measured based on women of age group 15 – 49 (Lerch, 2019). The total female population was 1, 208,994, representing 51.2 percent of the total population. A total of 640, 950 women were of child bearing ages, accounting for 27.2 percent of the total population. The average age at first birth was found to be 21.2 years.

Females accounting for 49.9 percent of the total females population resided in rural areas, followed by 22.4 percent who lived in towns and 20.4 percent were living in urban areas. The average age at first birth for women living in towns.

During the census period, 76.2 percent of women had completed school, 12.4 percent were still at school, 5.1 percent had discontinued and 1.6 percent never attended school. The average at which a woman had her first child was 21.8 years for women who had completed school and 20.8 years for females who were still at school. The average at first birth for females who had discontinued or never attended school was 19.3 years.

Women accounting for 65.6 percent of the total females' population indicated secondary as their highest level of education. Degree and diploma education levels followed with 10.3 percent and 9.0 percent, respectively. The average age at first birth was found to be higher for women with higher levels of education than those with lower education levels. Women who had post graduate and degree as their highest levels of education, on average, had their first child at 25.7 years and 24.6 years, respectively. Females who indicated primary as their highest level of education had their first child, on average at 19.4 years.

Varying levels of fertility have a substantial socioeconomic impact. As a result, policymakers should consider and implement interventions such as improving economic conditions, investing in higher quality education and expanding educational opportunities and creating new jobs in growing sectors with a higher value chain.

1.0 INTRODUCTION

Botswana, a landlocked country in Southern Africa, is renowned for its stable democracy, thriving economy, and remarkable progress in various social indicators. One crucial aspect of its demographic landscape is fertility levels and trends, which play a pivotal role in shaping the country's population dynamics, socio-economic development, and healthcare systems. Since gaining independence in 1966, the country has transitioned from one of the world's poorest nations to one of the fast growing economies in the world largely due to diamond mining. Botswana's steady economic growth has enabled improvements to infrastructure, health, and education programs.

It is believed that a woman's childbirth experience is the most fascinating of her life. It's an experience that has effects on the body, mind, and society. The mother's age at first birth is the age at which a woman conceives and gives birth to her first child (Talukder et al., 2021).Given that fertility and first birth are closely related, a woman's first birth marks the beginning of motherhood and affects the course of her reproductive life (Rabbi and Kabir, 2013). It significantly affects how many children she will have in her lifetime (Matthews and Hamilton, 2009).

The timing of a woman's first birth is significant in her life because motherhood involves a substantial commitment of time and resources, and it tends to set the stage within which other roles are assumed. An early age at first birth can have a negative effect on occupational attainment, marital stability, asset accumulation, and on the woman's health. At the macro-level, trends in the age at first birth have important effects on the pace of social change, period fertility trends, and the state of the economy (Kebede et al., 2022).

A number of factors affect the age at which a woman gives birth to her first child. This association has been a topic of interest by many researchers and a woman's education level and income status have been found to be negatively associated with a woman's age at first birth (Chisadza and Bittencourt, 2015; Lei, 2023; Ndagurwa and Chemhaka, 2020).Educated women generally have fewer children than uneducated women (Kim, 2016). This negative relationship is strong and varies across both developed and developing countries and among women of different education levels. This is not surprising, since countries differ in their various institutional aspects, including education quality.

Likewise, different education levels can generate different kinds of incentives. For example, better-educated women tend to have better jobs and earn higher incomes, thus the forgone earnings from taking care of children would be higher for these women. Thus, women with primary education tend to have up to 30% fewer children than uneducated women (Kim, 2016). Additionally, women with secondary education and above tend to have 10–50% fewer children than those with primary education.

It would be useful for policymakers to understand the mechanisms through which female education affects fertility in the contexts in which these outcomes are observed.

1.1 Background

Botswana's population grew from 596,944 in 1971 to 2, 359,609 in 2022 (Statistics Botswana, 2022).The country has experienced significant shifts in fertility levels over the past few decades. Historically, the country had high fertility rates, characteristic of many Sub-Saharan African nations. However, like many countries in the region, Botswana has undergone a demographic transition marked by declining fertility rates (Askew et al., 2015; Ndagurwa and Odimegwu, 2019; Bongaarts, 2020; Gaisie, 2013; Casterline, 2017; Bongaarts and Hodgson, 2022). According to Statistics Botswana (2014), Botswana's total fertility rate (TFR) has decreased from 6.5 children per woman in the 1980s to approximately 2.9 children per woman in 2022, reflecting a substantial decline. **(Table 1.1)**.

TABLE 1.1: Trends in Total Fertility Rate

CENSUS	1971	1981	1991	2001	2011	2022
Total Fertility Rate	6.5	6.6	4.2	3.3	2.8	2.9
% Decline in TFR	-0.4	-0.7	-2.3	- 0.5	- 0.5	- 2.4

1.2 Education in Botswana

Botswana's education system like many other African institutions, is heavily influenced by Western educational concepts and methods. It has undergone numerous changes in reaction to the country's shifting social and economic circumstances, as well as the country's efforts to stay up with global and new trends.

Botswana's first educational strategy, 'Education for Kagisano', directed the country's educational growth and administration from 1977 until 1993 (Republic of Botswana, 1977). In the early 1990s, the understanding that the country's socioeconomic condition had altered dramatically prompted a review of Botswana's educational development plans and initiatives.

Botswana has one of the highest literacy rates among the Sub-Saharan African countries (Zua, 2020). The 1994 – 2020 Revised National Policy on Education (RNPE) is the main policy framework for the provision of education in Botswana (Ministry of Education, 1994). The main goal of the RNPE is to improve access, ensure equity and inclusiveness for all, improve and maintain quality and effective management in the education system. The RNPE 1994 is committed towards an inclusive education system and provision of special education. This in turn facilitates increase in access to education by all including orphans, vulnerable children, children in difficult circumstances, children with special education needs and disability.

Botswana's education system comprises of seven (7) years of primary education, three (3) years of junior secondary education and two (2) years of senior secondary education. Vocational education follows with up to three (3) years of schooling and finally Tertiary education with four (4) or five (5) years for undergraduate degree, two (2) years for master degree and four (4) years of doctorate degree.
Across all levels of education, females outnumber males. **Table 1.2** shows that female enrolment in all levels of education increased by more than 50% between 1978 and 2012. The primary level has greater enrolment rates since it provides basic education.

TABLE 1.2: Education Trends – 1978 to 2022

Year	1978	1987	1996	2012	2020
PRE-PRIMARY					
Male	..	..	..	12	5,818**
Female	..	..	..	12	6,242**
% Females				49.6	51.8
PRIMARY					
Male	65	120	160	..	183,183*
Female	80	129	159	..	176,010*
% Females	55.2	51.7	49.9		49.0
SECONDARY					
Male	7	19	51	..	89, 287
Female	9	20	58	..	95, 950
% Females	55.8	51.7	53.2		51.8
TERTIARY					
Male	1	2	9	..	25, 840
Female	508	743	7	..	35
% Females	31.9	27.1	43.2		57.7
GRAND TOTAL					
Male	73, 398	141, 212	219, 239	11, 911	115, 127
Female	89, 737	149, 723	223, 685	11, 739	131, 267
% Females	55.0	51.5	50.5	49.6	53.3

Source: CSO (1987), Statistics Botswana (1996, 2012, 2017, 2020, 2022).* Represents 2017, ** Represents 2022;

Objectives of the analysis

- To understand the relationship between a woman's educational level and the age at which she has her first child.
- To guide in policy formulation related to family planning, healthcare, education and social welfare.

Economic Planning: Fertility trends have significant implications for economic development. High fertility rates can strain resources, while low fertility rates can lead to labour shortages and economic stagnation. Analysing fertility levels helps in forecasting labour supply, consumption patterns, and economic growth trajectories.

Social Cohesion and Welfare: Understanding fertility trends is essential for maintaining social cohesion and ensuring the welfare of families and communities. It helps in identifying vulnerable populations, such as single-parent households or those with limited access to resources, and designing social support programs accordingly.

International Comparisons: Studying fertility levels and trends allows for comparisons between different countries or regions, providing insights into cultural, socioeconomic, and policy factors influencing reproductive behaviour. This comparative analysis can facilitate knowledge sharing and best practices in population management and development strategies.

1.4 Definitions of main concepts

Age at first birth - the difference between the birth date of the first-born child and birth date of the woman. Mean age at first birth – average age of women at first birth means the average age of women delivering their first child (live birth)

Locality – any human settlement with a name and identifiable boundaries. This could be a part of city, town or a village.

Total Fertility Rate – represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year

2.0 LITERATURE REVIEW

Investigating the link between female education and a woman's age at first birth is of interest to scholars and researchers because it is a complex phenomenon that is influenced by a host of social, cultural, psychological, economic and political factors and variables. The age at first birth influences the fertility levels of a country.

The relationship between fertility and the Sustainable Development Goals (SDGs) in Botswana is multifaceted and interconnected, with fertility levels playing a crucial role in shaping the country's progress towards achieving sustainable development objectives. Goal 3 of Good Health and Well-being means that by lowering fertility rates, Botswana can enhance maternal health outcomes, reduce maternal mortality, and improve child health and survival. This goal necessitates access to family planning services, reproductive health education, and maternal care, all of which the country has successfully implemented.

High fertility rates are typically linked to lower levels of educational attainment, particularly among women and girls (Kim, 2016). Botswana's lower childbearing rates encourage women and girls to pursue education and skill development, leading in increased literacy rates, higher school enrolment, and more opportunities for personal and professional progress, so attaining Goal 4 of Quality Education.

Fertility rates are closely linked to gender dynamics within societies. Women's ability to control their fertility through access to contraception and reproductive healthcare is fundamental to achieving gender equality. By empowering women to make autonomous decisions about childbearing, Botswana promoted gender equality and women's rights, enabling them to participate more fully in social, economic, and political life hence attaining Goal 5 of Gender Equality.

Botswana's Vision 2036 serves as a roadmap for the country's long-term development aspirations, outlining goals and strategies to transform its socio-economic landscape. Fertility rates play a significant role in shaping Botswana's journey towards realizing this vision, as they influence various aspects of demographic, social, and economic development. The Vision's Pillar 2 of Human and Social Development recognizes the family as the foundation of society, which should be developed to ensure strong national building blocks. It is where life begins and grows, where ideals are instilled. It is essential to household, neighbourhood, and national socioeconomic stability.

Kitaw and Haile (2023) conducted a study to investigate the time to first childbirth and its predictors at the national level of Ethiopia. The study used data from the 2019 Ethiopia Demographic and Health Survey and included 8,885 women aged 15 to 49. The Kaplan-Meier survivor curve was also used to determine the time of first birth. The study discovered that the mother's educational level, knowledge of any contraceptive method, and media exposure were all significant predictors of the time to first childbirth.

Talukder et al., (2021) conducted research to investigate the risk variables that influence the age of the mother at first birth in Albania. The information was gathered from the 2017/2018 Albania Demographic and Health Survey. The study used a quantile regression model, and the mean age of the woman at first birth was 22.4 years. According to the study's findings, teenage females in rural regions become mothers earlier than girls in cities. Furthermore, ladies who practiced Islam conceived earlier than those of Catholic or Orthodox faith. Furthermore, women with limited education had insufficient knowledge of family planning.

A study to estimate the determinants of school attainment, early marriage and low age at first birth in Madagascar among females aged 12 – 25 was carried out by Glick et al., (2015). The data for the study was obtained from interviews of 2,100 households from 73 communities and included 2,336 females aged between 12 and 25, who at the time of the survey had ever attended school. The research found that an additional year of schooling delayed age at first birth by 0.75 years.

Shapiro and Tenikue (2017) undertook an investigation to find out how increased women's schooling contributed to fertility declines in urban and rural places in each of 30 countries in Sub – Saharan Africa. The study used data from the first and last Demographic and Health Surveys for each of the countries selected, along with a decomposition technique that allowed to quantify how much of the observed fertility decline is attributable to increased education and how much was due to reduced mortality. Results from the study revealed that in urban places, on average, increased women's schooling accounted for 54 percent of observed fertility decline. Rural on the other hand, increased women's education accounted for an average of 30 percent of the fertility decline.

Using structural equation modelling, to examine pathways between education and fertility, Snopkowski et al., (2016) found that education was associated with delayed age at first birth. The study was done in the rural areas of Matlab in Bangladesh, San Borja in Bolivia and rural Poland.

The existing literature on the relationship between female education and the woman's age at first child birth has to date shown contrasting pictures. It is against this background that this study seeks to determine the aforementioned association using data from the 2022 population and housing census.

3.0 METHODOLOGY

There are various types of variables that can affect age at first birth and these can be grouped into background factors (e.g. parents' socio-economic status, early adolescent factors, biological factors and simultaneous factors such as education (Rindfuss and St John, 1983). The effects of these variables on the age at first birth can be determined using a number of methods.

Descriptive analysis was utilised in this study through the use of cross tabulations of the age at first birth and locality type, educational attainment and highest level of education. The variable Educational attainment will be proxied by the individual's highest level of educational attainment and these have been grouped into eight (8) categories of pre-school, primary, secondary, non-formal, certificate, diploma, degree and post graduate. The variable residence or locality will be classified into three categories of rural area, urban area and towns.

4.0 FINDINGS AND DISCUSSIONS

Female Population

Table 4.1 below shows that the total female population was 1, 208,994. A total of 640, 950 women were of child bearing ages, representing 27.2 percent of the total population. The average age at first birth was found to be 21.2 years. It is observed from **Table 4.2** that the mean age at first birth decreased from an average of 30.5 years in 1971 to 21.2 years in 2022.

TABLE 4.1: Female Population

AGE GROUP	FREQUENCY	PERCENT
0-4	128,477	10.6
5-9	124,929	10.3
10-14	114,435	9.5
15-19	99,070	8.2
20-24	98,823	8.2
25-29	102,860	8.5
30-34	99,107	8.2
35-39	98,157	8.1
40-45	80,762	6.7
45-49	62,171	5.1
50+	200,203	16.6
TOTAL FEMALES	1,208,994	100

TABLE 4.2: Age at First Birth Trends

INDICATOR\CENSUS	1971	1981	1991	2001	2011	2022
Mean Age at First Birth	30.5	30.6	30	30.3	27.8	21.2
TFR	6.5	6.6	4.2	3.3	2.7	2.9
Percentage of women of childbearing ages	42.8	42.9	46.5	52.4	27.8	27.1

Average age at first birth based on locality and highest educational level

Figure 1.1A shows that 49.9 percent of the female population aged between 15 and 49 reside in the rural areas, followed by urban and towns with 27.0 percent and 23.1 percent, respectively. The results show that females in rural areas gave birth to their first born child earlier than their counterparts in the urban areas and towns. The results are similar to those of Talukder et al., (2021) and Haque et al., (2009).
According to **Figure 1.1B**, women accounting for 65.6 percent of the total females' population indicated secondary as their highest level of education. Degree and diploma education levels followed with 10.3 percent and 9.0 percent, respectively.

As more females enrol in higher education programs, the average age at first birth rises, as seen in **Figure 1.1C**. Compared to their counterparts who had a degree or postgraduate qualification, women who only completed their primary and non-formal education gave birth to their first child earlier. For females with primary and non-formal education, the mean age at first birth was 19.4 and 19.6 years, respectively. In contrast, the average age of first birth for females with degrees and postgraduate credentials was 25.7 years, and 24.6 years, respectively. It is evident that the higher a woman's educational level, the older she will be when giving birth to her first kid.

It has been found that a woman's residency and greatest level of education determine her age at first birth. **Figure 1.1D** demonstrates that, on average, women who lived in rural areas and had primary and non-formal education as their highest degree of schooling gave birth at 20.1 and 20.3 years of age, respectively.

Their counterparts in towns who had degree and post graduate qualification as their highest levels of education had their first child, on average at 25,0 and 26,5 years respectively. The findings are similar to those of Kebede et al., (2022).

FIGURE 1.1A: MEAN AGE AT FIRST BIRTH ACCORDING TO PLACE OF RESIDENCE

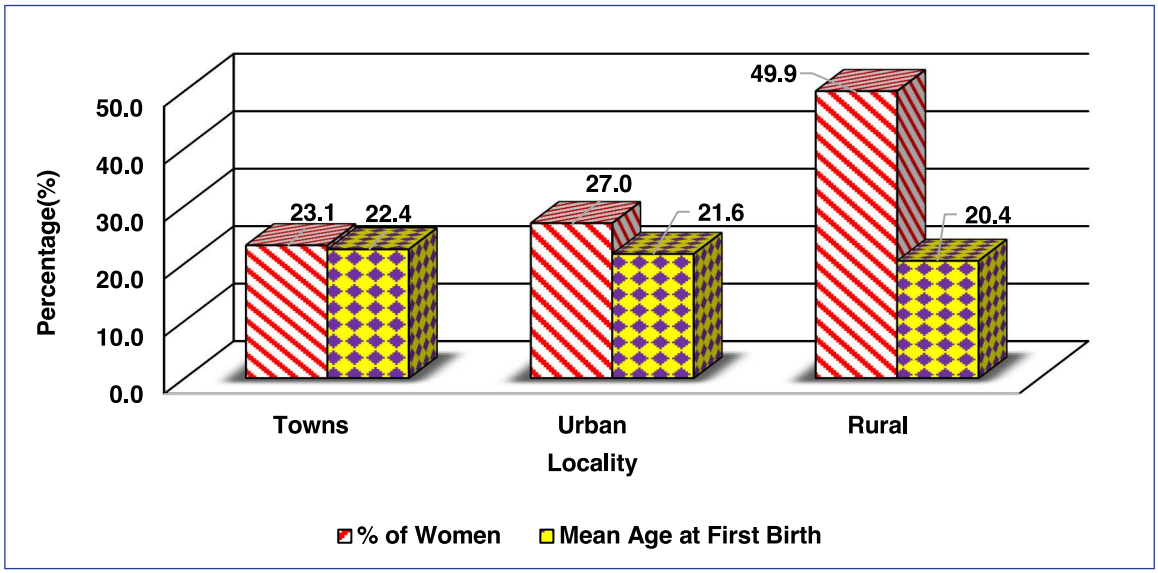


FIGURE 1.1B: FEMALES' HIGHEST LEVEL OF EDUCATION

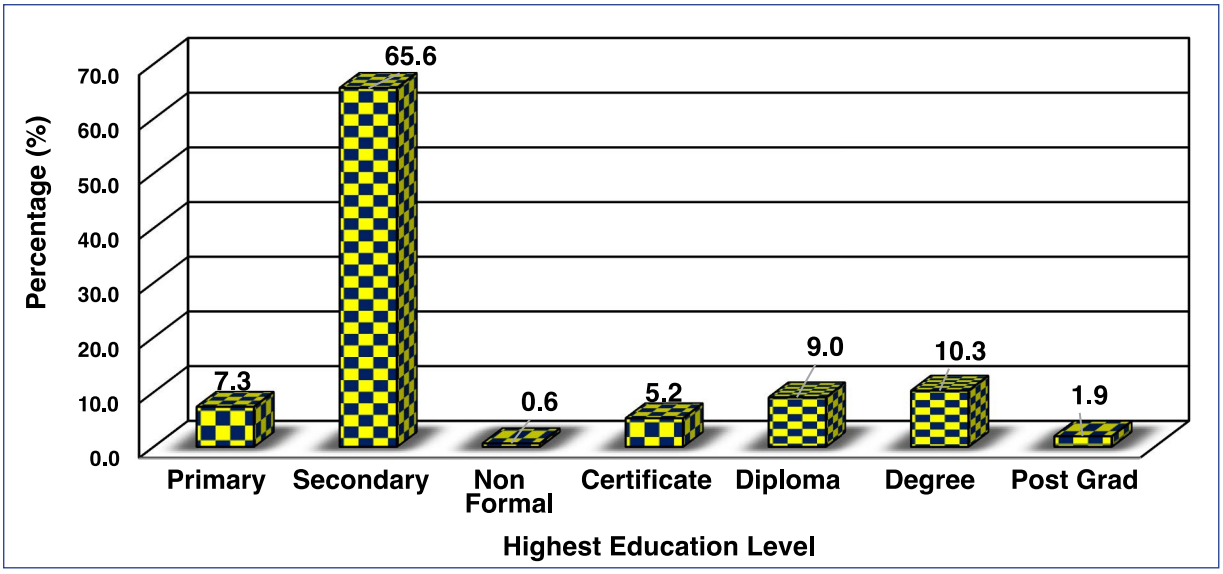


FIGURE 1.1C: MEAN AGE AT FIRST BIRTH ACCORDING TO HIGHEST LEVEL OF EDUCATION

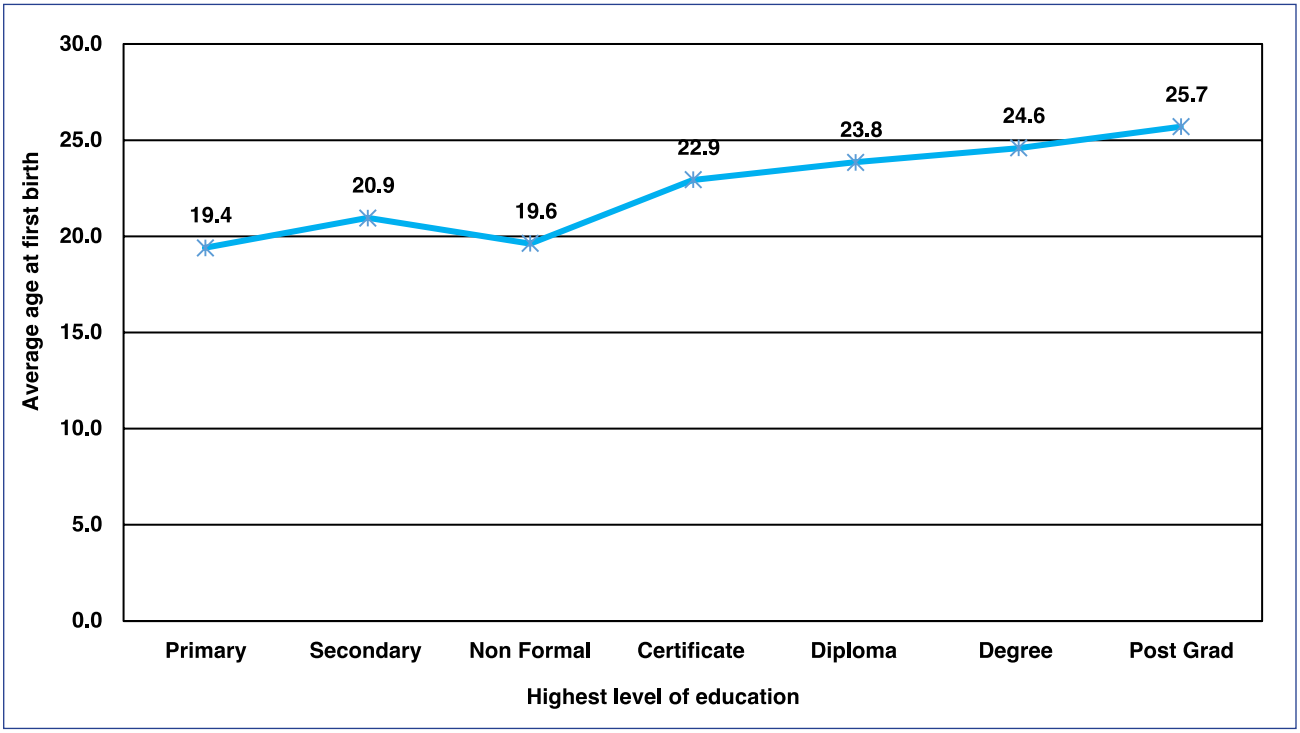
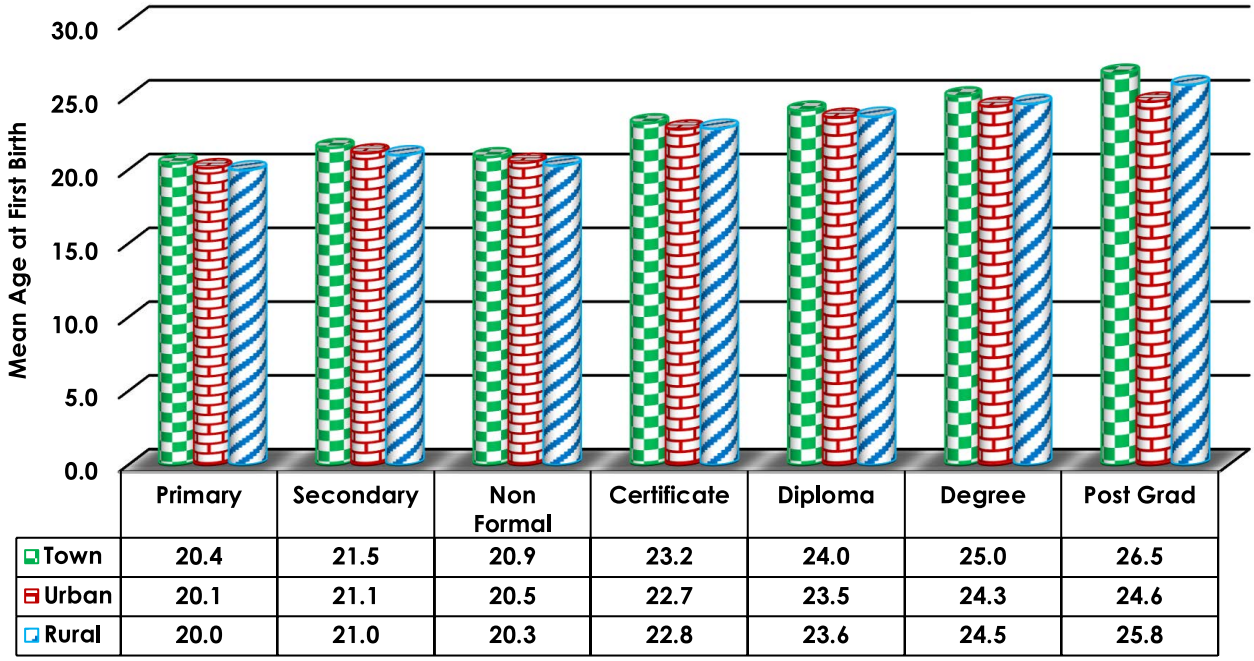


FIGURE 1.1D: MEAN AGE AT FIRST BIRTH ACCORDING TO HIGHEST LEVEL OF EDUCATION AND AREA OF RESIDENCE



	Primary	Secondary	Non Formal	Certificate	Diploma	Degree	Post Grad
Town	20.4	21.5	20.9	23.2	24.0	25.0	26.5
Urban	20.1	21.1	20.5	22.7	23.5	24.3	24.6
Rural	20.0	21.0	20.3	22.8	23.6	24.5	25.8

Females by educational attainment

Females aged between 15 and 29 who completed school accounted for 76.2 percent of the total female's population while those who were still at school accounted for 12.4 percent **(Figure 1.2A)**. Females who discontinued and never attended school accounted for 5.1 percent and 1.6 percent, respectively.

The average age at first birth is raised as females attend school as shown on **Table 1.2B.** Females who have never attended school or discontinued had their first child, on average at 19.3 years, while those who have completed school had their first child at an average age of 21.8 years.

It is clear that the majority of females have completed or are currently enrolled in school during the census period. **Figure 1.2C** shows that in total, 91.8 percent, 89.6 percent, and 87.2 percent of females of childbearing age said that they had completed school and were currently enrolled in towns, urban, and rural areas.

Figure 1.2D displays females' highest level of education by locality. It is observed that on average, secondary education is the highest level of education in all three localities followed by degree and diploma, respectively.

FIGURE 1.2A: FEMALE EDUCATIONAL ATTAINMENT

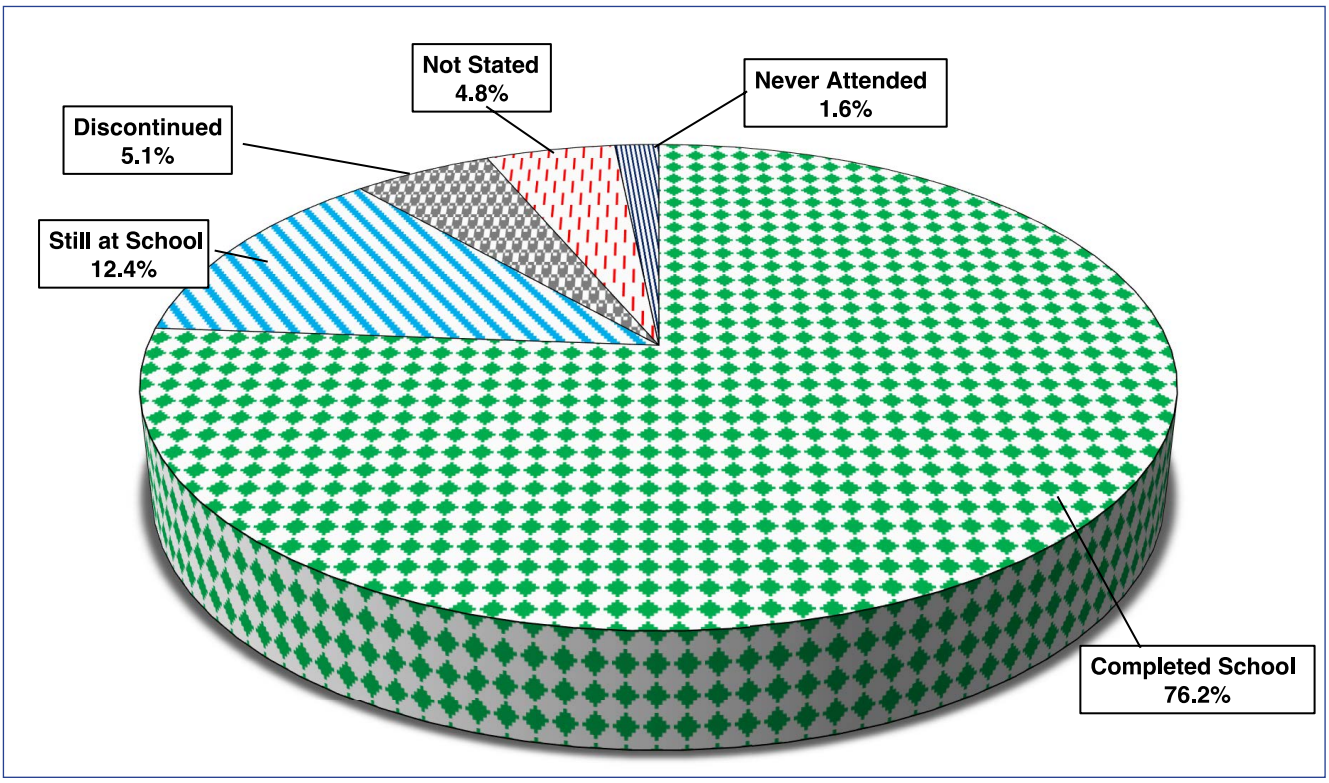


FIGURE 1.2B: MEAN AGE AT FIRST BIRTH ACCORDING TO EDUCATIONAL ATTAINMENT

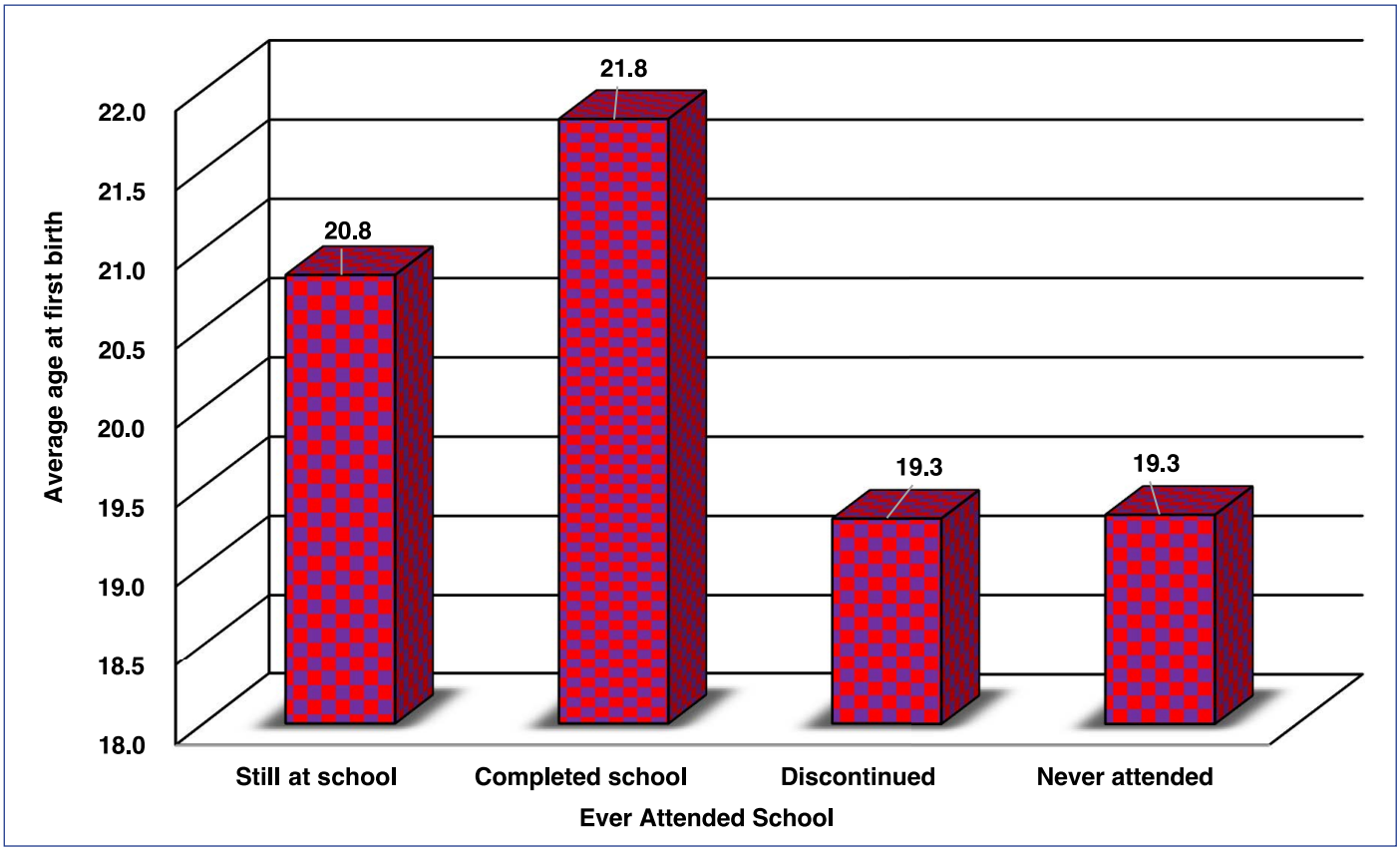
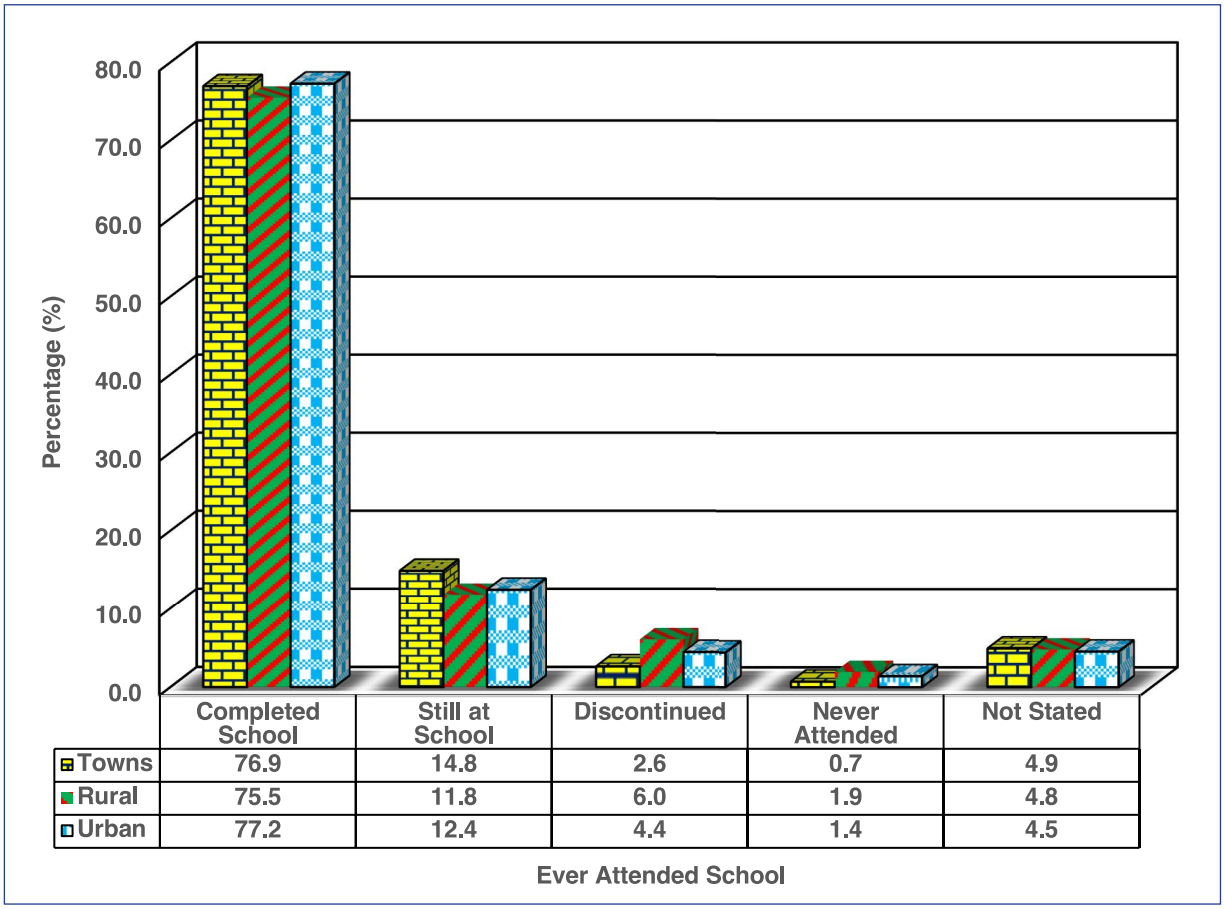
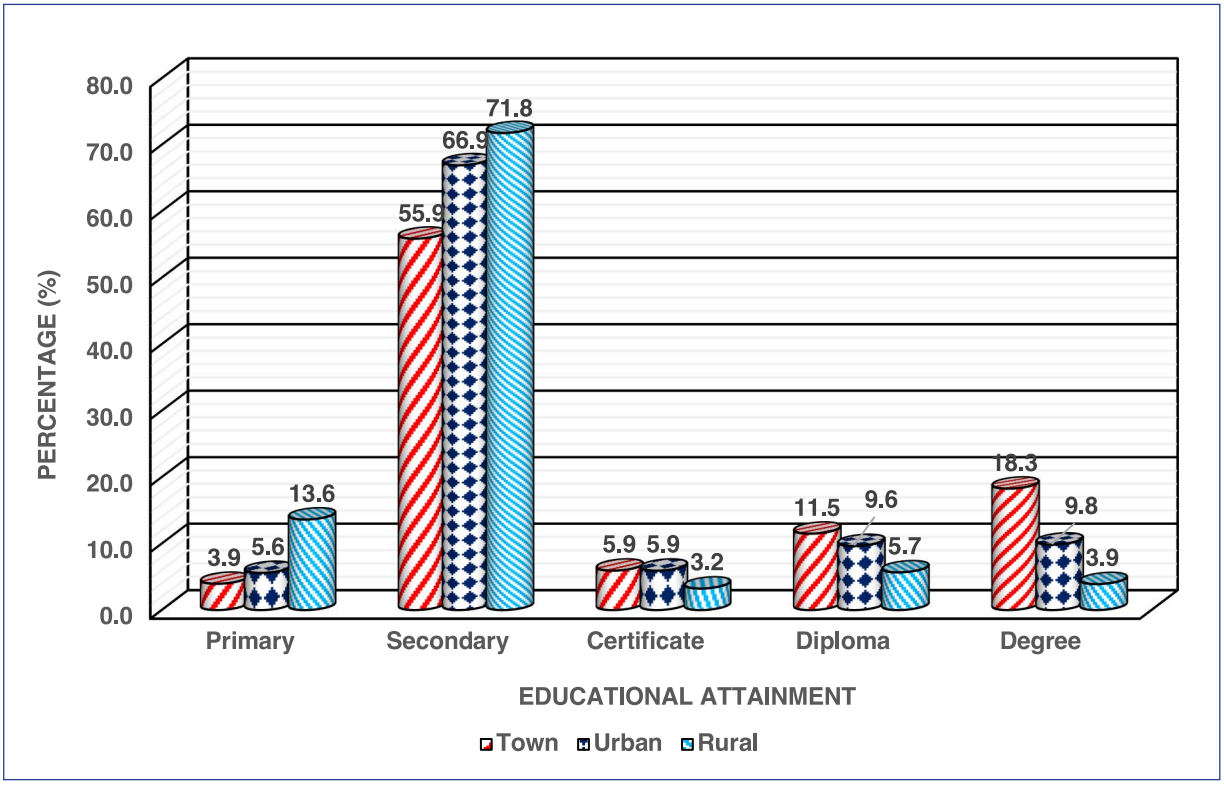


FIGURE 1.2C: FEMALE EDUCATIONAL ATTAINMENT ACCORDING TO LOCALITY



	Completed School	Still at School	Discontinued	Never Attended	Not Stated
Towns	76.9	14.8	2.6	0.7	4.9
Rural	75.5	11.8	6.0	1.9	4.8
Urban	77.2	12.4	4.4	1.4	4.5

FIGURE 1.2D: FEMALES ACCORDING TO HIGHEST LEVEL OF EDUCATION AND LOCALITY



5.0 POLICY IMPLICATIONS

The delayed age at first birth in Botswana has led to the drop in fertility levels. In order to maintain both the population's well-being and sustainable socioeconomic progress, a number of policy implications of this must be addressed. Here are some important considerations:

Economic Development

A declining fertility rate can lead to an aging population, which may strain the labour force and social security systems. To counteract this, Botswana may need to implement policies to create new jobs and at the same time producing skilled labour. Regulations should provide a flexible work market to help the youth bulge into rising sectors of the economy. Botswana's economy is mineral-based, making it prone to a lack of diversification. As a result, the country must invest in diversifying its economy by developing high-value-chain sectors.

Urbanization and Migration

Urbanization trends and rural-to-urban migration can also impact a woman's timing of the birth of her first child. Policies should address the unique needs of urban populations, such as affordable housing, transportation, and access to services, while also considering the potential impact of rural depopulation on agricultural productivity and food security.

Healthcare and Social Services

As the population ages, there will be increased demand for healthcare services and elderly care. Botswana should invest in healthcare infrastructure and services tailored to the needs of an aging population, including geriatric care, long-term care facilities, and preventative healthcare measures.

Education and Workforce Development

With fewer children being born, there may be a smaller pool of young people entering the workforce in the future. Investing in education and vocational training programs can help ensure that the workforce remains skilled and competitive. Bell (2020) suggests that educational policy should aim to increase the supply of highly educated workers who can readily integrate into various economic sectors. Rodrik (2018) recommends focusing educational and employment programs on acquiring skills suited to a country's strongest growing economic sectors.

6.0 Conclusion and Recommendations

The purpose of this paper was to analyse the effect of female education on a woman's age at first birth in Botswana using the 2022 PHC data. The results show that women with schooling had their first child at a later age than women without, or had lower levels of education. It was also discovered that women's place of residence affected their age at first child birth, with women residing in rural areas giving birth at an early age than their counterparts in urban areas and towns.

Changing fertility rates have significant socioeconomic repercussions. Therefore policy-making and enforcement of interventions, such as improvement of the economic conditions, investing in higher quality education and expanding educational opportunities, creating new jobs in growing sectors, developing an adaptive labour market, and supporting capital accumulation through fiscal frameworks are recommended.

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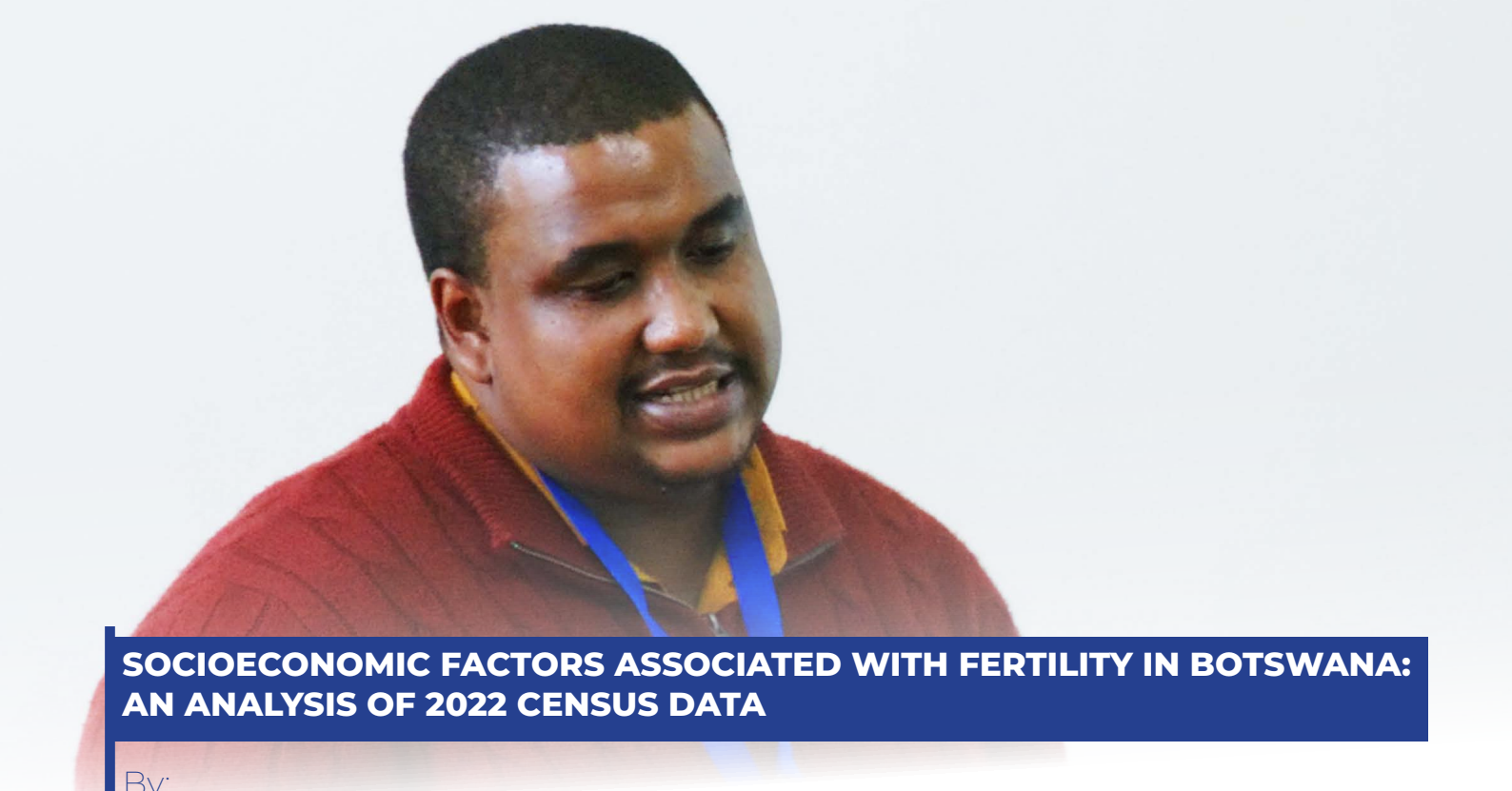
APPENDIX

APPENDIX 1: Women Population by Locality

LOCALITY TYPE	FREQUENCY	PERCENT
Town	234,060	19.4
Urban	585,936	48.5
Rural	388,998	32.1
Total	**1,208,994**	**100**

APPENDIX 2: Educational attainment by age group and locality

AGE GROUP	STILL AT SCHOOL	COMPLETED SCHOOL	DISCONTINUED	NEVER ATTENDED	NOT STATED	TOTAL	%
TOWN							
15-19	12,568	7,199	235	71	907	20,980	14.2
20-24	6,716	15,462	477	117	1,650	24,422	16.5
25-29	1,269	20,225	564	125	1,524	23,707	16
30-34	633	20,509	559	125	1,178	23,004	15.5
35-39	391	21,177	632	181	942	23,323	15.7
40-45	254	17,125	734	198	651	18,962	12.8
45-49	138	12,239	639	216	465	13,697	9.2
Total	**21,969**	**113,936**	**3,840**	**1,033**	**7,317**	**148,095**	**100**
%	**14.83**	**76.93**	**2.59**	**0.7**	**4.94**	**100**	
RURAL							
15-19	52,630	38,717	3,273	670	3,780	99,070	15.5
20-24	15,514	70,782	5,185	1,043	6,299	98,823	15.4
25-29	3,506	85,966	5,882	1,287	6,219	102,860	16
30-34	1,822	84,619	5,802	1,629	5,235	99,107	15.5
35-39	934	84,703	6,109	2,259	4,152	98,157	15.3
40-45	586	67,988	6,573	2,571	3,044	80,762	12.6
45-49	367	50,843	5,798	2,985	2,178	62,171	9.7
Total	**75,359**	**483,618**	**38,622**	**12,444**	**30,907**	**640,950**	**100**
%	**11.8**	**75.5**	**6**	**1.9**	**4.8**	**100**	
URBAN							
15-19	28,073	19,315	1,118	285	1,781	50,572	15.8
20-24	7,741	35,980	1,892	456	3,063	49,132	15.3
25-29	1,931	44,440	2,088	534	3,058	52,051	16.3
30-34	1,017	43,772	2,100	606	2,553	50,048	15.6
35-39	446	43,309	2,231	789	1,874	48,649	15.2
40-45	274	34,737	2,542	831	1,363	39,747	12.4
45-49	187	25,707	2,183	952	854	29,883	9.3
Total	**39,669**	**247,260**	**14,154**	**4,453**	**14,546**	**320,082**	**100**
%	**12.4**	**77.2**	**4.4**	**1.4**	**4.5**	**100**	



SOCIOECONOMIC FACTORS ASSOCIATED WITH FERTILITY IN BOTSWANA: AN ANALYSIS OF 2022 CENSUS DATA

By;
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ABSTRACT

This study investigates the socioeconomic determinants of fertility rates in Botswana, utilizing data from the 2022 Population and Housing Census to understand how factors such as age, education level, employment status, marital status, and locality type associate with fertility. The analysis combines traditional statistical methods with advanced machine-learning techniques. A Gradient Boosting Regression Tree (GBRT) model was employed to capture non-linear relationships, and SHAP (SHapley Additive exPlanations) values were used for interpreting the importance and interaction of features. The data was disaggregated into districts and further classified by locality types and age groups. Key findings revealed through SHAP analysis suggest that employment can both positively and negatively affect fertility rates, indicating that employed women might have better access to resources but face time constraints, whereas unemployment might lead to higher fertility due to the absence of career-related constraints but lower fertility due to economic instability. Marital status also shows contrasting impacts via SHAP analysis suggesting that being married negatively impacts fertility rates, possibly due to career-related constraints. Overall, the study highlights the complex interactions between socioeconomic factors and fertility rates in Botswana. The use of advanced analytical techniques provides nuanced insights that traditional methods might overlook. Policy recommendations include improving education and reproductive health services to enhance quality of life and health standards in alignment with Vision 2036, empowering women and improving family planning services as per the Revised National Population Policy (RNPP), targeting interventions to improve living standards in different regions as outlined in the African Agenda 2063, and ensuring healthy lives, equitable quality education, and gender equality through targeted interventions aligned with the Sustainable Development Goals (SDGs). Future research should explore additional socioeconomic and cultural factors, conduct longitudinal studies to understand temporal changes in fertility behavior and investigate the impact of specific policy interventions on fertility rates.

INTRODUCTION

The relationship between fertility and economic development has been a central theme in demographic and economic research for decades. Classical economic theories, such as the demographic transition model, propose that economic development leads to lower fertility rates through increased income, improved education, and better access to health- care. However, the nuances of this relationship, particularly in developing countries like Botswana, remain under-explored.

Understanding the socio-economic factors influencing fertility rates is crucial for formulating effective population and development policies. This report explores these factors in the context of Botswana, leveraging data from the 2022 Population and Housing Census. The analysis focuses on key variables such as age, education, employment, marital status, and residence.

Research Objectives

The primary objectives of this study are:

- **To analyse the socio-economic factors influencing fertility rates in Botswana.**
- **To explore the non-linear relationships between these socioeconomic factors and fertility rates.**
- **Provide insights that support Botswana's Vision 2036, the Revised National Population Policy (RNPP), African Agenda 2063, and Sustainable Development Goals (SDGs).**

Literature Review

This literature review examines the current state of research on fertility and economic development, highlighting key findings, limitations, and the research gap addressed by this study.

Theoretical Foundations

The demographic transition theory suggests a predictable shift from high fertility and high mortality rates to low fertility and low mortality rates as countries develop economically (Notestein, 1945). Initially, economic development improves living standards, leading to lower mortality rates. Subsequently, fertility rates decline due to changes in economic incentives, increased female labour force participation, and access to education and family planning services (Caldwell, 1982).

Easterlin's hypothesis further posits that fertility rates are influenced by the relative economic status of individuals within a society (Easterlin, 1975). As economic development progresses, the costs associated with raising children increase, leading to a preference for smaller families. However, these classical theories often fail to capture the complex and multifaceted nature of fertility behavior in different socioeconomic and cultural contexts.

Traditional Analyses of Fertility and Economic Development

Several traditional analytical approaches have been employed to study the relationship between fertility and economic development:

Aggregate Data Analysis: This method examines national-level data to identify broad trends in fertility and economic indicators such as Gross Domestic Product (GDP) per capita. However, it often overlooks individual and regional variations.

Cross-Sectional Studies: These studies analyze data collected at a single point in time from a specific population. They cannot account for temporal changes and may miss dynamic aspects of fertility behavior.

Basic Regression Analysis: Using linear regression to explore the relationship between fertility rates and selected socioeconomic factors, these models typically assume linear relationships and do not capture complex interactions between variables.

Demographic Transition Models: Theoretical qualitative models describe the transition from high to low fertility and mortality rates as economic development progresses. Nonetheless, these models may not adequately address unique socio-economic and cultural contexts.

Descriptive Statistics: This method summarizes fertility data using measures such as mean and standard deviation, providing a snapshot but lacking explanatory power for underlying causes and interactions.
Survey-Based Analyses: Utilizing survey data to explore fertility patterns, these analyses can be biased and may not capture all relevant variables.

Empirical Evidence on Fertility and Economic Development

Empirical studies have provided mixed evidence on the relationship between fertility and economic development. For instance, Gertler and Molyneaux, 1994 found that economic development in Indonesia led to a significant decline in fertility rates, driven by increased female education and labour force participation. Similarly, Schultz, 1997 demonstrated that in Latin America, economic growth and improved educational opportunities were strongly associated with reduced fertility.

In contrast, research in Sub-Saharan Africa presents a more complex picture. Studies by Bongaarts, 2017 and Cleland, 2001 indicate that while there is a general trend toward lower fertility with economic development, the pace and extent of this decline vary significantly across countries and regions. Factors such as cultural norms, access to family planning services, and gender inequalities play a crucial role in shaping fertility behavior, often leading to divergent outcomes even within the same country.

Socioeconomic Determinants of Fertility

Several studies have emphasized the importance of individual socioeconomic factors, such as age, marital status, education level, and employment status, in determining fertility rates. For example, Martin, 1995 found that younger women and those with higher education levels tend to have fewer children. Additionally, employment status, particularly female labour force participation, is negatively correlated with fertility (Brewster and Rindfuss, 2000).

Marital status also plays a significant role in fertility behavior. Married women generally exhibit higher fertility rates compared to their unmarried counterparts (Moffitt, 1998). However, the interaction between marital status and other socioeconomic factors, such as education and employment, is less understood, particularly in the context of developing countries.

Previous Research in Botswana

Gaisie, 1995 study on the determinants of fertility decline in Botswana provided critical insights into the multifaceted factors influencing fertility rates. Using a combination of quantitative and qualitative data analysis, the study identified several key determinants:

Socioeconomic Factors: Education and economic development were significant factors in the decline of fertility rates. Education contributed to greater awareness and use of family planning methods and a delay in the age of first childbirth. Economic improvements and increased employment opportunities, especially for women, had been linked to lower fertility rates.

Health and Family Planning Services: Improved access to healthcare and family planning services has been pivotal. The availability and use of contraceptives have increased, contributing to a reduction in unintended pregnancies and overall fertility rates. A decline in child mortality rates has also reduced the need for having more children as a form of insurance against child mortality.

Cultural and Social Changes: Fertility patterns are associated with shifts in societal norms and values regarding family size, as well as urbanization. Smaller family sizes were becoming more acceptable and desirable.

Population Policies: Government interventions and policies aimed at population control and reproductive health played a role in the fertility decline. These policies included promoting family planning, improving educational opportunities, and enhancing women's economic participation.

Research Gap

Despite the extensive body of literature, significant gaps remain, particularly in the context of Botswana and similar Sub-Saharan African countries. Previous studies have primarily focused on aggregate data and broad socioeconomic indicators, often overlooking the nuanced interplay between individual factors such as age, marital status, education level, employment status, and residential location. Moreover, traditional analyses have frequently failed to account for complex interactions between these factors, leading to a superficial understanding of fertility dynamics.

One notable methodological limitation in traditional analyses is the use of linear regression models, which assume linear relationships between predictors and outcomes. Such models may not capture the intricate, non-linear relationships that often exist in socioeconomic data. Additionally, previous studies have often relied on descriptive statistics or basic regression analyses that do not fully leverage the rich, detailed data available from large-scale surveys or censuses.

To overcome these limitations, the methodology used in this study builds on the approaches highlighted by previous research, such as Gaisie, 1995. Gaisie's comprehensive approach provides a foundational understanding of the factors influencing fertility decline, which this study builds upon by incorporating advanced machine learning techniques and detailed interaction analyses. To be precise, this study employs a more sophisticated analytical approach by utilizing Gradient Boosting Regression Trees (GBRT). GBRT is a robust machine-learning technique that constructs an ensemble of decision trees to improve predictive accuracy and handle complex, non-linear relationships between variables. This method is particularly well-suited for exploring the multifaceted nature of fertility behavior in Botswana.

Additionally, to interpret the complex relationships captured by the GBRT model, this study uses SHapley Additive exPlanations (SHAP) values. SHAP values provide insight into the contribution of each feature to the model's predictions, enhancing the interpretability of the machine learning model and offering clear, actionable insights for policymakers.

Furthermore, this study emphasizes the importance of cross-classifying data based on combinations of socioeconomic factors. Cross-classification allows the socioeconomic factors to be arranged as a contingency table to capture the interactions between the different factors. Moreover, cross-classification helps in identifying and controlling for confounding variables. This approach helps to uncover patterns that might be obscured in traditional aggregate analyses, offering a deeper understanding of the socioeconomic determinants of fertility.

This approach not only fills the existing research gap but also aligns with key national and international development objectives. For instance, it supports Vision 2036, which aims to improve the quality of life and health standards through better access to education and reproductive health services. By identifying key factors influencing fertility rates, this study directly supports these objectives. Furthermore, it aligns with the Revised National Population Policy (RNPP) by providing insights that can inform policies aimed at reducing high fertility rates through enhanced family planning services and women's empowerment. The findings on the impact of education and employment on fertility rates are particularly relevant here. The study also supports the objectives of the African Agenda 2063, which aims to achieve a high standard of living, quality of life, and well-being for all citizens. By revealing geographic variability in fertility rates, the study aids in targeting interventions to improve living standards in different regions. Additionally, the African Union's African Agenda for Sustainable Development (AADPD) aims to enhance reproductive health and economic opportunities, which this study supports by highlighting the relationship between unemployment and fertility. Finally, the study's findings align with Sustainable Development Goals (SDGs) 3, 4, and 5, which focus on ensuring healthy lives, inclusive and equitable quality education, and gender equality. The empirical evidence provided by this study supports targeted interventions in these areas.
The relationship between fertility and economic development is complex and context-dependent, influenced by a myriad of socioeconomic factors and their interactions.

METHODOLOGY

Data Source and Selection

This study utilizes the 2022 Population and Housing Census of Botswana, focusing on women of childbearing age (15-49 years). The census provides comprehensive data on various socio-economic and demographic variables, making it an ideal source for analyzing fertility rates and their determinants.

Variables Included in the Analysis

Including variables such as Educational Level, Marital Status, and Employment Status is essential for understanding the complex interplay of socioeconomic factors influencing fertility rates. These variables provide critical insights into how educational attainment, marital dynamics, and economic participation shape reproductive behavior and family planning decisions. To help in understanding the impact of urbanization on fertility rates, we included locality types in the study. Urban areas are expected to have lower fertility rates due to better access to resources, while rural areas might have higher fertility rates due to different socioeconomic and cultural factors World Health Organization (WHO).

Furthermore, to capture regional variations in fertility rates, we included different districts as they may have unique socioeconomic profiles, healthcare access, educational facilities, and cultural norms that can significantly influence fertility behavior as stated by the previous research. The variables included in this study are of the following types:

Age: Continuous variable representing the age of the respondent.

Number of Live Births in the Last 12 Months: Discrete target variable indicating the number of live births a woman has had in the past year.

Education Attainment Levels: Categorical variable representing the highest level of education attained by the respondent. This variable was encoded into two levels including basic education (preschool, primary, nonformal primary, and secondary) and higher education (apprentice certificate, brigade certificate, vocational certificate, college certificate, vocational diploma, college diploma, university: undergraduate degree, postgraduate degree, and other degrees).

Employment Status: Categorical variable indicating whether the respondent is employed, unemployed, or not part of the labour force (not working).

Marital Status: Categorical variable indicating the respondent's marital status. We encoded this variable into two levels with married being married and unmarried being never been married, living together, separated, divorced, or widowed.

Locality Type: Categorical variable indicating whether the respondent lived in an urban, urban-village, or rural area.

Census District: Categorical variable indicating the census district of the respondents. The census districts were re-coded into the 10 administrative districts as in **Table 1** below.

TABLE 1: The census districts grouped into the 10 administrative districts of Botswana

ADMINISTRATIVE DISTRICT	CENSUS DISTRICT
CENTRAL	Serowe-Palapye, Tutume, Mahalapye, Bobonong, Boteti
CHOBE	Chobe
GHANZI	Ghanzi, Central Kalahari Game Reserve
KGALAGADI	Kgalagadi South, Kgalagadi North
KGATLENG	Kgatleng
KWENENG	Kweneng East, Kweneng West
NORTH-EAST	North-East
NORTH-WEST	Ngamiland East, Ngamiland West, Delta
SOUTH-EAST	South-East
SOUTHERN	Southern, Barolong, Ngwaketse West

By analyzing these factors, this study aims to provide a comprehensive understanding of fertility behavior and inform policies that promote sustainable socioeconomic development in Botswana.

Data Preparation

The dataset was filtered to include only women aged 15-49 years. This age range is standard for analyzing fertility as it encompasses the typical childbearing years. The population of the females under study was 640,811.

Age was divided into 5-year intervals (15-19, 20-24, 25-29, etc.) to facilitate the calculation of Age-Specific Fertility Rates (ASFR) and Total Fertility Rate (TFR).

Categorical variables were encoded using label encoding to transform them into a format suitable for machine learning models.

Cross-classifying the data was done to fit the model to allow the capturing of interactions between socioeconomic factors more effectively.

For the traditional analysis, missing values were identified and excluded at every stage of the analysis.

Missing values were also identified and dealt with at the model development stage by dropping the respondents who did not report on the number of live births from the analysis. The data used for model development had 399,488 women who responded to the target variable.

Using Census data on births in the past 12 months, by combining the number of male and female children per respondent, fertility is measured from the Age-Specific Fertility Rates (ASFR) and Total Fertility Rate (TFR). The Age-Specific Fertility Rate (ASFR), which is the number of live births per 1,000 females in the age group was calculated using the formula:

$$ASFR_i = \left(\frac{\text{Number of live births to women in the } i^{th} \text{ age group}}{\text{Total number of women in the } i\text{^th age group}} \right) \times 1000.$$

Conversely, the Total Fertility Rate (TFR), which is an estimate of the average number of children a woman would have if she experienced the age-specific fertility rates of a particular year throughout her reproductive life was calculated by summing the ASFR values for each age group and multiplying by 5 (since each age group spanned five years) as given by

$$TFR = 5 \times \sum_{i=1}^{8} ASFR_i$$

Analytical Approach

To explore the non-linear relationships between fertility rates and socioeconomic factors, the study employs Gradient Boosting Regression Trees (GBRT). GBRT is a robust machine-learning technique that builds an ensemble of decision trees to enhance predictive accuracy. This model is particularly effective for handling complex, non-linear relationships between variables.

Model Training

The dataset was split into 80% training and 20% testing data sets to evaluate the model's performance. The GBRT model is trained on the training set using features such as age, education level, employment status, marital status, locality type, and district. Hyper parameters were optimized using cross-validation to ensure the model's robustness and accuracy.

Interpretation with SHAP Values

To interpret the complex relationships captured by the GBRT model, Shapley Additive explanations (SHAP) values are used. SHAP values provide insights into the contribution of each socioeconomic factor to the model's predictions.

SHAP Analysis

Socioeconomic Factor Importance

To identify the most influential socioeconomic factors affecting fertility rates, we computed socioeconomic factors' importance scores. These scores indicate the contribution of each variable to the model's predictions.

Global Interpretation

SHAP summary plots were used to visualize the overall importance of each feature across all predictions. These plots help identify which factors have the most significant associations with fertility.

Local Interpretation

SHAP dependence plots and interaction plots were employed to explore how specific socioeconomic factors interact and contribute to individual predictions. These plots highlight the nuanced effects of different socioeconomic factors on fertility behavior.

Partial Dependence Plots (PDPs)

To further understand the relationship between fertility rates and key socioeconomic indicators, Partial Dependence Plots (PDPs) were generated. PDPs depict the marginal effect of a feature on the predicted outcome, providing insights into the socioeconomic factor's influence while averaging out the effects of other variables.

Results

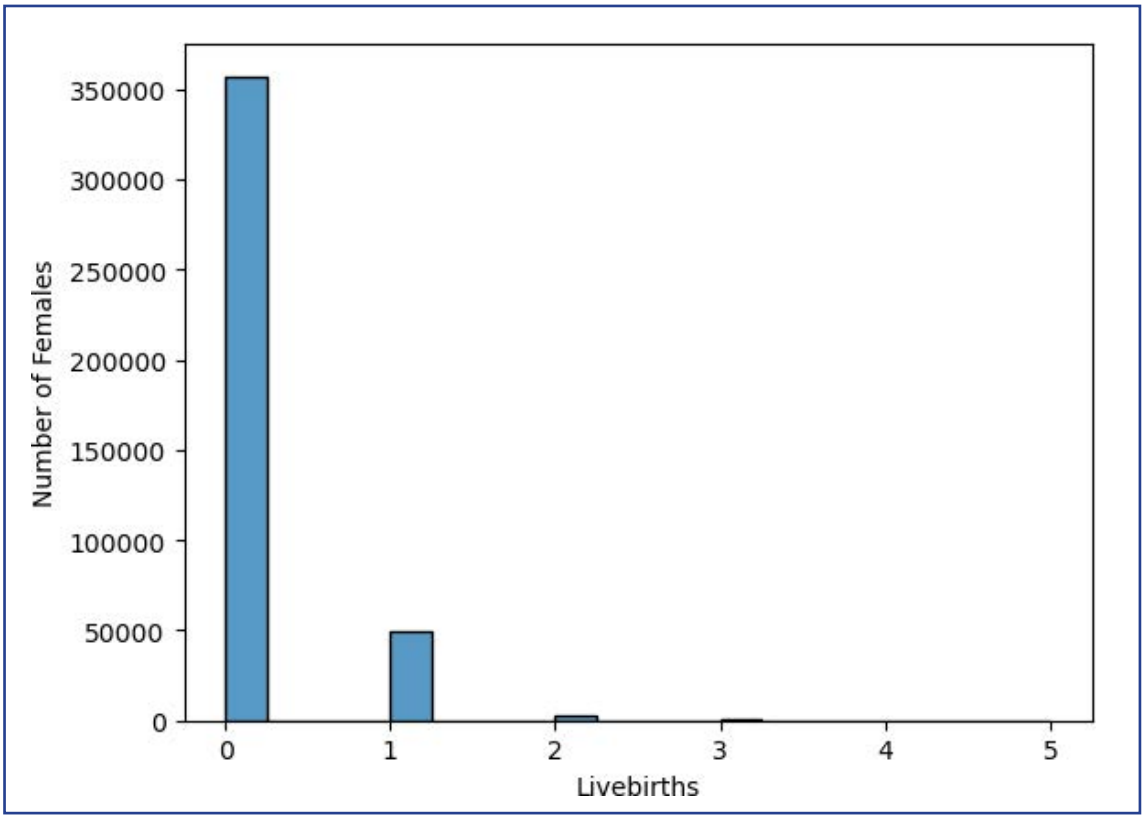
This section presents the findings from the analysis of the 2022 Population and Housing Census data, focusing on the socioeconomic factors associated with fertility in Botswana. The results are organized into subsections based on the primary research objectives: the analysis of socioeconomic factors, non-linear relationships, and cross-classification insights. Summary statistics, regression results, and SHAP values are used to illustrate the key findings.

4.0.1 Summary Statistics

Descriptive statistics revealed significant insights into the demographic composition and fertility patterns among 640,811 females in Botswana. Most of the females fell within the 25-29 age group, with the smallest cohort observed among those aged 45-49. There were 56060 recorded live births in 2021 to 409,822 women who responded to this question. Notably, the highest number of live births occurred within the 25-29 age group, reflecting a common trend of peak fertility during this life stage **(Table 2)**.

The histogram of live births shows a dominant number of females with zero live births, followed by a decreasing number of females with increasing numbers of live births. This distribution reflects the reproductive behavior of the female population and highlights the significant proportion of women, who had no live births in the period under consideration as well as the rarity of higher parity (three or more live births) in the population **(Figure 1)**.

FIGURE 1: THE NUMBER OF LIVE BIRTHS IN BOTSWANA REPORTED BY FEMALES IN 2022.



Age-Specific Fertility Rates (ASFR)

Table 2 illustrates a typical pattern of age-specific fertility rates in Botswana. The national total fertility rate (TFR) was 2.90 indicating that on average, a woman in Botswana would have approximately 2.9 children over her lifetime if she were to experience the current age-specific fertility rates throughout her childbearing years (15-49). This TFR is close to the replacement level fertility, which is around 2.1 children per woman. The replacement level fertility is the number of children needed to replace the parents and maintain a stable population size, not accounting for migration.

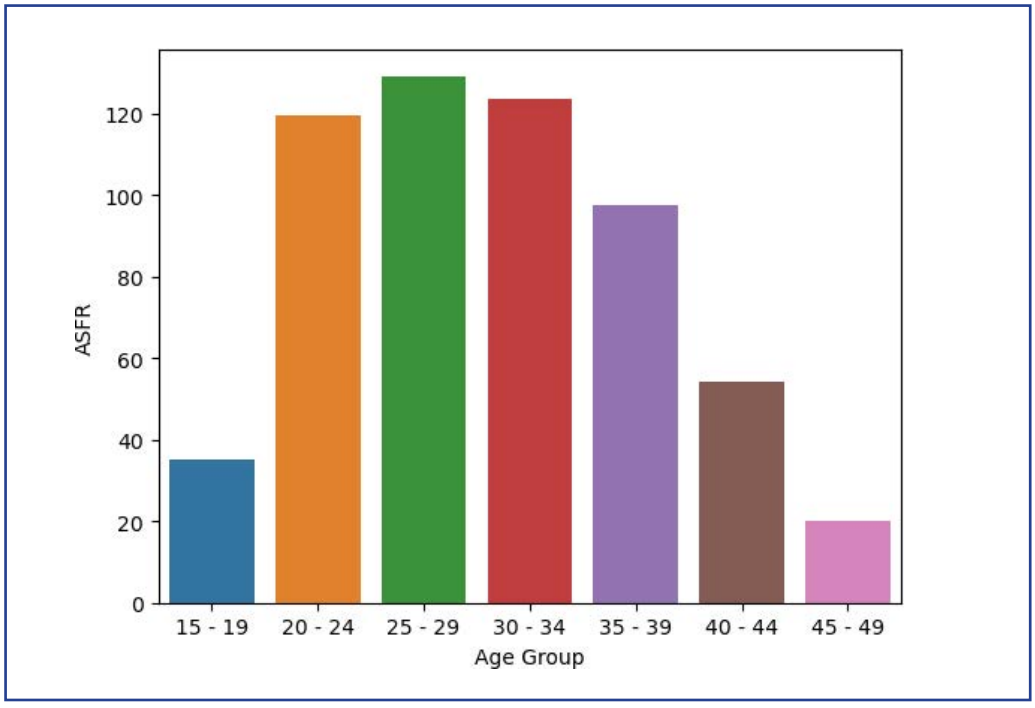
A TFR of 2.90 suggests that the population in Botswana is growing, as it is above the replacement level. Generally, fertility rates are lowest among the youngest and oldest age groups and highest among women in their twenties and early thirties. This pattern is consistent with broader demographic trends observed globally, where peak fertility usually occurs in the late twenties to early thirties.

From **Table 2**, we observe that the ASFR for women aged 15-19 years is 35.20, indicating that there are 35.20 live births per 1,000 women aged 15-19. This reflects the occurrence of teenage pregnancies, although the rate is relatively low compared to older age groups. For the age group 20-24, we see a rise to 119.60, showing that women in their early twenties have higher fertility rates. This is a common trend as many women start their families in this age group. The highest ASFR was recorded to be 129.18 for the 25-29 age group, indicating that women in this age bracket have the highest fertility rates. This aligns with the peak childbearing years for many women. The ASFR for women aged 30-34 is 123.58, slightly lower than the 25-29 age group but still relatively high. This suggests that many women continue to have children into their early thirties. The ASFR decreases to 97.64 for women aged 35-39. Fertility rates typically start to decline as women approach their late thirties. The ASFR continues to decline to 54.29 for women aged 40-44, reflecting a significant decrease in fertility as women enter their forties. The ASFR is lowest at 20.15 for women aged 45-49, as most women in this age group are nearing the end of their reproductive years. These fertility patterns are further elucidated by **Figure 2**. Generally, the age groups 25-29 and 30-34 exhibited the highest fertility rates, indicating the peak childbearing years for women in Botswana. The age group 20-24 also showed relatively high fertility rates, contributing significantly to the overall fertility, and the age groups 15-19, 40-44, and 45-49 showed the lowest fertility rates, with the 45-49 group having the fewest live births.

TABLE 2: The age-specific fertility rates (ASFR) of females in Botswana for the year 2022.

AGE GROUP	LIVE BIRTHS	FEMALE POPULATION	ASFR (PER 1,000 WOMEN)
15-19	3.481	98.905	35.20
20-24	11.828	98.896	119.60
25-29	13.282	102.821	129.18
30-34	12.247	99.102	123.58
35-39	9.588	98.196	97.64
40-44	4.381	80.703	54.29
45-49	1.253	62.188	20.15

FIGURE 2: THE NUMBER OF LIVE BIRTHS PER 1000 WOMEN FOR EACH AGE GROUP, ACROSS ALL OF THE SAMPLED VILLAGES



Fertility Rates by Education Level

Table 3 presents the Total Fertility Rate (TFR) in Botswana for the year 2022, categorized by educational level. It provides the number of live births, the female population, and the calculated TFR for women with basic education and higher education.

In **Table 3** we observe that the TFR for women with basic education is 3.30 and for women with higher education is 2.30. This indicates that, on average, a woman with basic education would have approximately 3.30 children over her lifetime if she experienced the current age-specific fertility rates throughout her reproductive years while a woman with higher education would have approximately 2.30 children over her lifetime if she experienced the current age-specific fertility rates throughout her reproductive years. This suggests that women with basic education tend to have more children compared to their counterparts with higher education.

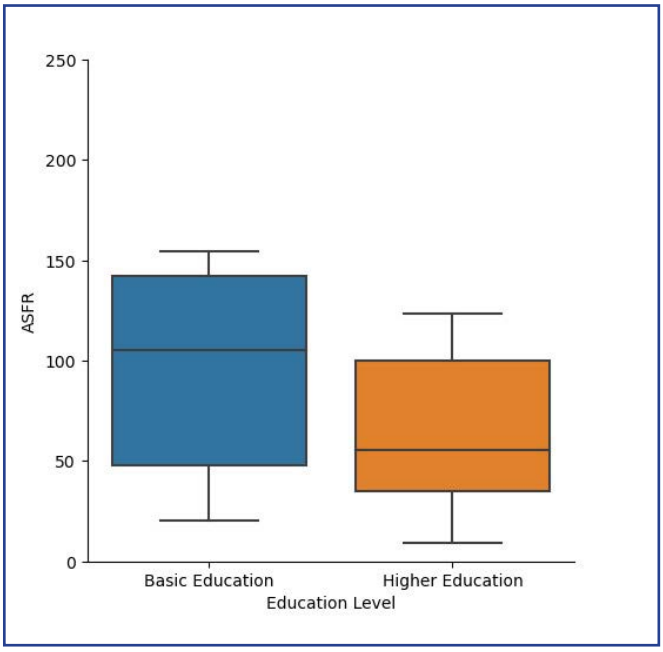
This is also confirmed by **Figure 3a** which visualizes the distribution of Age-Specific Fertility Rates (ASFR) for two educational levels: Basic Education and Higher Education. The median ASFR for women with Basic Education (around 100) is higher than that for women with Higher Education (around 50). This indicates that women with Basic Education generally have higher fertility rates. The interquartile range (IQR) for basic education is wider, suggesting more variability in ASFR values compared to higher education. Women with basic education have a broader range of fertility rates. The ASFR distribution for higher education is more concentrated, indicating more consistency in fertility rates among these women. The whiskers show that women with basic education have a higher maximum ASFR, reaching up to 200, whereas the maximum ASFR for higher education is around 150.

In conclusion, women with Basic Education tend to have higher fertility rates, as indicated in both **Table 3** and **Figure 3a**. This suggests that lower educational attainment is associated with higher fertility rates. In contrast, women with Higher Education tend to have lower and more consistent fertility rates.

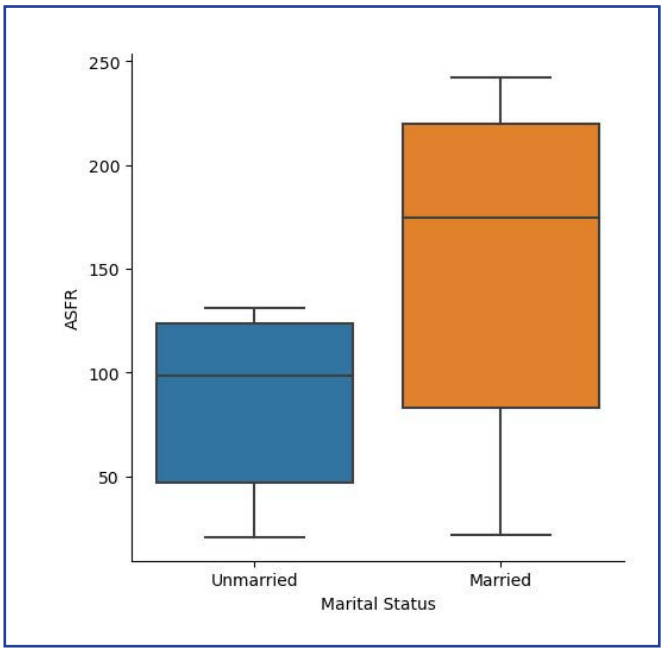
TABLE 3: Total Fertility Rate (TFR) in Botswana for the year 2021, categorized by educational level.

EDUCATIONAL LEVEL	LIVE BIRTHS	FEMALE POPULATION	TFR (PER WOMAN)
Basic Education	41,847	439,443	3.30
Higher Education	12,898	157,826	2.30

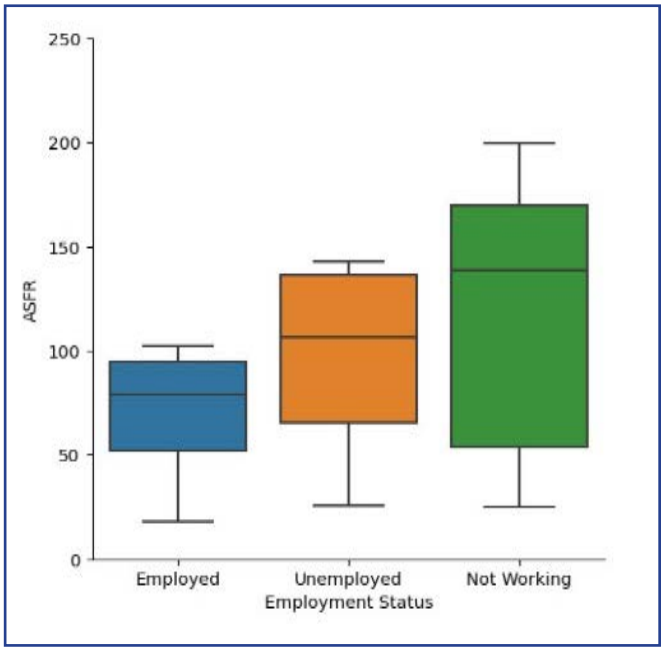
(a) Educational level



(b) Marital Status



(c) Employment Status



Fertility Rates by Marital Status

Table 4 presents the Total Fertility Rate (TFR) in Botswana for the year 2022, categorized by marital status. It provides the number of live births, the female population in each category, and the calculated TFR for married and unmarried women. The TFR for unmarried women is 2.95. This means that, on average, an unmarried woman in Botswana would have approximately 2.95 children over her lifetime if she experienced the current age-specific fertility rates throughout her reproductive years. On the other hand, the TFR for married women is 5.22. Indicating that, on average, a married woman in Botswana would have approximately 5.22 children over her lifetime if she experienced the current age-specific fertility rates throughout her reproductive years. This significantly higher TFR suggests that married women tend to have more children compared to their unmarried counterparts.

The box plot in **Figure 3b** visualizes the distribution of Age-Specific Fertility Rates (ASFR) for two marital statuses: Unmarried and Married. The median ASFR for unmarried women (around 100) is lower than that for married women (around 150). This indicates that unmarried women generally have lower fertility rates. The IQR for married women is wider, suggesting more variability in ASFR values compared to unmarried women. Married women have a broader range of fertility rates. The ASFR distribution for unmarried women is more concentrated, indicating more consistency in fertility rates among these women. The whiskers show that married women have a higher maximum ASFR, reaching up to 250, whereas the maximum ASFR for unmarried women is around 150.

Generally, married women tend to have higher fertility rates, as indicated in both **Table 4** and **Figure 3b**. This suggests that marital status is significantly associated with fertility behavior, with married women having more children on average.

TABLE 4: Total Fertility Rate (TFR) in Botswana for the year 2022, categorized by Marital Status.

MARITAL STATUS	LIVE BIRTHS	FEMALE POPULATION	TFR (PER WOMAN)
Unmarried	47,084	520,097	2.95
Married	8,972	90,657	5.22

Fertility Rates by Employment Status

Table 5 presents the Total Fertility Rate (TFR) in Botswana for the year 2021, categorized by employment status. It provides the number of live births, the female population in each category, and the calculated TFR for different employment statuses.

The TFR for employed women is 2.46. This means that, on average, an employed woman

In Botswana would have approximately 2.46 children over her lifetime if she experienced the current age-specific fertility rates throughout her reproductive years. The lower TFR among employed women suggests that employment is associated with reduced fertility rates, likely due to career considerations and access to reproductive health resources. Conversely, the TFR for unemployed women who are actively seeking employment is 3.40. This indicates that, on average, an unemployed woman in the labour force would have about 3.40 children over her lifetime. Higher fertility rates among unemployed women may be due to less stable economic conditions, which can impact access to family planning resources. The TFR for women not working (those not in the labour force) is 4.05. This high fertility rate suggests that women not engaged in formal employment or actively seeking jobs have the highest number of children, potentially due to more time available for child-rearing and cultural expectations.

The box plot in **Figure 3c** visualizes the distribution of Age-Specific Fertility Rates (ASFR) for four employment statuses: Employed, Unemployed, and Not Working.

The median ASFR for employed women is the lowest at around 100, indicating lower fertility rates among employed women while the median ASFR for unemployed women is higher at around 125, suggesting higher fertility rates among those actively seeking employment. The highest median ASFR is for women not working at around 150, indicating the highest fertility rates among women not engaged in the labour force. When looking at the variability of fertility in these groups, we observe that the ASFR distribution for employed women is more concentrated, indicating more consistency in fertility rates. The ASFR distribution for unemployed and non-working women is wider, suggesting more variability in fertility rates. The whiskers show that women not working have the highest maximum ASFR, reaching up to around 225, while employed women have the lowest maximum ASFR, around 150. Overall, employed women tend to have lower fertility rates, as indicated in both **Table 5** and **Figure 3c**. Unemployed women have higher fertility rates compared to employed women but lower than women not working. Women not working have the highest fertility rates, suggesting that those not engaged in formal employment or actively seeking jobs have more children.

TABLE 5: Total Fertility Rate (TFR) in Botswana for the year 2022, categorized by Employment Status.

EMPLOYMENT STATUS	LIVE BIRTHS	FEMALE POPULATION	TRF (PER WOMAN)
Employed	18,126	248,261	2.46
Unemployed	16	138	3.40
(In Labour Force)	15,560	138,211	3.40
Not Working			
(Not in Labour Force)	22,303	222,732	4.05

Fertility Rates by Residence in Botswana

Fertility Rates by Districts in Botswana

Table 6 presents the Total Fertility Rate (TFR) in Botswana for the year 2021, categorized by districts. It provides the number of live births, the female population, and the calculated TFR for each district. The TFR for the Central district is 3.30, indicating that women in this district, on average, would have approximately 3.30 children over their lifetimes if they experienced the current age-specific fertility rates throughout their reproductive years. This TFR suggests moderate fertility levels compared to other districts. The TFR for Chobe is 3.20, slightly lower than Central but still relatively high, indicating higher fertility rates among women in this district. The TFR for Ghanzi is 3.16, reflecting high fertility rates similar to those in

Chobe. The TFR for Kgalagadi is 2.95, indicating moderately high fertility rates, slightly lower than those in Ghanzi and Chobe. The TFR for Kgatleng is 2.90, reflecting moderate fertility rates, similar to Kgalagadi. The TFR for Kweneng is 2.98, indicating moderately high fertility rates, similar to Kgatleng and Kgalagadi. The TFR for the North-East is 2.53, suggesting lower fertility rates compared to most other districts. The TFR for North-West is 3.73, the highest among the districts, indicating significantly higher fertility rates. The TFR for the South-East is 1.93, the lowest among the districts, indicating lower fertility rates. The TFR for Southern is 3.33, indicating high fertility rates similar to Central.

Generally, as shown in **Table 6** and **Figure 4a**, high fertility rates were recorded in the north-west (high median and widespread) and southern (high median) districts while the Central, Kgalagadi, Kweneng, Ghanzi, Kgatleng, and Chobe districts show moderate and varied fertility rates. Additionally, the North-East and South-East showed lower and more consistent fertility rates.

TABLE 6: Total Fertility Rate (TFR) in Botswana for the year 2022 categorized by districts

DISTRICT	LIVE BIRTHS	FEMALE POPULATION	TRF (PER WOMAN)
Central	16,671	172,330	3.30
Chobe	833	8,280	3.20
Ghanzi	1,422	14,773	3.16
Kgalagadi	1,322	14,960	2.95
Kgatleng	2,846	32,803	2.90
Kweneng	9,943	109,238	2.98
North-East	3,821	49,295	2.53
North-West	5,956	52,094	3.73
South-East	7,595	128,820	1.93
Southern	5,651	58,218	3.33

Fertility Rates by Residential Type in Botswana

Table 7 presents the Total Fertility Rate (TFR) in Botswana for the year 2021, categorized by locality type: Town, Urban-Village, and Rural. It provides the number of live births, the female population, and the calculated TFR for each locality type. The TFR for towns (urban areas) is 1.96. This indicates that women living in towns, on average, would have approximately 1.96 children over their lifetimes if they experienced the current age-specific fertility rates throughout their reproductive years. This TFR is the lowest among the locality types, suggesting that highly developed areas have the most effective access to family planning, better education, and healthcare services, leading to lower fertility rates. The TFR for urban villages is 2.79. Women in urban villages, on average, would have about 2.79 children over their lifetimes. This is higher than in towns but lower than in rural areas, indicating a moderate fertility rate. Urban villages might have less access to family planning and healthcare services compared to towns but better access than rural areas. The TFR for rural areas is 3.93, the highest among the locality types. This means that women living in rural areas, on average, would have approximately 3.93 children over their lifetimes. Higher fertility rates in rural areas can be attributed to limited access to family planning and healthcare services, lower levels of female education, and cultural norms favoring larger families.

The box plot in **Figure 4b** visualizes the distribution of Age-Specific Fertility Rates (ASFR) across different locality types in Botswana: Town, Urban-Village, and Rural. Towns (urban areas) have the lowest median ASFR, indicating lower fertility rates while the narrow IQR suggests that fertility rates are relatively consistent among women living in urban areas. The lower median ASFR reflects better access to family planning, education, and healthcare services.

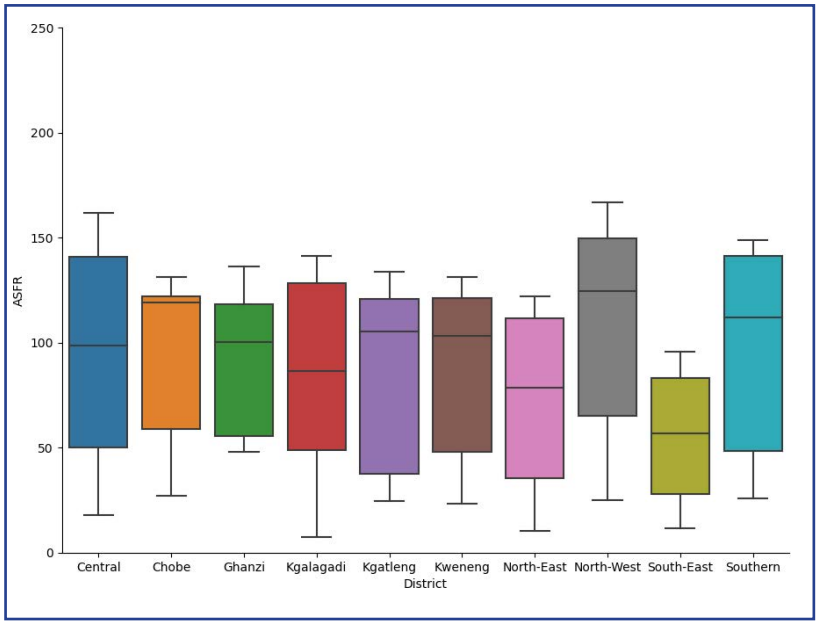
On the other hand, urban villages have a higher median ASFR compared to towns but lower than rural areas with a moderate IQR indicating some variability in fertility rates among women in urban villages. This suggests that while urban villages have better access to services than rural areas, they still experience higher fertility rates than urban areas. Lastly, rural areas have the highest median ASFR, indicating higher fertility rates and the wide IQR shows significant variability in fertility rates among women in rural areas. This high median ASFR is indicative of limited access to family planning, education, and healthcare services, as well as cultural norms favoring larger families.

TABLE 7: Total Fertility Rate (TFR) in Botswana for the year 2021, categorized by Locality Type

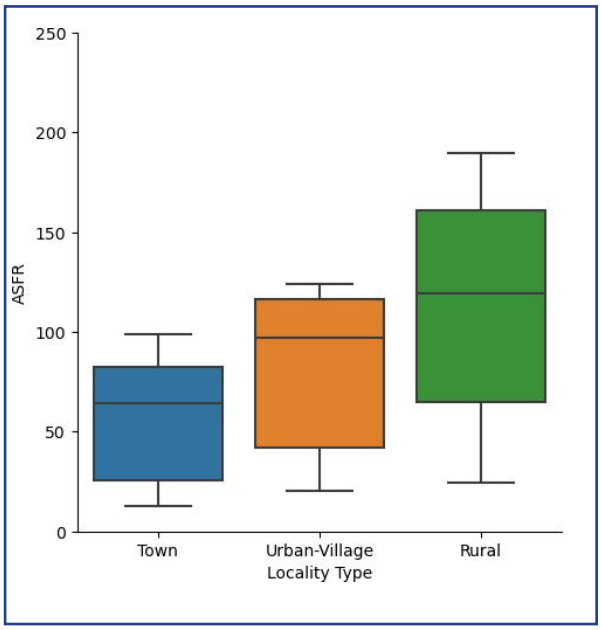
LOCALITY TYPE	LIVE BIRTHS	FEMALE POPULATION	TRF (PER WOMAN)
Town	8,883	148,048	1.96
Urban-Village	26,996	320,031	2.79
Rural	20,181	172,732	3.93

FIGURE 4: NUMBER OF LIVE BIRTHS PER 1000 WOMEN BY RESIDENCE

(a) Districts



(b) Locality Type



Analytical Approach Results

In this section, we employ a series of analytical methods to explore the socioeconomic factors associated with fertility behaviour in Botswana. We will begin with Partial Dependence Plots (PDPs) to illustrate the marginal effect of key socioeconomic factors on fertility rates. PDPs help to visualize how the predictions change as we vary a particular socioeconomic factor while averaging out the effects of other socioeconomic factors. This provides a clear understanding of the individual contributions of each socioeconomic factor to fertility estimates.

Following the PDPs, a SHAP summary plot is presented. The summary plot ranks socioeconomic factors by their importance and shows the distribution of the SHAP values for each socioeconomic factor. This plot provides an overview of which socioeconomic factors are most associated with fertility and the nature of their impact on fertility estimates. Next, the SHAP beeswarm plot is utilized for visualizing the distribution of the impact of each socioeconomic factor across all samples. The beeswarm plot highlights how the value of a socioeconomic factor affects fertility, allowing us to see the spread and density of SHAP values. This visualization helps in understanding the variability and the direction of the socioeconomic factor's association with fertility.

Lastly, we interpret SHAP interaction plots and waterfall plots. SHAP interaction plots will help us delve deeper into how pairs of socioeconomic factors interact and jointly impact fertility, while waterfall plots will provide a detailed breakdown of individual predictions, showing how each socioeconomic factor contributes to the final fertility estimates for specific groups.

GBRT Model Results

The Gradient Boosting Regression Trees model was trained using the transformed dataset. The objective was to predict fertility, which in this case, is the number of live births using the socioeconomic factors mentioned. The GBRT model's hyperparameters were tuned to optimize performance, and the model achieved an R-squared value of 0.98 on the training data and 0.96 on the test data, indicating a strong predictive performance.

SHAP Values Interpretation

In the partial dependence, beeswarm, and waterfall plots, the color-coding of the dots indicates the labels for each observation of the socioeconomic factors, with red representing high values and blue representing low values as they are coded in the analysis, for example, if the marital status is encoded as follows:

Married = 1
Unmarried = 0
Then, in these plots:

Red Dots: Represent instances where the feature value is high, i.e., the individual is married.

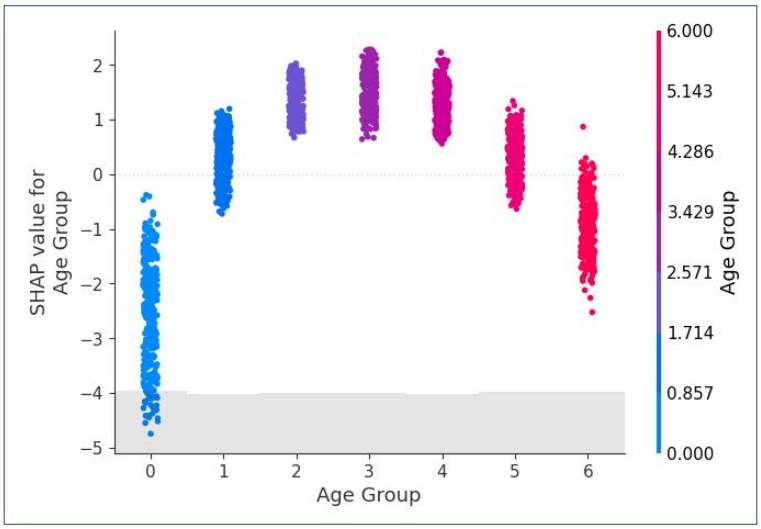
Blue Dots: Represent instances where the feature value is low, i.e., the individual is unmarried.

The analysis of socioeconomic factors associated with fertility in Botswana reveals several key insights, though with some contradictions when compared to traditional analysis, (see Figure 5). Employed women have higher fertility, likely due to better access to resources and support systems, despite the potential constraints on time. However, traditional analysis would suggest that employment correlates with lower fertility due to career aspirations delaying childbearing. For marital status, being married is associated with lower fertility, possibly because married women may face career-related constraints and limited support systems. This contrasts with traditional findings of married women typically exhibiting higher fertility, reflecting cultural norms that favor larger families within marriage.

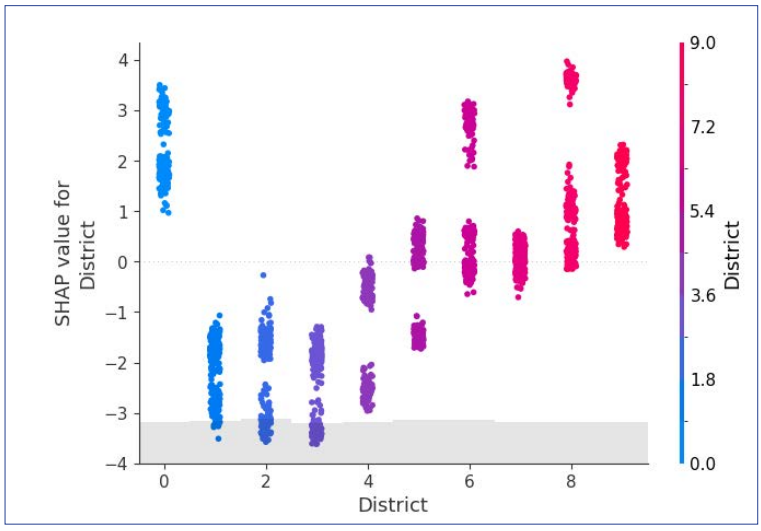
Younger women are associated with higher fertility, aligning with expected reproductive age patterns, while geographic variability across districts reflects differences in socioeconomic development and access to services. Higher education correlates with lower fertility, whereas basic education is associated with higher fertility. There are significant differences in fertility behaviour by locality type, with urban areas having lower fertility than rural areas, indicative of disparities in development and cultural norms. These findings underscore the complexity of fertility dynamics and highlight the need for targeted interventions to address these socioeconomic factors.

FIGURE 5: PARTIAL DEPENDENCE PLOTS ILLUSTRATING THE MARGINAL EFFECTS OF THE SOCIOECONOMIC FACTORS ON FERTILITY.

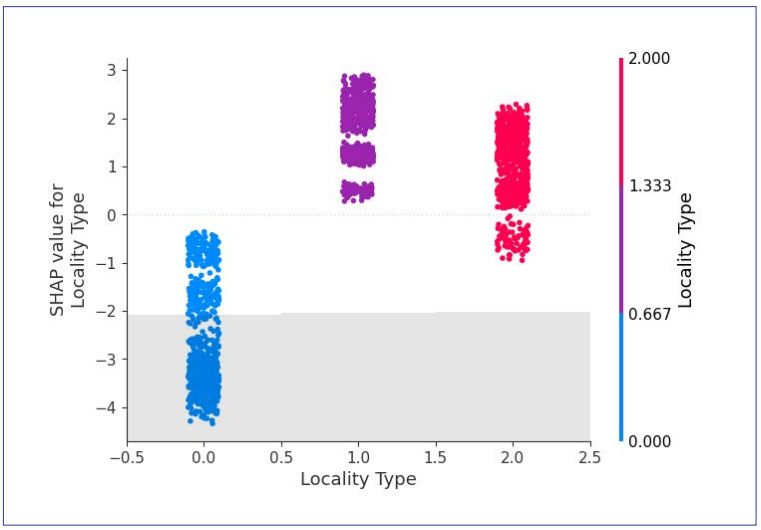
(a) Age Group



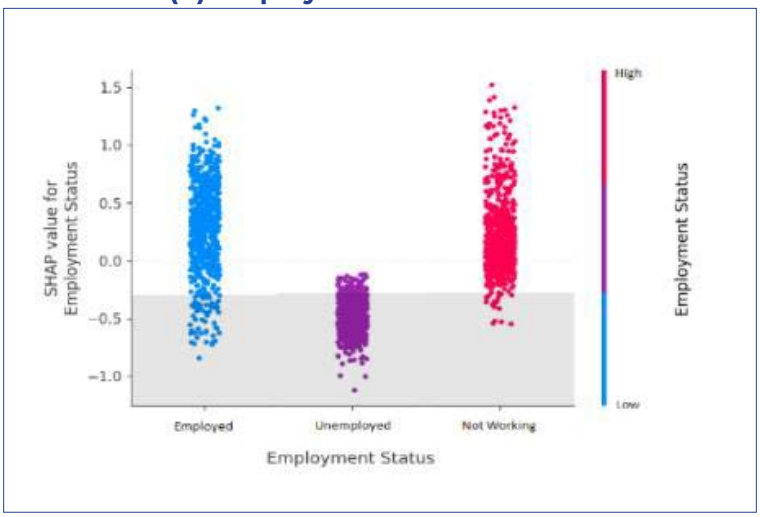
(b) District



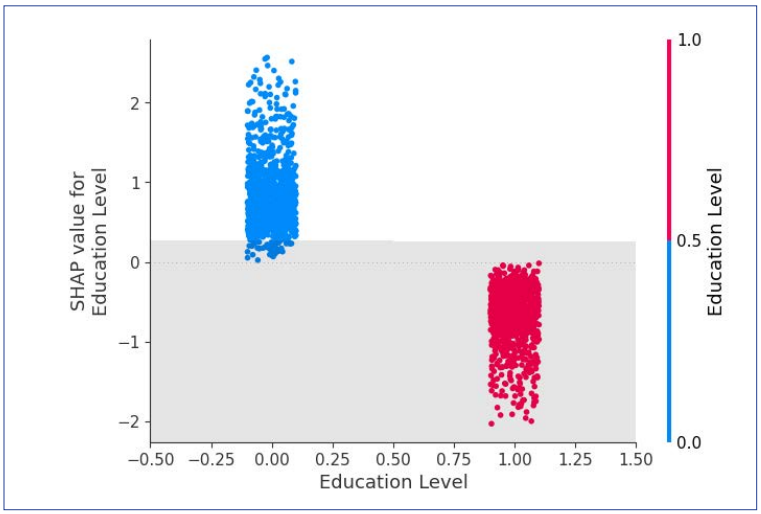
(c) Locality Type



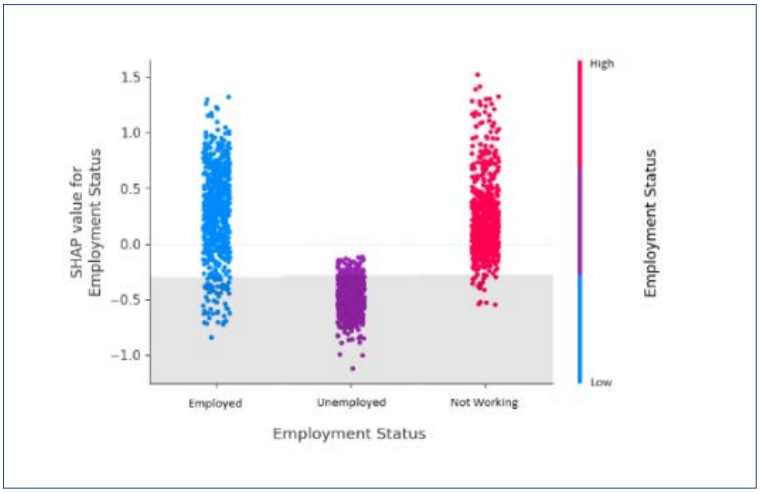
(d) Employment Status



(e) Educational Level



(f) Employment Status

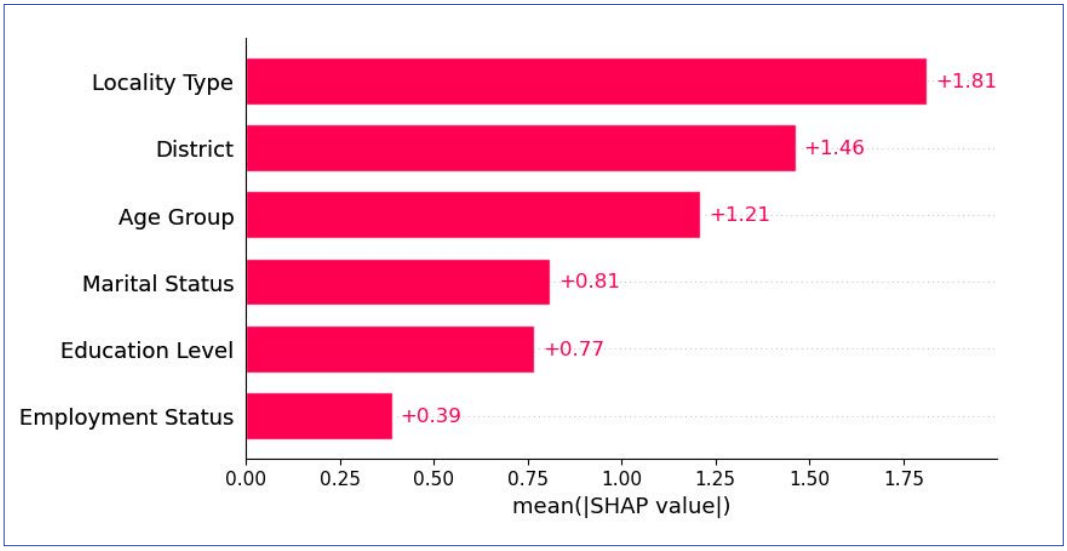


The SHAP summary plot in **Figure 6** provides insights into the importance and impact of each socioeconomic factor on fertility. Generally, Locality type, district, and age group are the factors mostly associated with fertility, reflecting the significant impact of geographic and demographic variables on fertility. Marital status, education level, and employment status also contribute to fertility patterns, indicating the multifaceted nature of reproductive behavior.

To be precise, locality type has the highest average absolute SHAP value, indicating it is the factor most associated with fertility. This SHAP value of +1.81 suggests a significant positive impact on fertility estimates when this feature changes. The second-highest average SHAP value is given by district, and it indicates a substantial positive impact on fertility.

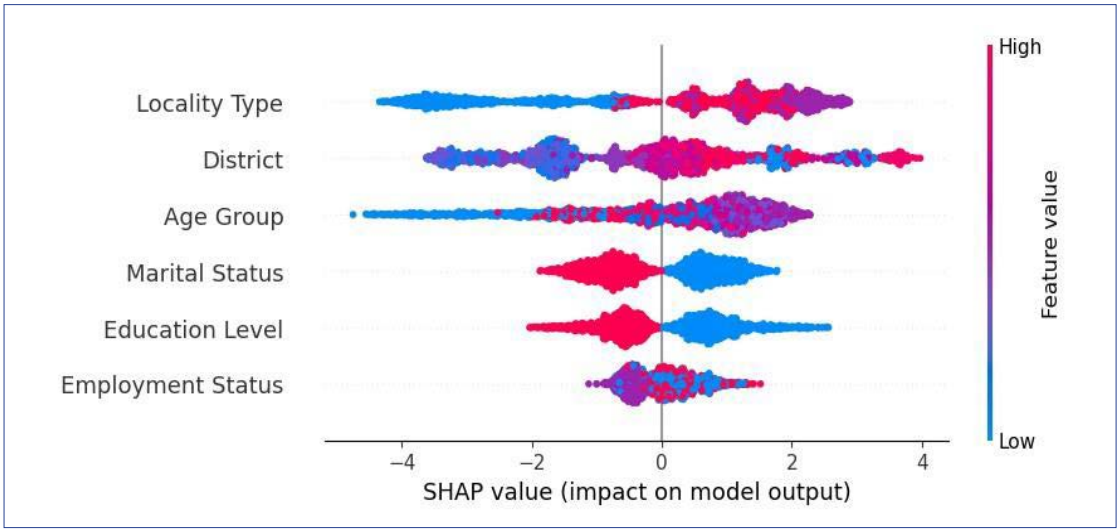
The age group has a mean absolute SHAP value of +1.21, this aligns with the understanding that fertility is closely related to age, with younger women associated with higher fertility, peaking in the mid-20s to early 30s. Marital Status, on the other hand, has a mean SHAP value of +0.81, reflecting a moderate impact on fertility compared to educational level which had a SHAP value of +0.77. Lastly, although employment status has the lowest mean SHAP value among the factors listed, it still plays a role in impacting fertility estimates.

FIGURE 6: THE OVERALL EFFECT, AS THE MEAN ABSOLUTE IMPORTANCE, OF EACH SOCIOECONOMIC FACTOR ON THE OVERALL PREDICTION OF FERTILITY.



The SHAP beeswarm plot in **Figure 7** provides a more detailed view, by showing how each socioeconomic factor impacts individual predictions on the number of live births by highlighting the variability and interactions within the dataset.

FIGURE 7: THE BEE SWARM PLOT SHOWING THE CONTRIBUTION OF EACH SOCIOECONOMIC FACTOR IN THE OVERALL PREDICTION OF FERTILITY.



Locality types have a wide range of SHAP values, indicating a significant impact on fertility estimates. The red dots mostly positioned on the right in **Figure 7**, indicate that rural areas are associated with higher fertility while the blue dots positioned on the left, indicate that urban areas are associated with lower fertility. This aligns with the observation that rural areas have higher fertility due to cultural norms and limited access to family planning. The district also shows variability, with some districts having higher fertility estimates reflecting the diverse socioeconomic and cultural contexts across different districts in Botswana, which associate with fertility differently. A similar trend is observed with age groups with some age groups associated with increasing fertility. More specifically, younger age groups are associated with lower fertility, while middle age groups are associated with higher fertility. This pattern is consistent with the typical fertility curve, where fertility peaks in the mid-20s to early 30s and then declines.

Furthermore, the results on marital status show a clear dichotomy, suggesting that being married negatively impacts fertility, while being unmarried has a positive impact. Again, this contradicts traditional expectations where married women are typically expected to have higher fertility. The model suggests a negative impact on married women, possibly due to interactions with other factors. This nuanced insight highlights the importance of considering multiple interacting factors when analyzing fertility behavior, as advanced analytical techniques like SHAP can reveal patterns that traditional methods might overlook. Higher education levels negatively impact fertility, while lower education levels have a positive impact. This supports the idea that education correlates with lower fertility due to career aspirations and better access to family planning.

Employment Status

Lastly, employment status exhibits a mix of impacts. Women who are either employed, unemployed, or not in the labour force tend to have both negative and positive SHAP values. This reflects the complex relationship between employment and fertility, where employment provides access to resources but also imposes career-related constraints on childbearing. Employed women typically associate with lower fertility due to career commitments and access to reproductive health resources, while women who are not working or unemployed might associate with higher fertility rates due to fewer career-related constraints but also face economic instability.

FIGURE 8: DEPENDENCE PLOTS ILLUSTRATING THE JOINT EFFECTS OF MARITAL STATUS AND EMPLOYMENT STATUS AGAINST THE OTHER SOCIOECONOMIC FACTORS ON FERTILITY.

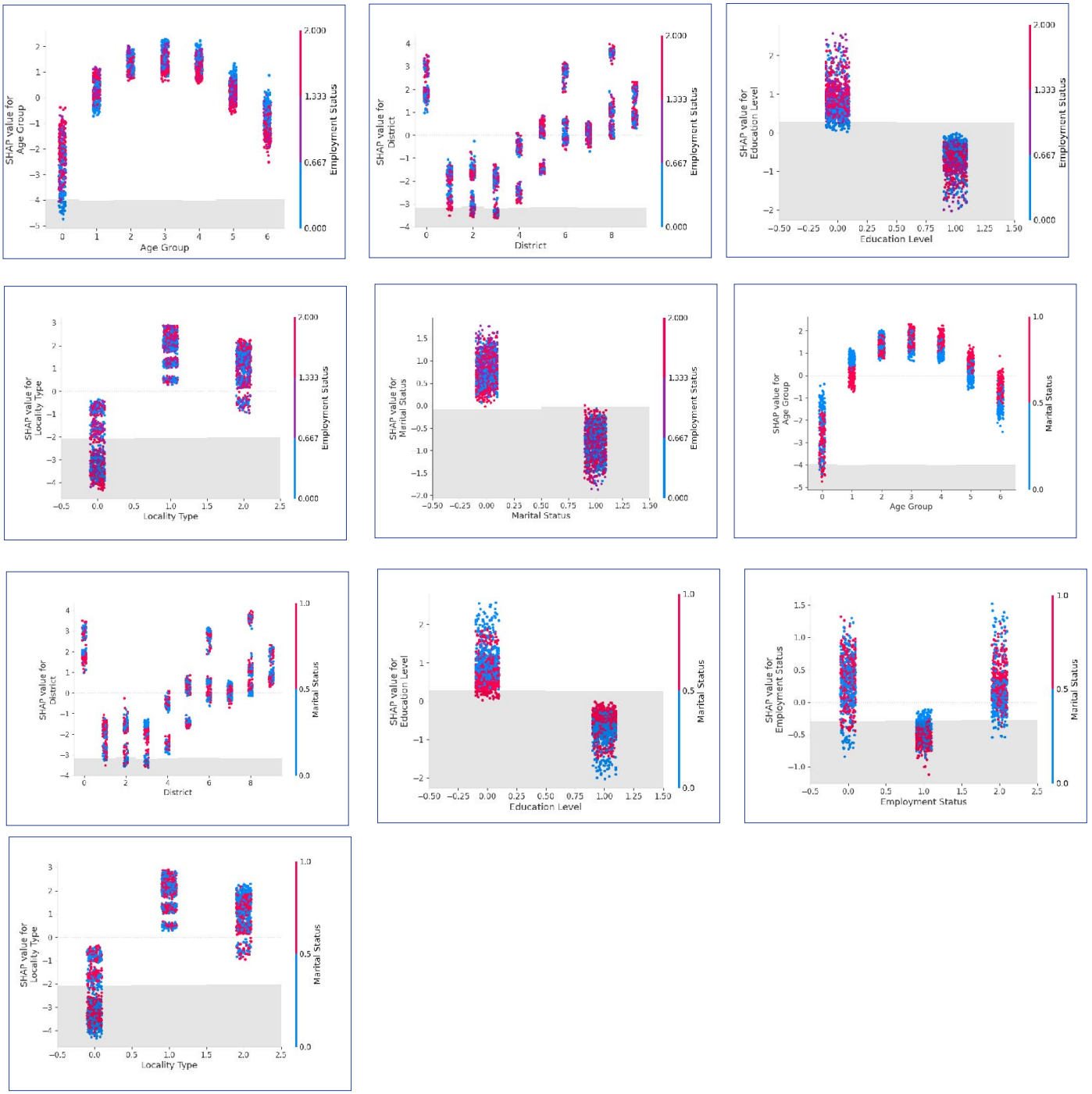
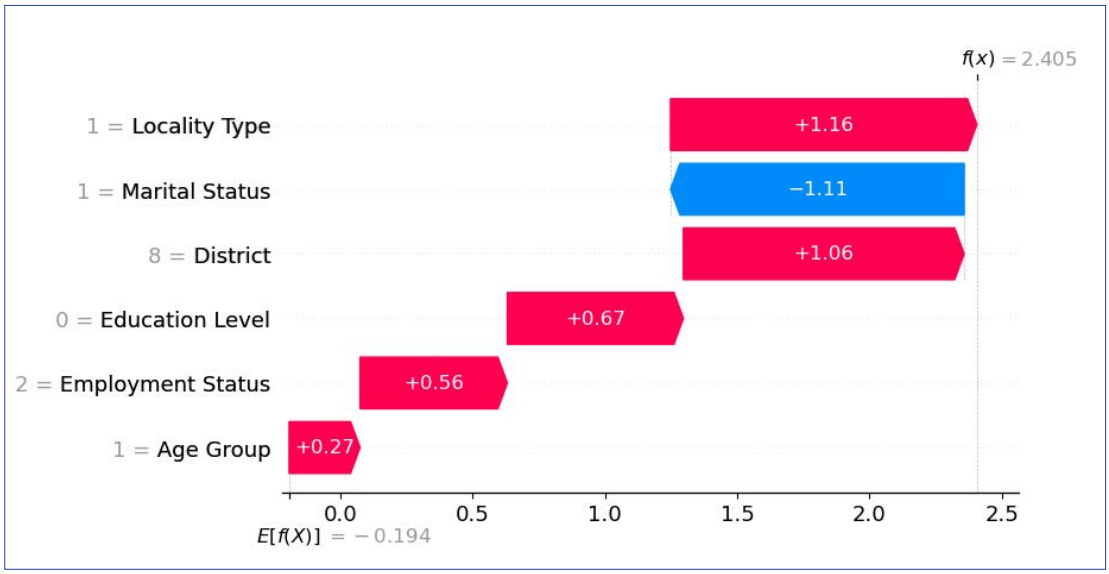


Figure 8 illustrates how interactions between two socioeconomic factors jointly influence fertility estimates. The results reveal complex interactions between socioeconomic factors and fertility in Botswana. Generally, employment status and marital status have significant and sometimes contradictory impacts on fertility. While traditional analyses suggest that employed women have lower fertility, SHAP values indicate that employed women might have better access to resources and support systems that facilitate childbearing, leading to higher fertility. Similarly, while marital status traditionally correlates with higher fertility, SHAP values suggest that married women may face constraints that reduce their likelihood of having children. Geographic variability in fertility reflects differences in socioeconomic development, access to services, and cultural norms. Higher education is associated with lower fertility, while basic education correlates with higher. Urban areas have lower fertility in contrast with rural areas which have higher fertility estimates, reflecting differences in development and cultural norms.

The waterfall plot in **Figure 9** provides estimates for women in the southeast district living in urban villages who were married, not working and not looking for jobs/businesses with basic education and in the age group 20-24 years. There were 39 respondents in this group with a record of 13 live births. The f(x) value is the natural logarithm (log fertility) of the estimated total number of children born for the women in this group. In this figure, various socioeconomic factors significantly contribute differently to the prediction of fertility estimates. The locality type (urban) has a substantial positive impact, increasing the estimated log-fertility by 1.16. Marital status, specifically being married, contributes negatively with a SHAP value of 1.20, indicating a lower predicted log-fertility. Conversely, residing in the southeast district (District 8) increases the predicted log-fertility by 1.06. Education level, especially having basic education, contributes 0.67, increasing the predicted log-fertility. Employment status, particularly when not working and not looking for jobs/businesses, adds 0.56 to the prediction, suggesting its importance in impacting fertility. Lastly, belonging to the age group 20-24 adds 0.28 to the log-fertility prediction, highlighting the insignificant role age plays in this instance in impacting fertility estimates. The model suggests that there were 11 children born alive to this group of women described by the waterfall plot.

FIGURE 9: THE WATERFALL PLOT SHOWING THE CONTRIBUTION OF EACH SOCIOECONOMIC FACTOR IN THE PREDICTION OF FERTILITY RATE FOR A SINGLE GROUP OF WOMEN.



Findings and Discussions

Key Findings

The analysis of fertility in Botswana using the 2022 Population and Housing Census data provides several important insights into the association of the socioeconomic factors of with fertility. Key findings from both traditional and advanced analytical approaches, including SHAP values and interaction plots, are summarized as follows:

Employment Status:

Traditional Analysis: Women not in the labour force have the highest fertility rates (TFR of 4.05), followed by unemployed women actively seeking jobs (TFR of 3.40), with employed women having the lowest fertility rates (TFR of 2.46). This aligns with global patterns where economic participation correlates with reduced fertility, as employment provides financial independence and career aspirations, often delaying childbearing.

Advanced Analytical Approach: The SHAP values suggest that employment can both positively and negatively impact fertility. Employed women might have better access to resources and support systems that facilitate childbearing while also potentially facing constraints on time and resources. Conversely, unemployment might lead to higher fertility due to a lack of career-related constraints, but in some contexts, it might also lead to lower fertility due to economic instability and lack of support.

Marital Status:

Traditional Analysis: Being married significantly increases fertility rates among women, highlighting cultural and social norms that favor larger families within marriage.

Advanced Analytical Approach: The SHAP values indicate that being married negatively impacts fertility, possibly due to career-related constraints and support systems. This contradiction with the traditional analysis suggests that while marriage traditionally correlates with higher fertility, other interacting factors might influence this relationship in contemporary settings.

Age Group:

Both traditional and advanced analyses consistently show that younger women have higher fertility, aligning with traditional reproductive age patterns. The SHAP values highlight that younger age groups positively impact fertility rates.

District:

Fertility shows significant geographic variability. Districts such as North-East and South-East (the urban areas of the country) have lower fertility, while rural districts like Central and North-West exhibit higher fertility. This geographic variability reflects differences in socioeconomic development, access to healthcare and family planning services, and cultural norms.

Education Level:

Traditional Analysis: Women with basic education levels have higher fertility rates (TFR of 3.30), while those with higher education have lower fertility rates (TFR of 2.30). This aligns with global trends where increased female education correlates with reduced fertility.

Advanced Analytical Approach: The SHAP values confirm this pattern, showing that higher education levels are associated with lower fertility rates, while basic education levels correlate with higher fertility rates.

Locality Type:

Traditional Analysis: Fertility rates are highest in rural areas (TFR of 3.93), followed by urban villages (TFR of 2.79), and towns (TFR of 1.96). This reflects differences in socioeconomic development, access to healthcare, and cultural norms.

Advanced Analytical Approach: The SHAP values show that urban areas have lower fertility as compared to rural areas, reinforcing the findings from traditional analysis.

These findings reveal the complex interplay between socioeconomic factors and fertility rates in Botswana. The use of SHAP values and interaction plots has provided different insights that highlight both the direct and interaction effects of various predictors on fertility rates. The identified contradictions between traditional and advanced analyses underscore the importance of considering multiple analytical approaches to gain a comprehensive understanding of fertility dynamics.

Discussion

The socioeconomic factors influencing fertility rates in Botswana demonstrate a complex interplay, reflective of both global trends and unique local dynamics. This discussion delves into these intricate relationships, comparing our findings with existing literature and addressing any contradictions observed in our advanced analytical approach.

Association of Socioeconomic Factors with Fertility

Age: The analysis reveals that fertility rates are highest among women aged 25-29, followed closely by those aged 30-34. This pattern aligns with global trends, where peak fertility typically occurs in the mid-to-late twenties, a period often associated with increased biological fertility and societal norms favoring childbearing during this age range. As women age beyond 35, fertility rates decline, reflecting biological constraints and potentially increased use of family planning methods.

Education Level: Our study indicates that women with basic education have higher fertility rates (TFR of 3.30) compared to those with higher education (TFR of 2.29). This finding is consistent with numerous studies (Martin, 1995; Schultz, 1997) which highlight that higher educational attainment often correlates with delayed childbearing and reduced fertility. Education empowers women with knowledge and opportunities, leading to greater career aspirations and a preference for smaller family sizes. Moreover, educated women are more likely to access and use contraceptive methods effectively, further contributing to lower fertility rates.

Marital Status: Married women exhibit significantly higher fertility rates (TFR of 5.22) than their unmarried counterparts (TFR of 2.78). This finding underscores the association of fertility behaviour with cultural and social norms in Botswana, where marriage is often associated with family formation and larger family sizes. These results are consistent with those of (Moffitt, 1998), who found that marital status significantly impacts fertility behavior. However, the SHAP values from our advanced analytical approach suggest a negative impact of being married on fertility rates. This contradiction may arise from complex interactions with other variables such as age and education, which necessitates a deeper investigation.

Employment Status: Women not in the labour force have the highest fertility rates (TFR of 4.05), followed by unemployed women actively seeking jobs (TFR of 3.40), with employed women having the lowest fertility rates (TFR of 2.46). These findings align with global patterns where economic participation often correlates with reduced fertility. Employment provides women with financial independence and career aspirations, often delaying childbearing and reducing overall fertility. However, the SHAP values indicate a different interaction. The SHAP values indicate that employment can both positively and negatively impact fertility rates. Employed women might have better access to resources and support systems that facilitate childbearing, while also potentially facing constraints on time and resources that limit childbearing. Conversely, unemployment might lead to higher fertility due to a lack of career-

related constraints, but in some contexts, it might also lead to lower fertility due to economic instability and lack of support. The contradiction observed may stem from the nuances in how SHAP values are interpreted based on specific interactions between socioeconomic factors and employment status.

Residence: Fertility rates are highest in rural areas (TFR of 3.93), followed by urban villages (TFR of 2.79), and towns (TFR of 1.96). This geographic variability reflects differences in socioeconomic development, access to healthcare and family planning services, and cultural norms. Rural areas often have limited access to healthcare and contraceptive methods, leading to higher fertility rates. Urbanization, associated with better access to education and employment opportunities, typically results in lower fertility rates. Additionally, there is considerable variability across different districts. For example, the North-East and South-East districts, which are urbanized regions, show lower fertility rates compared to rural districts such as Central and North-West. This variability further emphasizes the impact of localized socioeconomic conditions on fertility behavior.

Addressing the Contradictions in Marital Status and Employment Status Results

The contradictions observed in the SHAP plots, where marital status and employment status appear to negatively impact fertility rates, despite traditional measures showing higher fertility rates among married women and women not in the labour force, highlight the complexity of fertility dynamics. These discrepancies may result from interactions between multiple socioeconomic factors.

Marital Status: The negative impact observed in SHAP plots might reflect the influence of other factors such as age and education. Married women in higher age groups or with higher education might have fewer children, thus leading to a perceived negative impact when other factors are considered.
Employment Status: The SHAP values suggest that employment can both positively and negatively impact fertility rates, indicating that employed women might have better access to resources and support systems that facilitate childbearing, while also potentially facing constraints on time and resources that limit childbearing. Conversely, unemployment might lead to higher fertility due to economic instability and lack of support, but in some contexts, it might also lead to lower fertility due to a lack of career-related constraints and support systems.

Policy Implications

The insights gained from this study align with key national and international development frameworks, including Botswana's Vision 2036, the Revised National Population Policy (RNPP), the African Agenda 2063, and the Sustainable Development Goals (SDGs). These findings can inform targeted policy interventions aimed at reducing high fertility rates, improving education and employment opportunities for women, enhancing access to healthcare, and promoting family planning programs, ultimately contributing to sustainable development goals. To be precise, the findings of this study support the following framework:

Vision 2036: The findings support objectives to improve quality of life and health standards through better access to education and reproductive health services. Policies should focus on enhancing educational opportunities and healthcare access, particularly in rural areas.

Revised National Population Policy (RNPP): The significant impact of education and employment on fertility rates underscores the need for policies that empower women through education and improve family planning services.

African Agenda 2063: The study's insights into geographic variability in fertility rates can guide targeted interventions to improve living standards and healthcare access in different regions.

African Union's African Agenda for Sustainable Development (AADPD): By highlighting the relationship between unemployment and fertility, the study supports policies aimed at improving economic opportunities for women, thereby reducing high fertility rates.

Sustainable Development Goals (SDGs): The findings align with SDGs 3, 4, and 5, which aim to ensure healthy lives, inclusive and equitable quality education, and gender equality. The study provides empirical evidence to support interventions focused on education and reproductive health services.

Recommendations for Policymakers

These recommendations align with broader development frameworks, ensuring that policies are comprehensive and support sustainable development in Botswana.

Educational Initiatives: Expanding access to quality education, particularly for girls and young women, can significantly reduce fertility rates. Policies should focus on keeping girls in school and supporting higher educational attainment.

Employment Programs: Creating economic opportunities for women, especially in rural areas, can lower fertility rates. Employment policies should target women, providing them with skills and opportunities that can lead to economic independence and reduced fertility.

Reproductive Health Services: Enhancing access to reproductive health services and family planning can help manage fertility rates. Policies should aim to make these services widely available, especially in rural and underserved areas.

Regional Focus: Targeted interventions based on geographic variability are crucial. Policies should address the specific needs of different regions, recognizing that rural and urban areas may require different approaches to education, employment, and health services.

Conclusion

This study examined the socioeconomic factors influencing fertility rates in Botswana, utilizing data from the 2022 Population and Housing Census. The analysis employed advanced statistical models, specifically Gradient Boosting Regression Trees (GBRT), to capture non-linear relationships between variables. The key variables analyzed included age, education level, employment status, marital status, and residence. SHapley Additive exPlanations (SHAP) values were used to interpret the contributions of these variables. The study aims to inform policy recommendations that align with Botswana's Vision 2036, the Revised National Population Policy (RNPP), the African Agenda 2063, and the Sustainable Development Goals (SDGs).

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SPATIAL DISTRIBUTION AND SOCIAL DETERMINANTS OF FERTILITY AMONG WOMEN OF REPRODUCTIVE AGE IN BOTSWANA

By;
Dr Olusegun S. Ewemooje

EXECUTIVE SUMMARY

The fertility decline in Botswana is worrisome as fertility remains relatively low in the country resulting in a reduced population growth rate with a slight increase in the population. This poses great challenges in achieving the Sustainable Development Goals and Pillar 2 – Human and social development – of the Botswana Vision 2036. Though fertility decline has the potency to reduce Maternal and Infant Mortality, constituting an integral part of SDGs' targets, the country's Maternal Mortality Ratio increased from 118 in 2019 to 186 deaths per 100,000 live births in 2020 (WHO, 2023). This prevents Botswana from achieving SDG 3.1 of reducing the global maternal mortality ratio to less than 70 per 100,000 live births by 2030. This study therefore seeks to understand the spatial distribution and social determinants of fertility behaviour among women of reproductive age to record more successes in their fertility behaviour. To achieve this, the data from Botswana Census 2022 was analysed using descriptive and inferential approaches with the help of frequencies, tables, charts, maps, and multivariate Poisson regression analysis. All analyses were conducted using SPSS 27, ArcGIS Pro, and Microsoft Excel. The results show that the total fertility rate (TFR) was 2.9 children per woman in Botswana showing a slight increase over the census 2011 TFR of 2.8. The ASFRs further showed that fertility rates declined among youth (women aged 15-29 years) from the previous census (2011) which indicates that younger women are reducing their parity. The spatial differentials were observed in the TFRs by districts with Ngamiland West having the highest rate of 4.49 children per woman while commercial districts like Gaborone had a lower TFR of 1.76 children per woman. Social differentials indicated that women living in rural areas and those cohabiting are more likely to have higher TFRs while increased education reduced TFR among the women. The outcome of this study is expected to help the government and policymakers in identifying hotspots for immediate interventions, thereby solving the attendant fertility problems and challenges to achieve the SDGs targets and Botswana Vision 2036.

INTRODUCTION

The fertility rates of any nation play a vital role in shaping the demographic landscape such as population growth, age structure and social dynamics, and socio-economic development (Lal, et al., 2021). These patterns are crucial indicators of its socio-economic development and demographic trends. The world average fertility level dropped from 3.2 in the year 1990 to 2.5 children per woman in the year 2019 (UNDESA/ Population Division, 2020). This fertility decline is a significant demographic trend that has been observed in various countries around the world. However, the estimated world's population keeps increasing regardless of the global decline in fertility rate (UNDESA/Population Division, 2019). Though, the magnitude and pace of this fertility are unevenly distributed as a greater part of it is anticipated in sub-Saharan Africa (Biney et al, 2020). The Southern African Development Community (SADC) countries are not left out in this demographic transition, they are currently undergoing demographic change and are at different stages of the transition (Letamo, et al., 2023). While there might be variations among countries, fertility rates in Southern Africa have been gradually declining in recent years, albeit at a slower pace compared to other regions. Botswana, for example, has experienced a decline in fertility rates over the past few decades, with the Total Fertility Rate (TFR) estimated to be around 2.8 children per woman based on Botswana 2011 Population and Housing

Census data (Bainame and Letamo, 2014). Though, fertility decline has the potency to reduce both Maternal and Infant Mortality which constitutes an integral part of the targets of SDGs, the country's Maternal Mortality Ratio increased from 118 in 2019 to 186 deaths per 100,000 live births in 2020 (WHO, 2023). Therefore, understanding these spatial and social distributions of fertility rates is essential for identifying vulnerable populations and designing effective interventions to promote reproductive health and well-being. In Botswana, a country undergoing demographic transitions, exploring fertility patterns at spatial and social scales will provide insights into the underlying determinants of fertility and inform targeted policy and programmatic efforts.

LITERATURE REVIEW

Botswana, situated in Southern Africa, has experienced significant demographic transitions over the past few decades with a high of 6.6 children per woman in 1981 to 3.3 in 2001 and 2.8 children per woman in 2011 (Bainame and Letamo, 2014). While the fertility rate has declined, it remains relatively high compared to global standards. Fertility rates and their intentions are dynamic and vary across geographic regions and social groups due to differences in socioeconomic, cultural, and environmental factors (Ewemooje, et al., 2020; Gayawan, et al., 2022). The fertility decline in Botswana is worrisome as fertility remains relatively low in the country resulting in a reduced population growth rate with a slight increase in the population. This poses great challenges in efforts to achieve the Sustainable Development Goals (SDGs) - Goal 3 on ensuring healthy lives and promoting well-being as understanding fertility patterns is crucial for addressing various social and economic aspects targeted by this goal, such as maternal and child health (United Nations, 2018) and Pillar 2 – Human and social development – of the Botswana Vision 2036 (Government of Botswana, 2016).

Botswana can align her strategies with the Addis Ababa Declaration on Population and Development (AADPD), ensuring that population dynamics are considered in national development efforts by comprehensively studying fertility patterns. Addressing population dynamics, including fertility patterns, is crucial to achieving the demographic dividend outlined in the Africa Agenda 2063. Hence, harnessing her demographic dividend, ensuring sustainable economic growth, job creation, and social progress. Furthermore, the study's findings will inform various developmental frameworks at regional and global levels, such as the Southern African Development Community (SADC) Regional Indicative Strategic Development Plan, the World Population Prospects, and the Programme of Action of the International Conference on Population and Development (ICPD).

METHODOLOGY

This study presents the analysis of the Botswana 2022 Population and Housing Census (PHC) data to obtain the fertility and social spatial distribution among women of reproductive age to record more successes in fertility behaviour. The outcome of this study is expected to help the government and policymakers in identifying hotspots for immediate interventions, thereby solving the attendant fertility problems and challenges to achieve the Botswana Vision 2036. A cross-sectional approach was employed, integrating GIS techniques with demographic analysis to assess the spatial and social distribution of fertility rates. Key variables examined include the Total Fertility Rate (TFR), parity/total number of children (live births) ever born (CEB), and its components, spatial coordinates, and social indicators.

In measuring the TFR, the direct estimation method was adopted for the good quality of the data obtained. The variable on current fertility (i.e. children born in the last 12 months before enumeration day) was used in obtaining TFR. To ensure good quality data has been used, the distribution of women by age and parity, and age-specific fertility rate (ASFR) were examined for consistency with the known fertility behaviour of Botswana's population. Afterward, the data was analysed at two levels – univariate and bivariate levels using descriptive and inferential approaches with the help of frequencies, tables, charts, maps, and crosstabulations. All analyses were conducted using SPSS 27, ArcGIS Pro, and Microsoft Excel.

RESULTS

Descriptive Analysis

The results show that Botswana's population is comprised of 640,811 women of reproductive aged 15-49 years with most (50,160 – 96,190 women) women living in Kweneng East and Gaborone districts. Francistown, Ngamiland East, Central Tutume, Serowe-Palapye, Central Mahalapye, Kgatleng, South East, and Southern districts have 19,110 – 50,150 women living in them while Delta, Sowa, and Orapa districts have the least women as shown in **Figure 1**. The number of children born alive shows that Kweneng East, Gaborone, and Serowe Palapye have the highest with 74,817 – 139,883 children born while the least children were born in the Sowa, Delta, Orapa, and Jwaneng **(See Figure 2)**.

FIGURE 1: MAP OF BOTSWANA SHOWING POPULATION OF WOMEN OF REPRODUCTIVE AGE BY DISTRICT.

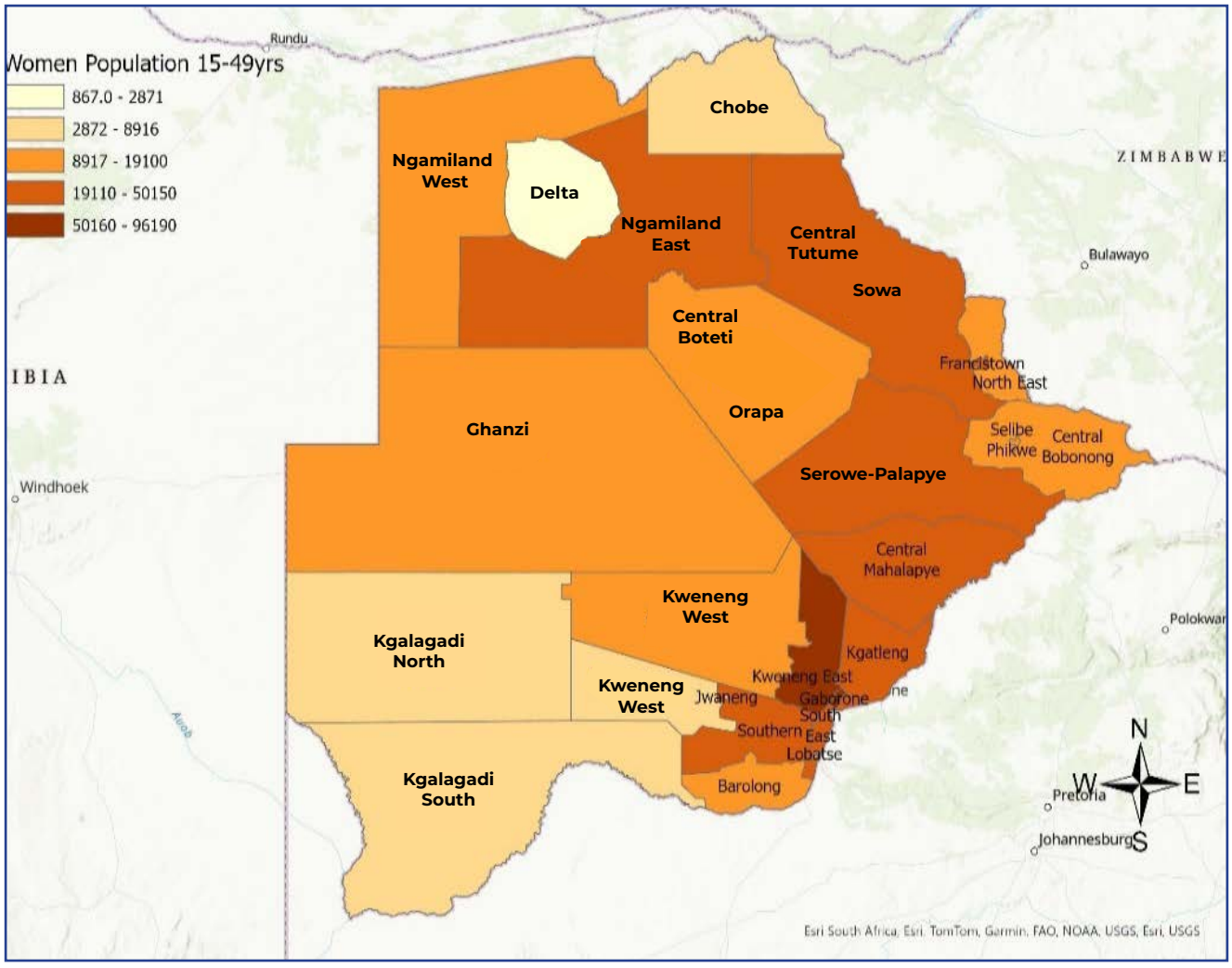


FIGURE 2: MAP OF BOTSWANA SHOWING THE NUMBER OF CHILDREN BORN ALIVE BY DISTRICT

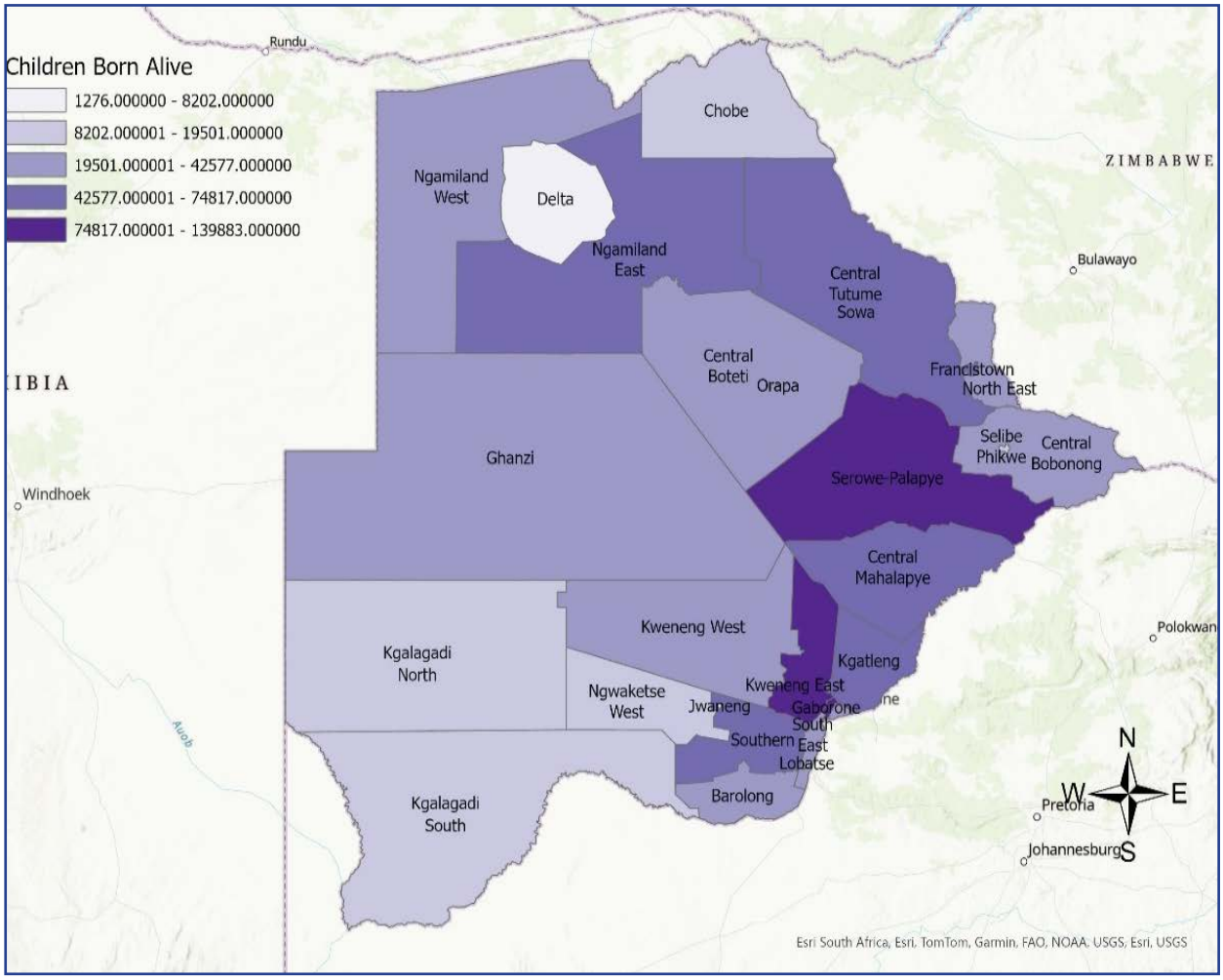


Figure 3 shows the children's deaths by the number of children born alive, the highest proportion of deaths among the children was recorded in Ngamiland West, Central Bobonong, Kweneng West, and Barolong districts with 31 – 38 children dying out of every 1000 children born alive. However, Kweneng East, Gaborone, South East, and Delta districts recorded the least (12 – 16 children out of every 1000) deaths among the children. More (708 – 748 children out of every 1000) children live with their mothers in Ngamiland West, Kgatleng, and Southern districts while children born in the Delta barely (266 children out of every 1000) live with their mothers as shown in **Figure 4**.

Further analysis shows that data on age at first birth among the women is skewed with most women having their first child very early. The median age at first birth is 20 years with 80,633 women having their first child at this age. Furthermore, 25% of the women had their first child at the age of 18 years and 75% of them had theirs by the age of 23 years (see Figure 5). Figure 6 shows that Kweneng East has the highest (8,438) number of children born in the last 12 months of the census enumeration while Delta, Orapa and Sowa districts have the least (39 – 329) children born in the last 12 months of the census enumeration.

FIGURE 3: MAP OF BOTSWANA SHOWING THE PROPORTION OF CHILDREN'S DEATHS BY DISTRICTS

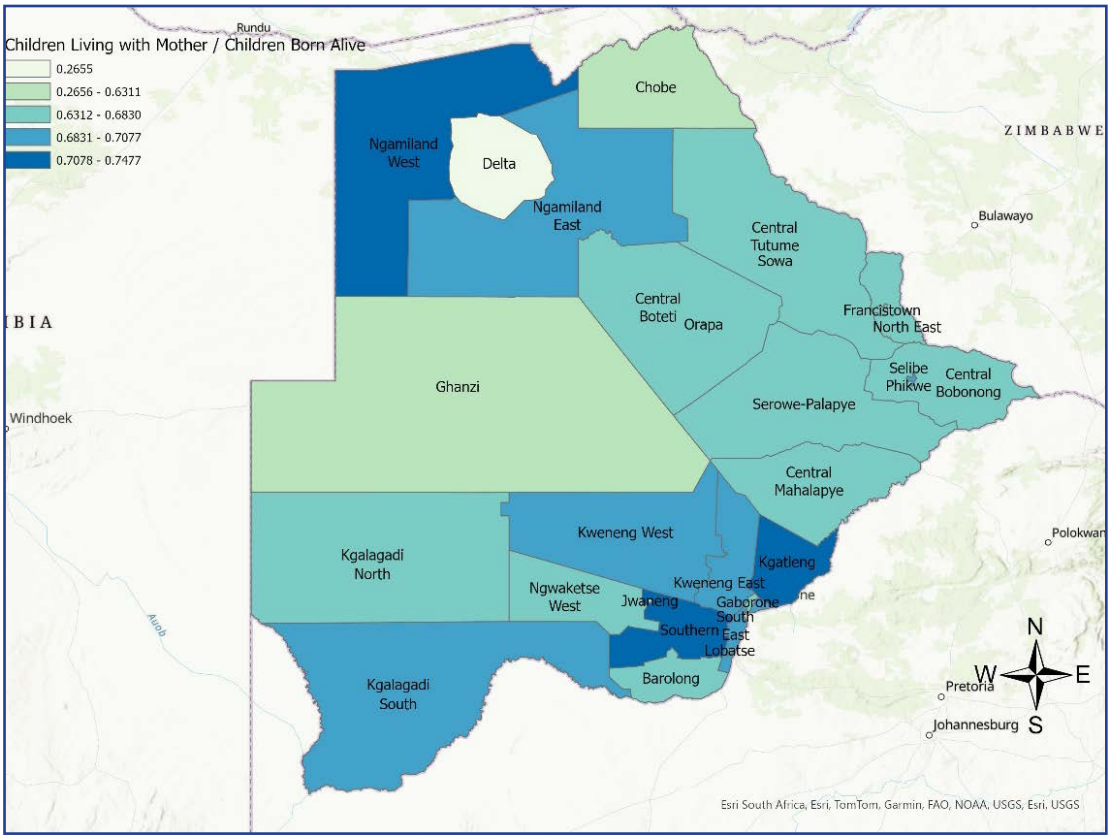


FIGURE 4: MAP OF BOTSWANA SHOWING THE PROPORTION OF CHILDREN LIVING WITH THEIR MOTHERS BY DISTRICT

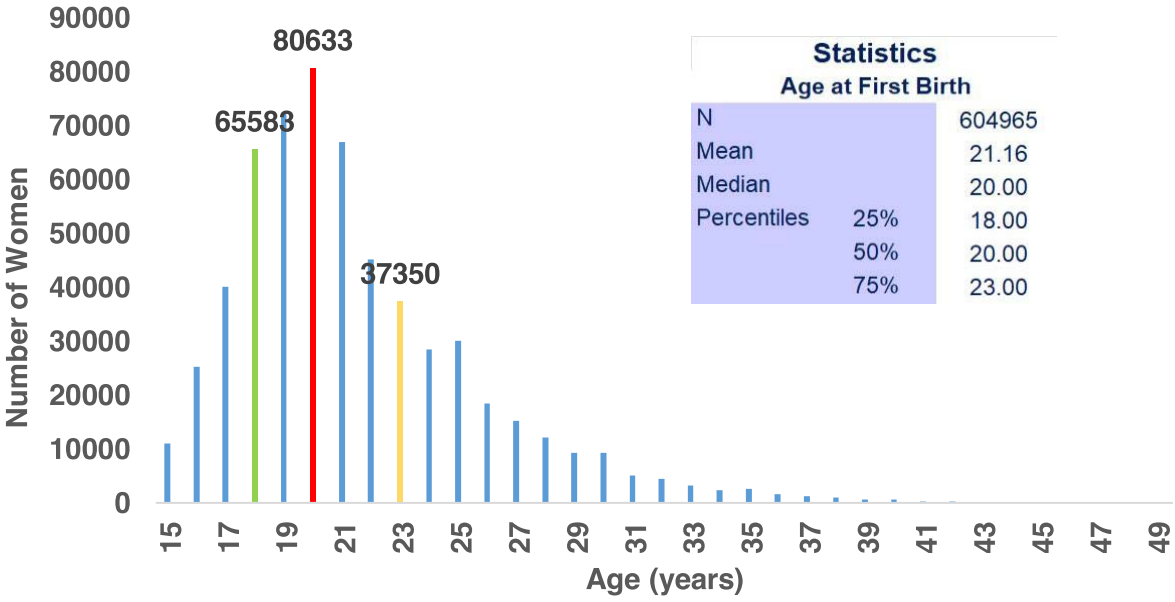
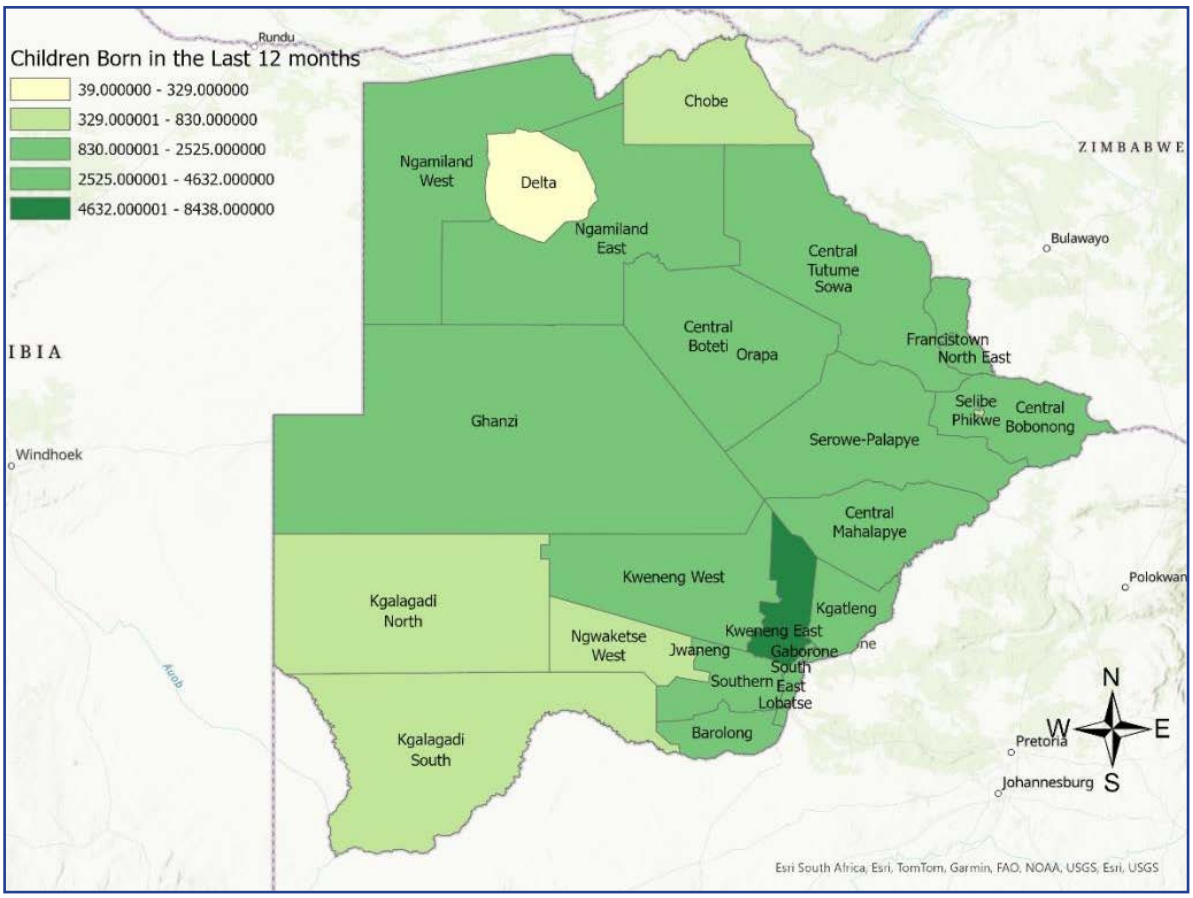


FIGURE 6: MAP OF BOTSWANA SHOWING CHILDREN BORN IN THE LAST 12 MONTHS BY DISTRICT



Distribution of women by parity and age

The distribution of women by age and reported total children ever born (CEB) is presented in **Table 1.** This shows that parity data as collected in the census 2022 is consistent with the expected trend e.g. the number of women without children decreases with an increase in age.

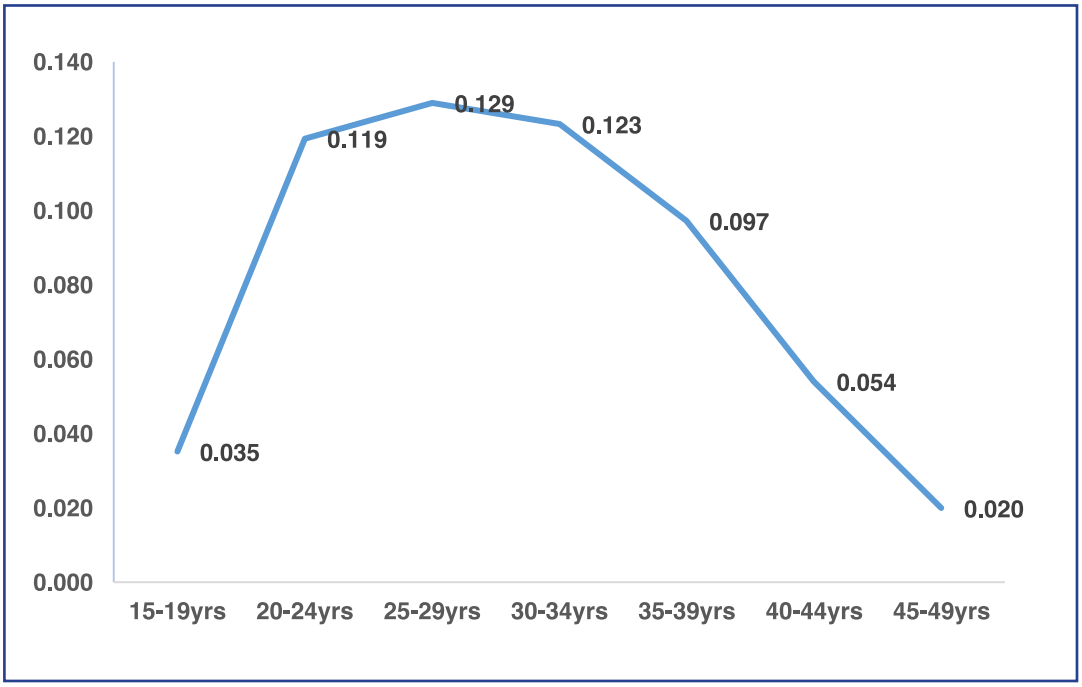
TABLE 1: Distribution of women of reproductive age by parity in Census 2022

	TOTAL CHILDREN EVER BORN											
AGE GROUP	0	1	2	3	4	5	6	7	8	9	10+	TOTAL
15-19yrs	88.373	5.983	628	65	30	14	0	0	0	0	0	**95.093**
20-24yrs	50.456	29.611	9.839	1.958	399	95	32	14	7	2	3	**92.416**
25-29yrs	25.678	33.187	23.79	9.6	2.985	910	231	70	21	2	2	**96.476**
30-34yrs	13.44	23.579	27.952	16.763	7.323	2.953	1.145	419	107	37	13	**93.731**
35-39yrs	8.173	16.121	26.609	21.815	11.361	5.363	2.581	1.081	509	172	115	**93.9**
40-44yrs	5.716	11.127	19.519	18.354	11.005	5.896	3.052	1.529	763	343	278	**77.582**
45-49yrs	3.897	8.213	14.046	13.518	8.966	5.207	2.908	1.619	807	375	393	**59.949**
Total	**195.733**	**127.821**	**122.383**	**82.073**	**42.069**	**20.438**	**9.949**	**4.735**	**2.216**	**931**	**805**	**609.153**

Pattern of Age-Specific Fertility Rates (ASFRs)

The pattern of ASFRs is presented in **Figure 7** as obtained from the data on the number of children born in the last 12 months of the census enumeration date. The line graph shows that the ASFRs are consistent with what is known about the fertility behaviour of Botswana's women of reproductive age. Hence, the census 2022 data can be said to be of good quality and correctly model the prevalence fertility behaviour of women.

FIGURE 7: AGE-SPECIFIC FERTILITY RATE IN BOTSWANA, CENSUS 2022



Fertility Level

Table 2 shows the observed fertility rates based on the Census 2022. The calculation of the current fertility rate using the direct method gives a total fertility rate (TFR) of 2.89. Hence, the average number of children born per woman of reproductive age is 2.89 (i.e. approximately 3 children/woman).

TABLE 2: Botswana Age-Specific Fertility Rate (ASFR) and Total Fertility Rate (TFR), Census 2022.

AGE GROUP	ASFR
15-19yrs	0.035
20-24yrs	0.119
25-29yrs	0.129
30-34yrs	0.123
35-39yrs	0.097
40-44yrs	0.054
45-49yrs	0.020
Total Fertility Rate	**2.89**

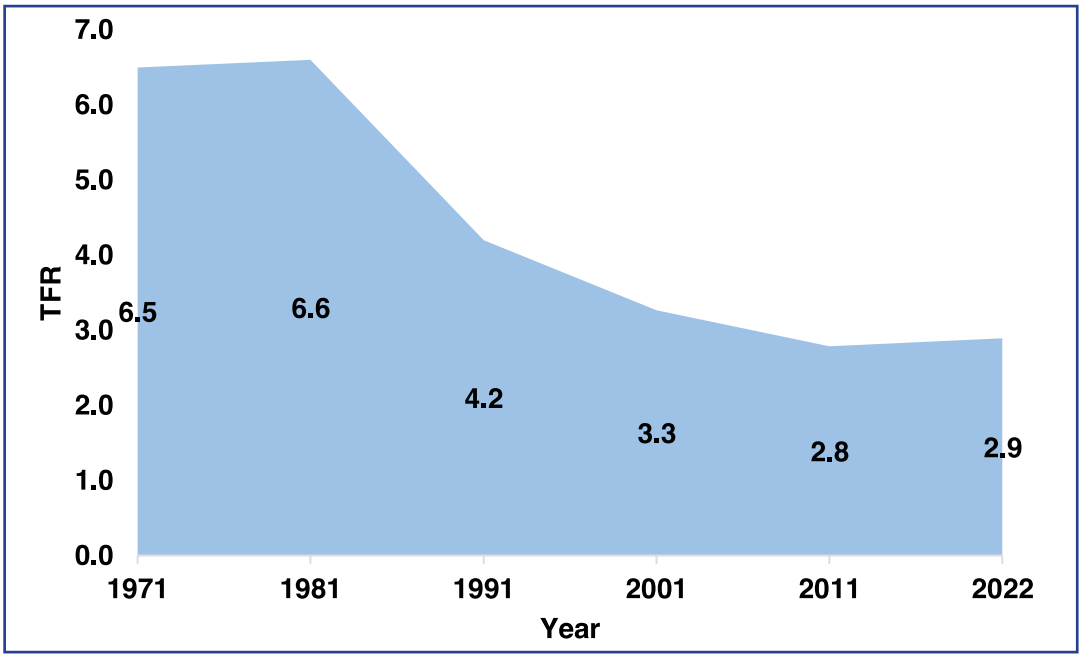
TABLE 3: Botswana Age-Specific Fertility Rate and Total Fertility Rates: 1971 – 2022.

AGE GROUP	1971	1981	1991	2001	2011	2022
15-19yrs	0.0955	0.1015	0.0536	0.0533	0.0375	0.0352
20-24yrs	0.2778	0.2599	0.134	0.1713	0.1323	0.1194
25-29yrs	0.276	0.2504	0.1338	0.2021	0.1316	0.1290
30-34yrs	0.2432	0.2336	0.1191	0.1296	0.1121	0.1233
35-39yrs	0.1983	0.1902	0.1023	0.0686	0.0863	0.0972
40-44yrs	0.1383	0.1341	0.0641	0.0258	0.0429	0.0540
45-49yrs	0.0709	0.0837	0.0358	0.0032	0.0139	0.0200
Total Fertility Rate	6.5	6.6	4.2	3.3	2.8	2.9

Fertility Trends

Table 3 and **Figure 8** show the total fertility rates in Botswana from 1971 to 2022. The previous censuses data show that the TFR started declining after the 1981 census and continued to 2011. However, the current census 2022 indicates a slight increase. The TFR was 6.5 children per woman in the year 1971 with a slight increase in the year 1981, it rose to 6.6 children per woman. Afterwards, TFR decreased to 4.2 children per woman in the year 1991, 3.3 in the year 2001, and 2.8 in the year 2011 while it currently slightly increased to 2.9 in the year 2022. However, analysis of age-specific fertility rate shows that there is a decrease in the fertility rate for age groups 15-29 years from 2011 to 2022. This is an indication that young adults are reducing their number of children.

FIGURE 8: TRENDS OF TOTAL FERTILITY RATES IN BOTSWANA, 1971 – 2022.



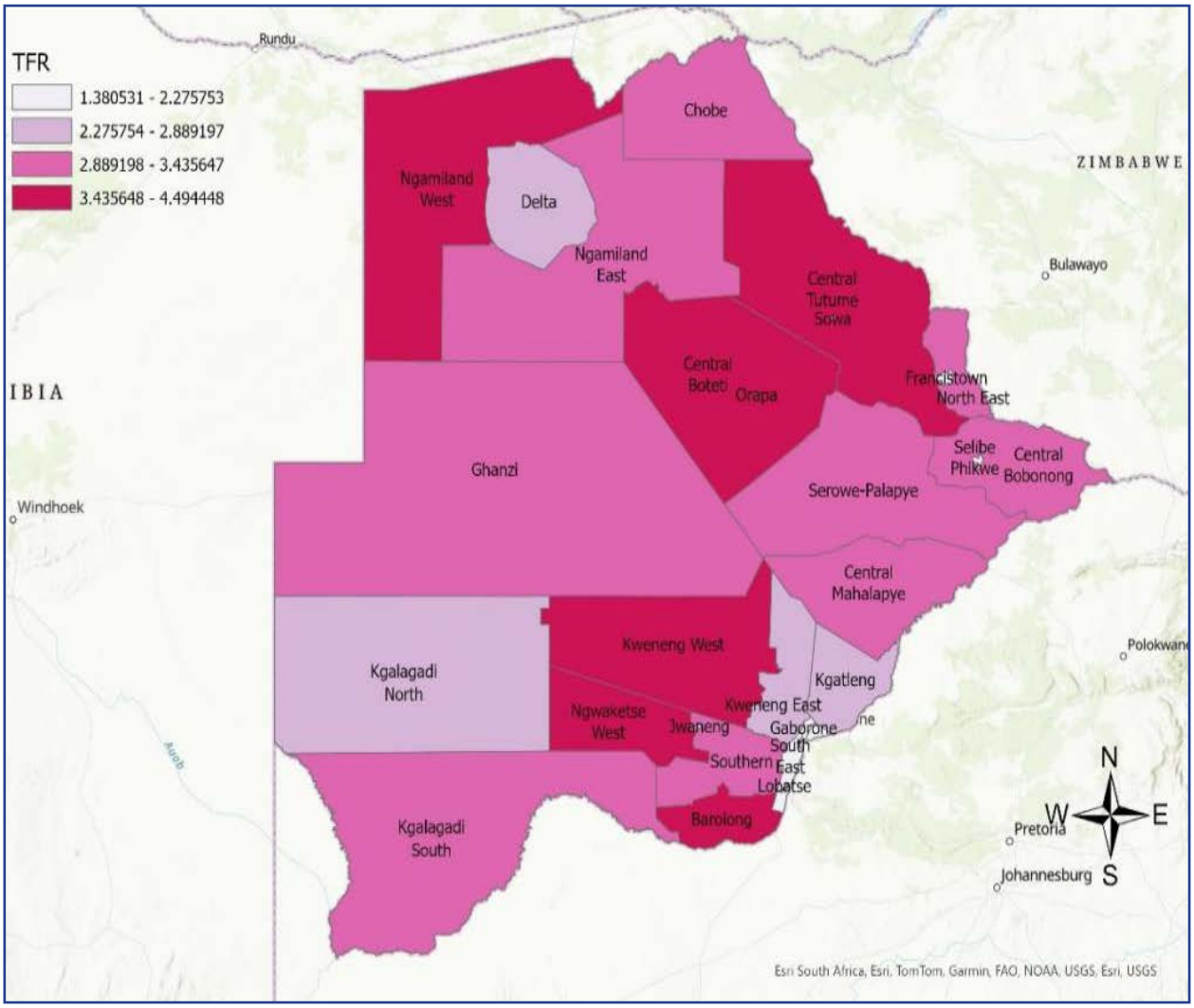
Spatial Distribution of Total Fertility Rate

The spatial distribution of total fertility rates shows that there are fertility differentials across the districts of Botswana. The highest fertility rate (4.49) was observed among women living in the Ngamiland West district while the Sowa and Gaborone districts had the lowest rates of 1.38 and 1.76, respectively as seen in **Table 4. Figure 9** shows that there is a significantly high fertility rate (3.4 – 4.5) among women living in Ngamiland West, Central Tutume, Central Boteti, Kweneng West, Ngwaketse West and Barolong districts. Whereas the lowest fertility rates (1.38 – 2.28) were observed among women living in Gaborone, Sowa, Francistown, Selibe Phikwe, Jwaneng, and South East districts. Furthermore, 44% (12 out of 27) of the districts have total fertility rates below the national value (2.89).

TABLE 4: Age-Specific Fertility Rate and Total Fertility Rates by District in Census 2022

DISTRICT	15-19yrs	20-24yrs	25-29yrs	30-34yrs	35-39yrs	40-44yrs	45-49yrs	TFR
GABORONE	0.008	0.046	0.081	0.093	0.072	0.036	0.013	1.76
FRANCISTOWN	0.024	0.094	0.103	0.104	0.074	0.039	0.009	2.23
LOBATSE	0.020	0.099	0.115	0.114	0.093	0.038	0.017	2.48
SELIBE PHIKWE	0.012	0.108	0.102	0.101	0.070	0.040	0.022	2.28
ORAPA	0.006	0.068	0.111	0.167	0.086	0.053	0.024	2.57
JWANENG	0.009	0.059	0.097	0.097	0.059	0.029	0.019	1.84
SOWA	0.000	0.058	0.076	0.077	0.050	0.015	0.000	1.38
SOUTHERN	0.033	0.138	0.142	0.139	0.117	0.062	0.031	3.31
BAROLONG	0.058	0.192	0.163	0.163	0.133	0.052	0.018	3.90
NGWAKETSE WEST	0.069	0.193	0.144	0.144	0.090	0.055	0.018	3.57
SOUTH EAST	0.017	0.071	0.095	0.097	0.088	0.047	0.023	2.19
KWENENG EAST	0.028	0.103	0.126	0.130	0.100	0.063	0.024	2.87
KWENENG WEST	0.072	0.193	0.166	0.122	0.124	0.054	0.018	3.74
KGATLENG (Wards)	0.028	0.114	0.133	0.127	0.105	0.047	0.024	2.89
CENTRAL SEROWE -PALAPYE	0.037	0.146	0.136	0.136	0.096	0.060	0.015	3.13
CENTRAL MAHALAPYE	0.045	0.170	0.151	0.135	0.109	0.061	0.017	3.44
CENTRAL BOBONONG	0.052	0.180	0.161	0.132	0.096	0.048	0.010	3.39
CENTRAL BOTETI	0.060	0.181	0.146	0.132	0.101	0.060	0.036	3.58
CENTRAL TUTUME	0.050	0.179	0.169	0.146	0.106	0.063	0.018	3.65
NORTH EAST	0.035	0.150	0.162	0.129	0.089	0.050	0.013	3.14
NGAMILAND EAST	0.046	0.148	0.140	0.124	0.115	0.071	0.020	3.32
NGAMILAND WEST	0.067	0.202	0.194	0.173	0.145	0.088	0.031	4.49
CHOBE	0.040	0.119	0.131	0.122	0.119	0.078	0.027	3.18
DELTA	0.020	0.146	0.114	0.113	0.059	0.043	0.048	2.71
GHANZI	0.057	0.129	0.137	0.108	0.100	0.054	0.048	3.16
KGALAGADI SOUTH	0.054	0.153	0.151	0.106	0.084	0.054	0.008	3.05
KGALAGADI NORTH	0.049	0.123	0.123	0.136	0.090	0.032	0.007	2.80
TOTAL	**0.035**	**0.119**	**0.129**	**0.123**	**0.097**	**0.054**	**0.020**	**2.89**

FIGURE 9: MAP OF BOTSWANA SHOWING TOTAL FERTILITY RATES BY DISTRICT



Fertility Social Differentials

The fertility social differentials considered are locality type, level of education, and relationship status based on available data. **Table 5** shows that there are differences in total fertility rates among women according to their social differentials. Women living in towns have the lowest fertility rates (1.96) as expected while those living in rural areas have the highest fertility rate of 3.92. Level of education also plays a significant role in the fertility behaviour of women. Women with primary education have the highest fertility rate of 4.28 while the lowest rate is recorded among women who have tertiary education. Thus, the fertility rates among women of reproductive age in Botswana decrease with an increase in their level of education. Furthermore, never-married women have the lowest fertility rate as expected while those cohabiting have a rate slightly higher than those who are ever-married.

TABLE 5: Age-Specific Fertility Rate and Total Fertility Rates by Social Differentials in Census 2022

	15-19YRS	20-24YRS	25-29YRS	30-34YRS	35-39YRS	40-44YRS	45-49YRS	TFR
LOCALITY TYPE								
Town	0.013	0.064	0.091	0.099	0.073	0.038	0.014	1.96
Urban-Village	0.028	0.111	0.124	0.121	0.097	0.056	0.020	2.78
Rural	0.065	0.189	0.173	0.149	0.119	0.065	0.024	3.92
LEVEL OF EDUCATION								
Non-Formal	0.079	0.149	0.112	0.188	0.111	0.079	0.020	3.69
Primary	0.099	0.194	0.182	0.159	0.128	0.072	0.021	4.28
Secondary	0.035	0.153	0.148	0.131	0.102	0.055	0.020	3.21
Certificate/Diploma	0.019	0.072	0.118	0.120	0.091	0.048	0.024	2.47
Tertiary	0.006	0.044	0.098	0.125	0.094	0.050	0.016	2.16
RELATIONSHIP STATUS								
Never Married	0.031	0.112	0.121	0.114	0.093	0.055	0.020	2.73
Ever Married	0.225	0.237	0.214	0.169	0.108	0.051	0.021	5.13
Cohabiting	0.307	0.224	0.176	0.152	0.122	0.074	0.024	5.40

DISCUSSION AND CONCLUSION

The Botswana census 2022 data have been analysed and it showed that it was of good quality. The differentials in women's population, children born alive, the proportion of children's deaths, and the proportion of children living with their mothers by districts have been established. The average age at first birth for women of reproduction age in Botswana is 20 years with at least 75% of women having their first birth at age 23 years. Hence, most women in Botswana have their first child very early in life. The parity observed in the census 2022 is consistent with known fertility behaviour among Botswana women.

The total fertility rate was derived as 2.9 children per woman in Botswana using the direct estimation method. The rate was derived using age-specific fertility rates (ASFRs) which are consistent with known fertility behaviour among the women. The ASFRs further revealed that fertility rates declined among youth (women aged 15-29 years) from the last census (2011) which indicated that younger women are reducing their parity. The TFR (2.9) showed that fertility among Botswana women slightly increased over the 2011 census. The spatial differentials were observed in the TFRs by districts with Ngamiland West having the highest rate of 4.49 children per woman while commercial districts like Gaborone had a lower TFR of 1.76 children per woman. Social differentials analysis indicated that age, early childbirth, living in rural areas, and cohabitation increased TFRs among women while increased education reduced TFR among women of reproductive age as corroborated by other studies (Biney, et al., 2020; Adebola, et al., 2023).

POLICY IMPLICATIONS

Economic Growth and Labour Force: Declining fertility rates observed in towns, urban villages, and younger women in Botswana will lead to a smaller working-age population and an increased aging population, where the proportion of older individuals increases relative to the working-age population. Policymakers must address the implications of an aging workforce, including potential labour shortages, increased dependency ratios, and social security and healthcare systems pressures. However, in districts where the fertility rates are higher, policies must be made to promote access to education, skills training, and employment opportunities, particularly for women and youth, to support sustainable economic growth and development.

Social Welfare and Healthcare: High fertility will put a heavy burden on healthcare systems, particularly maternal and child health services. Therefore, the Botswana government and policymakers need to invest in healthcare infrastructure, maternal and child health programs, family planning services, and reproductive health education to improve health outcomes for mothers and children, thereby reducing maternal and infant mortality rates, and promoting healthy families.

Family Welfare and Poverty Reduction: High fertility rates cause cycles of poverty, particularly among low-income families. Large family sizes sap household resources, limit economic opportunities, and worsen socioeconomic inequalities. Policymakers need to implement poverty reduction strategies, and targeted interventions to support vulnerable families, improve access to reproductive healthcare and family planning services, and empower women to make informed choices about their reproductive health and family size.

Cultural and Social Norms: Policymakers in Botswana need to address declining fertility rates which is challenging cultural and social norms about family size, marriage, and childbearing. Policies on promoting positive attitudes towards parenthood, addressing gender inequalities, and providing support for individuals who choose to have children should be put in place. Public awareness campaigns, education programs, and community engagement initiatives are also needed to change societal perceptions and encourage family formation.

In aligning fertility-related goals and strategies with these findings, Botswana will enhance its development outcomes and contribute to regional and global development agendas. By understanding and addressing factors influencing fertility rates, Botswana will promote sustainable development, improve the well-being of its population, and contribute to broader efforts for socio-economic transformation regionally and globally.

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A STUDY ON THE LEVELS, TRENDS AND DIFFERENTIALS IN INFANT AND UNDER-FIVE MORTALITY IN BOTSWANA

By;
Tiro Theodore Monamo and Boitumelo Dudu Gaongalelwe

EXECUTIVE SUMMARY

The levels of infant and under-five mortality in a country has long been treated as an index of general development. Over the last two decades, the international community has established periodic targets for the reduction of infant and under-five mortality. The report of the Commission on Information and Accountability for Women's and Children's Health has also reaffirmed the importance of frequent reporting on infant and under-five mortality. It is thus clear that the measurement of infant and under-five mortality has a very high priority both at the national and at the international level.

The objective of this paper is to estimate infant (<1 year) and under-five (<5 year) mortality rates using unit-level data from the 2022 Botswana Population and Housing Censuses using the information on children ever born and children surviving reported by women classified by the age of the mothers. The trends in infant and under-five mortality are also investigated using the published estimates derived from previous censuses and demographic health surveys. The paper also examined the regional estimates (by districts and rural, cities/towns, and urban villages), gender (male vs. female), and socioeconomic (mother's education, mother's marital status, and mother's employment status) differentials in infant and under-five mortality in Botswana. Additionally, the analysis assessed if there is progress in reducing the gap of infant and under-five mortality between these socio-economic groups in Botswana.

One census method was used to indirectly estimate infant and under-five mortality in Botswana using Princeton west model life tables. Estimates of infant and under-five mortality in Botswana using the Brass variant, age of the mothers, were calculated by the Child Mortality (CM) Indirect spreadsheet developed by Moultrie, et al. (2013). The paper used the direct estimation method to derive estimates for infant and under-five mortality at district level from the 2022 census data because if the population of a unit is too small, the indirect method may not work because of the influence of random factors, seasonal changes or location-specific factors.

The analysis of this paper revealed that researchers should rely on the direct estimates of infant and under-five mortality from the 2022 census because Botswana's 2021 vital statistics report indicated that infant and under-five mortality was a little bit higher than the estimates derived using indirect estimation techniques. In addition, the completeness of the vital registration of deaths in both the 2022 census and the 2021 vital statistics report was over 90 percent. The study concluded that, the levels and trends of infant and under-five mortality based on indirect techniques should not be used in the 2022 census.
Estimates from this study have shown declining infant and under-five mortality in Botswana from 2006 to 2022, a trend that has been supported by recent published estimates. Botswana has successfully reduced under-five mortality rates to 22.4 deaths per 1000 live births in 2022 and managed to achieve the targets set out in the 2030 Agenda for Sustainable Development of reducing under-five mortality to as low as 25 deaths per 1000 live births by 2030. Infant mortality rates also stood at 18.6 deaths per 1000 live births in the year 2022.

Results from this study shows that the socio-economic differentials in infant and under-five mortality by mother's marital status, mother's employment status and mother's level of education has been narrowing overtime from the year 2008 to 2018. Despite the substantial reduction in infant and under-five mortality and the narrowing gap between socio-economic groups, socio-economic inequalities in infant and under-five mortality disfavoring worse-off groups still exists.

Because of the vulnerability of male children depicted in this study, the findings suggest that extra attention must be given while giving care to these children both at home and health facilities. To tackle the socio-economic gap in Botswana, the government should focus more on: Policies that reduce inequalities; Policies that reduce exposures of disadvantaged people to health damaging factors; Policies that reduce vulnerabilities of disadvantaged people; and Policies that reduce unequal effects of illness in health, economic and social terms.

1.0 INTRODUCTION

The under-five mortality rate (U5MR), the probability of dying before 5 years of age (per 1000 live births), is a crucial global indicator of child health and one of the most critical measures of global health and social development. The 2017 Botswana Demographic Survey reported an under-five mortality rate of 48 deaths per 1000 live births in 2017, a decline from 152 deaths per 1000 live births in 1971. However, the level of under-5 mortality is still high when compared with countries with similar social and economic development. Further, looking at the progress, the country still lags in reducing under-five mortality to less than 25 deaths per 1000 live births by 2030. The Sustainable Development Goal (SDG) 3 calls for an end to preventable deaths of new-borns and children under five and further demands a reduction in under-5 mortality to less than 25 deaths per 1000 live births. Botswana, like other countries in sub-Saharan Africa, is committed to improving under-five mortality rates in line with the Sustainable Development Goal (SDG) targets.

The main purpose of the paper was to estimate infant (<1 year) and under-five (<5 year) mortality rates using unit-level data from the 2022 Botswana Population and Housing Censuses using the information on children ever born and children surviving reported by women classified by the age of the mothers. Additionally, the trends in infant and under-five mortality was investigated using the published estimates derived from previous censuses and demographic health surveys. Moreover, the paper also examined the regional estimates (by districts and rural, cities/towns, and urban villages), gender (male vs. female), and socioeconomic (mother's education, mother's marital status, and mother's employment status) differentials in infant and under-five mortality in Botswana. Further attempt was also to assess if there is progress in reducing the gap of infant and under-five mortality between these socio-economic groups in Botswana. The study's findings will have implications for health planning and monitoring progress toward SDG goals.

2.0 LITERATURE REVIEW

Children continue to face extensive regional variations in their chances of survival. Sub-Saharan Africa is still the region with the highest under-five mortality rate worldwide. The region accounted for 56 per cent of all under-five deaths in 2021, with 2.8 million children dying before reaching their fifth birthday (UN IGME, 2023). Hence, accelerating progress in preventing child deaths in this region is very important. Current trends foresee that close to 40 million children under 5 years of age will die between periods of 2021 to 2030. About 50 percent of these under-five deaths will be newborns whose deaths can be prevented by achieving high coverage of quality antenatal care, skilled care at birth, care of small and sick newborns and postnatal care for mother and baby (UN IGME, 2023). These deaths – particularly the regional and socio-economic disparities – reflect the broader influence of sustainable social and economic development on children's health. Basic health services like vaccination, medical treatment, adequate nutrition and clean water and sanitation become matters of life and death when children do not have access to them. Reducing inequalities is essential for ending these preventable childhood deaths and for ensuring that no child is left behind.

Of the 200 countries or territories analysed in the UN IGME 2022 report, 133 have already met the SDG target on under-five mortality, and 13 countries are expected to do so by 2030. The 133 countries that met the targets should aim to maintain progress and further reduce variations among their populations. In the remaining 54 countries, the pace of mortality decline must be accelerated to meet the target on time. Of these 54, 37 countries will need to more than double their current rate of progress or reverse a recent increasing trend to achieve the target of 25 or fewer deaths per 1,000 live births by 2030. Nearly 75 per cent (40) of the 54 countries that are off track to meet the SDG target on under-five mortality are in sub-Saharan Africa, 87 per cent (47) are classified as low- or lower-middle-income countries and about half (25) are classified as fragile and conflict-affected situations. The estimates and projection scenarios presented in the UN IGME 2022 report did not make any adjustment to the 2021 rates for COVID-19 related mortality, nonetheless the COVID-19 pandemic and its many impacts continued to be of significant concern to child health and survival. Based on the best available empirical evidence representing more than 110 countries or areas in 2020 and over 80 countries or areas in 2021, the UN IGME did not find significant excess mortality among children in 2020 or 2021 and therefore made no adjustment to its 2020 or 2021 estimates.

3.0 THEORETICAL FRAMEWORK

This study has its theoretical foundation in two theoretical models – (1) Mosley-Chen model and (2) Diderichsen and Hallqvist's 1998 model of the social production of disease. The former is a model designed by Mosley and Chen (1984) for the study of the determinants of child survival in developing countries; while the latter is a framework developed by Diderichsen and Hallqvist (1997) to directly incorporate the complex social dimension of health.

3.1 Mosley and Chen Framework

The Mosley and Chen framework's key concept are a set of proximate determinants, or intermediate variables, that directly influence the risk of morbidity and mortality. It assumes that more distal social and economic determinants must operate through these variables to affect child survival. The Mosley and Chen identifies five proximate determinants of child health and survival: (1) maternal factors, (2) environmental contamination, (3) nutrient deficiency, (4) injury and (5) personal illness control. In this framework, the individual, household, and community-level socio-economic characteristics influence child health and survival through each of these sets of intervening variables. The framework specifies the following variables to be causally prior to the proximate determinants: individual factors, such as maternal education; household factors, such as income and family composition; institutional factors, including community infrastructures and health programs; ecological factors, such as rainfall, temperature, seasonality and altitude; and cultural factors such as, norms and values.

3.2 Diderichsen and Hallqvist's 1998 model of the social production of disease

The Diderichsen and Hallqvist's 1998 model links more distal causes for child health by describing a framework that conceptualizes the relationship between distal and proximal factors and how they operate to cause inequalities in child mortality within sub-Saharan Africa. The framework defined policy entry points needing support of empirical evidence and acknowledged that the social context plays an important role for inequalities in children's chances of survival. The framework delineates four main mechanisms—social stratification, differential exposure, differential susceptibility, and differential consequences—that play a role in generating health inequities. For each mechanism, the possible policy entry points for interventions are identified.

4.0 METHOD

One census method was used to indirectly estimate infant and under-five mortality in Botswana using Princeton west model life tables. Estimates of infant and under-five mortality in Botswana using the Brass variant, age of the mothers, were calculated by the Child Mortality (CM) Indirect spreadsheet developed by Moultrie, et al. (2013). The estimates were obtained from the Botswana's 2001 census, the 2011 census data, the 2017 demographic survey data and the 2022 census data.

Due to absence of reliable vital statistics, estimation of infant and under-five mortality is usually done using indirect estimation methods. The indirect methods utilize data that are commonly collected in censuses and many general surveys: the number of children ever born, the number of children dead and the number of children still alive by age groups of mothers. The indirect methods are very dependent upon several assumptions that may or may not be true: little or no change in fertility levels and age patterns, no change or a linear decline in mortality, and no change in a pattern of mortality by age. The indirect methods are problematic in a number of settings, especially for a country affected by mortality which have different mortality patterns. (Note that the assumptions proposed could pose some problems if fertility and mortality levels and patterns have been changing in the recent past due to HIV/AIDs and the outbreak of the COVID-19 epidemic).

When using indirect methods, estimates of infant and child mortality for the recent years (2020-2023) should be interpreted with caution. This is because estimates of infant and under-five mortality derived from reports of women aged 15-19 and 20-24, concerning their children ever born and surviving could be more biased due to their biological and socio-economic characteristics (Moultrie et al. 2013).

Data on the average number of children ever born alive, by age of mother, and average number of children dead at the time of the census can be employed to estimate infant and under five mortality at national and district level by gender using indirect estimation techniques if certain assumption holds. However, when estimation areas become smaller, the number of dead children could be very small. In these cases, estimates could be affected by random errors and unexpected annual fluctuations. If the population of a unit is too small, the method may not work because of the influence of random factors, seasonal changes or location-specific factors, which are likely to produce distorted estimates in small areas. In this case, the paper used the direct estimation method to derive estimates for infant and under-five mortality at district level from the 2022 census data.

5.0 FINDINGS AND DISCUSSIONS

5.1 Levels and Trends of Infant mortality in Botswana

The analysis of this paper starts by looking at the levels and trends in infant and under-five mortality estimated from the 2001 census data, the 2011 census data, the 2017 Botswana Demographic Survey and the 2022 census data estimated using indirect estimation techniques.

5.1.2 Indirect Estimates of Infant and Under-five Mortality at National Level

Table 1 below indicates that infant mortality rate, that is, the probability of dying between ages 0 and 1, declined from as high as 46 deaths per 1000 live births in 1988 to 19.6 deaths per 1000 live births in 2021. Regarding the probability of dying by age 5 (Table 2), the number of deaths per 1000 live births declined from 65 deaths in 1988 to 27.7 deaths in 2021. The estimates from the 2011 census showed an increasing trend since the indirect estimation procedure gave biased results mainly due to errors in reporting children ever born during the census enumeration (Majelantle, 2014). The results from the 2022 census in table 1 also displayed lower estimates compared to the direct estimates in table 3, which means that the indirect estimation procedure also gave biased results due to underreporting of children ever born or dead during this census exercise. This analysis implies that researchers should rely on the direct estimates of infant and under-five mortality from the 2022 census because Botswana's 2021 vital statistics report indicated that infant mortality was a little bit higher than the estimates displayed in table 1. In addition, the coverage of the vital registration of deaths was over 90% for both the years 2021 and 2022.

TABLE 1: Indirect estimates of infant mortality

TIME LOCATION	IMR - 2001 PHC	TIME LOCATION	IMR - 2011 PHC	TIME LOCATION	IMR - 2017 BDS	TIME LOCATION	IMR - 2022 PHC
1988	46.5	1995	43.2	2003	26.0	2021	19.6
1991	41.8	1998	66.2	2006	35.0	2020	12.8
1994	44.7	2001	47.6	2008	28.0	2018	10.8
1997	53.4	2004	49.2	2011	27.4	2015	11.6
1999	53.7	2007	53.3	2013	20.8	2013	12.9

TABLE 2: Indirect estimates of under-five mortality

TIME LOCATION	U5MR - 2001 PHC	TIME LOCATION	U5MR - 2011 PHC	TIME LOCATION	U5MR - 2017 BDS	TIME LOCATION	U5MR - 2022 PHC
1988	64.7	1995	60.8	2003	36.2	2021	27.7
1991	58.6	1998	91.9	2006	49.2	2020	18.2
1994	62.6	2001	66.6	2008	39.5	2018	15.3
1997	74.5	2004	68.8	2011	38.6	2015	16.4
1999	74.8	2007	74.3	2013	29.4	2013	18.3

5.1.3 Direct Estimates of Infant Mortality in Botswana

Table 3 and 4 below shows the direct estimates of infant and under-five mortality at national level derived from Botswana's 2021 vital statistics report. Table 3 displays that infant mortality decreased from 20.8 deaths per 1000 live births in 2014 to 18.6 deaths per 1000 live births in the year 2021. **Table 4** shows that under-five mortality increased from 20.5 deaths per 1000 live in 2020 to 23.4 deaths in 2021. The results of infant and under-five mortality in table 3 and 4 shows estimates which are slightly higher than that produced using the indirect estimation method. This makes the use of the indirect estimation method questionable because the estimates in table 3 and 4 shows evidence that the infant and under-five mortality estimates were not as lower as the ones showed in table 1 and 2, which employed the use of the indirect estimation technique during the period of 2014-2021. This concludes that, the levels and trends of infant and under-five mortality based on indirect techniques should not be used in the 2022 census.

TABLE 3: Direct Estimates of Infant Mortality at National Level

	2014	2015	2016	2017	2018	2019	2020	2021
Infant Mortality rate	20.8	21.3	23.0	21.8	16.4	20.3	16.5	18.6

Source: Statistics Botswana – Vital statistics Report 2021

TABLE 4: Direct Estimates of Under-Five Mortality at National Level

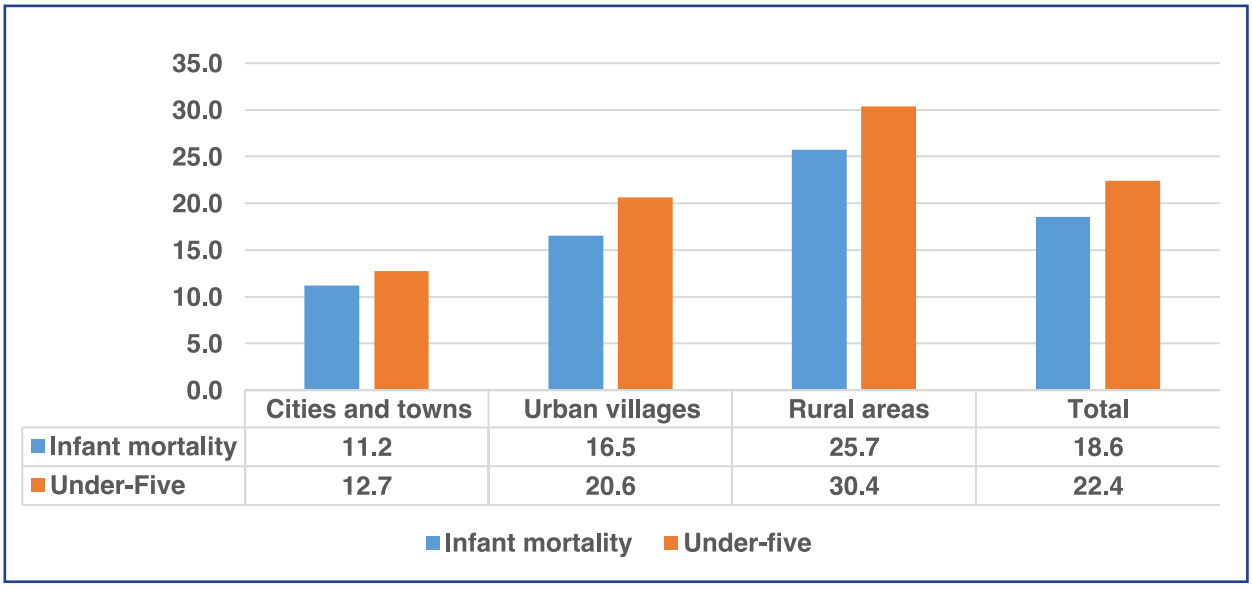
	2020	2021
Under-five mortality rate	20.5	23.4

Source: Statistics Botswana – Vital statistics Report 2021

5.1.4 Infant and under-five mortality by places of residence

Figure 1 below displays the distribution of infant and under-five mortality by places of residence. The graph reveals that the direct estimate of infant mortality stands at 18.6 deaths per 1000 live births, whereas the direct estimate of under-five mortality stands at 22.4 deaths per 1000 live births. The figure also shows that, both infant and under-five mortality is higher among rural areas, followed by urban areas and it's the least in cities and towns.

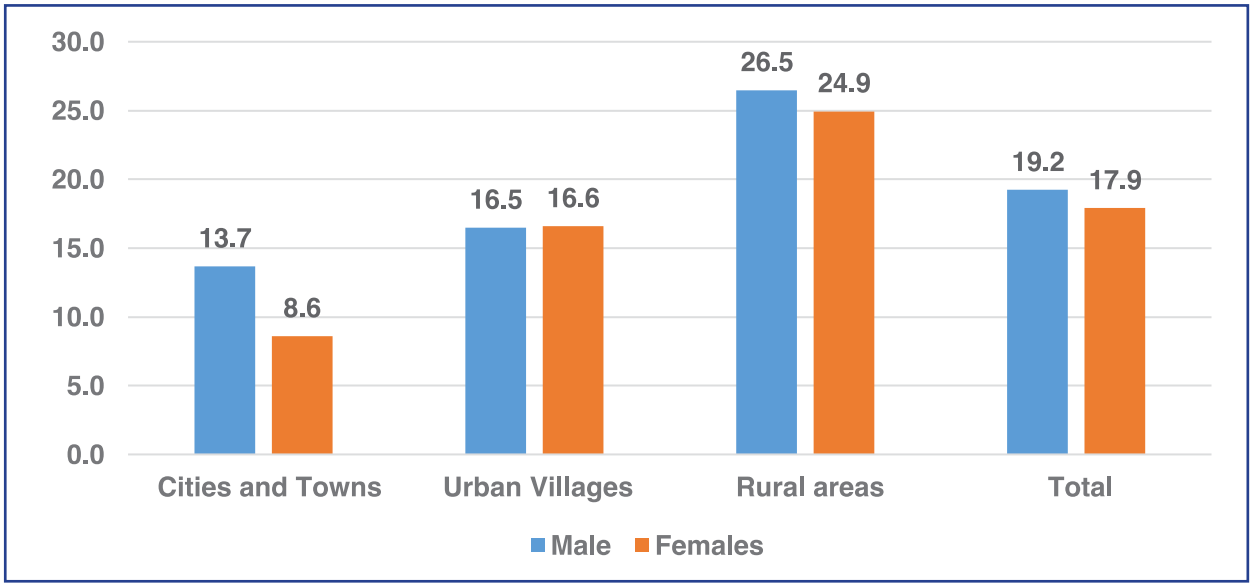
FIGURE 1: DIRECT ESTIMATES OF INFANT AND UNDER-FIVE MORTALITY RATES BY PLACES OF RESIDENCE, 2022



Direct Estimates of Infant Mortality Rates by Sex and Places of Residence

At national level, **Figure 2** below shows that the probability of dying before age one is higher among males compared to females at 19.2 infant deaths per 1000 live births and 17.9 respectfully. Male infants in the urban villages experienced the same mortality level (16.5 deaths per 1000 births) as female infants (16.6) during the year preceding the 2022 census. In the cities and towns, female infants experience lower mortality compared to male infants (with an infant mortality rate of 8.6 deaths per 1000 births and 13.7 per live births respectively.

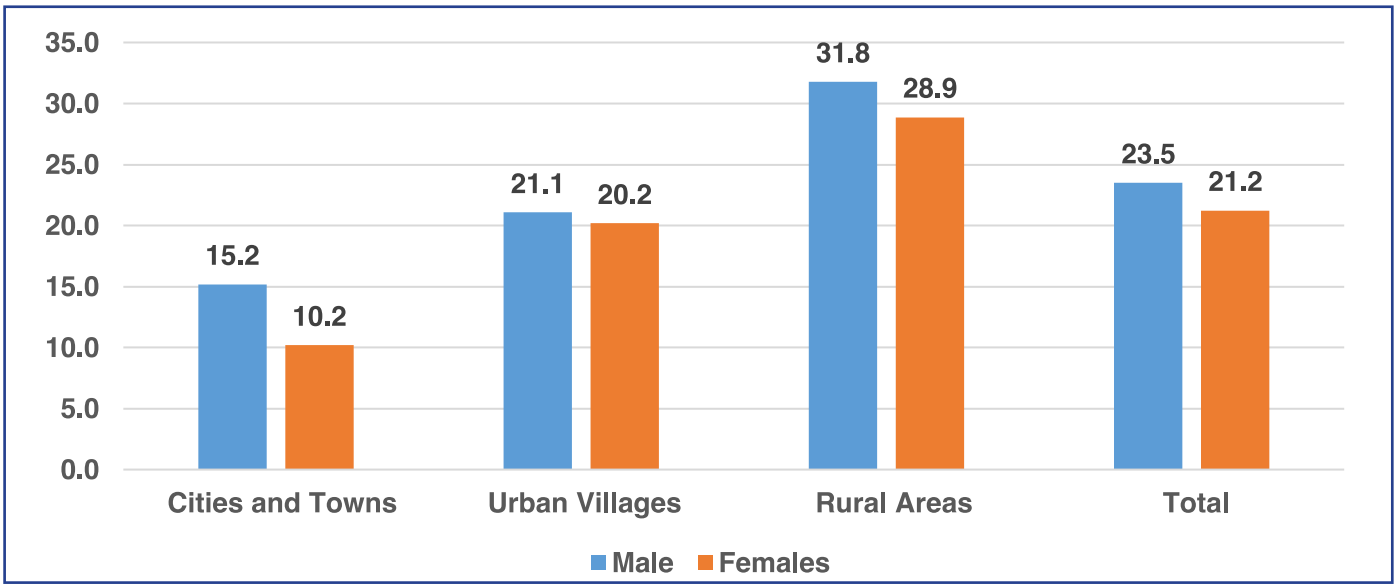
FIGURE 2: DIRECT ESTIMATES OF INFANT MORTALITY RATES BY SEX AND PLACES OF RESIDENCE, 2022



Direct Estimates of Under-five Mortality Rates by Sex and Places of Residence

Figure 3 below demonstrates that at national level the probability of dying between exact birth and exact age five is higher for the males (23.5) compared to the females (21.2). Male children in all locality types experienced higher under-five mortality level compared to the female under-fives.

FIGURE 3: DIRECT ESTIMATES OF UNDER-FIVE MORTALITY RATES BY SEX AND PLACES OF RESIDENCE



5.1.5 Infant Mortality Rates by District

The 2022 PHC data shows that infant mortality also varies by districts. **Table 5** below shows the direct estimates of infant mortality by sex and district. Orapa and Sowa did not experience infant mortality in the year 2022. Gaborone (8), South East (8) and Lobatse (10) recorded the lowest infant mortality rates of less than 10 deaths per 1000 live births in 2022. Ngamiland west (29), Central Bobonong (28), Ghanzi (25) and Kgalagadi North (25) recorded the highest level of infant mortality in 2022. The level of infant mortality in all other districts ranged between 11 and 24. There are sex differentials in the level of infant mortality by districts with females largely experiencing lower infant mortality in most districts.

TABLE 5: Direct Estimates Of Infant Mortality Rates By Sex And District, 2022

	MALE	FEMALE	TOTAL
Orapa	0	0	**0**
Sowa	0	0	**0**
Gaborone	11	4	**8**
South East	9	7	**8**
Lobatse	17	7	**10**
Kweneng East	11	11	**11**
Francistown	14	10	**12**
Kgatleng (Wards)	14	9	**12**
Central Boteti	13	16	**14**
Central Serowe -Palapye	18	13	**15**
Southern	18	14	**16**
North East	16	17	**17**
Jwaneng	19	17	**18**
Ngamiland East	16	21	**18**
Selibe Phikwe	24	18	**21**
Barolong	18	23	**21**
Central Tutume	22	19	**21**
Kgalagadi South	12	32	**22**
Kweneng West	31	15	**23**
Central Mahalapye	19	26	**23**
Chobe	18	29	**23**
Ngwaketse West	27	21	**24**
Ghanzi	30	19	**25**
Kgalagadi North	30	19	**25**
Central Bobonong	22	34	**28**
Ngamiland West	30	28	**29**

5.1.6 Under-five Mortality Rates by District

Table 6 below shows the direct estimates of under-five mortality by sex and district. Sowa did not experience under-five mortality in the year 2022. Orapa (4) and Gaborone (8) recorded the lowest under-five mortality rates of less than 10 deaths per 1000 live births in 2022. Ngamiland west (36), Central Bobonong (34), Ghanzi (33), Kgalagadi North (28), Ngwaketse West (28), Central Mahalpye (28), Chobe (28), Kweng West (26), Kgalagadi South (25), Central Tutume (25) and Barolong (25) recorded the highest level of under-five mortality in 2022. The level of under-five mortality in all other districts ranged between 11 and 24. There are sex differentials in the level of under-five mortality by districts with females largely experiencing lower under-five mortality in most districts.

TABLE 6: Direct Estimates Of Under-Five Mortality Rates By Sex And District

	MALE	FEMALE	TOTAL
SOWA	0	0	**0**
ORAPA	9	0	**4**
GABORONE	12	6	**9**
LOBATSE	23	7	**11**
SOUTH EAST	13	8	**11**
FRANCISTOWN	15	13	**14**
KWENENG EAST	15	14	**14**
KGATLENG (Wards)	17	11	**14**
JWANENG	19	17	**18**
NORTH EAST	17	19	**18**
SOUTHERN	21	16	**19**
CENTRAL SEROWE -PALAPYE	22	16	**19**
CENTRAL BOTETI	16	21	**19**
NGAMILAND EAST	22	24	**23**
SELIBE PHIKWE	26	21	**24**
BAROLONG	25	24	**25**
CENTRAL TUTUME	26	24	**25**
KGALAGADI SOUTH	12	37	**25**
KWENENG WEST	34	18	**26**
NGWAKETSE WEST	34	21	**28**
CENTRAL MAHALAPYE	25	31	**28**
CHOBE	22	33	**28**
KGALAGADI NORTH	30	26	**28**
GHANZI	38	28	**33**
CENTRAL BOBONONG	31	37	**34**
NGAMILAND WEST	38	33	**36**

5.2 Socio-economic differentials of infant and under-five mortality in Botswana

To investigate the socioeconomic (mother's education, mother's marital status, and mother's employment status) differentials of infant and under-five mortality, this study used the indirect estimation techniques while assuming that errors are the same in all age-groups. A study by Monamo et al. (2023) acknowledged that indirect estimation methods can be applied to investigate the socioeconomic differentials of under-five mortality, assuming that errors are the same across all age groups. Moreover, this section intended in socio-economic differentials of infant and under-five mortality not the levels.

5.2.1 Infant and Under-five Mortality by mother's marital status

Figure 4 and **5** below shows the differences of infant and under-five mortality by mother's marital status. Both the figures display that infant and under-five mortality has been lower among mothers who were married compared to those who were living together from a period of 2010 to 2017. The graphs also shows that the variation of infant and under-five mortality between the two groups has been narrowing overtime from the year 2010 to 2017.

FIGURE 4: INFANT MORTALITY BY MOTHER'S MARITAL STATUS

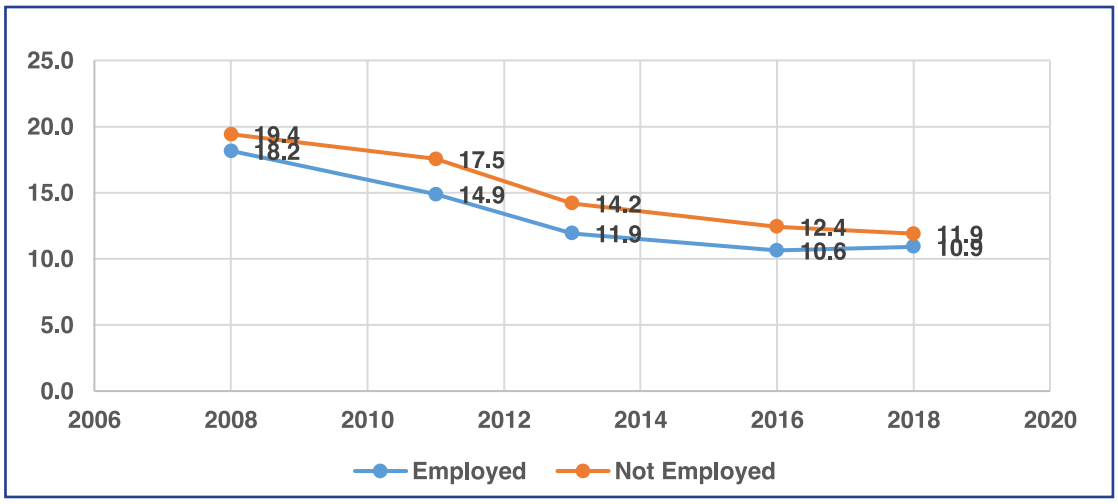
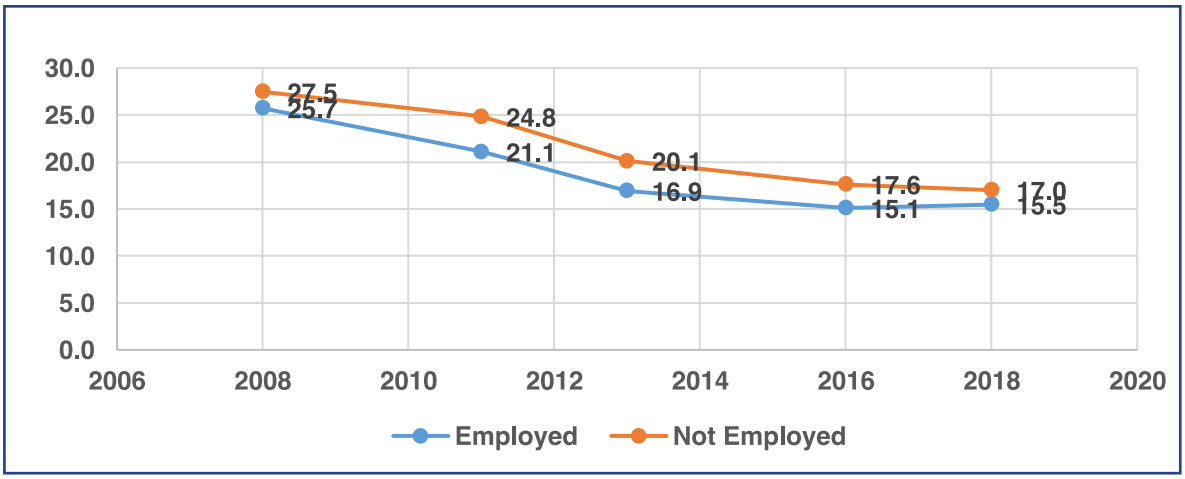


FIGURE 5: UNDER-FIVE MORTALITY BY MOTHER'S MARITAL STATUS



5.2.2 Infant and Under-five Mortality by mother's employment status

Figure 6 and 7 below shows the differences of infant and under-five mortality by mother's employment status. Both the figures display that infant and under-five mortality has been higher among mothers who were not employed compared to those who were employed from a period of 2008 to 2018. The graphs also shows that the gap of infant and under-five mortality between the two groups widened from the year 2008 to 2011, then narrowed down from the year 2011 to 2018.

FIGURE 6: INFANT MORTALITY BY MOTHER'S EMPLOYMENT STATUS

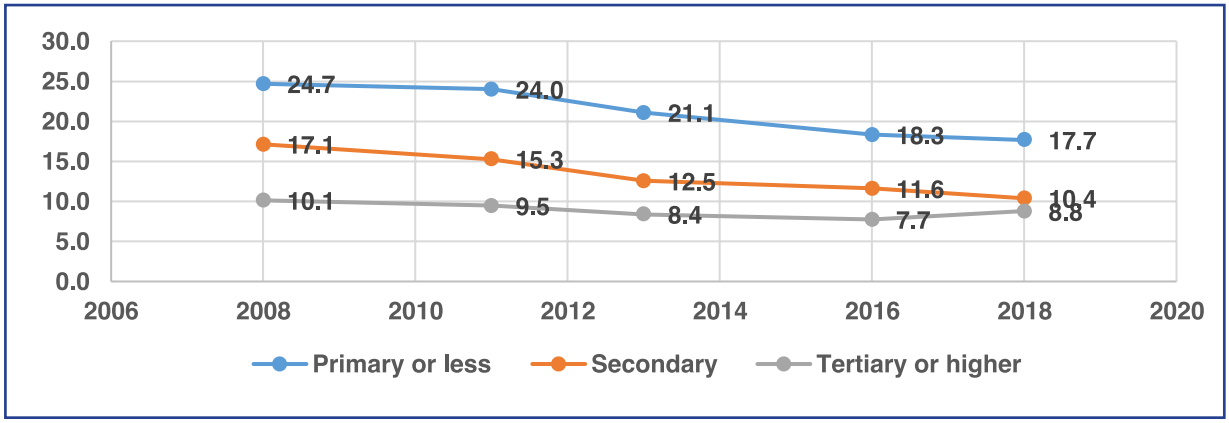
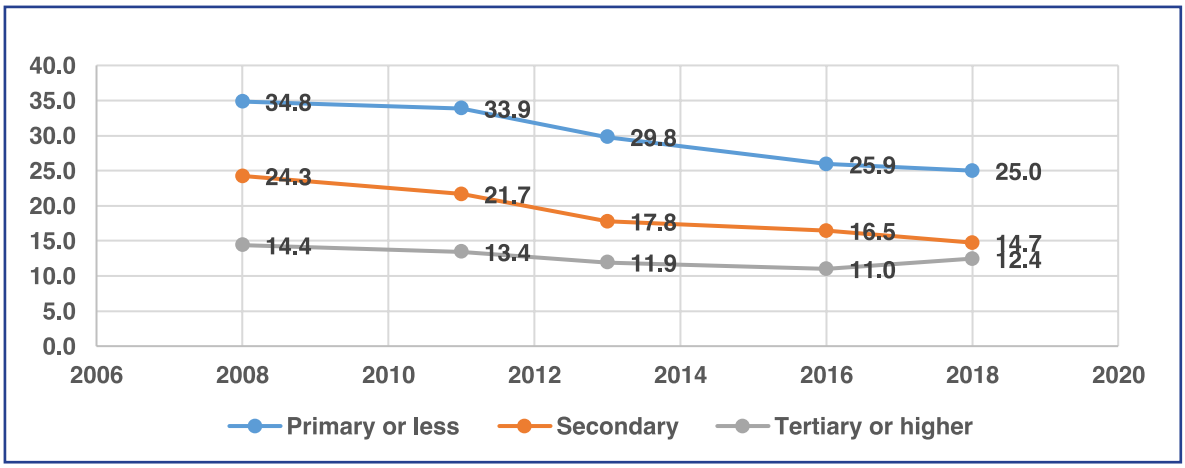


FIGURE 9: UNDER-FIVE MORTALITY BY MOTHER'S LEVEL OF EDUCATION



6.0 CONCLUSION

Estimates from this study have shown declining infant and under-five mortality in Botswana from 2006 to 2022, a trend that has been supported by recent published estimates. As the estimates from this study indicate, Botswana has successfully reduced U5MR and managed to achieve the targets set out in the 2030 Agenda for Sustainable Development of reducing under-five mortality to as low as 25 deaths per 1000 live births by 2030. The reason for this transition has been appreciated as resulting from the government improving its health services and delivery efforts such as PMTCT programs, national ART programme, nutrition programmes and other HIV interventions. Botswana has also made significant progress in uplifting the status of women in the society and enhancing their access to economic opportunities through various policy instruments and programmes.

Results from this study shows that the socio-economic differentials in infant and under-five mortality by mother's marital status, mother's employment status and mother's level of education has been narrowing overtime from the year 2008 to 2018. Despite the substantial reduction in infant and under-five mortality and the narrowing gap between socio-economic groups, socio-economic inequalities in infant and under-five mortality disfavoring worse-off groups still exists. The findings from this report show that an improvement in socio-economic status leads to a decrease in infant and under-five mortality. Women with higher education tend to have smaller families, in part because of increased employment opportunities and better knowledge about contraception; fewer children in a family improves the chances that an infant will survive.

More education also helps women make better decisions about many health and disease factors such as prenatal care, basic hygiene, nutrition and immunization—which are vital to reducing the leading causes of death in children under five. There is nothing new about the belief that the spread of education with its influence on knowledge and outlook is a central force behind the demographic transition. Infant and under-five mortality in cities and towns tend to have lower mortality rates than rural areas, possibly because people residing in rural areas are less educated than their urban counterparts. The study acknowledges that employed mothers have a low risk of experiencing infant and under-five mortality than unemployed mothers. This may imply that households with higher income can afford better health care as well as housing and sanitary conditions, such as clean water and toilet facilities. As a result, high income households are more likely to have better health outcomes as compared to low-income households.

RECOMMENDATIONS

Because of the vulnerability of male children depicted in this study, extra attention must be given while giving care to these children both at home and health facilities.

To tackle the socio-economic gap in Botswana, the government should focus more on:

Policies that reduce inequalities

Policies to reduce inequality can either be applied 'downstream' by redistribution to reduce the effects of inequality, (e.g. through improvements in education and skills in order to raise the level of achievement, and enable young people to leave education with a set of key skills that will enable them to work in higher value-added and higher paid employment) or 'upstream' at the source of the inequality to prevent it from happening – such as opening up of more opportunities to earn income and raising the minimum wage, which will impact on the low paid, while having no direct effect on the higher paid.

Policies that reduce exposures of disadvantaged people to health damaging factors

Another common way to attempt to address health inequalities is to direct policies at the most disadvantaged groups in an attempt to raise their health status.

Policies that reduce vulnerabilities of disadvantaged people

A focus on the gaps that exist in health continues to concentrate on those in the lowest-income groups with poorer health, but specifically in relation to other groups. This approach is demonstrated by the common surveillance statistics which focus on the health outcomes of those in the lowest-income (or most disadvantaged) group with either an average for the population or with the health outcomes of those in the highest income (or most advantaged) category.

Policies that reduce unequal effects of illness in health, economic and social terms

Approaching inequalities across the health gradient means looking not only at the gaps that exist between those at the top and at the bottom of the scale or at the situation of those most disadvantaged, but also at how health is distributed across all population groups. "It locates the causes of health inequalities not in the disadvantaged circumstances and health damaging behaviours of the poorest groups, but in the systematic differences in life chances, living standards and lifestyles associated with people's unequal positions in the socioeconomic hierarchy" (Graham & Kelly, 2004).

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ADOLESCENT MORTALITY IN BOTSWANA: CAUSES AND DETERMINANTS

By;
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EXECUTIVE SUMMARY

Background: Global statistics show that in 2020 adolescent (10 – 19year) mortality constitute 43% of all deaths in the age group 5-24 years. The greatest percentage being from the sub-Saharan Africa in which Botswana is not spared. The premature deaths of adolescents is a cause of concern as this hinders progress towards attainment of the Sustainable Development Goal number 3.3, 3.4, 3.5 and 3.6. The leading causes of adolescent mortality across the globe include injuries, violence, self-harm, and complicated pregnancy. There seem to be a gap in the study of adolescent mortality in Botswana yet these adolescents constitute more than 30% of the population in Botswana. Thus, the survival of adolescents is a global and national priority. Objective: To identify the leading causes of mortality and to analyse the determinants of adolescent mortality in Botswana at different social levels based on data from the Botswana Population and Housing Census of 2022 to inform the mitigation of the scourge. Methods: Frequency tables will be used to identify the leading causes of death in Botswana. A logistic regression model will be used to examine how different social levels, including the household and community influence adolescent mortality based on the leading causes. Effects of demographic and individual characteristics such as age and gender on adolescent mortality will also be assessed. Results: the leading causes of death among adolescents in Botswana are diseases, road accidents, and suicide in that order. Most deaths due to road accidents were recorded in Ngamiland East and Ghanzi districts. Kweneng district had the highest number of deaths due to diseases. Conclusion: Results can assist in informing policy on strategies to improve health and safeguard the lives of adolescents. The results of the study will also serve as a springboard for future studies on adolescent mortality.

Keywords: adolescent mortality, Leading causes, Determinants, Botswana.

1.0 INTRODUCTION

Mortality is an important indicator of health and with or without data its estimates provide a proxy for broader health outcomes (Vos et al., 2019). Previous research reveals a global significant increase in adolescent mortality compared to previous years (Viner et al., 2011). In 2021, the global adolescent mortality rate was 22% (WHO, 2022). Globally, deaths among adolescents account for 43% of all deaths in the age group of 5 to 24 years (WHO, 2022). This impedes the realisation of SDG 3 which includes indicators of causes and interventions for the death of adolescents.

Adolescence is the stage of transition from childhood to adulthood that exposes individuals to household and community influences that negatively impact their survival (Wet and Odiwegwu, 2017). This includes drug abuse and early sexual behaviour that results in early pregnancies, sexually transmitted diseases, and road traffic accidents among other social ills that result in death. Worldwide, the leading causes of death among adolescents are injuries, violence, self-harm, and infectious diseases. Nevertheless, in sub-Saharan Africa, communicable diseases including HIV/AIDS are leading causes of death among adolescents. Thus, adolescent mortality in sub-Saharan African countries including Botswana is a cause for concern.

Wet (2017) used a logistic regression model to examine the determinants of adolescent mortality in South Africa. The study revealed that having four household assets, six or more people living in a residence,

and high racial diversity increase the odds of adolescent mortality. In 2023, Zhu et al. used data from the Global Burden of Diseases (1990 to 2019) to study mortality among adolescents in China. In their study, they used autoregressive integrated moving averages to predict the trends in mortality up to 2030. Their results showed a downward trend in mortality rates. They also observed that the leading causes of death were injuries with constant sexual and age disparities.

According to the Adolescent Health Report of 2018, the adolescents in Botswana constitute an average of 23.05% (24.1% (1990), 25.0 (1995), 24.9 (2000), 23.7 (2005), 21.5 (2010), 19.1 (2015) of the population. The 2018 report shows that the leading cause of mortality among adolescents is HIV/AIDS. Among adolescent girls, some of the leading causes include maternal conditions. According to WHO (2006) adolescents aged 15 to 19 are twice likely to die during pregnancy or childbirth and those under 15 are five times more likely to die than those over 20 in developing countries.

The household and community of adolescents influence their health and development outcomes (Vu, 2005). Thus, in assessment of the determinants of mortality focusing only on the individual characteristics, demographic and socio-economic factors is not sufficient. At the household level, the determinant may include education, gender, place of residence, age, household size, and household hardship. Determinants at the community level may include the availability of health facilities, employment opportunities education facilities and road network facilities. As such, this study proposes logistic regression modelling of adolescent mortality. The multilevel logistic model helps in examining the hierarchical social structures. The multilevel analysis also allows researchers to deal with the micro-level (which in this case is the household level) of individuals and the macro-level (which is the community level) of the groups simultaneously.

1.1 Statement of the problem

Adolescents embody any country's potential social and economic development since they constitute future parents and employers. However, the recently observed foregoing rising trend in adolescent mortality is a cause of concern. The previously used individual characteristics and demographic features are insufficient to examine mortality determinants in adolescents. This study proposes a logistic regression model to analyse adolescent mortality using Botswana Census data for 2021. The leading causes of adolescent mortality will also be determined. The results of this study will inform policymakers on formulating or amending policies on curbing the mortality of adolescents.

1.2 Objectives of the study

- **To identify the leading causes of mortality among adolescents in Botswana using Census 2021 data.**
- **To assess the determinants of adolescent mortality for each of the leading cause of death using a logistic regression model.**

2.0 METHODS

For this study, the Botswana Housing Census data for 2021 will be used. The leading causes of death among adolescents (10 to 19 years) will be determined. Demographic distributions of the cause of death are presented in the form of frequency tables and bar graphs. A logistic regression model will be used to examine the determinants for each of the top three causes of death. The data will be analysed using a freely available R software.

2.1 The Logistic regression model

We define a logistic regression model as

$$ln\left(\frac{P(Y)}{1-P(Y)}\right) = \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k, \quad \textbf{(1)}$$

Where Y is the dependent variable defined as

$$Y_i = \begin{cases} 1, & \text{if death occurs due to a cause of interest otherwise)s} \\ 0, & \end{cases} \quad \textbf{(2)}$$

$$P(Y) = \frac{e^{\beta_0+\beta_1 X_1+\cdots+\beta_k X_k}}{1+e^{\beta_0+\beta_1 X_1+\cdots+\beta_k X_k}},$$

In $\left(\frac{P(Y)}{1-P(Y)}\right)$ is the odds of outcomes $X_1, X_2, \ldots, X_k$ are the predictor variables, and $\beta_0, \beta_1, \ldots, \beta_k$ are the regression coefficients $k = 7$ variables will be considered including AGE, Month, HOUSEHOLD, District, Gender, Locality, and YEAR.

The parameter $\beta_0, \beta_1, \beta_2, \ldots, \beta_k$ are obtained using the method of maximum likelihood estimation (MLE). The same logistic regression model for the cause of death can be proposed by the substitution of relevant variables. The odds ratio is defined as the ratio of the odds for Y=1 (success, death from mentioned cause) to the odds for Y=0 (failure) and this is defined as:

$$ODDS\ RATIO = \frac{p(1) \div (1-p(1))}{p(0) \div (1-p(0))} \quad \textbf{(3)}$$

Thus the $ODDS\ RATIO = e^{\beta_i}$. The formula for calculating the odds ratio for a continuous random variable is the same as the one for binary-coded variables only the interpretation differs.

Likelihood ratio test

Test for significance for the multiple logistic regression model is done by fitting the full model and the reduced model and then comparing the two fits. This is done using the likelihood ratio test whereby a statistic called the deviance (D) is computed which measures how close the predicted values from the fitted model match the actual values of the raw data.

The deviance (D) statistic is defined as:

$$D = 2[log(likelihood(\ saturated\ model)) - log(likelihood(\ proposed\ model))] \quad (4)$$

If the proposed model is a good approximation then the deviance should be relatively small.

In addition, multicollinearity among the predictor variables for the fitted models was tested using the variance inflation factor (VIF). Variables with VIF greater than 5 are dropped.

3.0 Findings and Discussions

3.1 Causes of adolescents mortality

Adolescents (10 to 19 years old) constitute 36.6% (345 deaths) of the 5 to 24 year-olds deaths. This is lower than the 43% global estimate presented by WHO (2022). This is presented in **Figure1** below.

FIGURE 1: DISTRIBUTION OF 5 TO 20 YEAR OLDS DEATHS BY AGE GROUP

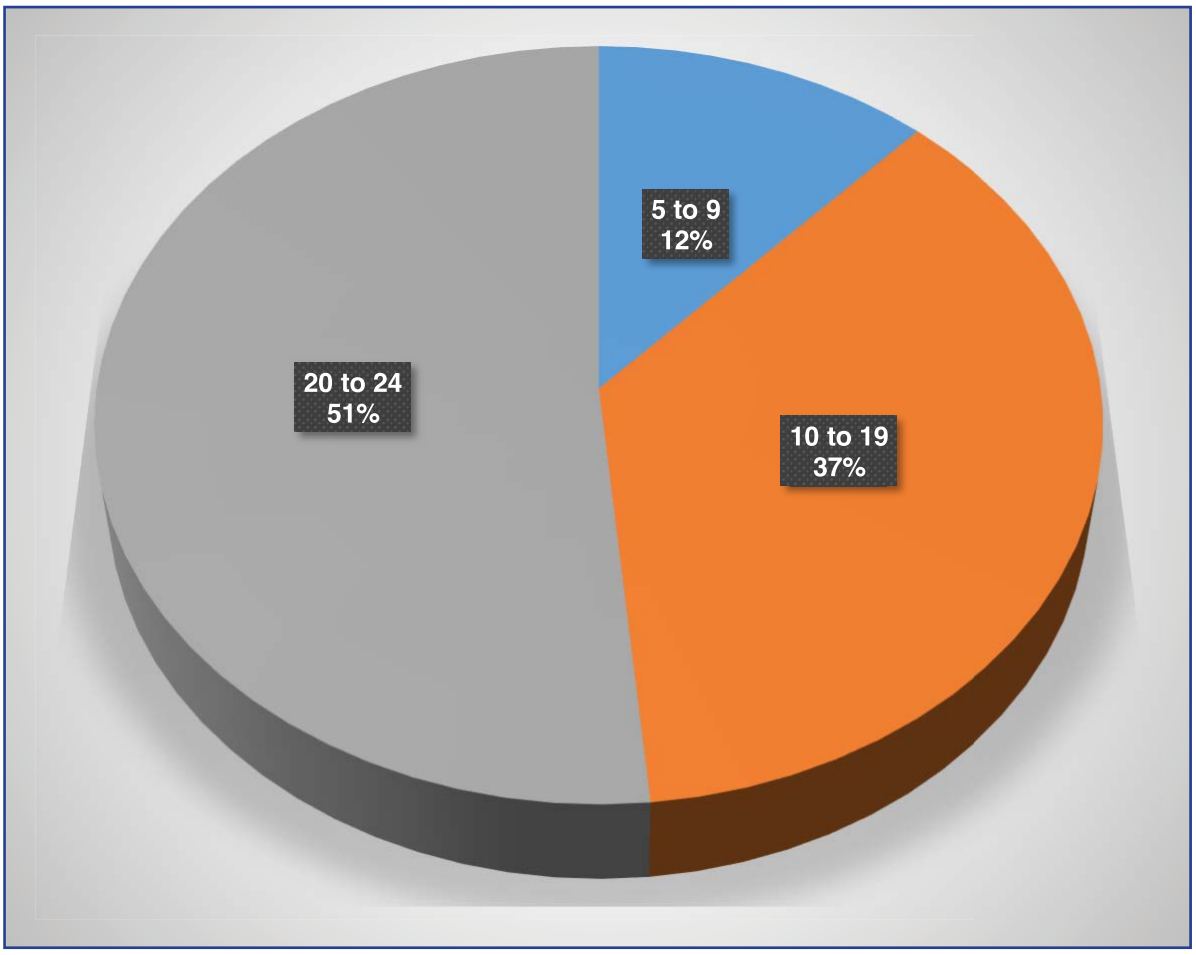


Table 1 below presents the frequencies for each of the causes of death for adolescents. The results show that adolescent deaths were mainly due to diseases (40.8%) followed by road accidents (28.8%) and then suicides (9.7%). This corroborates with the findings from Statistics Botswana (2022) which argues that adolescent deaths are mainly due to road accidents because of them being vulnerable road users. However, the disease is not specified in the data. The cause of about 15.3% of the deaths is not specified.

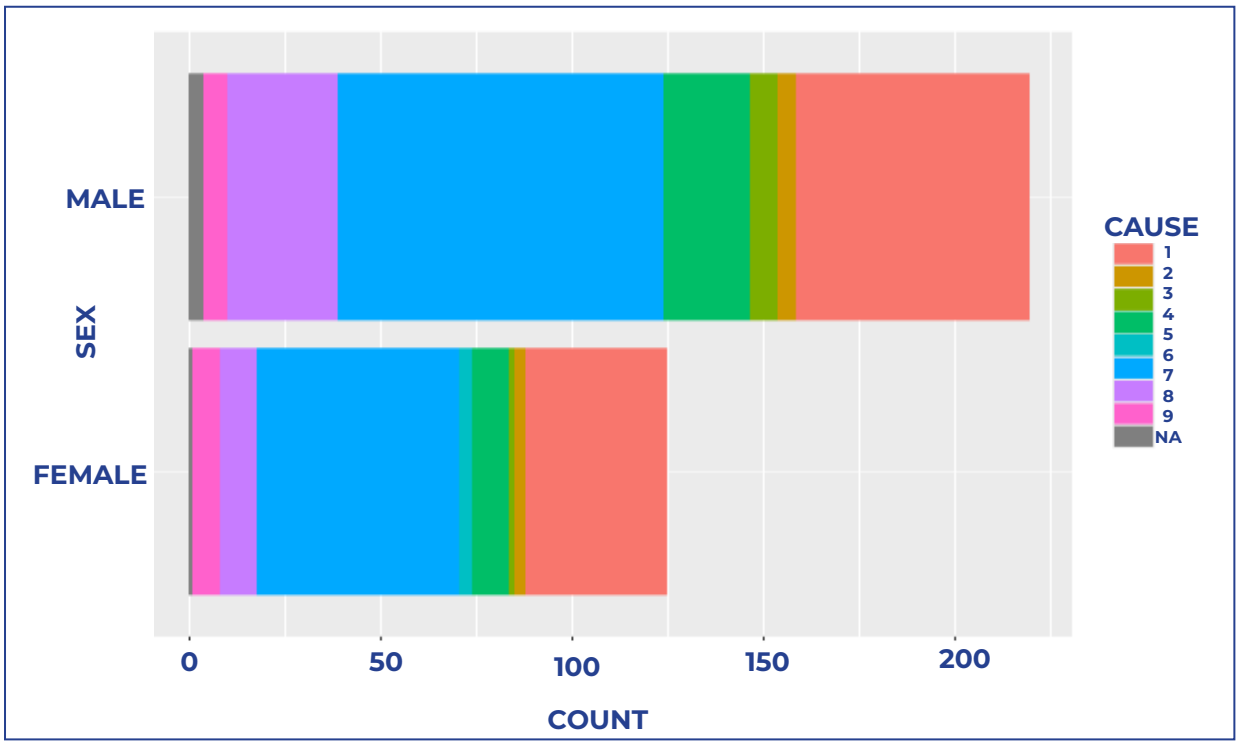
TABLE 1: Causes of death for the adolescent group (10 to 19 years)

Cause	Frequency	Proportion
Road Accidents (1)	98	28.8%
Violence (2)	8	2.4%
Homicide (3)	8	2.4%
Suicide (4)	33	9.7%
Gender based violence (5)	3	0.9%
Diseases (6)	138	40.6%
Other (7)	39	11.5%
Don't Know (9)	13	3.8%
N/A	5	3.6%

3.2 Gender distribution of adolescent mortality

Figure 1 shows the distribution of causes of death by gender where male = 1 and female = 2. The results show that in almost all the causes (road accidents (1), violence (2), homicide (3), suicide (4), and diseases (6)) males are dominating but for deaths due to gender-based violence only females are affected.

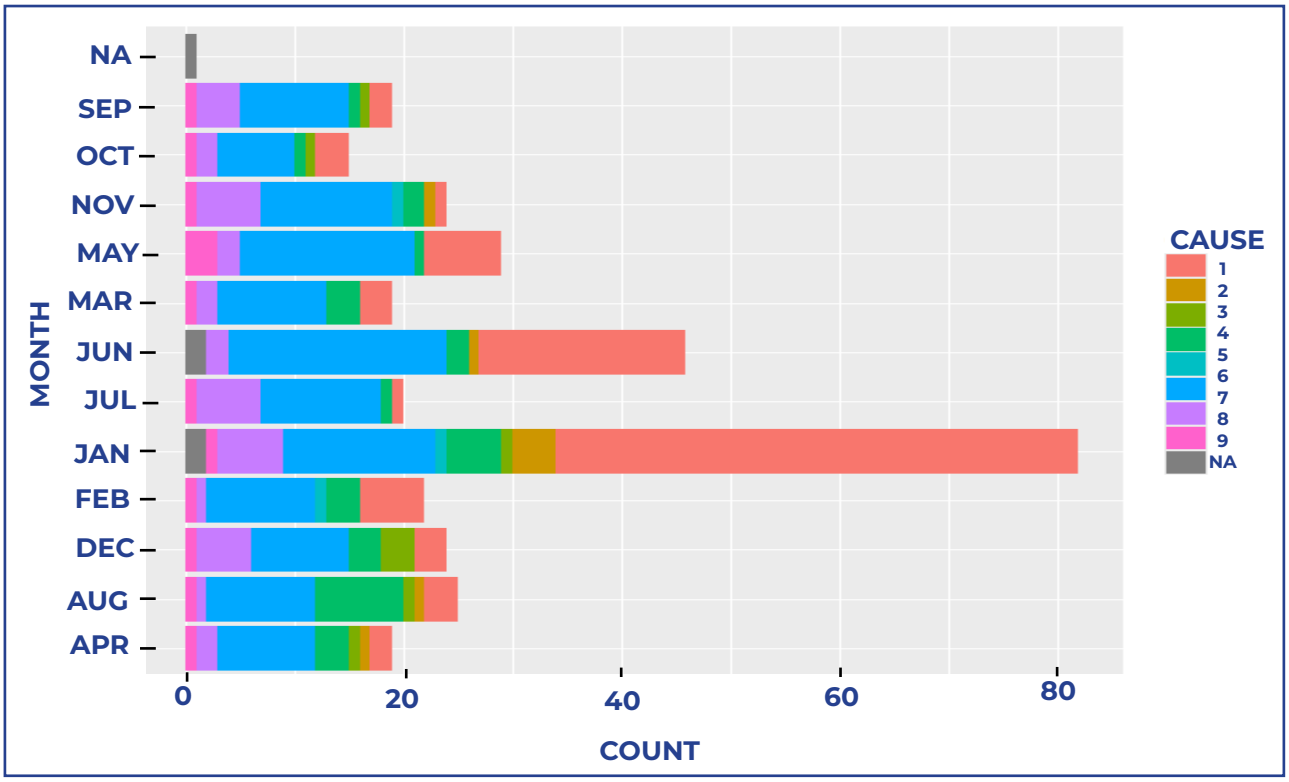
FIGURE 2: DISTRIBUTION OF CAUSE OF DEATH BY GENDER



3.3 Distribution of adolescent mortality by month of death

Figure 2 presents the causes of death by month of death. Most of the deaths occurred in January and these were mainly due to road accidents. The month of June had the second-highest recorded number of deaths mainly due to diseases followed by road accidents.

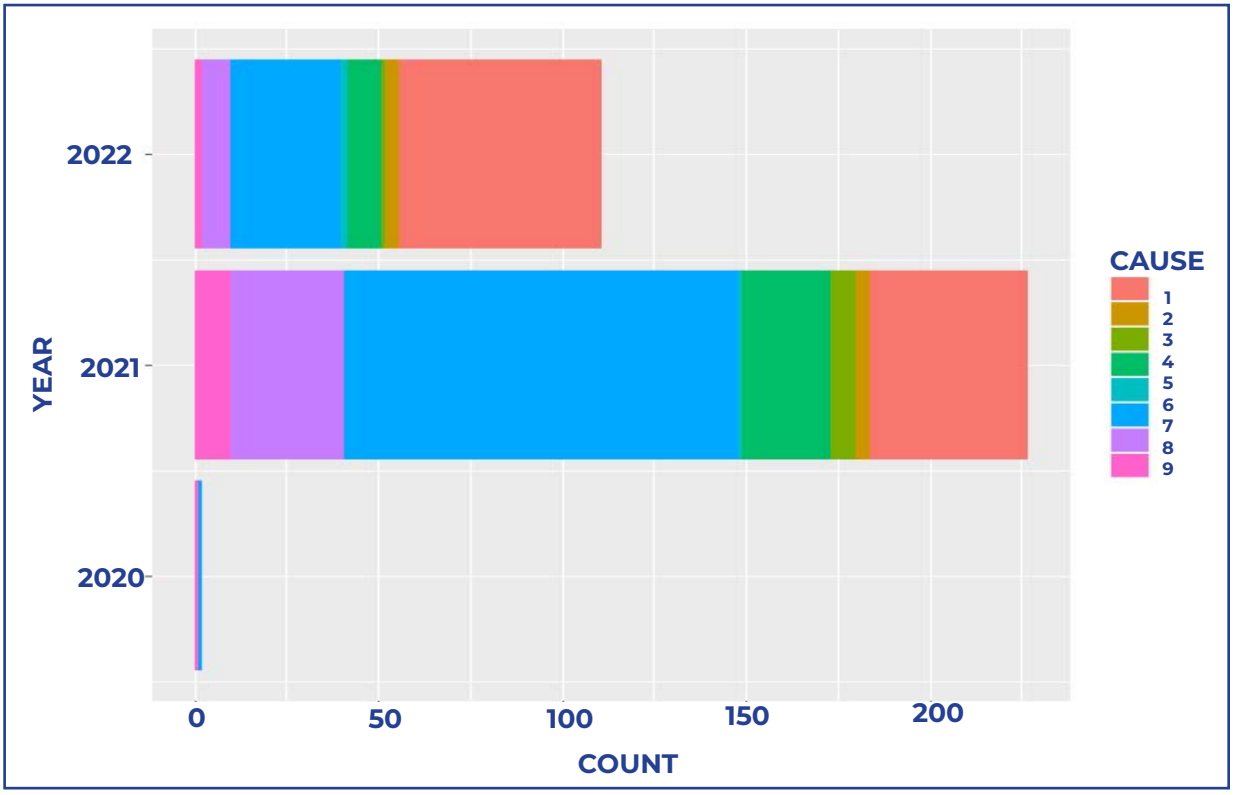
FIGURE 3: DISTRIBUTION OF CAUSE OF DEATH BY MONTH OF DEATH



3.4 Distribution of adolescent mortality by year of death

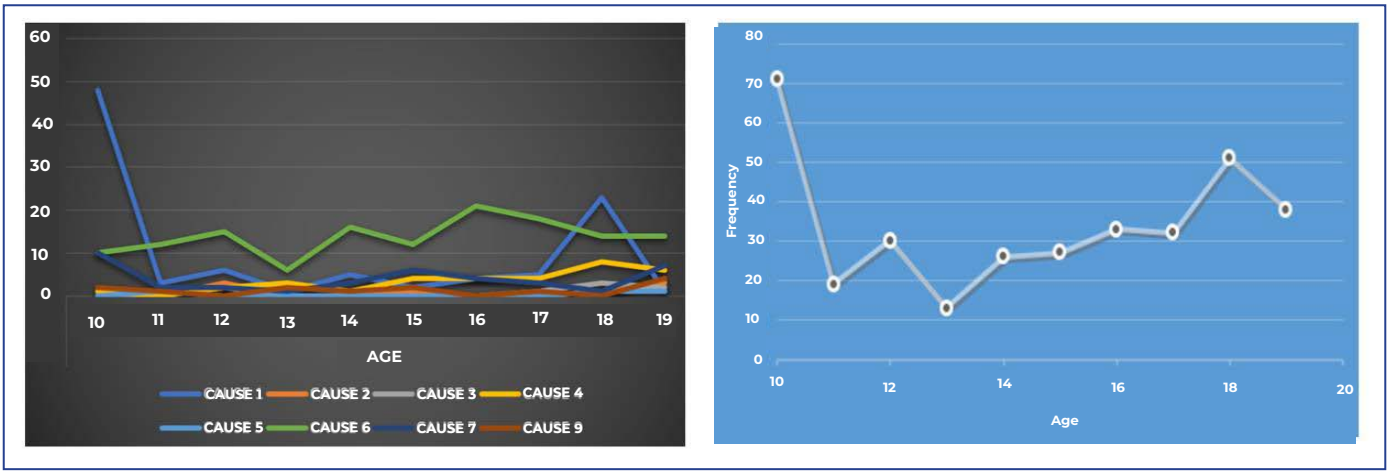
The 2021 Botswana Census data show that the highest number of adolescents deaths was recorded in 2021 with the major cause being diseases. In 2022 there was a decline in the number of deaths. However, a notable increase in the number of deaths due to road accidents is observed from 29 deaths in 2021 to 82 deaths in 2022.

FIGURE 4: NUMBER OF ADOLESCENT DEATHS BY CAUSE AND YEAR OF DEATH



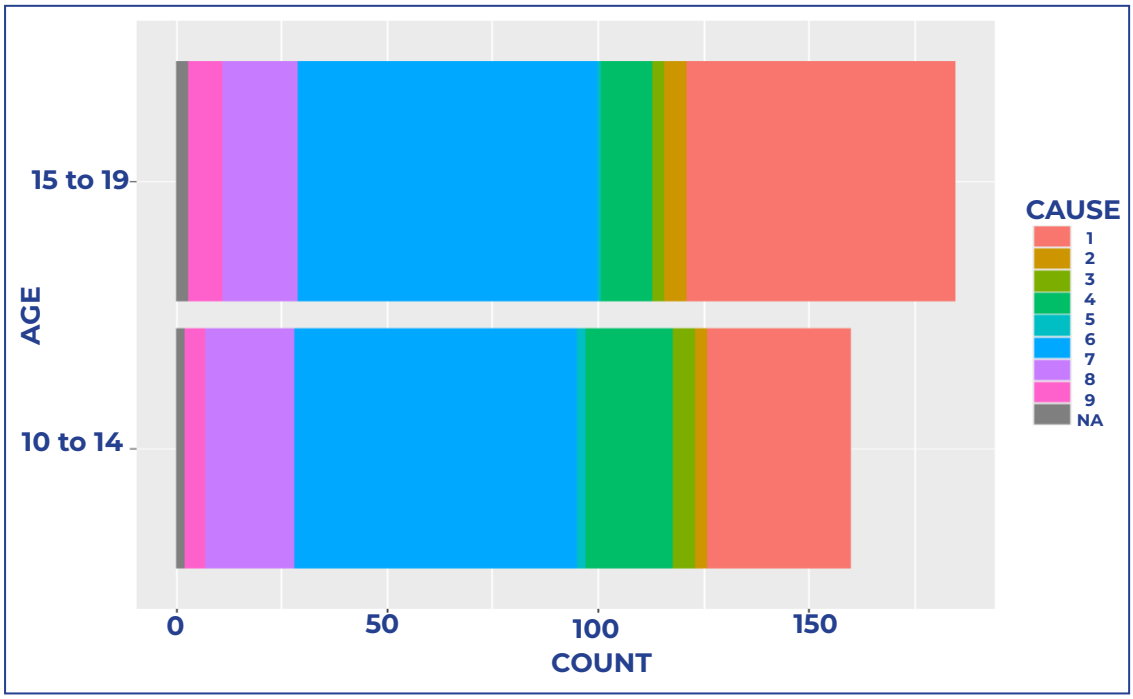
Road accidents are the major causes of death among the 10 year olds. The 18 year olds also die mostly due to road accidents although the frequency is lower than that of the 10-year-olds. Overall, diseases remain the major cause of death for all adolescents. There is need, in future censuses, to capture these diseases so that proper mitigation measures can be put in place.

FIGURE 5: ADOLESCENTS DEATH TREND BY AGE



The 15 to 19 year age group recoded more deaths than the 10 to 14 year age group. The 10 to 14 age group records more deaths due to suicide (4) compared to the 15 to 19 age group. For the 15 to the 19 year age group there are more deaths due to diseases and road accidence than the 10 to 14 year age group **(Figure 4). Table 2** gives the statistics.

FIGURE 6: DISTRIBUTION OF CAUSE OF DEATH BY AGE GROUP



3.4 Distribution of adolescent mortality by household

TABLE 2: Distribution of adolescent deaths by household number

CAUSE	HOUSEHOLD					
	1	2	3	4	5	8
1	89	4	3	1	1	0
2	8	0	0	0	0	0
3	6	1	0	0	1	0
4	30	1	2	0	0	0
5	3	0	0	0	0	0
6	124	9	4	0	0	1
7	33	6	0	0	0	0
9	12	1	0	0	0	0

Results from **Table 2** show that most of the adolescent deaths were from Household number 1.

3.5 Distribution of adolescent mortality by District

TABLE 3: Adolescents mortality by cause and District

DISTRICT	CAUSE								
	Road Accident	Violence	Homicide	Suicide	GBV	Disease	None of the above	Don't know	Total
Gaborone	2	0	0	0	0	8	1	0	**11**
Francistown	1	0	0	2	0	2	0	0	**5**
Lobatse	0	0	0	0	0	2	0	0	**2**
Selibe Phikwe	0	0	0	1	0	2	0	0	**3**
Southern	1	0	0	2	0	12	1	0	**16**
Barolong	2	0	1	1	0	17	2	1	**24**
Ngwaketse West	0	1	0	2	0	0	1	0	**4**
South East	1	0	0	0	1	1	0	0	**3**
Kweneng	9	1	4	3	0	22	4	3	**46**
Kgatleng (ward)	2	0	0	0	0	4	3	0	**9**
Central Serowe -Palapye	2	2	1	2	0	14	4	0	**25**
Central Mahalapye	1	4	0	2	1	8	3	2	**21**
Central Boteti	0	0	0	2	0	7	3	1	**13**
Central Tutume	5	0	0	6	0	6	5	3	**25**
North East	1	0	1	0	0	6	3	0	**11**
Ngamiland East	41	0	1	2	0	9	3	0	**57**
Ngamiland West	2	0	0	4	0	6	2	2	**16**
Chobe	0	0	0	1	0	1	0	1	**3**
Ghanzi	28	0	0	2	1	7	3	0	**41**
Kgalagadi South	0	0	0	1	0	2	0	0	**3**

Results from **table 2** show that Ngamiland East District recorded the highest number of deaths followed by Kweneng District and then Ghanzi District. For Ngamiland East and Ghanzi Districts these deaths were mainly due to road accidents. The high numbers of deaths due to road accidents in the Ghanzi Disrtict could be attributed to poor road infrastructure as highlighted by LaRocco (2020). LaRocco further argued that infrastructure allocation is either delayed on denied to create a "people-free wilderness that appeal for foreign tourist consumers." Ngamiland east District is socially vulnerable with most roads either not tarred or in a bad state (Dintwa, 2019). In Kweneng District the major cause of death was diseases.

3.5.1 Analysis of the factors that influence different causes of death

As demonstrated in the exploratory data analysis above, the major cause of deaths among the adolescent group in Botswana is diseases and road accidents. In this section, we analyse the factors that influence these deaths. Among the factors are District, Locality, Year of death, sex, age, and household to mention a few. In this section, a logistic regression model is fitted for the leading causes of death that is road accidents and diseases. From the fitted models coefficients are extracted.

3.5.2 A logistic regression model for death due to road accident

To understand the impact of some variables on adolescent deaths due to road accidents we extract the coefficient values of the variables. The results are ranked based on their relative influence. The top 14 variables are presented in **Table 4** below and **Figure 3** presents all the variables.

4: The determinants of adolescent deaths due to road accidents from the fitted Logistic regression model

	ESTIMATE	STD. ERROR	Z VALUE	ODDS RATIO	Pr(>|z|)
(Intercept)	0.9925	1.7277	0.574	2.70	0.5656
Gaborone(Ref)					
South East	2.0499	1.6513	1.241	7.77	0.2145
Central Mahalapye	-1.7736	1.4354	-1.236	1.17	0.2166
Ngamiland East	2.3892	1.0331	2.313	10.90	0.0207 *
Ghanzi	2.314	1.0496	2.205	10.11	0.0275 *
SEX(Male)	1.1667	0.3944	2.958	3.21	0.0031 **
AGE	-0.1797	0.1307	-1.375	0.84	0.1691
AGEC2 (15-19years)	-0.9418	0.37158	-2.535	0.39	0.01126 *
Son/Daughter (Ref)					
Nephew/Niece	1.29283	0.47046	2.748	3.643	0.00600 **

Null deviance: 411.08 on 343 degrees of freedom
Residual deviance: 232.12 on 309 degrees of freedom
AIC: 302.12

The results from **Table 4** show that at 5% level of significance the districts, Ngamiland East and Ghanzi contribute to road accident deaths in Botswana. Compared to Gaborone District, which is the reference category, Ngamiland East is 10.9 times more likely to experience adolescent deaths due to road accidents whereas Ghanzi is 10.11 times more likely to experience adolescent deaths from road accidents. Gender also contributes significantly to road accident deaths with the odds of male adolescents 3.21 times more compared to their female counterparts. Although age does not contribute significantly to adolescent deaths, the results show that for every unit increase in age, the number of adolescent deaths decreases by approximately 16%. Adolescents living with an aunt or uncle are 3.643 times more likely to die due to road accidents as compared to those living with their biological parents.

TABLE 5: Test for Multicollinearity

	GVIF	Df	GVIF^(1/(2*Df))
factor(DISTRICT)	2.572254	20	1.023901
factor(AGEC)	1.356313	1	1.164608
factor(SEX)	1.34181	1	1.158365
factor(RELATIONSHIP)	2.068977	7	1.053305

Since none of the predictor variables in our models have a VIF over 5, we can assume that multicollinearity is not an issue in our model.

3.5.2 Logistic regression model for deaths due to Disease

The parameters from the fitted logistic regression model for the response variable, death due to diseases is presented in **Table 5.** The contribution of variables is ranked based on their p-values and 15 of the explanatory variables are presented.

TABLE 6: Logistic regression model for the determinants of adolescent deaths due to diseases

	ESTIMATE	STD. ERROR	Z VALUE	ODDS RATIO	Pr(>|z|)
(Intercept)	-1.47562	1.24747	-1.183	0.23	0.236854
Gaborone (Ref)					
Barolong	1.68485	0.82523	1.484	5.39	0.0237742*
Kweneng	1.97684	0.73993	2.32	7.22	0.0186776*
Central Serowe-Palapye	1.22078	0.82905	1.027	3.38	0.042625 *
Central Boteti	-1.69144	0.9584	-1.765	0.18	0.077587 .
Central Tutume	-1.08286	0.8107	-1.336	0.34	0.181641
North East	-1.00269	0.95265	-1.053	0.37	0.292554
Ngamiland West	-1.32589	0.89646	-1.479	0.27	0.139133
AGEC(15-19years)	-1.98431	0.59635	-3.327	0.14	0.000877 ***
SEX(Male)	-0.02755	0.27251	-0.101	0.97	0.919463
AGE	-0.18358	0.09327	1.968	1.20	0.049043 *
Son/Daughter (Ref)					
Nephew/Niece	0.77623	0.38525	-2.015	2.17	0.04392*

Null deviance: 463.35 on 343 degrees of freedom
Residual deviance: 408.95 on 309 degrees of freedom
AIC: 478.95

There is an increase in the number of adolescent deaths due to diseases in the Barolong, Kweneng and Central Serowe/Palapye Districts compared to the Gaborone District. The odds of deaths due to diseases for Barolong, Kweneng, and Central Serowe-Palapye are 5.39, 7.22, and 3.38, respectively, times more than that of the Gaborone district. There is also a significant reduction of about 86% in deaths due to diseases for adolescents in the age group 15 to 19 years compared to the 10 to 14 year age group. Male adolescents are 3% less likely to die of diseases than their female counterparts. However, if age is taken as a continuous variable, the number of deaths due to diseases increases by approximately 20% for every unit increase in age. Adolescents living with an aunt or uncle are 2.17 times more likely to die due to diseases compared to those living with their biological parent.

4.0 POLICY IMPLICATIONS

The major cause of death among adolescents is attributed to diseases, suicide, and road accidents. The following policy implications hold. To address SDGS goal number 3.3, 3.4, NDP 11 strategies as well as pillar 2 of vision 2036 access to disease prevention and treatment should be promoted by providing free clinical visits and pharmaceuticals. Furthermore, new HIV infections, TB and Hepatitis B incidence among adolescents should be reduced by advocating and promoting preventative measures such as condom use. Prevention against tropical diseases such as malaria among adolescents in affected areas especially the Ngamiland region should be heightened. Mental health awareness among adolescents should be promoted to reduce suicide tendencies, and also, medical research for vaccines and medication should be prioritized in funding as well as enhancing training for medical personnel through grants and scholarships for specialized disease control. In addition, for SDGS 3.5 prevention and treatment (rehabilitation) of substance abuse including narcotic drugs and alcohol abuse should be advanced through strengthening laws against illegal drugs and promoting responsible consumption. SDGS 3.6 can be addressed by reducing the number of national deaths from road traffic accidents among adolescents by promoting transport policies and road traffic designs that enable safe walking, and cycling including standardized road-worthy transport. This also calls for the need to protect public areas, especially around schools. Road traffic police officers can be deployed around school premises to control and monitor the picking and dropping of children.

5.0 CONCLUSION AND RECOMMENDATIONS

A substantial increase on the number of deaths among adolescents due to road accidents and suicide are a cause of concern particularly among the 10-year-olds. Male adolescents dominated the number of deaths than their female counterparts except for death due to gender-based violence. Furthermore, Ngamiland East recorded the highest number of deaths among adolescents. Results from a logistic regression model showed that age group 10-14 has the highest impact on the cause of death due to road accidents as compared to other factors. The derived parameters of adolescent mortality can give great encouragement and aspirations to planners and policy makers for further efforts in the reduction of mortality levels to ensure that all the mortality targets set have been met.

Therefore the study recommends that Motor Vehicle Fund should intensify raising road safety awareness targeting adolescent population in Ngamiland East and Ghanzi district, since the two regions recorded the highest number of adolescent death due to road accidents. Furthermore, life insurance institutions should consider those two regions when packaging their insurance policies.

This study recommends that in future censuses cause of death due to diseases, should be elaborated as per those specific diseases that lead to adolescent mortality for a more informative analysis. In addition, Cause of death due to drug and alcohol abuse was not captured. It is not clear as to whether there were no such deaths or they were captured under "don't know". However, this is an important indicator of SDGS 3.5 as it would give insight on the extent of drug use in Botswana and its associated mortality rates. Some responses on the causes of death specified none of the above and did not list those specific options not listed in the options provided. Inclusion of such information could perhaps shed some light on the main causes of death particularly to adolescents in Botswana.

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Statistics Botswana (2022) Transport & Infrastructure Statistics Report

ADULT MORTALITY ANALYSIS IN BOTSWANA USING 2022 POPULATION AND HOUSING CENSUS DATA

By;
Tebogo Laletatsang and Tiro Theodore Monamo

EXECUTIVE SUMMARY

The study of mortality is a core area of demography. It has been argued that it antedates other core subjects, including migration, fertility, and family and population composition. Demographic research on adult mortality is significant for understanding the health consequences of social inequality, human behaviour, biological factors and various other forces in human populations. Understanding adult mortality patterns is also crucial to comprehending the dynamics of human society. It is thus clear that the measurement of adult mortality has a very high priority. Therefore, the accurate estimation of adult mortality levels, trends, causes, and differentials is a cornerstone of public health.

The objective of this paper is to construct life tables for Botswana using the information on deaths that occurred during the last one year from the date of the census which was collected in the year 2022. The study also analyses the levels and patterns of adult mortality in Botswana. The paper also compares and examines the changes in the age patterns of mortality and trends over time in adult mortality using the estimates from the previous censuses. The impact of the COVID-19 deaths on the overall levels of adult mortality was also assessed.

This study uses the age specific mortality rates of specific populations and geographical areas to compare rates of one population group or geographical area with another. The age range for which the deaths and the population used is restricted to five-year age groupings. This study also constructs life tables using the MORTPAK software in order to estimate life expectancies at birth.

Estimates from this study showed that life expectancy at birth increased from 68 years in 2011 to 69 years in 2022. Seven districts in Botswana now have a life expectancy at birth of 70 years and above compared to four districts in 2011. Sex differentials in life expectancy at birth still exists across all districts, with females experiencing higher life expectancy at birth compared to males.

The levels of adult mortality were slightly higher in the year 2022 compared to the years 2017 and 2011. Evidence showed that Botswana was heavily affected by the COVID-19 pandemic in 2021 hence increasing the number of deaths among the older adults. The study revealed that the older population were relatively at higher risk of dying compared to the younger population. The analysis of this paper depicts that differentials in levels of mortality exist mostly in older ages. However, there was no sex differentials of mortality between age 1 up to 45 years across all the places of residence.

This paper's findings suggest the following ways in which changes in policy and further research are likely to impact future trends and disparities in mortality in Botswana: social and economic policies that are not specifically directed at health; public health policies aimed at improving population health; and health care access and delivery policies that provide all individuals with greater access to health care and focuses most centrally on downstream targets.

1.0 INTRODUCTION

Demographic research on adult mortality is significant for understanding the health consequences of social inequality, human behaviour, biological factors, and various other forces in human populations. In turn, mortality patterns may profoundly influence the size and composition of these populations. Thus, understanding adult mortality patterns is crucial to comprehending the dynamics of the human society. A comprehensive exploration of adult mortality levels and patterns has the potential to contribute to the growing body of knowledge on this fundamental aspect of the human experience. By understanding the complexities and implications of mortality, this research strives to inform evidence-based policies, healthcare interventions, and societal responses to ultimately enhance the quality of life and reduce premature deaths in Botswana. This is in line with Sustainable Development Goal number 3, which seeks to ensure healthy lives and promote well-being at all ages. Further, analysis and tracking of adult mortality levels and trends will also help Botswana to understand its progress of achieving the country's Revised National Population Policy objective of improving overall population health by eliminating excess mortality.

The objective of this paper is to construct life tables for Botswana using the information on deaths that occurred during the last one year from the date of the census which was collected in the year 2022. While constructing the life table, the study will analyse the levels and patterns of adult mortality in Botswana. Moreover, the paper will also compare and examine the changes in the age patterns of mortality and trends over time in adult mortality using the estimates from the previous censuses. Life tables will be constructed for the whole country, rural, cities/towns, urban villages and districts by gender using the reported age specific death rates which will be derived from Botswana's 2022 population and housing census. The impact of the COVID-19 deaths on the overall levels of adult mortality will also be assessed.

2.0 LITERATURE REVIEW: OVERVIEW OF THE LEVELS AND TRENDS OF MORTALITY IN BOTSWANA

Botswana experienced declines in mortality levels since the 1980s, from the mid-1990s the country started experiencing an increase in the level of mortality. Between 1991 and 2001, the level of mortality went up because of the increased number of deaths associated with HIV/AIDS epidemic (Majelantle, 2015). Majelantle (2015) emphasised that, the introduction of free ARV's decreased mortality levels between the years 2001 and 2011. This demographic change could have also resulted from the socio-economic change and investment in public health and other social services offered by the Government of Botswana (UNFPA, 2018). It is known that mortality is influenced by socio-economic and health conditions that prevail at a particular time and by the National policies and interventions programmes.

The estimates from the recent Botswana's vital statistics report indicates that crude death rate decreased from 5.8 in the year 2016 to 5.2 in the year 2020, and then increased from 5.2 in 2020 to 7.3 in 2021, while the infant mortality rate increased from 16.5 in 2020 to 18.6 deaths per 1000 live births in 2021 (Statistics Botswana, 2024). The reason behind the increase in these death rates in 2021 could be that, Botswana was heavily affected by the COVID-19 pandemic in 2021 (UNICEF, 2022). Life expectancy at birth (the average number of years a newly born baby would expect to live) has increased from 55.5 in 1971 to 56.5 in 1981 increased to 65.3 years in 1991, declined to 55.6 in 2001 and increased to a record high of 68 years in 2011 (Majelantle, 2015).

3.0 THEORETICAL FRAMEWORK

3.1 The social ecological theory

The social ecological theory is based on the premises that there are interrelationships between an individual and their environment. An individual's interaction with their environment (e.g. place of residence, district of residence, community structure, societal customs, economy) influence personal outcomes such as health and mortality (Bronfenbrenner, 1979). The theory illustrates why there are differences in health outcomes like mortality across different community environments. The model is used to study health outcomes and population segments as it relates to the environment.

The social ecological framework is a multilevel conceptualization of health that include intrapersonal, interpersonal, organisational, environmental, and public policy factors. At individual level are personal factors that directly influence health outcome/ mortality (age, sex, education level, socioeconomic status, employment); at social environment level are the relationships (family, peers), cultural norms and values, socioeconomic status of the community, institutions and organisations, access to social support, influence of health and other professionals, and the overall society in which the individual interacts; at physical environment level is the natural and built environments; and at policy level are the legislation and policies (health, education, environmental policies). These levels allow the design of appropriate strategies and interventions that target both the individual and the specific levels where the need is required. A study by Chisumpa et al. (2017) has also applied this model to investigate the relationship between the environment and adult mortality in sub-Saharan Africa.

4.0 METHODS

This study uses the age specific mortality rates of specific populations and geographical areas to compare rates of one population group or geographical area with another. The age range for which the deaths and population used is restricted to five-year age groupings and thus provide much more specific and useful comparisons.

Life expectancy and life span are also critical measures used in mortality analysis. Life span refers to the maximum number of years a person can live. Life expectancy is a summary measure of the average number of additional years a group of individuals can expect to live at a given age (Modig et al. 2020). This study also constructs life tables using the MORTPAK software in order to estimate life expectancies at birth. The life table is one of the most fundamental and elegant demographic tools because in addition to providing life expectancies at birth, it also provides information on life expectancy at any age, the proportion of the population that survives from one age to another, mortality probabilities by age and more. Life tables are constructed with data on the age-specific distribution of a population and the number of individuals who die in specific age groups during a particular year. This study assumes that the deaths taking place in the last twelve months prior the 2022 census were accurately reported. This is because the age specific death rates reported in the 2022 census were consistent with the deaths reported in the Botswana's 2021 vital statistics report. An overall of 17520 deaths were reported in 2022 census whereas the 2021 vital statistics reported an overall deaths of 17590 (Statistics Botswana, 2024). The analysis from Botswana's 2022 PHC data also showed that the coverage of the vital registration of deaths was over 90%. In addition, the U.S. Census Bureau recommends that if the completeness of the vital registration data is more than 70%, then the data is sufficient to be used for data analysis.

5.0 EVALUATION AND ASSESSMENT OF THE AGE-SEX DATA

Population statistics, whether they are obtained by enumeration, registration or other means are subject to errors. The errors may be large or small depending on the obstacles to accurate recording which are present in the concerned area, the methods used in compiling the data and the relative efficiency with which these methods are applied. The significance of errors given their magnitude, depends on the uses to which data are put. Some applications are valid even if the statistics are subject to large errors; other applications require more accurate data. When dealing with any problem, it is advisable to know whether the data are accurate enough to provide an acceptably accurate answer. Therefore, this study starts by evaluating the quality and the accuracy of the age-sex data collected from Botswana's 2022 PHC data.

5.1 Whipple's index

The Whipple's index was developed to reflect preference for or avoidance of a terminal digit. The original Whipple's index measures age heaping for ages ending 0 and 5 in the age range 23 to 62 years. It assumes a linear distribution of ages in each 5-year age range. The choice of the range 23 to 62 is standard, but largely arbitrary. In computing indexes of heaping, ages during childhood and old age are often excluded because they are strongly affected by other types of errors of reporting than preference for specific terminal digits.

Whipple's Index Interpretation (Ranges between 100 to 500)

Less than 105 = Highly accurate
105 – 109.9 = Fairly accurate
110 – 124.9 = Approximate
125 – 174.9 = Rough
175 or more = Very rough

Table 2 below shows the results of age-sex accuracy index for males and females for Botswana's 2022 PHC data.

TABLE 2: US Age-Sex Accuracy index, Botswana's 2022 Population and Housing Census

INDICATOR	SCORE
Males age ratio score	3.9
Females age ratio score	3.4
Sex ratio score	3.0
UN age-sex accuracy index	16.3

The UN age-sex accuracy score is 16.3, which, according to the classification, shows accurate data. The accuracy is slightly higher in female age data than for males. It is recommended that data is subjected to smoothing if the accuracy index is above 20. Therefore, this data was not subjected to any smoothing. The data is more accurate and can be analysed to produce reliable results.

5.3 Conclusion on the assessment of the quality of age-sex data

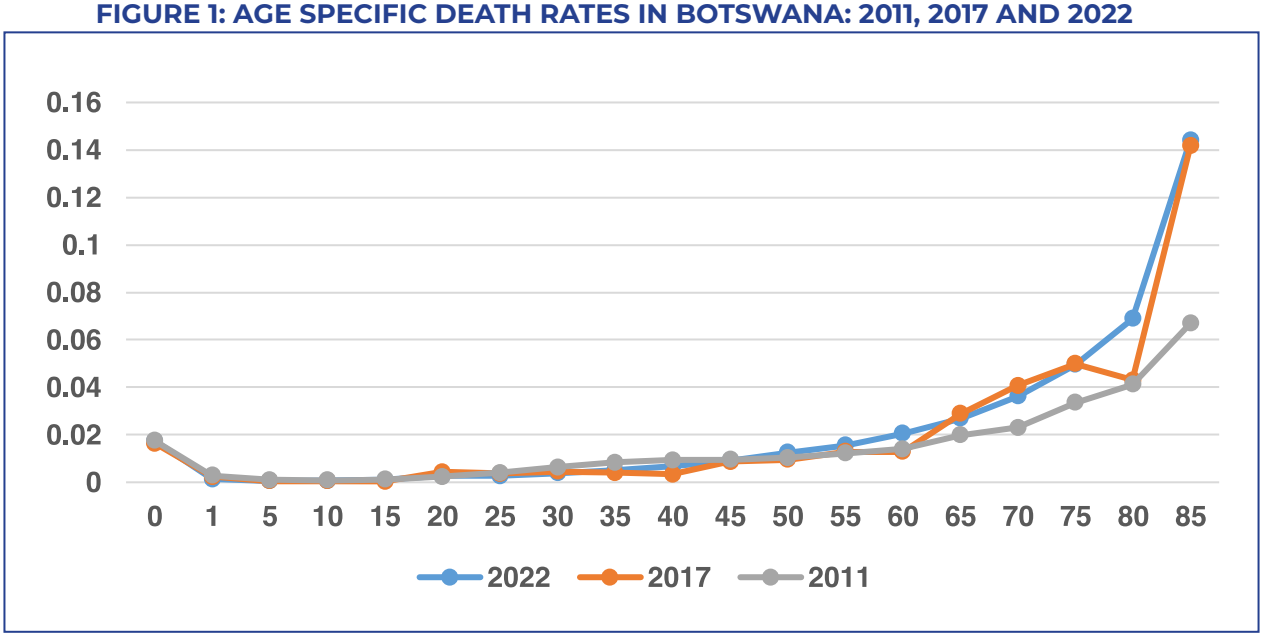
The assessment of the quality of the age-sex data from the 2022 population and housing census showed that the quality of the data was highly accurate. Therefore, this study will draw meaningful conclusions from its results.

6.0 FINDINGS AND DISCUSSIONS

6.1 Adult Mortality Patterns in Botswana

Figure 1 below shows the age pattern of mortality by age calculated from the age distribution of deaths from Botswana's 2011 census data, 2017 demographic survey data and 2022 census data. The age pattern of mortality shows that mortality during the first year of life up to 25 years of age was the same in the years 2011, 2017 and 2022. From ages 50 – 62 years and ages 76 – 84 years, mortality in 2022 was high compared to the years 2017 and 2011. This is because Botswana was heavily affected by the COVID-19 pandemic in 2021, with older adults being affected the most. Evidence showed that the risk of death increased exponentially with age, with the risk of death being as low as 0.1% in children and as high as 14.8% in older adults (Promislow, 2020). In the year 2011, the lower level of mortality between ages 50 to 85 years is believed to have been the result of the introduction of free ARVs between the period of 2001 and 2011 (Majelantle, 2015).

FIGURE 1: AGE SPECIFIC DEATH RATES IN BOTSWANA: 2011, 2017 AND 2022

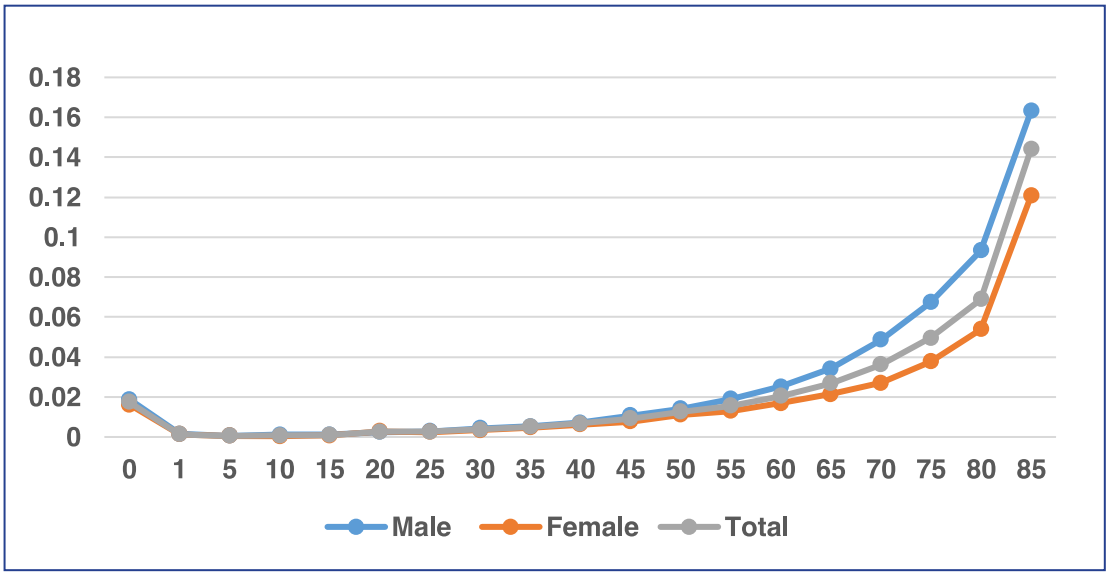


Source: Statistics Botswana (2011, 2017 and 2022)

6.1.1 Age Patterns of Mortality in Botswana

The data on the Distribution of deaths by age and sex in 2022 shows that the levels of mortality between males and females were the same from age 0 up to age 45 years (see figure 2). There was no gap of mortality between males and females from age 0 up to age 45 years. From age 45 years up to 85 years, the level of mortality was higher among males than females. The gender differentials in mortality at ages 45 and above can be explained by differentials in health seeking behaviours between men and women (Letshwenyo-Maruatona, 2017) and high risk behaviours among men (Keetile, 2014). The most common high-risk behaviours among men include violence, reckless driving, alcoholism, tobacco use disorder, risky sexual behaviours, and eating disorders.

FIGURE 2: AGE SPECIFIC DEATHS RATES BY SEX IN BOTSWANA



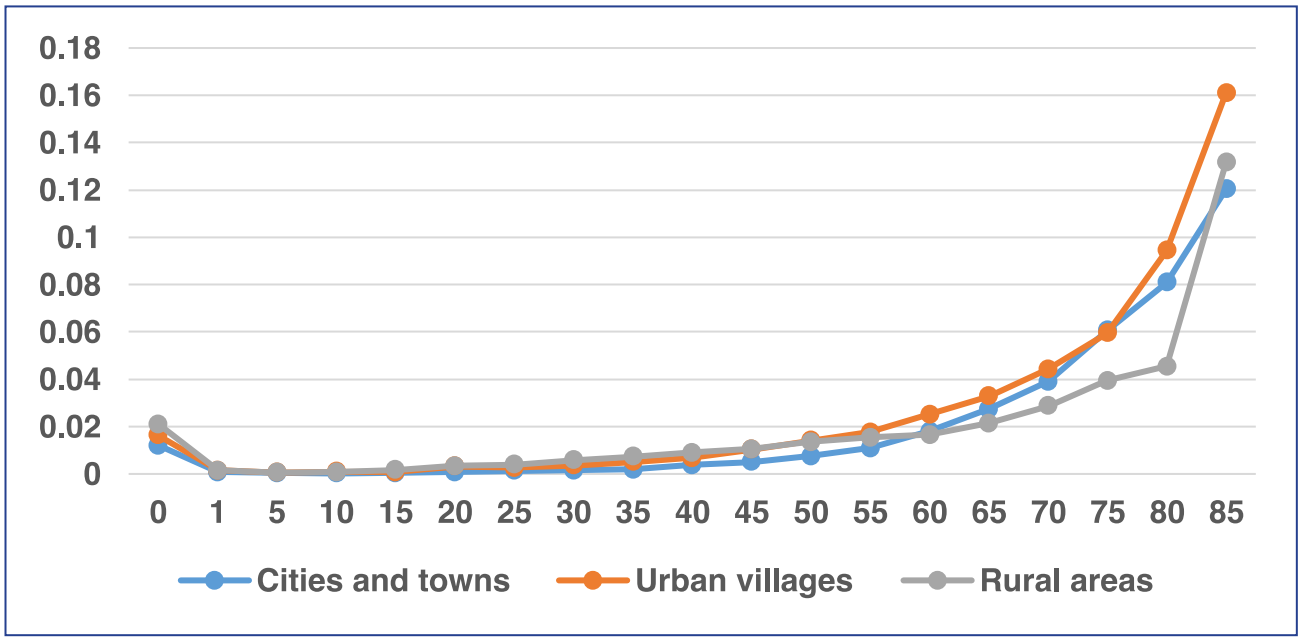
Source: Statistics Botswana (2022)

6.1.2 Age Patterns of Mortality by Places of Residence

Figure 3 below shows the age patterns of mortality in 2022 by places of residence (cities/ towns, urban villages and rural area). The graph shows that, the level of infant mortality (under 1 year) is higher in rural areas, followed by urban areas and it is the lowest in cities and towns. There is no variation in mortality across all the three places of residence among the deaths occurring between ages 1 to 10 years of age. Mortality differences for ages 15 to 55 years is very small compared to those aged 55 years and above for all the three places of residence. From age 55 years and above, urban villages experienced the highest mortality compared to rural areas and cities/towns.

This finding clearly indicates that the intervention programmes aimed at narrowing the gap of mortality across the three places of residence for all ages are becoming successful. However, rural areas did not gain the same benefits as urban and cities/ towns residence from the population health intervention programmes in Botswana, although the mortality gap between the three groups is not that much.

FIGURE 3: AGE SPECIFIC DEATHS RATES BY PLACE OF RESIDENCE

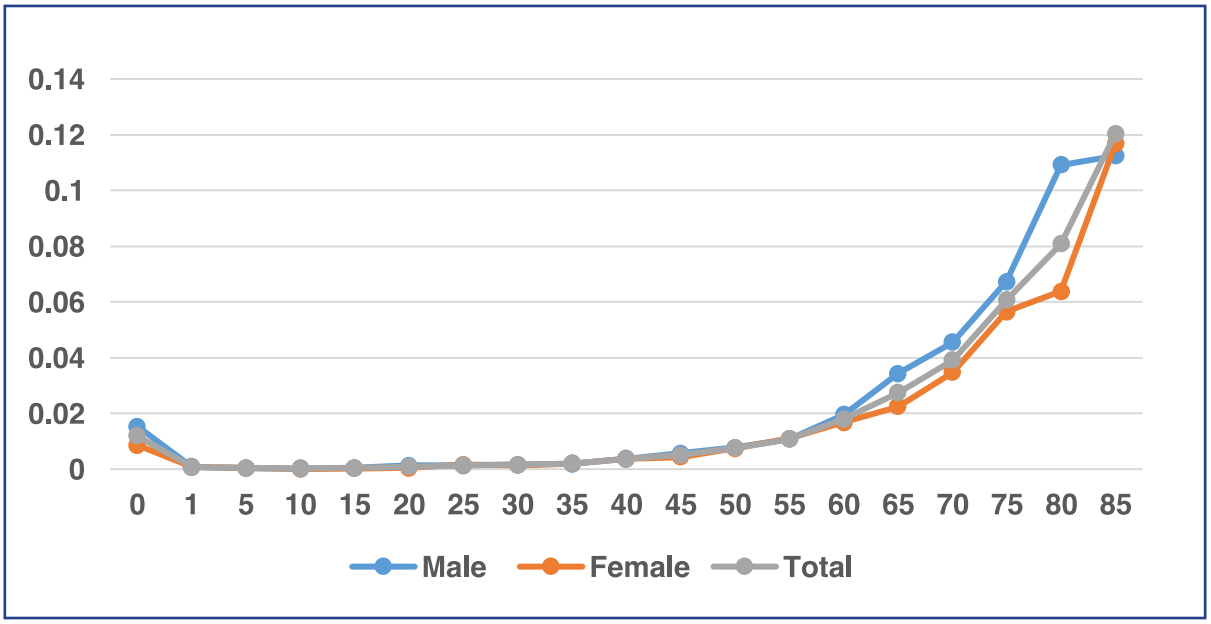


Source: Statistics Botswana (2022)

6.1.3 Age Specific Death Rates by Sex in Cities and Towns

The sex differentials in the age pattern of mortality are more noticeable when we disaggregate the data by places of residence. In cities and towns, infant mortality is higher among males than females (see figure 4). There are no gender differentials in mortality among those who are aged between 1 and 55 years. From age 60 years and above, males experienced higher levels of mortality compared to their female counterparts, although the gap between the two genders narrowed down at the age of 85 years.

FIGURE 4: AGE SPECIFIC DEATH RATES BY SEX IN CITIES AND TOWNS

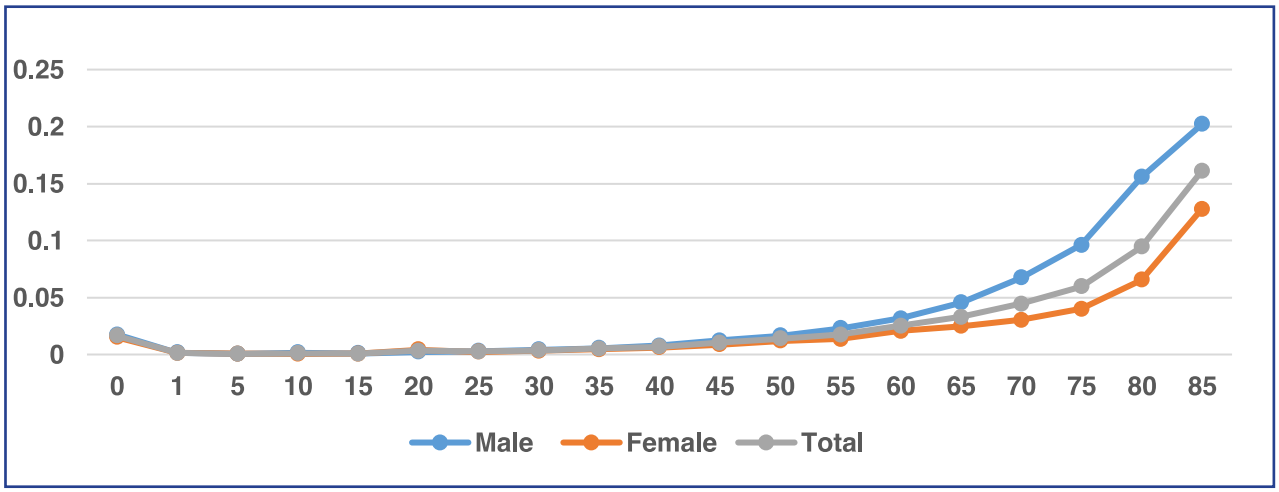


Source: Statistics Botswana (2022)

6.1.4 Age Specific Death Rates by Sex in Urban Villages

In urban villages there are no gender differentials in mortality from infant stage up to the age of 40 years. The sex differentials in urban villages are slightly different from that of cities/towns **(see figure 5 below)**. The mortality differentials for those aged 55 years and above is slightly higher than those in cities and towns, with males experiencing higher levels of mortality as compared to females.

FIGURE 5: AGE SPECIFIC DEATH RATES BY SEX IN URBAN VILLAGES

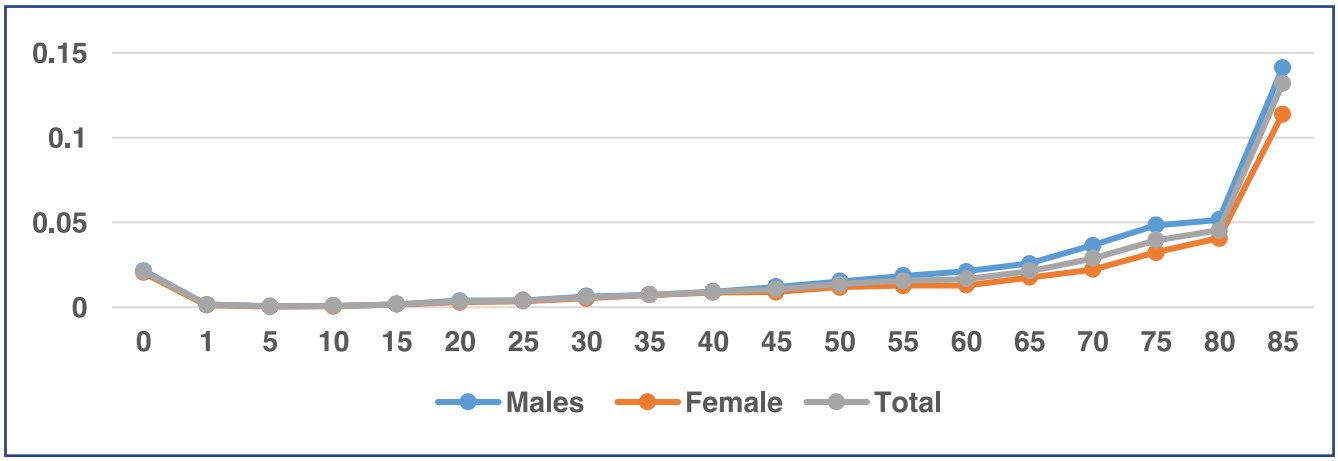


Source: Statistics Botswana (2022)

6.1.5 Age Specific Death Rates by Sex in Rural Areas

For the rural areas (see figure 6 below) there is yet another slightly sex differential of mortality by age. There are no sex differentials in mortality from infant stage up to the age of 40 years. From age 45 to 85 years, the level of mortality is higher among males than females, however, the differential is not as wider as the one in urban villages.

FIGURE 6: AGE SPECIFIC DEATH RATES BY SEX IN RURAL AREAS



Source: Statistics Botswana (2022)

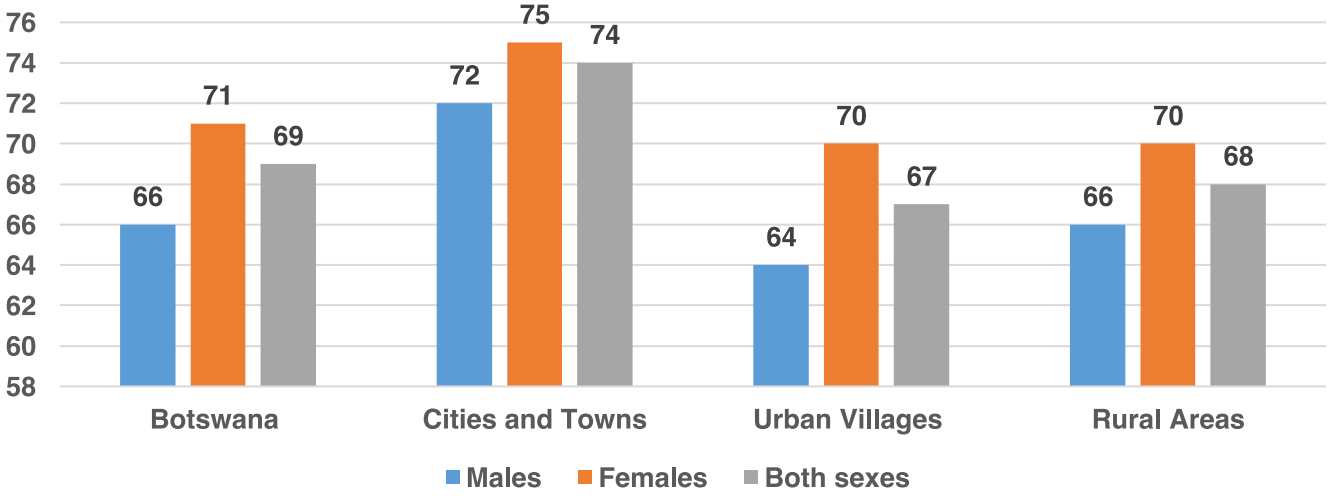
6.2 Analysis of Life Expectancy in Botswana

The 2022 census shows that the average life expectancy at birth for both sexes in Botswana stands at 69 years, for females it is 71 years and 66 years for males showing a gap of 5 years. The sex differentials in life expectancy at birth are more prominent in cities and towns, where females expect to live up to 75 years while males expects to live up to 72 years, showing a gap of 3 years. In urban villages, life expectancy at birth is 67 years, the gap between female life expectancy and male life expectancy is 6 years, 70 for females and 64 for males. In rural areas, life expectancy at birth is estimated at 68 years, at birth males expects to live up to 66 years while female expects to live up to 70 years showing a gap of 4 years. **(See Table 3 and figure 7)**

TABLE 3: Life Expectancy at Birth by sex for Botswana and Places of Residence

	MALES	FEMALES	BOTH SEXES
Botswana	66	71	69
Cities and Towns	72	75	74
Urban Villages	64	70	67
Rural Areas	66	70	68

FIGURE 7: LIFE EXPECTANCY AT BIRTH BY SEX FOR BOTSWANA AND PLACES OF RESIDENCE



Source: Statistics Botswana (2022)

Life expectancy at birth by sex and district

Table 4 below shows several districts and sub-districts in Botswana ranked by the level of life expectancy at birth from the highest to the lowest. The table shows that the level life expectancy at birth for both sexes for seven districts in Botswana is more than 70 years. The estimated life expectancy is as high as 76 years in Gaborone followed by Francistown with Life expectancy at birth of 73 years, South-East with 72 years, Kweneng East with 71 years and Kgatleng wards, Central Serowe/ Palapye and North-East all recording a life expectancy of 70 years.

All other districts and sub-districts that were data permitted recorded estimates of life expectancy at birth of more than 60 years, except for Ghanzi district. Only one district recorded an estimated life expectancy at birth of less than 60 years: Ghanzi (58).

Generally, females expect to live longer than their male counterparts in all districts with the exception of Lobatse and Kgalagadi South, where males expect to live longer than females.

TABLE 4: Life Expectancy at Birth by sex and district

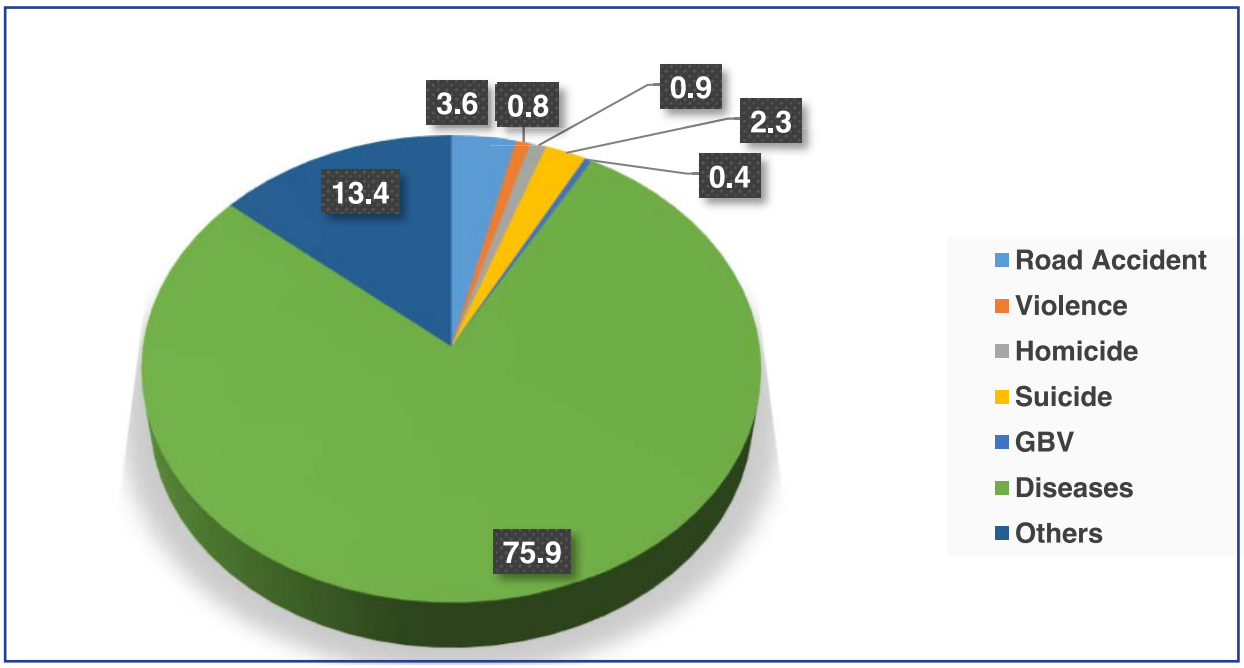
	MALES	FEMALES	BOTH SEXES
Gaborone	74	78	76
Francistown	72	73	73
South East	69	74	72
Kweneng East	68	73	71
Kgatleng Wards	68	73	70
Central Serowe/ Palapye	67	73	70
North East	66	74	70
Central Boteti	66	72	69
Selibe Phikwe	66	72	69
Lobatse	68	67	68
Kweneng West	65	71	68
Central Mahalapye	65	70	68
Central Bobonong	65	71	68
Kgalagadi North	66	70	68
Southern	64	69	67
Central Tutume	64	70	67
Ngwaketse West	64	68	66
Ngamiland West	62	70	66
Barolong	63	66	65
Kgalagadi South	66	61	64
Ngamiland East	61	62	62
Chobe	59	62	61
Ghanzi	56	60	58

Source: Statistics Botswana (2022)

6.3 Causes of Death during Adulthood in Botswana, 2022

Figure 8 below shows the distribution of causes of death for adults who died at the ages of 18 years and above in the 2022 census data. The chart displays that majority of the deaths were caused by diseases (75.9%), followed by other factors (13.4%) and road accidents (3.6%). Evidence from the 2019 Botswana's Centre for Disease Control and Prevention (CDC) Factsheet shows that the top five major diseases that causes death in Botswana are: HIV/AIDs, Lower respiratory infections, Ischemic heart disease, Stroke and diabetes (Centers for Disease Control and Prevention (CDC), 2019).

FIGURE 8: CAUSES OF DEATH DURING ADULTHOOD IN BOTSWANA, 2022



Source: Statistics Botswana (2022)

7.0 CONCLUSIONS

Estimates from this study showed that the levels of adult mortality was slightly higher in the year 2022 compared to the years 2017 and 2011. These higher rates in 2022 could have been caused by the direct impact of the COVID-19 crisis in the year 2021. Botswana was heavily affected by the COVID-19 pandemic in 2021. Evidence has shown that, the mortality risk from COVID-19 seemed to generally follow a similar pattern to the mortality risk from all causes, so those who were at a higher risk of dying during regular times were also at a higher risk of dying from COVID-19. It is also evident in this study that 75.9 percent of the adulthood deaths in the year preceding the 2022 census were attributed to diseases.

As with baseline mortality, the mortality risk from COVID-19 differs considerably across ages and genders. The mortality risk from COVID-19 increases exponentially with age, similarly to the normal mortality pattern observed across ages. Given the exponential pattern of mortality risk across ages, the age structure of a population is clearly a determinant in the overall mortality for COVID-19 experienced in any given population. Therefore, the older population were relatively at higher risk of dying compared to the younger population. The results from this study also revealed that, the level of mortality was higher among males in older ages compared to that of females in older ages in the year preceding the 2022 census. Again, the differences between genders in mortality risk from COVID-19 are largely in line with differences in baseline mortality. One global study concluded that males were nearly 40% more likely to die of COVID-19 than females, and nearly three times more likely to require intensive care (Peckham, et al., 2020).

The analysis of this paper depicts that differentials in levels of mortality exist mostly in older ages. These differentials in mortality are usually associated with differing levels of social and economic development between places of residence, differentials in individual living standards and their socio-economic characteristics. However, there is no sex differentials of mortality between age 1 up to 45 years across all the places of residence. This means policies, healthcare interventions, and societal responses that enhance the quality of life and reduce premature deaths in Botswana are becoming successful across all places of residence.

Overall, Botswana's goal to ensure healthy lives and promote well-being at all ages is becoming fruitful. This is shown by the national increase of life expectancy at birth from 68 years in the year 2011 to 69 years in the year 2022. Seven districts in Botswana now have a life expectancy at birth of 70 years and above compared to four districts in 2011. However, sex differentials in life expectancy at birth still exists across all districts, with females experiencing higher life expectancy at birth compared to males. In this context, it is difficult to explain the widening sex differential in life expectancy because the health inequalities may be related to biological variations mainly outside the control of the individual's concerns.

8.0 RECOMMENDATIONS

This paper's findings suggest the following ways in which changes in policy and further research are likely to impact future trends and disparities in mortality in Botswana.

Social and Economic Policies

These are policies that are not specifically directed at health. For example, minimum wage laws, family leave policies, civil rights legislation, zoning regulations, and tax law. The health-in-all-policies approach recognizes that a broad range of policies outside of the health care and public health sector have important health implications (WHO, 2014). Social and economic policies tend to operate on broad scales and have their greatest influence on upstream influences on health at all ages. Therefore, Policies targeting upstream social and economic factors may be important for mortality disparities because they tend to focus on vulnerabilities of population subgroups that are due to social and economic inequalities. Research on the mortality of economic and social structure and change is vital. Further research in this area would be stimulating and can provide stronger empirical support for social and economic policies to promote the public health and well-being in Botswana.

Public Health Policies

These are policies aimed at improving population health by promoting and supporting healthy behaviours, by eliminating environmental hazards, and by promoting access to preventive interventions. The public health strategies to promote healthy behaviours can include communication and education campaigns, strategies that create healthier environments (e.g., building walkable neighbourhoods, subsidising access to healthy foods, limiting portion sizes, restricting advertising of unhealthy products), and laws and regulations (e.g., limits on the density of tobacco outlets, taxation of unhealthy products, restrictions on sales to minors, required use of seatbelts). Strategies to eliminate environmental hazards may include creating and enforcing air pollution and water quality standards and cleaning up hazardous sites. Preventive interventions include facilitating access to screening programs and tobacco cessation programs and implementing harm reduction strategies. The major feature of public health strategies is that they impact the population as a whole and are more focused on preventing than on treating adverse health outcomes.

Health Care Access and Delivery

These are policies that provide all individuals with greater access to health care and focuses most centrally on downstream targets. These policies tend to have their greatest influence on individual-level health outcomes that are highly sensitive to interventions by the health care system.

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APPENDICES A: LIFE TABLES

TABLE A1: Botswana –BOTH SEXES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.017413	0.017142	100,000.000000	1,714.204223	98,443.129390	0.980653	6,892,909.226514	68.929092
1	0.001340	0.005343	98,285.795777	525.115814	391,883.602945	0.995621	6,794,466.097124	69.129685
5	0.000511	0.002553	97,760.679963	249.598318	488,179.404020	0.996833	6,402,582.494179	65.492410
10	0.000758	0.003782	97,511.081645	368.808738	486,633.386380	0.995951	5,914,403.090159	60.653651
15	0.000967	0.004824	97,142.272907	468.615216	484,662.888477	0.991198	5,427,769.703779	55.874436
20	0.002699	0.013413	96,673.657692	1,296.684416	480,396.894798	0.986206	4,943,106.815302	51.131890
25	0.002702	0.013421	95,376.973276	1,280.095659	473,770.318966	0.984110	4,462,709.920503	46.790224
30	0.003824	0.018948	94,096.877616	1,782.901267	466,241.943699	0.978264	3,988,939.601537	42.391838
35	0.005005	0.024731	92,313.976350	2,283.017979	456,107.806635	0.971335	3,522,697.657839	38.159960
40	0.006736	0.033146	90,030.958371	2,984.201461	443,033.371274	0.961179	3,066,589.851203	34.061504
45	0.009238	0.045191	87,046.756910	3,933.708452	425,834.186721	0.947140	2,623,556.479930	30.139623
50	0.012556	0.060932	83,113.048458	5,064.239349	403,324.767275	0.932227	2,197,722.293209	26.442566
55	0.015597	0.075135	78,048.809108	5,864.166764	375,990.217066	0.914449	1,794,397.525935	22.990710
60	0.020471	0.097504	72,184.642345	7,038.267571	343,823.755687	0.889194	1,418,407.308868	19.649710
65	0.026847	0.125992	65,146.374774	8,207.942594	305,725.938772	0.855483	1,074,583.553181	16.494909
70	0.036162	0.166107	56,938.432180	9,457.871159	261,543.246159	0.808717	768,857.614409	13.503316
75	0.049570	0.220824	47,480.561021	10,484.844023	211,514.394031	0.749601	507,314.368250	10.684675
80	0.068848	0.295058	36,995.716998	10,915.899267	158,551.354601	0.463991	295,799.974220	7.995519
85	0.190019	...	26,079.817731	26,079.817731	137,248.619618	...	137,248.619618	5.262637

TABLE A2: Botswana - MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.018710	0.018399	100000	1839.883435	98335.63345	0.979234841	6644480.671	66.44480671
1	0.001445	0.005761	98160.11657	565.5375824	391281.787	0.995371405	6546145.038	66.68843994
5	0.000510	0.002548	97594.57898	248.6860474	487351.1798	0.995987667	6154863.251	63.06562634
10	0.001099	0.005480	97345.89294	533.4800398	485395.7646	0.994740745	5667512.071	58.22035117
15	0.001084	0.005404	96812.4129	523.1704701	482842.9445	0.991385808	5182116.307	53.52739542
20	0.002509	0.012475	96289.24243	1201.245113	478683.6428	0.986361365	4699273.362	48.80372141
25	0.002905	0.014425	95087.99731	1371.684081	472155.0514	0.982409411	4220589.719	44.38614587
30	0.004280	0.021185	93716.31323	1985.35778	463849.566	0.976360004	3748434.668	39.99767531
35	0.005305	0.026193	91730.95545	2402.745683	452884.164	0.969595215	3284585.102	35.80672507
40	0.007236	0.035568	89328.20977	3177.24634	439114.3183	0.956579927	2831700.938	31.69996293
45	0.010699	0.052165	86150.96343	4494.036229	420047.9424	0.939922444	2392586.62	27.77202395
50	0.014157	0.068447	81656.9272	5589.180365	394812.4885	0.921095181	1972538.677	24.15641569
55	0.018950	0.090594	76067.74683	6891.287095	363659.8805	0.896480936	1577726.189	20.74106641
60	0.025086	0.118227	69176.45974	8178.51127	326014.1502	0.863666018	1214066.308	17.55028102
65	0.034191	0.157826	60997.94847	9627.087328	281567.343	0.814604148	888052.1581	14.55872173
70	0.048715	0.217508	51370.86114	11173.56061	229365.9256	0.749713872	606484.815	11.80600834
75	0.067390	0.288288	40197.30053	11588.38889	171958.8162	0.673924001	377118.8894	9.38169689
80	0.093354	0.378153	28608.91165	10818.54927	115887.1735	0.435137784	205160.0731	7.171194615
85	0.199281	...	17790.36238	17790.36238	89272.89968	...	89272.89968	5.018048413

TABLE A3: Botswana - FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.016120	0.015889	100000	1588.921989	98566.2632	0.981999362	7140514.337	71.40514337
1	0.001233	0.004918	98411.07801	484.0038174	392433.4179	0.995945827	7041948.074	71.55645702
5	0.000512	0.002558	97927.07419	250.5149524	489009.0836	0.997694944	6649514.656	67.90271956
10	0.000411	0.002051	97676.55924	200.3623589	487881.8903	0.997198194	6160505.572	63.07046051
15	0.000849	0.004239	97476.19688	413.2180586	486514.9399	0.991020759	5672623.682	58.19496311
20	0.002882	0.014315	97062.97882	1389.499171	482146.405	0.986047039	5186108.742	53.43034806
25	0.002509	0.012470	95673.47965	1193.009871	475419.0352	0.985714962	4703962.337	49.16683656
30	0.003391	0.016817	94480.46978	1588.905031	468627.6563	0.980091431	4228543.302	44.75573959
35	0.004715	0.023314	92891.56475	2165.683532	459297.9502	0.973018917	3759915.646	40.47639477
40	0.006245	0.030764	90725.88122	2791.118051	446905.594	0.965832389	3300617.695	36.38011173
45	0.007768	0.038131	87934.76317	3353.010669	431635.8973	0.954277095	2853712.101	32.45260462
50	0.011055	0.053835	84581.7525	4553.431638	411900.2504	0.941870735	2422076.204	28.63591889
55	0.012884	0.062456	80028.32086	4998.280895	387956.7915	0.928733507	2010175.954	25.11830727
60	0.016950	0.081395	75030.03996	6107.106088	360308.4716	0.908975336	1622219.162	21.62092894
65	0.021334	0.101376	68922.93388	6987.144721	327511.5139	0.887268215	1261910.691	18.30901007
70	0.026954	0.126463	61935.78916	7832.585411	290590.5564	0.852497937	934399.1768	15.08657901
75	0.037789	0.173027	54103.20374	9361.332972	247727.8499	0.800707903	643808.6204	11.8996395
80	0.053917	0.239034	44741.87077	10694.83042	198357.6472	0.499198997	396080.7706	8.852575087

TABLE A4: Cities and towns - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.015355	0.015143	100000	1514.257491	98616.01967	0.983648435	7213684.961	72.13684961
1	0.000781	0.003118	98485.74251	307.0940386	393208.1976	0.997363464	7115068.941	72.24465958
5	0.000298	0.001490	98178.64847	146.2949231	490527.505	0.998479183	6721860.743	68.46560681
10	0.000311	0.001552	98032.35355	152.1060537	489781.5026	0.998416777	6231333.238	63.56404812
15	0.000366	0.001830	97880.24749	179.1419944	489006.0692	0.996114776	5741551.736	58.65894174
20	0.001279	0.006376	97701.1055	622.9547239	487106.1709	0.993424699	5252545.666	53.76137393
25	0.001254	0.006250	97078.15078	606.7610264	483903.3011	0.992887985	4765439.495	49.08869254
30	0.001635	0.008142	96471.38975	785.4459351	480461.7736	0.991299131	4281536.194	44.38140889
35	0.001936	0.009639	95685.94381	922.28452	476281.3386	0.986310783	3801074.421	39.72448062
40	0.003780	0.018738	94763.65929	1775.640857	469761.4201	0.97669026	3324793.082	35.08510654
45	0.005651	0.027884	92988.01844	2592.906119	458811.4034	0.967363864	2855031.662	30.7032208
50	0.007696	0.037789	90395.11232	3415.935069	443837.5723	0.955956242	2396220.259	26.5082945
55	0.010735	0.052367	86979.17725	4554.829621	424289.2978	0.929638872	1952382.686	22.4465527
60	0.019504	0.093333	82424.34763	7692.897244	394435.8244	0.875526848	1528093.388	18.53934465
65	0.034240	0.158226	74731.45038	11824.46444	345339.1541	0.819318896	1133657.564	15.16975194
70	0.045495	0.204628	62906.98595	12872.51358	282942.8944	0.758808991	788318.41	12.5314923
75	0.067227	0.288473	50034.47237	14433.58743	214699.6122	0.644635493	505375.5157	10.10054652
80	0.109195	0.424511	35600.88494	15112.97016	138402.9903	0.523858054	290675.9034	8.164850506
85	0.134547	...	20487.91478	20487.91478	152272.9131	...	152272.9131	7.432328511

TABLE A5: Cities and towns - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.008604	0.008537	100000	853.6565159	99210.88709	0.990320291	7490418.495	74.90418495
1	0.000645	0.002577	99146.34348	255.4842716	395949.2583	0.997604731	7391207.608	74.5484639
5	0.000389	0.001942	98890.85921	192.0768905	493974.1038	0.998899652	6995258.349	70.73715817
10	0.000051	0.000257	98698.78232	25.34052117	493430.5603	0.999172992	6501284.246	65.86995394
15	0.000335	0.001671	98673.4418	164.921939	493022.4894	0.998222907	6007853.685	60.8862281
20	0.000368	0.001841	98508.51986	181.3067127	492146.3428	0.995615779	5514831.196	55.98329163
25	0.001519	0.007569	98327.21315	744.1923335	489988.6644	0.992183031	5022684.853	51.08133031
30	0.001478	0.007365	97583.02082	718.7312871	486158.4381	0.991585563	4532696.189	46.44964002
35	0.002016	0.010031	96864.28953	971.6604538	482067.6886	0.986296955	4046537.751	41.77533093
40	0.003588	0.017789	95892.62907	1705.873117	475461.8935	0.980344386	3564470.062	37.17147081
45	0.004384	0.021698	94186.75596	2043.623023	466116.398	0.971609496	3089008.169	32.79662982
50	0.007437	0.036553	92143.13293	3368.094922	452883.1184	0.955563822	2622891.771	28.46540689
55	0.010913	0.053198	88775.03801	4722.697246	432758.7234	0.933873638	2170008.652	24.44390564
60	0.016730	0.080439	84052.34077	6761.092975	404141.9633	0.907359736	1737249.929	20.66866804
65	0.022491	0.106708	77291.24779	8247.625922	366702.145	0.869675488	1333107.966	17.24785152
70	0.034657	0.160078	69043.62187	11052.39622	318911.8668	0.796964451	966405.8207	13.99703252
75	0.056545	0.247821	57991.22565	14371.43123	254161.421	0.740822348	647493.9539	11.16537798
80	0.063793	0.275368	43619.79442	12011.50516	188288.4605	0.52129955	393332.5329	9.017294514
85	0.154154	...	31608.28927	31608.28927	205044.0724	...	205044.0724	6.487034799

TABLE A6: Urban Villages - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.017488	0.017215	100000	1721.498974	98436.86522	0.980290618	6410288.707	64.10288707
1	0.001496	0.005962	98278.50103	585.9214247	391708.4439	0.995341196	6311851.842	64.22413627
5	0.000493	0.002461	97692.5796	240.4319641	487861.8181	0.995031358	5920143.398	60.59972438
10	0.001502	0.007482	97452.14764	729.1722472	485437.8076	0.993968844	5432281.58	55.74306685
15	0.000946	0.004721	96722.97539	456.5838263	482510.0566	0.99254293	4946843.772	51.14445407
20	0.002229	0.011088	96266.39156	1067.443004	478911.9454	0.986958385	4464333.716	46.37479024
25	0.002959	0.014693	95198.94856	1398.720318	472666.1601	0.982687381	3985421.77	41.86413643
30	0.004089	0.020250	93800.22824	1899.407835	464483.0709	0.976445216	3512755.61	37.44932903
35	0.005519	0.027237	91900.82041	2503.072588	453542.2723	0.968203098	3048272.539	33.16915481
40	0.007621	0.037434	89397.74782	3346.515485	439121.0331	0.95238373	2594730.267	29.02455968
45	0.012177	0.059179	86051.23233	5092.44878	418211.7275	0.931143665	2155609.234	25.05030057
50	0.016443	0.079093	80958.78355	6403.282261	389415.2006	0.906946147	1737397.507	21.46027189
55	0.023008	0.108991	74555.50129	8125.868254	353178.6158	0.87356422	1347982.306	18.08025273
60	0.031589	0.146712	66429.63304	9746.01637	308524.202	0.8270015	994803.6902	14.9753001
65	0.045455	0.204605	56683.61667	11597.72615	255149.978	0.757107787	686279.4882	12.10719302
70	0.067216	0.287997	45085.89051	12984.616	193176.0351	0.668557024	431129.5102	9.562404231
75	0.096141	0.386792	32101.27452	12416.51029	129149.1951	0.538452124	237953.4751	7.412586531
80	0.155587	0.549644	19684.76422	10819.62152	69540.65841	0.360864679	108804.28	5.527334683
85	0.225785	...	8865.142709	8865.142709	39263.62162	...	39263.62162	4.428989235

TABLE A7: Urban Villages - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.015289	0.015080	100000	1508.033176	98635.5923	0.982462306	7021343.127	70.21343127
1	0.001398	0.005572	98491.96682	548.8097107	392595.5607	0.995419412	6922707.535	70.28702704
5	0.000601	0.003001	97943.15711	293.9040013	488981.0256	0.997426819	6530111.974	66.67246765
10	0.000429	0.002144	97649.25311	209.390611	487722.789	0.997882448	6041130.949	61.86561347
15	0.000515	0.002571	97439.8625	250.5533711	486690.0108	0.989643464	5553408.16	56.99318551
20	0.004066	0.020149	97189.30913	1958.28319	481649.5883	0.982765577	5066718.149	52.13246389
25	0.002326	0.011563	95231.02594	1101.191639	473348.6357	0.986605166	4585068.561	48.14679371
30	0.003296	0.016351	94129.8343	1539.095605	467008.2092	0.98062125	4111719.925	43.68136793
35	0.004582	0.022663	92590.7387	2098.394578	457958.1738	0.973807679	3644711.716	39.36367467
40	0.006119	0.030154	90492.34412	2728.736801	445963.1864	0.964247596	3186753.542	35.21572541
45	0.008603	0.042150	87763.60732	3699.242149	430018.9304	0.949894928	2740790.355	31.22923543
50	0.011941	0.058022	84064.36517	4877.620692	408472.8011	0.938477352	2310771.425	27.4881208
55	0.013613	0.065899	79186.74448	5218.317259	383342.4726	0.918595231	1902298.624	24.02294269
60	0.020785	0.098949	73968.42722	7319.073328	352136.567	0.891869837	1518956.151	20.53519601
65	0.024709	0.116432	66649.35389	7760.126009	314059.9825	0.872321323	1166819.584	17.50684015
70	0.030368	0.141276	58889.22788	8319.638969	273961.2194	0.841130504	852759.602	14.48074007
75	0.040130	0.182864	50569.58891	9247.342361	230437.1386	0.775025199	578798.3826	11.44558212
80	0.065493	0.283062	41322.24655	11696.77187	178594.5892	0.487329339	348361.244	8.430355876
85	0.174507	...	29625.47468	29625.47468	169766.6548	...	169766.6548	5.730428175

Table A8: Rural Areas -MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.021607	0.021196	100000	2119.604488	98099.64267	0.976175231	6589795.495	65.89795495
1	0.001631	0.006499	97880.39551	636.1195412	389987.973	0.994624307	6491695.852	66.32273826
5	0.000624	0.003116	97244.27597	303.0294207	485463.8063	0.996143722	6101707.879	62.74619065
10	0.000922	0.004599	96941.24655	445.8038658	483591.7231	0.993928672	5616244.073	57.9345147
15	0.001721	0.008573	96495.44268	827.2901351	480655.679	0.98616423	5132652.35	53.19061924
20	0.003924	0.019443	95668.15255	1860.104936	474005.4376	0.980022415	4651996.671	48.62638764
25	0.004035	0.019980	93808.04761	1874.281794	464535.9536	0.974393425	4177991.233	44.53766324
30	0.006502	0.032014	91933.76582	2943.130094	452640.779	0.965617613	3713455.28	40.39272455
35	0.007373	0.036212	88990.63573	3222.492811	437077.9084	0.959894647	3260814.501	36.64222055
40	0.009165	0.044833	85768.14291	3845.219623	419548.7444	0.948650216	2823736.592	32.922907
45	0.012064	0.058612	81922.92329	4801.668921	398005.0071	0.933861128	2404187.848	29.34694895
50	0.015340	0.073931	77121.25437	5701.659651	371681.4047	0.918601064	2006182.841	26.01335854
55	0.018557	0.088715	71419.59472	6335.976041	341426.934	0.906027452	1634501.436	22.88589627
60	0.020989	0.099761	65083.61868	6492.820964	309342.1752	0.891197485	1293074.502	19.867895
65	0.025692	0.120888	58590.79771	7082.92385	275684.9685	0.857620024	983732.3269	16.78987768
70	0.036523	0.167650	51507.87386	8635.291679	236432.9493	0.807810365	708047.3584	13.7463907
75	0.048387	0.215560	42872.58219	9241.596198	190992.9872	0.783948643	471614.409	11.00037332
80	0.051609	0.229769	33630.98599	7727.346026	149728.6931	0.466438834	280621.4218	8.344133054
85	0.197900	...	25903.63996	25903.63996	130892.7287	...	130892.7287	5.053063157

Table A9: Rural Areas -FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.020374	0.020011	100000	2001.068478	98219.1121	0.977953329	7008646.548	70.08646548
1	0.001263	0.005037	97998.93152	493.5846062	390757.5524	0.995901197	6910427.436	70.51533449
5	0.000455	0.002274	97505.34692	221.7156326	486972.4455	0.997457651	6519669.884	66.86474219
10	0.000563	0.002811	97283.63128	273.5058641	485734.3918	0.994608185	6032697.438	62.01143356
15	0.001857	0.009246	97010.12542	896.9380446	483115.4018	0.987801581	5546963.046	57.17921735
20	0.002968	0.014735	96113.18737	1416.257446	477222.1576	0.983413945	5063847.645	52.68629397
25	0.003727	0.018471	94696.92993	1749.142107	469306.9248	0.97807343	4586625.487	48.43478548
30	0.005262	0.025987	92947.78782	2415.413002	459016.6337	0.968964193	4117318.562	44.29711195
35	0.007364	0.036180	90532.37482	3275.489224	444770.6819	0.960075915	3658301.929	40.40877019
40	0.008760	0.042869	87256.8856	3740.6329	427013.6193	0.956963406	3213531.247	36.82839726
45	0.008917	0.043628	83516.25269	3643.640038	408636.4078	0.949652601	2786517.627	33.36497433
50	0.011890	0.057770	79872.61266	4614.212105	388062.6275	0.939439224	2377881.219	29.77092072
55	0.012825	0.062125	75258.40055	4675.406937	364561.2536	0.93816556	1989818.592	26.43982037
60	0.012944	0.062721	70582.99361	4427.036444	342018.8125	0.927607125	1625257.338	23.02618882
65	0.017579	0.084301	66155.95717	5577.034678	317259.0873	0.906080296	1283238.526	19.39717269
70	0.022187	0.105284	60578.92249	6377.98063	287462.2076	0.873913738	965979.4386	15.94580093
75	0.032275	0.149594	54200.94186	8108.11488	251217.1724	0.838031393	678517.231	12.51855056
80	0.040774	0.186236	46092.82698	8584.166182	210527.877	0.507306698	427300.0586	9.270424198
85	0.173033	...	37508.6608	37508.6608	216772.1817	...	216772.1817	5.779256765

Table A10: Gaborone - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.014459	0.014270	100000	1427.012452	98692.17922	0.985207471	7418972.037	74.18972037
1	0.000404	0.001615	98572.98755	159.1560299	393911.5562	0.998127127	7320279.858	74.26253419
5	0.000316	0.001577	98413.83152	155.2025971	491681.1511	0.998668161	6926368.302	70.38002885
10	0.000217	0.001086	98258.62892	106.7334072	491026.3111	0.998610283	6434687.15	65.48724749
15	0.000399	0.001991	98151.89551	195.4535397	490343.9236	0.995893675	5943660.839	60.55574177
20	0.001313	0.006547	97956.44197	641.320912	488330.4122	0.993323791	5453316.916	55.67083497
25	0.001255	0.006257	97315.12106	608.8586803	485070.2163	0.993122853	4964986.504	51.01968172
30	0.001518	0.007560	96706.26238	731.131545	481734.3169	0.992534678	4479916.287	46.32498638
35	0.001560	0.007773	95975.13084	746.0545234	478138.0151	0.988028166	3998181.97	41.65852066
40	0.003501	0.017369	95229.07631	1654.00773	472413.8263	0.978424206	3520043.955	36.96396197
45	0.005211	0.025740	93575.06858	2408.655995	462221.1227	0.968655542	3047630.129	32.56882603
50	0.007671	0.037672	91166.41259	3434.434877	447733.052	0.9544681	2585409.006	28.35922719
55	0.011114	0.054138	87731.97771	4749.652421	427346.9155	0.937749699	2137675.954	24.36598388
60	0.015115	0.072992	82982.32529	6057.083119	400744.4415	0.901447581	1710329.039	20.61076299
65	0.028007	0.131522	76925.24217	10117.38364	361250.1073	0.826471636	1309584.597	17.02412057
70	0.049669	0.221969	66807.85853	14829.2864	298562.9671	0.724977619	948334.49	14.19495417
75	0.077170	0.321356	51978.57213	16703.65033	216451.4689	0.694203884	649771.5229	12.50075745
80	0.066265	0.282271	35274.9218	9957.084027	150261.4504	0.65323218	433320.054	12.28408263

Table A11: Gaborone - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.003986	0.003971	100000	397.148156	99627.43994	0.994763975	7752915.874	77.52915874
1	0.000665	0.002657	99602.85184	264.6050116	397754.5475	0.997842152	7653288.434	76.83804522
5	0.000308	0.001540	99338.24683	153.008502	496308.7129	0.998960874	7255533.887	73.03867461
10	0.000107	0.000537	99185.23833	53.28237638	495792.9857	0.998894275	6759225.174	68.14749138
15	0.000353	0.001763	99131.95595	174.7510808	495244.7749	0.998631469	6263432.188	63.18277621
20	0.000197	0.000983	98957.20487	97.26649525	494567.0171	0.996999229	5768187.413	58.28971646
25	0.001165	0.005809	98859.93838	574.3124312	493082.9347	0.993663241	5273620.396	53.34436257
30	0.001241	0.006187	98285.62595	608.0775552	489958.3872	0.992774877	4780537.461	48.63923301
35	0.001756	0.008746	97677.54839	854.2513594	486418.3774	0.987721922	4290579.074	43.92594967
40	0.003215	0.015952	96823.29703	1544.550597	480446.0946	0.983863528	3804160.697	39.28972482
45	0.003283	0.016289	95278.74644	1551.967263	472693.3898	0.978443009	3323714.602	34.88411347
50	0.005789	0.028568	93726.77917	2677.558346	462503.5424	0.962777153	2851021.212	30.41842724
55	0.009554	0.046726	91049.22083	4254.342401	445287.8439	0.944420512	2388517.67	26.23325766
60	0.013682	0.066290	86794.87843	5753.642657	420538.9736	0.909963532	1943229.826	22.38876143
65	0.024173	0.114145	81041.23577	9250.416629	382675.1299	0.886974285	1522690.853	18.78908728
70	0.023725	0.112169	71790.81914	8052.740066	339422.9996	0.847894706	1140015.723	15.87968679
75	0.043841	0.197956	63738.07907	12617.31573	287794.9643	0.796862164	800592.7231	12.56066601
80	0.047059	0.211111	51120.76334	10792.13743	229332.918	0.552780967	512797.7588	10.03110527

Table A12: Francistown - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.015534	0.015317	100000	1531.66418	98600.87708	0.984051301	7170309.16	71.7030916
1	0.000476	0.001903	98468.33582	187.4342559	393424.7735	0.998240646	7071708.283	71.81707931
5	0.000199	0.000995	98280.90156	97.80174453	491160.0035	0.998467508	6678283.51	67.95097932
10	0.000415	0.002070	98183.09982	203.2777511	490407.3047	0.997916765	6187123.506	63.01617608
15	0.000437	0.002183	97979.82207	213.8453886	489385.6713	0.99736428	5696716.201	58.14172838
20	0.000670	0.003343	97765.97668	326.8499276	488095.7877	0.994732535	5207330.53	53.26321801
25	0.001489	0.007420	97439.12675	722.9682164	485524.7601	0.992121622	4719234.742	48.4326461
30	0.001683	0.008381	96716.15854	810.600736	481699.6125	0.987479504	4233709.982	43.77458789
35	0.003580	0.017758	95905.5578	1703.109639	475668.4945	0.977673266	3752010.37	39.12192845
40	0.005362	0.026470	94202.44816	2493.556808	465048.3703	0.970979217	3276341.875	34.77979542
45	0.006353	0.031279	91708.89135	2868.605662	451552.3023	0.965645632	2811293.505	30.65453593
50	0.007713	0.037859	88840.28569	3363.390312	436039.5084	0.958043432	2359741.203	26.56161205
55	0.009756	0.047680	85476.89538	4075.559083	417744.7872	0.940019346	1923701.694	22.50551668
60	0.016238	0.078335	81401.3363	6376.533524	392688.1817	0.872049151	1505956.907	18.5003954
65	0.038934	0.177712	75024.80277	13332.83704	342443.3954	0.837352207	1113268.726	14.8386758
70	0.030303	0.140849	61691.96574	8689.264544	286745.7328	0.823579765	770825.3302	12.49474419
75	0.052980	0.236057	53002.70119	12511.68113	236157.9834	0.645693493	484079.5974	9.133111831
80	0.130435	0.491206	40491.02006	19889.43571	152485.6733	0.384944012	247921.614	6.12287894

Table A13: Francistown - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.010417	0.010318	100000	1031.788972	99051.73703	0.988407327	7267607.904	72.67607904
1	0.000732	0.002922	98968.21103	289.2061543	395151.9265	0.996909402	7168556.167	72.43291652
5	0.000584	0.002913	98679.00487	287.4982864	492676.2787	0.998291567	6773404.241	68.64078382
10	0.000100	0.000500	98391.50659	49.18345743	491834.5743	0.999322893	6280727.962	63.83404605
15	0.000205	0.001026	98342.32313	100.9450797	491501.5495	0.997821462	5788893.388	58.86472074
20	0.000749	0.003738	98241.37805	367.2262416	490430.7945	0.994846185	5297391.838	53.92220614
25	0.001324	0.006598	97874.15181	645.7408675	487903.2049	0.99102346	4806961.044	49.11369299
30	0.002259	0.011236	97228.41094	1092.502541	483523.5222	0.988944733	4319057.839	44.42176723
35	0.002221	0.011049	96135.9084	1062.224221	478178.0407	0.983592958	3835534.317	39.89699979
40	0.004634	0.022927	95073.68418	2179.708246	470332.5537	0.974515023	3357356.276	35.31320265
45	0.005783	0.028532	92893.97593	2650.420928	458346.1395	0.957284449	2887023.722	31.07869691
50	0.012195	0.059293	90243.55501	5350.8248	438767.6318	0.933665377	2428677.583	26.91247683
55	0.015004	0.072403	84892.73021	6146.468841	409662.1466	0.90931209	1989909.951	23.44028689
60	0.022022	0.104176	78746.26136	8203.439769	372510.7426	0.919774844	1580247.805	20.06759149
65	0.012329	0.059881	70542.8216	4224.156248	342626.0102	0.882154956	1207737.062	17.12062311
70	0.042607	0.194180	66318.66535	12877.78678	302249.233	0.775612108	865111.0517	13.04475968
75	0.054622	0.239609	53440.87857	12804.89982	234428.1647	0.765244724	562861.8187	10.53242076
80	0.055249	0.243905	40635.97875	9911.321382	179394.9163	0.453786437	328433.654	8.082336493

Table A14: Lobatse - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.010870	0.010761	100000	1076.118564	99002.90803	0.980629457	6798988.272	67.98988272
1	0.004708	0.018624	98923.88144	1842.334452	391311.8204	0.988296382	6699985.364	67.7286947
5	0.000686	0.003426	97081.54698	332.5850479	484576.2723	0.996638441	6308673.544	64.98324079
10	0.000661	0.003297	96748.96194	318.9876843	482947.3405	0.996502831	5824097.271	60.1980337
15	0.000750	0.003741	96429.97425	360.7633221	481258.392	0.996190679	5341149.931	55.3888972
20	0.000765	0.003815	96069.21093	366.5329727	479425.1244	0.996326681	4859891.539	50.58739935
25	0.000711	0.003550	95702.67796	339.7328186	477664.043	0.996316378	4380466.415	45.77161797
30	0.000770	0.003842	95362.94514	366.3622371	475904.5094	0.996557569	3902802.372	40.92577432
35	0.000772	0.003855	94996.5829	366.2288654	474266.2408	0.976388702	3426897.862	36.07390663
40	0.010517	0.051465	94630.35404	4870.129929	463068.1993	0.950554988	2952631.621	31.20173914
45	0.006742	0.033060	89760.22411	2967.450233	440171.7867	0.982273909	2489563.422	27.73570863
50	0.001587	0.007907	86792.77387	686.3005934	432369.2614	0.967348225	2049391.635	23.61246846
55	0.015982	0.077629	86106.47328	6684.386832	418251.6374	0.852580163	1617022.374	18.77933577
60	0.044843	0.201338	79422.08645	15990.71958	356593.0493	0.843988855	1198770.737	15.09366966
65	0.021277	0.100950	63431.36686	6403.416237	300960.5595	0.853971588	842177.6872	13.276991
70	0.048193	0.217194	57027.95063	12386.10923	257011.7669	0.692144399	541217.1276	9.490383604
75	0.103448	0.412222	44641.8414	18402.33674	177889.2549	0.532105053	284205.3607	6.366344932
80	0.162162	0.584980	26239.50466	15349.58452	94655.77132	0.109676087	106316.1058	4.051757349
85	0.933929	...	10889.92014	10889.92014	11660.33452	...	11660.33452	1.070745641

Table A15: Lobatse - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.018657	0.018350	100000	1835.032413	98357.73843	0.98025997	6738185.57	67.3818557
1	0.000904	0.003608	98164.96759	354.2243923	391772.2467	0.996155942	6639827.831	67.63948478
5	0.000662	0.003304	97810.74319	323.127482	488245.8973	0.996663053	6248055.585	63.8790319
10	0.000675	0.003370	97487.61571	328.5728055	486616.6466	0.996685551	5759809.687	59.08247571
15	0.000752	0.003753	97159.04291	364.6646424	485003.7804	0.9896318	5273193.041	54.27382653
20	0.003311	0.016420	96794.37827	1589.321602	479975.1641	0.989917324	4788189.26	49.46763796
25	0.000724	0.003614	95205.05666	344.0519589	475135.7301	0.99336061	4308214.096	45.25194614
30	0.002212	0.011008	94861.0047	1044.205835	471981.1186	0.987634015	3833078.366	40.40731361
35	0.002764	0.013735	93816.79887	1288.582183	466144.6071	0.977697868	3361097.248	35.82617706
40	0.006504	0.032036	92528.21669	2964.218443	455748.5884	0.967399107	2894952.641	31.28724128
45	0.006826	0.033602	89563.99824	3009.493552	440890.7774	0.940960978	2439204.052	27.23420236
50	0.017974	0.086150	86554.50469	7456.652185	414861.0173	0.923579699	1998313.275	23.08733996
55	0.013072	0.063321	79097.85251	5008.590863	383157.2135	0.912451029	1583452.257	20.01890326
60	0.024561	0.115900	74089.26164	8586.966337	349612.1939	0.887112236	1200295.044	16.20066144
65	0.023810	0.112735	65502.29531	7384.410891	310145.2549	0.814169208	850682.8501	12.98706933
70	0.063492	0.275860	58117.88441	16032.42633	252510.7167	0.694585829	540537.5952	9.30071011
75	0.081818	0.340976	42085.45808	14350.12085	175390.3656	0.534631173	288026.8785	6.843857513
80	0.190476	0.643972	27735.33723	17860.79173	93769.15683	1.68E-01	112636.5129	4.061119284
85	0.523367	...	9874.545498	9874.545498	18867.35606	...	18867.35606	1.910706276

Table A16: Selibe Phikwe - MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.023560	0.023076	100000	2307.571469	97943.58897	0.976280871	6574366.218	65.74366218
1	0.000608	0.002427	97692.42853	237.0574679	390196.8467	0.996218314	6476422.629	66.2940079
5	0.000808	0.004032	97455.37106	392.965299	486294.4421	0.996904155	6086225.783	62.45141459
10	0.000432	0.002156	97062.40576	209.2315173	484788.95	0.997994986	5599931.34	57.69413293
15	0.000457	0.002284	96853.17425	221.2238449	483816.9412	0.989261424	5115142.39	52.81336859
20	0.004152	0.020566	96631.9504	1987.355379	478621.436	0.985394333	4631325.449	47.92747564
25	0.001347	0.006711	94644.59502	635.1929014	471630.8507	0.987215497	4152704.013	43.87682162
30	0.004079	0.020201	94009.40212	1899.121525	465601.2848	0.981971095	3681073.162	39.15643627
35	0.003010	0.014942	92110.2806	1376.300524	457207.0034	0.978573926	3215471.878	34.90893586
40	0.005882	0.029006	90733.98007	2631.82857	447410.8525	0.971307581	2758264.874	30.39946966
45	0.005728	0.028256	88102.1515	2489.373768	434573.5531	0.96165838	2310854.022	26.22925754
50	0.010817	0.052804	85612.77773	4520.67524	417911.2992	0.925274402	1876280.469	21.91589291
55	0.021622	0.103101	81092.10249	8360.705603	386682.6274	0.845548527	1458369.17	17.9841085
60	0.045455	0.204338	72731.39689	14861.76921	326958.9259	0.805189756	1071686.542	14.73485438
65	0.039474	0.179576	57869.62768	10391.99907	263263.9778	0.775502776	744727.6162	12.86905837
70	0.064286	0.276440	47477.62861	13124.69645	204161.9456	0.727599361	481463.6384	10.1408527
75	0.064516	0.278979	34352.93217	9583.748463	148548.1013	0.564139768	277301.6928	8.072140435
80	0.177778	0.601478	24769.1837	14898.11403	83801.89133	0.34912968	128753.5916	5.198136245
85	0.219593	...	9871.06967	9871.06967	44951.70023	...	44951.70023	4.553883392

Table A17: Selibe Phikwe - FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.014851	0.014654	100000	1465.429683	98672.26523	0.984489582	7202448.026	72.02448026
1	0.000575	0.002297	98534.57032	226.3211193	393572.5258	0.997586929	7103775.761	72.09424812
5	0.000394	0.001970	98308.2492	193.7106801	491056.9693	0.997953958	6710203.235	68.25676675
10	0.000425	0.002122	98114.53852	208.1786046	490052.2461	0.997863054	6219146.265	63.38659244
15	0.000447	0.002235	97906.35991	218.7940539	489005.0307	0.997493802	5729094.019	58.5160558
20	0.000665	0.003320	97687.56586	324.3216544	487779.4873	0.98838662	5240088.989	53.64130985
25	0.004301	0.021298	97363.2442	2073.611563	482114.7186	0.982763462	4752309.501	48.8100981
30	0.002121	0.010546	95289.63264	1004.888187	473804.7299	0.989449288	4270194.783	44.8127951
35	0.002347	0.011672	94284.74445	1100.483063	468805.7528	0.984449604	3796390.053	40.26515716
40	0.003882	0.019229	93184.26139	1791.796618	461515.6375	0.983427043	3327584.3	35.70972448
45	0.002974	0.014769	91392.46477	1349.790351	453866.9589	0.965832144	2866068.663	31.36001058
50	0.010791	0.052536	90042.67442	4730.496065	438359.2982	0.965563879	2412201.704	26.78953862
55	0.003221	0.015979	85312.17836	1363.168809	423263.9043	0.957576579	1973842.406	23.13670151
60	0.016471	0.079520	83949.00955	6675.65452	405307.6017	0.913309011	1550578.501	18.47047999
65	0.019169	0.091829	77273.35503	7095.931311	370171.0848	0.840017727	1145270.9	14.82103241
70	0.056701	0.251238	70177.42372	17631.20108	310950.2732	0.663408792	775099.8147	11.04485992
75	0.104348	0.409651	52546.22264	21525.61513	206287.1452	0.608397132	464149.5415	8.833166653
80	0.089552	0.362314	31020.6075	11239.20966	125504.5076	0.513288834	257862.3963	8.312615938
85	0.149454	...	19781.39784	19781.39784	132357.8887	...	132357.8887	6.691028095

Table A18: Southern - MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.020819	0.020436	100000	2043.649162	98163.27853	0.977940865	6370101.156	63.70101156
1	0.001082	0.004316	97956.35084	422.7552605	390807.1539	0.99535487	6271937.878	64.02788409
5	0.000796	0.003974	97533.59558	387.550707	486699.1011	0.996997178	5881130.724	60.29851241
10	0.000406	0.002028	97146.04487	197.0375332	485237.6305	0.996973749	5394431.623	55.52909158
15	0.000956	0.004769	96949.00734	462.3469127	483769.1795	0.990872804	4909193.992	50.63686702
20	0.002657	0.013199	96486.66043	1273.574295	479353.7234	0.989818667	4425424.813	45.86566467
25	0.001454	0.007248	95213.08613	690.0710678	474473.2636	0.981456646	3946071.089	41.44462962
30	0.006800	0.033499	94523.01506	3166.467104	465674.9377	0.964789094	3471597.826	36.72754009
35	0.006836	0.033616	91356.54796	3071.060678	449278.1012	0.961068941	3005922.888	32.9032013
40	0.009542	0.046666	88285.48728	4119.915548	431787.2289	0.93837513	2556644.787	28.95883418
45	0.016216	0.078066	84165.57173	6570.460404	405178.397	0.912735716	2124857.558	25.2461608
50	0.019791	0.094324	77595.11133	7319.082287	369820.7942	0.901680118	1719679.161	22.16221011
55	0.021708	0.103003	70276.02904	7238.64088	333460.0572	0.886749208	1349858.367	19.20794879
60	0.027642	0.129664	63037.38816	8173.695013	295695.4417	0.826534593	1016398.309	16.12373766
65	0.049785	0.221778	54863.69315	12167.5497	244402.5115	0.766441409	720702.8677	13.13624414
70	0.055456	0.243302	42696.14344	10388.06153	187320.2054	0.716683371	476300.3562	11.15558263
75	0.079385	0.329869	32308.08192	10657.43289	134249.2762	0.654310281	288980.1509	8.944515853
80	0.091633	0.371774	21650.64902	8049.146114	87840.68163	0.432300232	154730.8747	7.146708375
85	0.203341	...	13601.50291	13601.50291	66890.19305	...	66890.19305	4.917853086

Table A19: Southern - FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.014286	0.014103	100000	1410.284215	98719.89594	0.984620009	6918392.939	69.18392939
1	0.000782	0.003120	98589.71578	307.6363171	393590.1085	0.995861943	6819673.043	69.17225583
5	0.000928	0.004630	98282.07947	455.0398334	490272.7978	0.997337404	6426082.934	65.3840758
10	0.000137	0.000686	97827.03963	67.11957696	488967.3992	0.99769949	5935810.136	60.67657938
15	0.000990	0.004940	97759.92006	482.9328779	487842.5251	0.993373733	5446842.737	55.716522
20	0.001668	0.008308	97276.98718	808.1883756	484609.9503	0.985377138	4959000.212	50.9781435
25	0.004326	0.021412	96468.7988	2065.575936	477523.5657	0.979313318	4474390.262	46.381735
30	0.003869	0.019165	94403.22287	1809.256566	467645.1875	0.974377814	3996866.696	42.33824413
35	0.006733	0.033135	92593.9663	3068.125436	455663.0957	0.965331154	3529221.509	38.11502682
40	0.007309	0.035911	89525.84087	3214.965803	439865.7818	0.956617737	3073558.413	34.33152242
45	0.010905	0.053165	86310.87506	4588.695671	420783.4088	0.932679637	2633692.631	30.51403
50	0.016966	0.081475	81722.17939	6658.309224	392456.1168	0.913295274	2212909.222	27.07844111
55	0.018409	0.087903	75063.87017	6598.367812	358428.3165	0.920149349	1820453.105	24.25205497
60	0.015300	0.073703	68465.50236	5046.094926	329807.5823	0.910196057	1462024.789	21.35418187
65	0.023488	0.111180	63419.40743	7050.994399	300189.561	0.871097684	1132217.207	17.85285061
70	0.031592	0.146555	56368.41303	8261.063568	261494.4315	0.839952717	832027.6456	14.76052989
75	0.038462	0.175603	48107.34946	8447.805983	219642.9582	0.802445469	570533.2141	11.85958529
80	0.052761	0.234475	39659.54348	9299.158685	176251.4967	0.497701935	350890.2559	8.847561649
85	0.173847	...	30360.3848	30360.3848	174638.7592	...	174638.7592	5.752191891

Table A20: Barolong - MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.019847	0.019498	100000	1949.847661	98242.32383	0.976931699	6262420.755	62.62420755
1	0.002106	0.008382	98050.15234	821.8115494	390223.5255	0.992455716	6164178.431	62.86760687
5	0.001123	0.005599	97228.34079	544.3917863	484780.7245	0.992540056	5773954.906	59.3855131
10	0.001875	0.009331	96683.949	902.1830389	481164.2874	0.988724205	5289174.181	54.70581452
15	0.002819	0.014003	95781.76596	1341.18849	475738.7776	0.983615226	4808009.894	50.19754904
20	0.003712	0.018390	94440.57747	1736.801412	467943.9051	0.981910473	4332271.116	45.87298418
25	0.003680	0.018241	92703.77606	1691.037183	459479.0213	0.97560328	3864327.211	41.68467969
30	0.006561	0.032315	91012.73888	2941.077451	448269.2403	0.959941519	3404848.19	37.41067714
35	0.009774	0.047753	88071.66143	4205.726971	430312.2556	0.946107458	2956578.949	33.57015073
40	0.012346	0.059931	83865.93446	5026.193012	407121.6344	0.933167778	2526266.694	30.12267985
45	0.015557	0.074966	78839.74145	5910.279735	379912.791	0.911658121	2119145.059	26.87914776
50	0.021470	0.101963	72929.46171	7436.098486	346350.581	0.893102289	1739232.268	23.8481435
55	0.023305	0.110070	65493.36322	7208.880296	309326.4966	0.886767962	1392881.687	21.2675242
60	0.025054	0.117912	58284.48293	6872.460741	274300.8269	0.869341281	1083555.191	18.59080044
65	0.031212	0.144771	51412.02219	7442.961389	238461.0321	0.849605914	809254.3639	15.74056669
70	0.034417	0.158584	43969.0608	6972.776783	202597.9032	0.815456116	570793.3318	12.98170398
75	0.050000	0.223279	36996.28402	8260.484967	165209.6993	0.706194088	368195.4286	9.952227321
80	0.094595	0.384063	28735.79905	11036.36208	116670.113	0.425229974	202985.7292	7.063862358
85	0.205055	...	17699.43696	17699.43696	86315.61626	...	86315.61626	4.876743618

Table A21: Barolong - FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.025397	0.024844	100000	2484.443204	97824.95161	0.97439725	6566932.65	65.6693265
1	0.000703	0.002806	97515.5568	273.6288364	389373.6732	0.996559699	6469107.698	66.33923766
5	0.000566	0.002826	97241.92796	274.849926	485522.515	0.996289879	6079734.025	62.52173473
10	0.000921	0.004596	96967.07803	445.6890744	483721.1675	0.990069441	5594211.51	57.69186432
15	0.003575	0.017736	96521.38896	1711.948239	478917.5461	0.97802949	5110490.342	52.94671365
20	0.005000	0.024702	94809.44072	2341.977417	468395.4834	0.973508129	4631572.796	48.85138823
25	0.005699	0.028106	92467.4633	2598.888619	455986.8105	0.968903262	4163177.313	45.02315911
30	0.006941	0.034122	89868.57468	3066.466942	441807.1081	0.964521614	3707190.502	41.251244
35	0.007493	0.036783	86802.10774	3192.800777	426132.5051	0.960916811	3265383.394	37.61871087
40	0.008746	0.042835	83609.30697	3581.439382	409477.888	0.946172254	2839250.889	33.95855069
45	0.013699	0.066319	80027.86758	5307.350856	387436.6164	0.925251689	2429773.001	30.36158621
50	0.016730	0.080263	74720.51673	5997.323523	358476.3838	0.9246159	2042336.385	27.33300671
55	0.014559	0.070220	68723.1932	4825.751978	331452.9642	0.924312959	1683860.001	24.50206288
60	0.017544	0.084117	63897.44123	5374.84695	306366.27	0.904889539	1352407.037	21.1652769
65	0.023013	0.109013	58522.59428	6379.715315	277227.6328	0.867047906	1046040.767	17.87413528
70	0.033755	0.155606	52142.87896	8113.743013	240369.6386	0.85081483	768813.134	14.7443553
75	0.031120	0.144550	44029.13595	6364.42075	204510.0531	0.813519309	528443.4954	12.00213186
80	0.056716	0.250528	37664.7152	9436.073644	166372.8771	0.486397959	323933.4423	8.600448472
85	0.179161	...	28228.64155	28228.64155	157560.5651	...	157560.5651	5.581585102

Table A22: Ngwaketse West - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.028470	0.027776	100000	2777.573733	97562.27517	0.969783878	6409034.14	64.0903414
1	0.001657	0.006601	97222.42627	641.8056596	387329.664	0.992328864	6311471.864	64.91786007
5	0.001439	0.007168	96580.62061	692.3342358	481172.2674	0.994598455	5924142.2	61.33882929
10	0.000726	0.003622	95888.28637	347.2953023	478573.1936	0.991912265	5442969.933	56.76365841
15	0.002786	0.013840	95540.99107	1322.29127	474702.6205	0.987076251	4964396.739	51.96090896
20	0.002245	0.011163	94218.6998	1051.779352	468567.683	0.982347529	4489694.119	47.65183693
25	0.004571	0.022585	93166.92045	2104.211879	460296.3054	0.986015751	4021126.436	43.16045241
30	0.001247	0.006215	91062.70857	565.9095793	453859.4073	0.990266183	3560830.131	39.10305532
35	0.003315	0.016463	90496.79899	1489.861676	449441.6227	0.96482299	3106970.723	34.33238256
40	0.011611	0.056568	89006.93731	5034.909636	433631.6102	0.942994157	2657529.101	29.85755022
45	0.011513	0.056065	83972.02768	4707.869324	408912.0747	0.905739294	2223897.49	26.48378933
50	0.030108	0.140680	79264.15835	11150.85655	370367.734	0.842064936	1814985.416	22.89793336
55	0.035616	0.163079	68113.3018	11107.82967	311873.6824	0.849830262	1444617.682	21.20903911
60	0.028846	0.134117	57005.47213	7645.375807	265039.6932	0.86962878	1132743.999	19.8707941
65	0.027451	0.128182	49360.09632	6327.070561	230486.1452	0.880138696	867704.306	17.57906428
70	0.026042	0.122762	43033.02576	5282.806716	202859.7753	0.774535891	637218.1609	14.80765411
75	0.080808	0.336336	37750.21905	12696.7416	157122.1769	0.687974487	434358.3856	11.50611563
80	0.060976	0.263086	25053.47745	6591.222529	108096.049	0.610094044	277236.2086	11.06577756
85	0.109154	...	18462.25492	18462.25492	169140.1596	...	169140.1596	9.161403109

Table A23: Ngwaketse West - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.020661	0.020288	100000	2028.844705	98196.08276	0.978572364	6780189.924	67.80189924
1	0.000810	0.003232	97971.15529	316.6722924	391090.0991	0.996188913	6681993.841	68.20368527
5	0.000698	0.003486	97654.483	340.3781104	487421.4697	0.996326314	6290903.742	64.42001994
10	0.000774	0.003862	97314.10489	375.8753533	485630.8361	0.995529749	5803482.272	59.63659923
15	0.001064	0.005306	96938.22954	514.3191927	483459.9445	0.994382196	5317851.436	54.85814484
20	0.001302	0.006492	96423.91035	625.9685391	480743.9611	0.987159078	4834391.492	50.13685376
25	0.004603	0.022803	95797.94181	2184.445436	474570.7653	0.950277895	4353647.531	45.44614893
30	0.013464	0.064861	93613.49637	6071.866684	450974.108	0.967524658	3879076.765	41.43715293
35	0.001160	0.005782	87541.62969	506.1817191	436328.5694	0.98786431	3428102.657	39.15968517
40	0.004615	0.022857	87035.44797	1989.385187	431033.4213	0.966237377	2991774.088	34.37420221
45	0.008993	0.044039	85046.06278	3745.329261	416480.6025	0.948141179	2560740.667	30.1100437
50	0.011086	0.053848	81300.73352	4377.853958	394882.4093	0.963068945	2144260.064	26.37442458
55	0.004785	0.023655	76922.87956	1819.612371	380298.9852	0.946658984	1749377.655	22.74196786
60	0.021538	0.103246	75103.26719	7754.136036	360013.4511	0.800603737	1369078.67	18.22928244
65	0.065637	0.280901	67349.13115	18918.44777	288228.1145	0.777351058	1009065.219	14.98260187
70	0.030457	0.140902	48430.68338	6823.992829	224054.4297	0.832301466	720837.1042	14.88389289
75	0.042857	0.192085	41606.69055	7992.035609	186480.8303	0.865111927	496782.6745	11.9399709
80	0.018182	0.087260	33614.65494	2933.214343	161326.7905	0.480097223	310301.8442	9.231147688
85	0.205950	...	30681.4406	30681.4406	148975.0538	...	148975.0538	4.855542988

Table A24: South East - MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.010684	0.010579	100000	1057.897876	99019.23644	0.987089105	6886301.335	68.86301335
1	0.001325	0.005281	98942.10212	522.54998	394525.316	0.995981965	6787282.098	68.5985233
5	0.000436	0.002180	98419.55214	214.5149691	491561.4733	0.998333271	6392756.782	64.95413404
10	0.000231	0.001153	98205.03717	113.2048954	490742.1736	0.998457903	5901195.309	60.09055624
15	0.000472	0.002360	98091.83228	231.5073227	489985.4018	0.994151221	5410453.135	55.1570198
20	0.002045	0.010178	97860.32496	995.9846761	487119.5853	0.988923122	4920467.734	50.28051701
25	0.002127	0.010577	96864.34028	1024.580803	481723.8209	0.99046546	4433348.148	45.76862998
30	0.001761	0.008767	95839.75948	840.1834534	477130.8061	0.989793869	3951624.327	41.23157601
35	0.002606	0.012954	94999.57602	1230.647848	472261.1465	0.97770612	3474493.521	36.57377924
40	0.006804	0.033506	93768.92818	3141.829554	461732.6133	0.960705584	3002232.375	32.01734768
45	0.008673	0.042453	90627.09862	3847.383558	443589.0999	0.959991788	2540499.761	28.03245166
50	0.008119	0.039842	86779.71506	3457.444396	425841.8929	0.932108655	2096910.662	24.1636039
55	0.021248	0.101223	83322.27067	8434.123017	396930.914	0.893976053	1671068.769	20.05548763
60	0.022337	0.105840	74888.14765	7926.129832	354846.7317	0.88165718	1274137.855	17.01387863
65	0.030377	0.141923	66962.01782	9503.437781	312853.1688	0.772858253	919291.1229	13.72854572
70	0.075188	0.316398	57458.58004	18179.78599	241791.1535	0.697830577	606437.9541	10.55434982
75	0.063545	0.272970	39278.79404	10721.92631	168729.2602	0.68239131	364646.8006	9.283553874
80	0.096591	0.389448	28556.86773	11121.41746	115139.3808	0.41230693	195917.5404	6.860610285
85	0.215844	...	17435.45027	17435.45027	80778.15961	...	80778.15961	4.632983855

Table A25: South East - FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.005394	0.005367	100000	536.6709725	99498.80194	0.992158674	7371817.635	73.71817635
1	0.001292	0.005150	99463.32903	512.2456124	396580.5351	0.996788674	7272318.833	73.11557842
5	0.000218	0.001088	98951.08342	107.661033	494486.2645	0.998876701	6875738.298	69.48623563
10	0.000232	0.001159	98843.42238	114.5213155	493930.8086	0.998953474	6381252.034	64.55919757
15	0.000213	0.001065	98728.90107	105.1608105	493413.8972	0.997106861	5887321.225	59.63118359
20	0.001015	0.005062	98623.74026	499.1890628	491986.3822	0.995712885	5393907.328	54.69177415
25	0.000655	0.003268	98124.55119	320.704954	489877.1798	0.993134956	4901920.946	49.95611074
30	0.002368	0.011779	97803.84624	1152.037292	486514.1512	0.985864558	4412043.766	45.11114783
35	0.003198	0.015871	96651.80895	1533.918164	479637.0586	0.980506996	3925529.615	40.61516962
40	0.004759	0.023527	95117.89078	2237.865849	470287.4914	0.972741302	3445892.556	36.22759638
45	0.006284	0.030949	92880.02493	2874.574706	457468.0666	0.966060314	2975605.065	32.03708296
50	0.007749	0.038048	90005.45023	3424.50802	441941.7439	0.949476828	2518136.998	27.97760571
55	0.013228	0.064107	86580.94221	5550.442301	419613.4452	0.932142121	2076195.254	23.9798182
60	0.014667	0.070797	81030.49991	5736.710842	391139.3667	0.91787234	1656581.809	20.44392927
65	0.020165	0.096151	75293.78906	7239.552728	359016.0057	0.891706591	1265442.442	16.80673078
70	0.027536	0.129534	68054.23633	8815.365014	320136.9386	0.783057846	906426.4364	13.31917725
75	0.074899	0.316955	59238.87132	18776.05745	250685.7415	0.664139968	586289.4978	9.897040317
80	0.083969	0.345505	40462.81387	13980.11169	166490.4204	0.503907757	335603.7563	8.294127972
85	0.156597	...	26482.70218	26482.70218	169113.336	...	169113.336	6.385803641

Table A26: Kweneng East - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.014480	0.014290	100000	1429.001839	98690.43773	0.983527357	6798132.056	67.98132056
1	0.001289	0.005139	98570.99816	506.5739404	393073.241	0.995802879	6699441.619	67.96564652
5	0.000508	0.002539	98064.42422	248.9736046	489699.6871	0.996521699	6306368.378	64.30842202
10	0.000886	0.004420	97815.45062	432.3555069	487996.3643	0.995323576	5816668.691	59.46574548
15	0.001041	0.005192	97383.09511	505.5761151	485714.2865	0.993490508	5328672.326	54.71865851
20	0.001624	0.008091	96877.51899	783.8414457	482552.5332	0.990386182	4842958.04	49.99052505
25	0.002268	0.011281	96093.67755	1083.993049	477913.3608	0.986311063	4360405.506	45.37661184
30	0.003300	0.016373	95009.6845	1555.573626	471371.2348	0.980857044	3882492.146	40.8641726
35	0.004506	0.022292	93454.11087	2083.234216	462347.796	0.972441565	3411120.911	36.50049077
40	0.006662	0.032782	91370.87666	2995.326505	449606.2142	0.966475528	2948773.115	32.27257112
45	0.007077	0.034796	88375.55015	3075.08687	434533.4034	0.954229675	2499166.901	28.27894023
50	0.012221	0.059408	85300.46328	5067.498957	414644.6682	0.928807027	2064633.497	24.20424717
55	0.017241	0.082760	80232.96433	6640.084047	385124.8817	0.907700117	1649988.829	20.56497405
60	0.021772	0.103418	73592.88028	7610.852032	349577.9001	0.877030026	1264863.947	17.18731408
65	0.032107	0.149185	65982.02825	9843.541946	306590.3149	0.803596989	915286.0474	13.87174768
70	0.056274	0.246971	56138.4863	13864.57286	246375.054	0.741442423	608695.7324	10.84275285
75	0.063492	0.274360	42273.91344	11598.28036	182672.9172	0.646962029	362320.6784	8.570786306
80	0.120172	0.462979	30675.63307	14202.18179	118182.4411	0.342143535	179647.7612	5.85636687
85	0.268012	...	16473.45129	16473.45129	61465.32014	...	61465.32014	3.731174425

Table A27: Kweneng East - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.012422	0.012283	100000	1228.302761	98878.3731	0.985774784	7344049.946	73.44049946
1	0.001096	0.004372	98771.69724	431.8062913	394009.0189	0.996172854	7245171.573	73.35270908
5	0.000569	0.002841	98339.89095	279.3658438	491001.0401	0.996871882	6851162.554	69.66819353
10	0.000684	0.003416	98060.5251	334.9977672	489465.1311	0.996852359	6360161.514	64.85954983
15	0.000647	0.003229	97725.52734	315.5363638	487924.4706	0.992502136	5870696.383	60.07331496
20	0.002536	0.012607	97409.99097	1228.088608	484266.0795	0.988028406	5382771.913	55.25893041
25	0.002031	0.010105	96181.90237	971.898521	478468.6425	0.989170012	4898505.833	50.92960019
30	0.002450	0.012177	95210.00384	1159.402236	473286.833	0.985183949	4420037.191	46.42408373
35	0.003645	0.018071	94050.60161	1699.625439	466274.5912	0.977724133	3946750.358	41.96411602
40	0.005456	0.026934	92350.97617	2487.426612	455887.9203	0.968068001	3480475.766	37.68748215
45	0.007587	0.037261	89863.54956	3348.409428	441330.5078	0.956161919	3024587.846	33.65756039
50	0.010204	0.049771	86515.14013	4305.953472	421983.4251	0.949593842	2583257.338	29.85902045
55	0.010185	0.049644	82209.18666	4081.19478	400712.8617	0.953055856	2161273.913	26.28993183
60	0.009695	0.047392	78127.99188	3702.648497	381901.7394	0.927373018	1760561.051	22.53431848
65	0.021975	0.104570	74425.34338	7782.682683	354165.3686	0.875243792	1378659.312	18.52405712
70	0.030376	0.141291	66642.6607	9416.010421	309981.04	0.849168885	1024493.943	15.37294479
75	0.034832	0.160218	57226.65028	9168.742159	263226.2541	0.828315537	714512.9033	12.48566708
80	0.043369	0.196763	48057.90812	9456.037283	218034.3959	0.516860522	451286.6492	9.390476341
85	0.165494	...	38601.87083	38601.87083	233252.2532	...	233252.2532	6.042511624

Table A28: Kweneng West - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.031019	0.030203	100000	3020.348639	97370.28642	0.96808957	6534343.172	65.34343172
1	0.001320	0.005262	96979.65136	510.2928041	386674.4985	0.992784337	6436972.886	66.37446923
5	0.001494	0.007442	96469.35856	717.8847399	480552.0809	0.990738402	6050298.387	62.71730711
10	0.002231	0.011095	95751.47382	1062.387424	476101.4005	0.99249249	5569746.306	58.16877886
15	0.000811	0.004046	94689.08639	383.0781636	472527.0643	0.989853394	5093644.906	53.79336838
20	0.003682	0.018263	94306.00823	1722.318355	467732.5182	0.981411301	4621117.841	49.00130891
25	0.003468	0.017193	92583.68987	1591.809214	459037.9792	0.979207029	4153385.323	44.86087483
30	0.005139	0.025387	90991.88066	2310.029241	449493.2157	0.970904568	3694347.344	40.60084611
35	0.006936	0.034133	88681.85142	3026.95055	436415.0163	0.950359343	3244854.128	36.58983294
40	0.013669	0.066185	85654.90087	5669.096169	414751.088	0.932167901	2808439.112	32.78783915
45	0.013780	0.066604	79985.8047	5327.408751	386617.6512	0.930039964	2393688.024	29.92641048
50	0.015789	0.076045	74658.39595	5677.419058	359569.8665	0.903045867	2007070.373	26.88338461
55	0.024038	0.113154	68980.97689	7805.482885	324708.0818	0.910582559	1647500.506	23.88340352
60	0.013193	0.063763	61175.49401	3900.705978	295673.5162	0.934992783	1322792.424	21.62291365
65	0.015723	0.075893	57274.78803	4346.738929	276452.6036	0.867983681	1027118.908	17.93317695
70	0.043860	0.198844	52928.0491	10524.40122	239956.3485	0.783525995	750666.3046	14.1827692
75	0.051205	0.227035	42403.64788	9627.122312	188012.0367	0.732132166	510709.9561	12.04400993
80	0.075472	0.316954	32776.52557	10388.65354	137649.6596	0.573441131	322697.9193	9.845397392
85	0.120984	...	22387.87202	22387.87202	185048.2597	...	185048.2597	8.265558222

Table A29: Kweneng West - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.015038	0.014836	100000	1483.558614	98656.6466	0.983505123	7089224.135	70.89224135
1	0.000987	0.003938	98516.44139	387.9235475	393095.9151	0.995553191	6990567.488	70.9583841
5	0.000880	0.004389	98128.51784	430.7028842	489565.832	0.996951394	6597471.573	67.23296875
10	0.000341	0.001702	97697.81495	166.2943957	488073.3388	0.997293019	6107905.741	62.51834541
15	0.000910	0.004541	97531.52056	442.9045279	486752.1336	0.990615491	5619832.402	57.62067863
20	0.003063	0.015211	97088.61603	1476.827511	482184.2037	0.98168719	5133080.269	52.87005293
25	0.003835	0.018987	95611.78852	1815.355879	473354.0559	0.986032125	4650896.065	48.64354215
30	0.002049	0.010197	93796.43264	956.4389982	466742.3058	0.976266918	4177542.009	44.53838906
35	0.008362	0.041041	92839.99364	3810.283637	455665.0723	0.958827253	3710799.703	39.96984013
40	0.007762	0.038091	89029.71001	3391.234688	436904.0895	0.950537318	3255134.631	36.56234117
45	0.012579	0.060999	85638.47532	5223.819245	415293.6416	0.94334825	2818230.542	32.90846236
50	0.010204	0.049713	80414.65607	3997.617796	391766.5299	0.952701934	2402936.9	29.88182773
55	0.009569	0.046739	76417.03828	3571.64336	373236.7307	0.94783219	2011170.37	26.31835014
60	0.012514	0.060774	72845.39492	4427.103251	353765.7878	0.922134721	1637933.64	22.48506774
65	0.020934	0.099814	68418.29167	6829.076034	326219.7161	0.865461362	1284167.852	18.76936446
70	0.035885	0.164501	61589.21563	10131.47929	282330.5599	0.854880969	957948.1356	15.55382912
75	0.026163	0.122715	51457.73634	6314.625664	241359.0226	0.852859507	675617.5757	13.1295627
80	0.041812	0.190655	45143.11068	8606.773739	205845.3371	0.525984381	434258.5531	9.619597467
85	0.159957	...	36536.33694	36536.33694	228413.2161	...	228413.2161	6.251672587

Table A30: Kgatleng Wards - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.016367	0.016126	100000	1612.613533	98530.68573	0.981953971	6761477.273	67.61477273
1	0.001173	0.004681	98387.38647	460.5275053	392446.3	0.996426525	6662946.587	67.7215528
5	0.000337	0.001682	97926.85896	164.721213	489222.4918	0.998689997	6270500.287	64.03248663
10	0.000188	0.000937	97762.13775	91.63201497	488581.6087	0.997492192	5781277.796	59.13616384
15	0.001002	0.004999	97670.50573	488.2350433	487356.3398	0.993102125	5292696.187	54.18929847
20	0.001720	0.008567	97182.27069	832.559312	483994.6168	0.989262339	4805339.847	49.44667184
25	0.002634	0.013087	96349.71138	1260.941852	478797.6469	0.984057944	4321345.23	44.85062974
30	0.003802	0.018840	95088.76953	1791.500314	471164.6282	0.97919199	3842547.583	40.41010944
35	0.004669	0.023089	93297.26921	2154.140301	461360.6299	0.971754868	3371382.955	36.1359232
40	0.007105	0.034950	91143.12891	3185.471668	448329.4381	0.953666533	2910022.325	31.92804943
45	0.011967	0.058172	87957.65724	5116.704112	427556.7809	0.93764242	2461692.887	27.98724937
50	0.013546	0.065553	82840.95313	5430.455383	400895.3748	0.926946069	2034136.106	24.55471635
55	0.017347	0.083274	77410.49775	6446.268105	371608.3918	0.89651565	1633240.732	21.09843987
60	0.026565	0.124716	70964.22964	8850.357423	333152.7388	0.870500986	1261632.34	17.77842649
65	0.028997	0.135386	62113.87222	8409.374663	290009.7877	0.831679346	928479.601	14.94802317
70	0.046263	0.207776	53704.49756	11158.49446	241195.1506	0.772138873	638469.8133	11.88857251
75	0.058824	0.257488	42546.00309	10955.06767	186236.1517	0.64500309	397274.6627	9.337531937
80	0.123249	0.468649	31590.93542	14805.06251	120122.8933	0.430801077	211038.511	6.680350175
85	0.184631	...	16785.87291	16785.87291	90915.61773	...	90915.61773	5.416198383

Table A31: Kgatleng Wards - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.011374	0.011256	100000	1125.627828	98968.6636	0.987758508	7247631.215	72.47631215
1	0.000596	0.002380	98874.37217	235.2991752	394910.5904	0.998178241	7148662.552	72.30045961
5	0.000175	0.000875	98639.073	86.33599719	492979.525	0.999102181	6753751.961	68.46933731
10	0.000184	0.000920	98552.737	90.70658399	492536.9185	0.99827813	6260772.436	63.52712899
15	0.000599	0.002991	98462.03042	294.48326	491688.8342	0.995658867	5768235.518	58.58334927
20	0.001205	0.006011	98167.54716	590.061324	489554.3478	0.989799962	5276546.683	53.7504179
25	0.002885	0.014325	97577.48583	1397.771567	484560.8746	0.987005029	4786992.336	49.0583693
30	0.002208	0.010979	96179.71426	1055.982565	478264.02	0.987777296	4302431.461	44.73325268
35	0.003022	0.015010	95123.7317	1427.82113	472418.3404	0.973294655	3824167.441	40.20203342
40	0.007874	0.038641	93695.91057	3620.490239	459802.2456	0.967084781	3351749.101	35.77262957
45	0.005368	0.026501	90075.42033	2387.121909	444667.7539	0.955414425	2891946.855	32.10583802
50	0.013971	0.067686	87688.29842	5935.292356	424841.9863	0.923456348	2447279.101	27.90884468
55	0.016811	0.080672	81753.00607	6595.16237	392323.0293	0.918795342	2022437.115	24.73838226
60	0.017090	0.081963	75157.8437	6160.192105	360464.572	0.909783878	1630114.086	21.68920774
65	0.021157	0.100561	68997.65159	6938.472307	327944.8562	0.889620786	1269649.514	18.40134388
70	0.026037	0.122401	62059.17929	7596.101345	291746.5609	0.858544187	941704.6574	15.17430086
75	0.036269	0.166804	54463.07794	9084.669401	250477.3138	0.793860708	649958.0965	11.93392149
80	0.059369	0.260150	45378.40854	11805.21541	198844.0978	0.502243646	399480.7826	8.803322891
85	0.167333	...	33573.19313	33573.19313	200636.6849	...	200636.6849	5.976097777

Table A32: Central Serowe/ Palapye - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.018483	0.018179	100000	1817.924012	98354.3503	0.9798446	6668515.857	66.68515857
1	0.001234	0.004921	98182.07599	483.1189002	391567.9499	0.996444258	6570161.507	66.91813593
5	0.000258	0.001288	97698.95709	125.8089356	488180.2631	0.997063625	6178593.557	63.24114137
10	0.000920	0.004587	97573.14815	447.5831368	486746.7829	0.995900437	5690413.294	58.31945983
15	0.000786	0.003921	97125.56501	380.7944711	484751.3336	0.992650436	5203666.511	53.5766923
20	0.002400	0.011939	96744.77054	1155.006674	481188.6225	0.985324466	4718915.177	48.77695353
25	0.003479	0.017255	95589.76387	1649.357652	474126.9224	0.976657729	4237726.555	44.33243041
30	0.005976	0.029459	93940.40622	2767.417166	463059.7235	0.970107188	3763599.633	40.0636934
35	0.005963	0.029380	91172.98905	2678.62505	449217.5661	0.969089063	3300539.909	36.20085229
40	0.006928	0.034081	88494.364	3015.997639	435331.8302	0.955466663	2851322.343	32.22038347
45	0.012079	0.058776	85478.36636	5024.077982	415945.0509	0.916682903	2415990.513	28.26435057
50	0.022649	0.107339	80454.28838	8635.862444	381289.7168	0.894171601	2000045.462	24.85940156
55	0.021239	0.100826	71818.42594	7241.170318	340938.4366	0.886792107	1618755.745	22.53956034
60	0.027082	0.126792	64577.25562	8187.906773	302341.5145	0.876319453	1277817.308	19.78742045
65	0.026647	0.125203	56389.34885	7060.138748	264947.7505	0.820535277	975475.7939	17.29893701
70	0.055046	0.242593	49329.2101	11966.9162	217398.9759	0.741655197	710528.0434	14.40379933
75	0.060459	0.260910	37362.2939	9748.19105	161235.0803	0.754061853	493129.0675	13.19857579
80	0.055644	0.244993	27614.10285	6765.250886	121581.2234	0.633674522	331893.9872	12.01900308
85	0.099133	...	20848.85196	20848.85196	210312.7638	...	210312.7638	10.08749854

Table A33: Central Serowe/ Palapye - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.011199	0.011085	100000	1108.544051	98983.74814	0.986624769	7262257.253	72.62257253
1	0.001258	0.005016	98891.45595	496.063044	394328.6365	0.995995183	7163273.505	72.43571688
5	0.000521	0.002603	98395.39291	256.082262	491336.7589	0.997490448	6768944.869	68.79331104
10	0.000484	0.002416	98139.31064	237.1317857	490103.7238	0.997998023	6277608.11	63.96629514
15	0.000354	0.001767	97902.17886	173.03884	489122.5473	0.995432945	5787504.386	59.11517449
20	0.001657	0.008255	97729.14002	806.7750593	486888.6979	0.991521823	5298381.839	54.21496432
25	0.001689	0.008411	96922.36496	815.2622496	482760.7696	0.983743909	4811493.141	49.64275421
30	0.005071	0.025057	96107.10271	2408.152103	474912.9666	0.977240256	4328732.371	45.04071239
35	0.003926	0.019447	93698.95061	1822.159827	464104.0691	0.971306686	3853819.405	41.12980327
40	0.008139	0.039933	91876.79078	3668.877838	450787.3852	0.957213586	3389715.336	36.89414167
45	0.009044	0.044244	88207.91294	3902.672411	431499.8095	0.949798352	2938927.95	33.3181894
50	0.011634	0.056555	84305.24053	4767.865762	409837.8079	0.940521921	2507428.141	29.74225712
55	0.012824	0.062149	79537.37477	4943.133639	385461.4424	0.932629587	2097590.333	26.3723858
60	0.015040	0.072482	74594.24113	5406.702955	359492.7459	0.926795456	1712128.89	22.95256128
65	0.015421	0.074259	69187.53817	5137.81656	333176.2434	0.918932365	1352636.145	19.55028579
70	0.018964	0.090650	64049.72161	5806.116358	306166.4332	0.895461311	1019459.901	15.91669527
75	0.026667	0.125523	58243.60526	7310.938642	274160.1957	0.824843641	713293.4679	12.24672588
80	0.055140	0.244821	50932.66661	12469.36296	226139.294	0.485032658	439133.2722	8.621839409
85	0.180584	...	38463.30365	38463.30365	212993.9782	...	212993.9782	5.537589286

Table A34: Central Mahalapye - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.018121	0.017828	100000	1782.803518	98384.34247	0.979697941	6503350.972	65.03350972
1	0.001494	0.005955	98217.19648	584.8865349	391464.6279	0.995616787	6404966.63	65.21227299
5	0.000377	0.001883	97632.30995	183.8767683	487701.8578	0.997691107	6013502.002	61.59335987
10	0.000548	0.002735	97448.43318	266.5437939	486575.8064	0.995724188	5525800.144	56.70486393
15	0.001411	0.007037	97181.88938	683.8326544	484495.2998	0.98623164	5039224.337	51.8535333
20	0.004419	0.021883	96498.05673	2111.672686	477824.594	0.973608504	4554729.038	47.20021513
25	0.005950	0.029324	94386.38404	2767.813547	465214.088	0.968917282	4076904.444	43.19377721
30	0.006654	0.032739	91618.5705	2999.510288	450753.9697	0.963510823	3611690.356	39.42094202
35	0.008213	0.040251	88619.06021	3567.000004	434306.3285	0.959218949	3160936.386	35.6688096
40	0.008588	0.042065	85052.06021	3577.727907	416594.8601	0.947430018	2726630.057	32.05836579
45	0.013011	0.063029	81474.3323	5135.207998	394694.4756	0.940637716	2310035.197	28.35291965
50	0.011368	0.055287	76339.1243	4220.568734	371264.51	0.934207763	1915340.722	25.08989642
55	0.016714	0.080384	72118.55557	5797.199827	346838.1872	0.903018555	1544076.212	21.41024872
60	0.024763	0.116942	66321.35574	7755.775439	313201.3187	0.851498325	1197238.024	18.05207404
65	0.039365	0.179257	58565.5803	10498.2886	266690.3983	0.823623736	884036.7058	15.09481681
70	0.038570	0.176253	48067.2917	8472.017228	219652.5423	0.754183789	617346.3075	12.84337614
75	0.076682	0.320823	39595.27447	12703.06875	165658.3867	0.693630113	397693.7651	10.04397041
80	0.067194	0.287107	26892.20572	7720.932709	114905.6454	0.504792561	232035.3785	8.628350568
85	0.163676	...	19171.27301	19171.27301	117129.7331	...	117129.7331	6.10964817

Table A35: Central Mahalapye - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.023585	0.023105	100000	2310.499508	97965.17662	0.974496873	6993911.633	69.93911633
1	0.001507	0.006006	97689.50049	586.7117511	389283.2597	0.995149839	6895946.457	70.59045672
5	0.000519	0.002590	97102.78874	251.4963779	484885.2028	0.997321031	6506663.197	67.00799515
10	0.000554	0.002768	96851.29236	268.1006785	483586.2101	0.996427482	6021777.994	62.17550481
15	0.000970	0.004841	96583.19169	467.5517261	481858.5894	0.99341475	5538191.784	57.3411552
20	0.001759	0.008759	96115.63996	841.9090625	478685.4302	0.987711551	5056333.195	52.60676823
25	0.003307	0.016413	95273.7309	1563.72401	472803.1289	0.979371736	4577647.765	48.04732345
30	0.005223	0.025806	93710.00689	2418.290312	463050.0212	0.96149709	4104844.636	43.80369581
35	0.010294	0.050202	91291.71657	4583.019374	445221.2481	0.956093701	3641794.614	39.8918407
40	0.007290	0.035790	86708.6972	3103.328549	425673.231	0.960191602	3196573.366	36.86566019
45	0.009312	0.045525	83605.36865	3806.117173	408727.8617	0.951234739	2770900.135	33.1426101
50	0.010512	0.051214	79799.25148	4086.85513	388796.141	0.949154513	2362172.274	29.60143397
55	0.010553	0.051437	75712.39635	3894.396359	369027.6117	0.939497753	1973376.133	26.06410876
60	0.014977	0.072301	71817.99999	5192.520851	346700.612	0.914262883	1604348.521	22.3390866
65	0.021186	0.100796	66625.47914	6715.582752	316975.5011	0.88142044	1257647.909	18.87638071
70	0.029187	0.136113	59909.89639	8154.499403	279388.6855	0.85859966	940672.408	15.70145276
75	0.032393	0.150139	51755.39698	7770.505579	239883.0305	0.808771024	661283.7225	12.7770969
80	0.056063	0.247283	43984.8914	10876.72624	194010.4442	0.539605777	421400.6921	9.580578208
85	0.145601	...	33108.16516	33108.16516	227390.2478	...	227390.2478	6.868101773

Table A36: Central Bobonong - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.021930	0.021507	100000	2150.738122	98073.65457	0.975683001	6522958.731	65.22958731
1	0.001733	0.006904	97849.26188	675.5074532	389767.8459	0.993439389	6424885.076	65.66104795
5	0.001013	0.005054	97173.75443	491.1240043	484640.9621	0.996312884	6035117.23	62.10645319
10	0.000463	0.002313	96682.63042	223.6468833	482854.0349	0.997002272	5550476.268	57.40923932
15	0.000913	0.004555	96458.98354	439.3730365	481406.5697	0.987389654	5067622.233	52.53655022
20	0.004639	0.022967	96019.6105	2205.26989	475335.8662	0.97540835	4586215.663	47.76332292
25	0.004902	0.024226	93814.34061	2272.777419	463646.5731	0.967676662	4110879.797	43.81931132
30	0.008381	0.041077	91541.56319	3760.273033	448659.9683	0.958224707	3647233.224	39.84237429
35	0.008363	0.040960	87781.29016	3595.483273	429917.0668	0.957423012	3198573.256	36.43798411
40	0.009104	0.044512	84185.80689	3747.310669	411612.493	0.954918808	2768656.189	32.88744613
45	0.009788	0.047828	80438.49622	3847.208831	393056.5111	0.933468693	2357043.696	29.30243362
50	0.018321	0.087764	76591.28739	6721.941144	366905.9478	0.907132695	1963987.185	25.642436
55	0.020147	0.095971	69869.34624	6705.414222	332832.3811	0.888733096	1597081.237	22.8581105
60	0.026786	0.125439	63163.93202	7923.191501	295799.1525	0.88256045	1264248.856	20.01536028
65	0.023153	0.109419	55240.74052	6044.40263	261060.6333	0.872668729	968449.7035	17.53143956
70	0.032915	0.152425	49196.33789	7498.75947	227819.4509	0.819954133	707389.0702	14.3788969
75	0.046784	0.209587	41697.57842	8739.251528	186801.5003	0.774221617	479569.6193	11.50113837
80	0.057432	0.252022	32958.32689	8306.209111	144625.7597	0.506005776	292768.119	8.882978797
85	0.166408	...	24652.11778	24652.11778	148142.3592	...	148142.3592	6.009315734

Table A37: Central Bobonong - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.029348	0.028622	100000	2862.195999	97526.6777	0.970223578	7095031.328	70.95031328
1	0.000988	0.003943	97137.804	382.9891159	387585.1115	0.996180888	6997504.65	72.03688329
5	0.000426	0.002129	96754.81488	205.9925712	483259.093	0.997151607	6609919.538	68.31618195
10	0.000715	0.003569	96548.82231	344.6120636	481882.5814	0.997490395	6126660.445	63.45660463
15	0.000328	0.001639	96204.21025	157.7012014	480673.2464	0.993161021	5644777.864	58.67495663
20	0.002950	0.014662	96046.50905	1408.218324	477385.932	0.983449621	5164104.618	53.76670812
25	0.003361	0.016672	94638.29072	1577.806268	469485.0141	0.976851756	4686718.686	49.5224359
30	0.006294	0.031019	93060.48446	2886.654444	458617.2605	0.963256514	4217233.672	45.3171257
35	0.008661	0.042431	90173.83001	3826.194633	441766.0637	0.947647108	3758616.411	41.68189829
40	0.012260	0.059440	86347.63538	5132.468283	418638.3329	0.951107664	3316850.347	38.41275251
45	0.007615	0.037336	81215.1671	3032.233144	398170.1267	0.962706932	2898212.015	35.68560059
50	0.007908	0.038770	78182.93395	3031.128407	383321.1412	0.960934139	2500041.888	31.9768236
55	0.008040	0.039405	75151.80555	2961.349747	368346.3708	0.960941519	2116720.747	28.16593336
60	0.008442	0.041390	72190.4558	2987.968139	353959.3212	0.934357092	1748374.376	24.2189131
65	0.018822	0.089950	69202.48766	6224.763728	330724.402	0.923358287	1394415.055	20.14978221
70	0.012586	0.061028	62977.72393	3843.418987	305377.1172	0.918396027	1063690.653	16.8899507
75	0.024096	0.114282	59134.30495	6758.003291	280457.1312	0.83301614	758313.5355	12.82358077
80	0.052838	0.235683	52376.30165	12344.19474	233625.3169	0.511097236	477856.4042	9.123523218
85	0.163911	...	40032.10692	40032.10692	244231.0873	...	244231.0873	6.100880171

Table A38: Central Boteti - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.013777	0.013605	100000	1360.512454	98750.52357	0.983715856	6628128.016	66.28128016
1	0.001545	0.006158	98639.48755	607.4283996	393107.4042	0.995992484	6529377.492	66.1943574
5	0.000223	0.001116	98032.05915	109.3985807	489886.7993	0.998166266	6136270.088	62.59452409
10	0.000511	0.002552	97922.66057	249.9303234	488988.477	0.994623417	5646383.289	57.66166132
15	0.001877	0.009348	97672.73024	913.0653413	486359.3898	0.989515801	5157394.812	52.80281199
20	0.002251	0.011194	96759.6649	1083.106627	481260.301	0.984368379	4671035.422	48.27461347
25	0.004074	0.020172	95676.55827	1929.986361	473737.4223	0.980465973	4189775.121	43.79103091
30	0.003664	0.018155	93746.57191	1701.923928	464483.4229	0.980440025	3716037.699	39.63918491
35	0.004291	0.021228	92044.64798	1953.899376	455398.1387	0.978960026	3251554.276	35.32583748
40	0.004428	0.021914	90090.74861	1974.227811	445816.5736	0.967601999	2796156.137	31.03710626
45	0.009265	0.045355	88116.5208	3996.507429	431373.008	0.947256703	2350339.564	26.6730863
50	0.012422	0.060343	84120.01337	5076.036836	408620.9735	0.921784666	1918966.556	22.81224739
55	0.020548	0.097915	79043.97653	7739.600215	376660.5476	0.89367047	1510345.582	19.10766194
60	0.024896	0.117529	71304.37632	8380.342265	336610.4084	0.836851456	1133685.035	15.89923499
65	0.047801	0.213992	62924.03405	13465.24421	281692.9103	0.778006083	797074.6263	12.66725248
70	0.052198	0.231296	49458.78984	11439.60753	219158.7977	0.693307948	515381.716	10.42042714
75	0.097872	0.391149	38019.18231	14871.16733	151944.5364	0.605901966	296222.9184	7.791406873
80	0.101449	0.403481	23148.01499	9339.774643	92063.49324	0.361903759	144278.382	6.232861957
85	0.264450	...	13808.24034	13808.24034	52214.88874	...	52214.88874	3.781429599

Table A39: Central Boteti - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.013237	0.013079	100000	1307.938142	98808.77873	0.981940676	7185216.576	71.85216576
1	0.002662	0.010576	98692.06186	1043.815607	392161.5591	0.993347406	7086407.798	71.80321968
5	0.000441	0.002200	97648.24625	214.8478046	487704.1117	0.998228185	6694246.239	68.55470012
10	0.000269	0.001342	97433.39845	130.8007607	486839.9903	0.996698433	6206542.127	63.70035559
15	0.001332	0.006640	97302.59769	646.115424	485232.6553	0.988192127	5719702.137	58.78262526
20	0.003279	0.016265	96656.48226	1572.141506	479503.0899	0.98632247	5234469.481	54.15538988
25	0.002182	0.010853	95084.34076	1031.986557	472944.6719	0.982334907	4754966.391	50.00788094
30	0.005409	0.026718	94052.3542	2512.895625	464590.0603	0.966844326	4282021.72	45.52806526
35	0.007393	0.036278	91539.45857	3320.888399	449186.2637	0.97164605	3817431.659	41.70258071
40	0.004307	0.021307	88218.57017	1879.629791	436450.059	0.968206306	3368245.396	38.18068451
45	0.008912	0.043616	86338.94038	3765.774396	422573.6994	0.960687196	2931795.336	33.95681396
50	0.006843	0.033645	82573.16599	2778.177216	405961.1425	0.959069417	2509221.637	30.38785793
55	0.010239	0.049959	79794.98877	3986.466777	389344.9162	0.947607929	2103260.495	26.35830303
60	0.011364	0.055305	75808.52199	4192.571792	368946.3295	0.930845945	1713915.578	22.60848165
65	0.017828	0.085495	71615.9502	6122.778199	343432.1948	0.903108196	1344969.249	18.78030306
70	0.022774	0.107853	65493.172	7063.603953	310156.4298	0.882129612	1001537.054	15.29223617
75	0.028391	0.132942	58429.56805	7767.771365	273598.171	0.828788879	691380.6244	11.83271839
80	0.051780	0.231760	50661.79669	11741.36545	226755.1215	0.457241156	417782.4533	8.246498953
85	0.203743	...	38920.43123	38920.43123	191027.3318	...	191027.3318	4.908150444

Table A40: Central Tutume - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.021365	0.020963	100000	2096.343367	98119.09575	0.976442848	6427880.57	64.2788057
1	0.001608	0.006409	97903.65663	627.462449	390102.3283	0.995510922	6329761.474	64.65296284
5	0.000289	0.001444	97276.19418	140.4844719	486029.7597	0.996242223	5939659.146	61.05974022
10	0.001219	0.006075	97135.70971	590.072014	484203.3685	0.995091529	5453629.386	56.14443342
15	0.000811	0.004045	96545.6377	390.5648445	481826.6705	0.991297245	4969426.018	51.4722999
20	0.003084	0.015320	96155.07285	1473.107537	477633.4512	0.980120091	4487599.347	46.67043781
25	0.004870	0.024081	94681.96532	2280.041539	468138.1415	0.96832217	4009965.896	42.35195037
30	0.007980	0.039147	92401.92378	3617.29291	453308.541	0.959630597	3541827.755	38.33067116
35	0.008306	0.040697	88784.63087	3613.290524	435008.7457	0.9560034	3088519.214	34.7866425
40	0.010153	0.049577	85171.34034	4222.505309	415869.8399	0.933452373	2653510.468	31.154969
45	0.017563	0.084226	80948.83503	6818.027526	388194.6888	0.915384569	2237640.628	27.64265387
50	0.017156	0.082237	74130.80751	6096.314887	355347.4278	0.912507361	1849445.939	24.94841216
55	0.019797	0.094356	68034.49262	6419.455508	324257.1436	0.899476449	1494098.511	21.96089739
60	0.023104	0.109365	61615.03711	6738.541752	291661.664	0.868143354	1169841.368	18.98629657
65	0.033951	0.156651	54876.49536	8596.436619	253204.1353	0.832865548	878179.7037	16.0028387
70	0.038634	0.176046	46280.05874	8147.39903	210885.0009	0.811248905	624975.5685	13.50420863
75	0.045822	0.205579	38132.65971	7839.25557	171080.2261	0.771845733	414090.5676	10.85921021
80	0.061657	0.268760	30293.40414	8141.659682	132047.5424	0.456617601	243010.3415	8.021889529
85	0.199632	...	22151.74446	22151.74446	110962.799	...	110962.799	5.009212671

Table A41: Central Tutume - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.019712	0.019372	100000	1937.173053	98272.26369	0.978664202	7044828.656	70.44828656
1	0.001215	0.004846	98062.82695	475.1638895	391059.8375	0.995701325	6946556.392	70.83781498
5	0.000583	0.002909	97587.66306	283.8774225	487228.6217	0.997236619	6555496.554	67.17546408
10	0.000524	0.002617	97303.78563	254.6819697	485882.2233	0.997499689	6068267.933	62.36415051
15	0.000592	0.002957	97049.10367	286.9550692	484667.3668	0.986971208	5582385.709	57.52124954
20	0.005414	0.026766	96762.1486	2589.890209	478352.7362	0.974192174	5097718.343	52.68298003
25	0.004114	0.020357	94172.25839	1917.069077	466007.4921	0.978389075	4619365.606	49.0522972
30	0.004841	0.023925	92255.18931	2207.162369	455936.6391	0.972706888	4153358.114	45.02031967
35	0.006367	0.031359	90048.02694	2823.822301	443492.7093	0.962866192	3697421.475	41.06054958
40	0.008770	0.042936	87224.20464	3745.043523	427024.1362	0.954565653	3253928.766	37.30534178
45	0.009771	0.047712	83479.16112	3982.966174	407622.5735	0.946852254	2826904.63	33.86359652
50	0.012074	0.058618	79496.19494	4659.925677	385958.3526	0.93971342	2419282.056	30.43267741
55	0.012568	0.060913	74836.26927	4558.465796	362690.2434	0.939903669	2033323.704	27.17029755
60	0.012388	0.060091	70277.80347	4223.048741	340893.8906	0.934088877	1670633.46	23.77185082
65	0.015273	0.073627	66054.75473	4863.407296	318425.1914	0.917083698	1329739.57	20.13086833
70	0.019597	0.093522	61191.34743	5722.726529	292022.552	0.895648718	1011314.378	16.52708137
75	0.025397	0.119753	55468.6209	6642.530038	261549.6244	0.84530719	719291.8263	12.9675448
80	0.045455	0.205823	48826.09086	10049.53526	221089.7779	0.516999357	457742.2019	9.374950848
85	0.163854	...	38776.5556	38776.5556	236652.424	...	236652.424	6.102976923

Table A42: North East - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.013373	0.013211	100000	1321.051133	98785.26552	0.984755335	6614888.905	66.14888905
1	0.001196	0.004770	98678.94887	470.6637122	393592.4021	0.996702869	6516103.639	66.03337099
5	0.000234	0.001170	98208.28516	114.8767326	490754.2339	0.996894203	6122511.237	62.34210512
10	0.001011	0.005044	98093.40842	494.7965104	489230.0508	0.995028718	5631757.003	57.41218593
15	0.001054	0.005258	97598.61191	513.1390741	486797.9502	0.992107225	5142526.952	52.69057471
20	0.002322	0.011553	97085.47284	1121.587971	482955.7635	0.98272661	4655729.002	47.95495007
25	0.004474	0.022129	95963.88487	2123.550281	474613.4804	0.981529041	4172773.239	43.48274608
30	0.003065	0.015214	93840.33459	1427.727157	465846.9144	0.97091305	3698159.758	39.40906407
35	0.009491	0.046452	92412.60743	4292.722252	452296.8485	0.950913909	3232312.844	34.97696834
40	0.009921	0.048421	88119.88518	4266.819126	430095.3644	0.946040764	2780015.995	31.54811187
45	0.012590	0.061091	83853.06605	5122.68744	406887.7471	0.929492202	2349920.631	28.02426603
50	0.016821	0.080803	78730.37861	6361.631475	378198.9881	0.909042388	1943032.884	24.67958262
55	0.020937	0.099465	72368.74714	7198.182444	343798.9115	0.901252434	1564833.896	21.62306185
60	0.020067	0.095407	65170.56469	6217.717957	309849.6059	0.913654601	1221034.984	18.73598901
65	0.017956	0.086225	58952.84673	5083.206783	283095.5179	0.826835258	911185.3782	15.45617266
70	0.064073	0.278410	53869.63995	14997.83525	234073.3557	0.700976196	628089.8603	11.65944047
75	0.069343	0.292701	38871.8047	11377.7999	164079.8505	0.730851235	394016.5046	10.13630593
80	0.059113	0.257829	27494.0048	7088.746425	119917.9614	0.478473922	229936.6542	8.363156108
85	0.185471	...	20405.25837	20405.25837	110018.6928	...	110018.6928	5.391683399

Table A43: North East - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.016327	0.016090	100000	1608.965683	98549.14462	0.983080178	7367745.018	73.67745018
1	0.000583	0.002328	98391.03432	229.0822745	392990.9444	0.997917077	7269195.874	73.88067342
5	0.000239	0.001196	98161.95204	117.4045736	490516.2488	0.996815184	6876204.929	70.04959443
10	0.001038	0.005176	98044.54747	507.4770907	488954.0446	0.996532475	6385688.68	65.13048247
15	0.000367	0.001832	97537.07038	178.6791846	487258.5842	0.995305421	5896734.636	60.45634355
20	0.001779	0.008864	97358.39119	862.9377095	484971.1101	0.989330582	5409476.052	55.56250453
25	0.002426	0.012064	96495.45348	1164.084315	479796.7504	0.982697995	4924504.942	51.03354369
30	0.004700	0.023247	95331.36917	2216.194371	471495.3048	0.973908707	4444708.191	46.62377379
35	0.005778	0.028495	93115.1748	2653.274468	459193.3826	0.965097486	3973212.886	42.66987518
40	0.007838	0.038396	90461.90033	3473.41089	443166.379	0.973697606	3514019.504	38.84529831
45	0.003311	0.016426	86988.48944	1428.84108	431510.0423	0.963217239	3070853.125	35.30183297
50	0.012953	0.062926	85559.64836	5383.910821	415637.9114	0.934869497	2639343.082	30.84798889
55	0.012006	0.058185	80175.73754	4665.001865	388567.205	0.95389313	2223705.171	27.73538778
60	0.007491	0.036769	75510.73567	2776.416495	370651.5875	0.950359711	1835137.966	24.30300737
65	0.013841	0.067031	72734.31918	4875.464696	352252.3357	0.923108553	1464486.378	20.13473687
70	0.018349	0.087923	67858.85448	5966.369661	325167.1439	0.883752207	1112234.043	16.39040404
75	0.031365	0.145629	61892.48482	9013.361866	287367.181	0.857530645	787066.8988	12.71667959
80	0.031707	0.147762	52879.12296	7813.512499	246426.164	0.506851505	499699.7177	9.449848821
85	0.177933	...	45065.61046	45065.61046	253273.5537	...	253273.5537	5.620107021

Table A44: Ngamiland East - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.020045	0.019689	100000	1968.899884	98226.22783	0.977021895	6092729.435	60.92729435
1	0.001959	0.007799	98031.10012	764.5147095	390284.7196	0.994467574	5994503.207	61.14899455
5	0.000432	0.002157	97266.58541	209.8521808	485808.2966	0.980900605	5604218.488	57.61709907
10	0.007348	0.036078	97056.73323	3501.605644	476529.652	0.978088208	5118410.191	52.73627105
15	0.001369	0.006821	93555.12758	638.102017	466088.0335	0.98845917	4641880.539	49.61652727
20	0.003719	0.018440	92917.02556	1713.380423	460708.9909	0.979271837	4175792.506	44.94109105
25	0.004448	0.022002	91203.64514	2006.638991	451159.3399	0.975109969	3715083.515	40.73393677
30	0.005670	0.027965	89197.00615	2494.405569	439929.9699	0.969346744	3263924.175	36.59230635
35	0.006668	0.032796	86702.60058	2843.490936	426444.6841	0.968470431	2823994.205	32.57104384
40	0.006489	0.031957	83859.10965	2679.878672	412999.0672	0.950644092	2397549.521	28.59020959
45	0.014649	0.070851	81179.23097	5751.599151	392615.1232	0.919074691	1984550.453	24.44652936
50	0.018782	0.089851	75427.63182	6777.247273	360842.623	0.890447318	1591935.33	21.10546615
55	0.027963	0.130877	68650.38455	8984.737914	321311.3459	0.858326019	1231092.707	17.93278676
60	0.032819	0.151696	59665.64663	9051.019556	275789.8885	0.832584616	909781.3613	15.24799299
65	0.040706	0.184665	50614.62708	9346.746996	229618.4184	0.807271596	633991.4729	12.52585487
70	0.047131	0.211701	41267.88008	8736.438248	185364.4271	0.698746454	404373.0545	9.798735813
75	0.104956	0.417880	32531.44184	13594.223	129522.7361	0.491010999	219008.6274	6.732213976
80	0.181818	0.610602	18937.21883	11563.10692	63597.088	0.289305978	89485.89127	4.725397751
85	0.284838	...	7374.11191	7374.11191	25888.80327	...	25888.80327	3.510768969

Table A45: Ngamiland East - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.021231	0.020839	100000	2083.876765	98150.59225	0.97674248	6233253.296	62.33253296
1	0.001474	0.005875	97916.12323	575.263652	390220.6476	0.994810537	6135102.704	62.65671578
5	0.000714	0.003565	97340.85958	346.9769089	485836.8556	0.997388341	5744882.056	59.0181973
10	0.000331	0.001655	96993.88267	160.5591891	484568.0154	0.99849104	5259045.201	54.22038025
15	0.000389	0.001944	96833.32349	188.2633265	483836.8216	0.973069048	4774477.185	49.30613774
20	0.012070	0.058801	96645.06016	5682.813111	470806.6352	0.960609481	4290640.364	44.39585797
25	0.001988	0.009886	90962.24705	899.290424	452261.3176	0.990049593	3819833.729	41.99361661
30	0.002460	0.012233	90062.95662	1101.697015	447761.1335	0.982076093	3367572.411	37.39131533
35	0.004884	0.024140	88961.25961	2147.565306	439735.5045	0.975764171	2919811.278	32.82115485
40	0.005030	0.024863	86813.6943	2158.454893	429078.1502	0.958072871	2480075.773	28.56779444
45	0.012663	0.061492	84655.23941	5205.585214	411088.1353	0.93832472	2050997.623	24.22765132
50	0.012228	0.059366	79449.6542	4716.579476	385734.1593	0.931384388	1639909.488	20.64086376
55	0.018976	0.091226	74733.07472	6817.598269	359266.7738	0.756633642	1254175.328	16.78206514
60	0.095199	0.381038	67915.47645	25878.35582	271833.3276	0.719139907	894908.5546	13.17679859
65	0.027933	0.129897	42037.12063	5460.508233	195486.194	0.834093771	623075.227	14.82202438
70	0.050096	0.223323	36576.6124	8168.399281	163053.8168	0.748619787	427589.033	11.69023059
75	0.065268	0.280446	28408.21312	7966.966819	122065.3136	0.6796428	264535.2162	9.311927335
80	0.092896	0.377019	20441.2463	7706.742061	82960.81148	0.417695879	142469.9027	6.969726827
85	0.213993	...	12734.50424	12734.50424	59509.09121	...	59509.09121	4.673059124

Table A46: Ngamiland West - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.033113	0.032191	100000	3219.061814	97215.66433	0.963920748	6231435.488	62.31435488
1	0.002530	0.010058	96780.93819	973.4210727	384744.7096	0.991319179	6134219.824	63.38252076
5	0.001056	0.005265	95807.51711	504.4092613	477776.5624	0.996778683	5749475.114	60.01068901
10	0.000234	0.001167	95303.10785	111.2185991	476237.4928	0.995003232	5271698.552	55.31507493
15	0.002486	0.012375	95191.88925	1178.018183	473857.8443	0.974959444	4795461.059	50.37678206
20	0.007442	0.036572	94013.87107	3438.249756	461992.1806	0.966968589	4321603.215	45.96771908
25	0.005523	0.027239	90575.62131	2467.223594	446731.9269	0.96733466	3859611.034	42.61202935
30	0.008207	0.040251	88108.39772	3546.485802	432139.2767	0.951840326	3412879.107	38.73500365
35	0.011227	0.054609	84561.91192	4617.814846	411327.5899	0.948916798	2980739.83	35.249201
40	0.009799	0.047842	79944.09707	3824.650456	390315.6597	0.940929919	2569412.24	32.14011209
45	0.015075	0.072735	76119.44662	5536.578163	367259.682	0.91928127	2179096.581	28.62733083
50	0.017635	0.084352	70582.86845	5953.790635	337614.9469	0.927988357	1811836.899	25.66964107
55	0.012870	0.062390	64629.07782	4032.210334	313302.7398	0.909784355	1474221.952	22.81050576
60	0.026622	0.125227	60596.86748	7588.364171	285037.931	0.860040903	1160919.212	19.15807302
65	0.032110	0.148497	53008.50331	7871.605371	245144.2796	0.852891672	875881.281	16.52341089
70	0.032110	0.148739	45136.89794	6713.626663	209081.5144	0.81758742	630737.0015	13.97386684
75	0.050388	0.224171	38423.27128	8613.377562	170942.4159	0.752677515	421655.4871	10.97396117
80	0.064935	0.280271	29809.89372	8354.838499	128664.5128	0.486805725	250713.0712	8.410398023
85	0.175791	...	21455.05522	21455.05522	122048.5584	...	122048.5584	5.688568833

Table A47: Ngamiland West - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.026690	0.026083	100000	2608.349752	97726.1713	0.969530766	6983917.553	69.83917553
1	0.002593	0.010304	97391.65025	1003.558974	387039.2116	0.993126093	6886191.381	70.70617824
5	0.000421	0.002105	96388.09127	202.9221474	481433.151	0.997756754	6499152.17	67.42692052
10	0.000477	0.002382	96185.16913	229.0669808	480353.1782	0.994840432	6017719.019	62.56389705
15	0.001966	0.009791	95956.10215	939.4654661	477874.7632	0.983566022	5537365.841	57.70728194
20	0.004675	0.023124	95016.63668	2197.151131	470021.3798	0.974263186	5059491.077	53.24847578
25	0.005283	0.026063	92819.48555	2419.116365	457924.527	0.97769636	4589469.698	49.44511026
30	0.003845	0.019042	90400.36918	1721.36428	447711.1432	0.976642267	4131545.171	45.70274666
35	0.005688	0.028045	88679.0049	2487.04528	437253.626	0.974198674	3683834.027	41.54121972
40	0.004715	0.023301	86191.95962	2008.354009	425971.9026	0.972845216	3246580.401	37.66685913
45	0.006452	0.031759	84183.60561	2673.578927	414404.7275	0.967530293	2820608.499	33.50543705
50	0.006832	0.033606	81510.02669	2739.191418	400949.1273	0.95833428	2406203.771	29.52034086
55	0.010649	0.051944	78770.83527	4091.651596	384243.2933	0.936866814	2005254.644	25.4568158
60	0.015695	0.075657	74679.18367	5649.985396	359984.7899	0.90729187	1621011.351	21.70633463
65	0.022847	0.108101	69029.19828	7462.120421	326611.2733	0.896668958	1261026.561	18.2680169
70	0.021314	0.101388	61567.07786	6242.178059	292862.1902	0.846215856	934415.2875	15.1771908
75	0.045977	0.205951	55324.8998	11394.23569	247824.6289	0.828790091	641553.0973	11.59610048
80	0.029570	0.138252	43930.66411	6073.496044	205394.5968	0.478334402	393728.4684	8.962497527
85	0.201011	...	37857.16806	37857.16806	188333.8716	...	188333.8716	4.974853674

Table A48: Chobe - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.027397	0.026752	100000	2675.185256	97644.26102	0.972329339	5935286.791	59.35286791
1	0.000826	0.003296	97324.81474	320.8261763	388520.4087	0.995853002	5837642.53	59.98102895
5	0.000720	0.003593	97003.98857	348.5588723	484148.5457	0.996196532	5449122.122	56.17420688
10	0.000805	0.004014	96655.4297	388.0184753	482307.1023	0.99078415	4964973.576	51.36776683
15	0.003257	0.016169	96267.41122	1556.554507	477862.2322	0.982558048	4482666.474	46.5647348
20	0.003003	0.014887	94710.85671	1409.992137	469527.382	0.992103104	4004804.241	42.28453189
25	0.000608	0.003035	93300.86458	283.173116	465819.5732	0.989695973	3535276.859	37.89114791
30	0.004476	0.022183	93017.69146	2063.387504	461019.7557	0.967749387	3069457.286	32.9986397
35	0.008021	0.039347	90954.30396	3578.755869	446151.5858	0.961864911	2608437.53	28.67854974
40	0.007519	0.036928	87375.54809	3226.598166	429137.5556	0.948690742	2162285.945	24.74703727
45	0.014052	0.067982	84148.94992	5720.639138	407118.8259	0.930411666	1733148.389	20.59619746
50	0.015254	0.073674	78428.31078	5778.123527	378788.105	0.877163533	1326029.563	16.90753696
55	0.040541	0.185409	72650.18726	13469.96418	332259.1126	0.778630506	947241.4581	13.03838977
60	0.059524	0.260209	59180.22308	15399.23114	258707.0811	0.651999851	614982.3454	10.39168684
65	0.110390	0.425303	43780.99194	18620.18584	168676.9782	0.635995012	356275.2644	8.137669993
70	0.069565	0.296604	25160.8061	7462.797648	107277.7168	0.485471627	187598.2862	7.455972811
75	0.240741	0.708433	17698.00845	12537.84705	52080.28769	0.381925686	80320.56936	4.538395921
80	0.111111	0.428298	5160.1614	2210.088845	19890.79963	0.295658597	28240.28168	5.472751623
85	0.353324	...	2950.072555	2950.072555	8349.48205	...	8349.48205	2.830263288

Table A49: Chobe - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.044674	0.043094	100000	4309.35395	96463.22863	0.955173327	6210593.518	62.10593518
1	0.001689	0.006728	95690.64605	643.7894944	381123.4346	0.993255293	6114130.289	63.894754
5	0.000733	0.003656	95046.85656	347.5206259	474365.4812	0.996052836	5733006.855	60.31769027
10	0.000850	0.004239	94699.33593	401.4386283	472493.0831	0.995212311	5258641.374	55.52986536
15	0.001135	0.005660	94297.8973	533.7469061	470230.9331	0.993142471	4786148.291	50.75562051
20	0.001699	0.008463	93764.1504	793.5534689	467006.311	0.988186918	4315917.357	46.02950423
25	0.003218	0.015971	92970.59693	1484.843938	461489.5271	0.978859835	3848911.046	41.39922915
30	0.005416	0.026745	91485.75299	2446.762891	451733.5623	0.967355094	3387421.519	37.02676547
35	0.007768	0.038126	89038.9901	3394.671362	436986.7627	0.959928994	2935687.957	32.97081373
40	0.008679	0.042508	85644.31874	3640.584575	419476.2636	0.946851447	2498701.194	29.17532921
45	0.013550	0.065630	82003.73416	5381.866149	397181.7072	0.925958813	2079224.931	25.35524695
50	0.017241	0.082756	76621.86801	6340.929233	367773.9022	0.900793222	1682043.224	21.95252174
55	0.023810	0.112233	70280.93878	7887.815262	331288.2384	0.905670379	1314269.321	18.70022433
60	0.017182	0.082626	62393.12352	5155.291266	300037.9444	0.810679231	982981.083	15.75463813
65	0.069149	0.293851	57237.83225	16819.40895	243234.53	0.778478359	682943.1386	11.93167372
70	0.026490	0.124101	40418.4233	5015.968641	189352.8178	0.802296958	439708.6086	10.87891542
75	0.074468	0.319554	35402.45466	11312.9822	151917.1898	0.504539459	250355.7908	7.071707123
80	0.215686	0.686274	24089.47246	16531.96835	76648.21672	0.221360158	98438.601	4.086374294
85	0.346827	...	7557.50411	7557.50411	21790.38429	...	21790.38429	2.883277861

Table A50: Ghanzi - **MALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.022375	0.021936	100000	2193.62027	98037.9509	0.96881498	5630797.066	56.30797066
1	0.005208	0.020575	97806.37973	2012.34128	386369.5393	0.986403441	5532759.115	56.56848899
5	0.000962	0.004798	95794.03845	459.5909022	477821.215	0.98947017	5146389.576	53.72348488
10	0.003285	0.016290	95334.44755	1552.959546	472789.8389	0.981904894	4668568.361	48.97042445
15	0.004310	0.021337	93781.488	2001.011532	464234.6568	0.970540159	4195778.522	44.73994401
20	0.007564	0.037131	91780.47647	3407.885698	450558.3777	0.96577968	3731543.865	40.65727275
25	0.005954	0.029319	88372.59077	2591.027084	435140.1258	0.97365416	3280985.487	37.12673193
30	0.005096	0.025172	85781.56369	2159.251567	423675.9934	0.966335163	2845845.362	33.17548946
35	0.009068	0.044399	83622.31212	3712.731176	409413.0101	0.948886564	2422169.368	28.96558714
40	0.011862	0.057667	79909.58094	4608.143003	388486.5045	0.932069031	2012756.358	25.18792283
45	0.016469	0.079193	75301.43794	5963.376733	362096.2398	0.911897083	1624269.854	21.57023688
50	0.020873	0.099399	69338.06121	6892.105321	330194.5047	0.875475735	1262173.614	18.20318584
55	0.033843	0.156666	62445.95589	9783.183015	289077.2767	0.800452391	931979.1091	14.92457111
60	0.055556	0.244103	52662.77287	12855.14441	231392.5975	0.738668818	642901.8323	12.20789938
65	0.063953	0.274598	39807.62846	10931.08982	170922.4964	0.713778278	411509.2349	10.33744663
70	0.074510	0.314797	28876.53864	9090.253097	122000.7651	0.561143267	240586.7384	8.3315643
75	0.161538	0.558918	19786.28554	11058.90824	68459.90797	0.494973679	118585.9733	5.993341856
80	0.110000	0.427098	8727.377302	3727.443779	33885.85253	0.323987385	50126.06535	5.743542833
85	0.307874	...	4999.933524	4999.933524	16240.21282	...	16240.21282	3.248085748

Table A51: Ghanzi - **FEMALES**

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.016517	0.016274	100000	1627.428553	98533.39749	0.977296498	6004082.814	60.04082814
1	0.003458	0.013712	98372.57145	1348.841176	390114.8517	0.989408042	5905549.417	60.03247989
5	0.001362	0.006787	97023.73027	658.4576457	483472.5072	0.994739307	5515434.565	56.84624318
10	0.000746	0.003724	96365.27263	358.9024837	480929.1069	0.977278576	5031962.058	52.21758753
15	0.009554	0.046773	96006.37014	4490.462163	470001.7127	0.966028099	4551032.951	47.40344775
20	0.002949	0.014629	91515.90798	1338.771732	454034.8612	0.982068291	4081031.238	44.59368134
25	0.004843	0.023945	90177.13625	2159.289293	445893.2401	0.969385225	3626996.377	40.22079795
30	0.007628	0.037459	88017.84695	3297.042831	432242.3188	0.958717541	3181103.137	36.14156955
35	0.009298	0.045480	84720.80412	3853.075743	414398.2931	0.942172991	2748860.818	32.4461134
40	0.014249	0.068794	80867.72838	5563.191418	390434.8794	0.940058987	2334462.525	28.86766541
45	0.010761	0.052449	75304.53696	3949.612135	367031.8172	0.917208109	1944027.646	25.81554478
50	0.025278	0.119259	71354.92483	8509.721028	336644.5591	0.873878452	1576995.829	22.10072861
55	0.026420	0.123676	62845.2038	7772.428623	294186.4263	0.886902453	1240351.269	19.73660987
60	0.022609	0.107112	55072.77518	5898.940301	260914.6632	0.854901944	946164.8431	17.18026448
65	0.042216	0.191497	49173.83488	9416.631289	223056.4528	0.793635955	685250.18	13.93526012
70	0.050000	0.222633	39757.20359	8851.281045	177025.6209	0.712388311	462193.7271	11.62540837
75	0.084967	0.346707	30905.92254	10715.31225	126110.983	0.702145898	285168.1062	9.226972787
80	0.056338	0.247077	20190.61029	4988.637138	88548.30947	0.443292399	159057.1232	7.877776894
85	0.215604	...	15201.97315	15201.97315	70508.81377	...	70508.81377	4.638135659

Table A52: Kgalagadi South - MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.013055	0.012900	100000	1289.98278	98812.68125	0.986252562	6568370.885	65.68370885
1	0.000560	0.002235	98710.01722	220.6567139	394313.5995	0.996172095	6469558.204	65.5410503
5	0.000984	0.004907	98489.36051	483.2648548	491238.6404	0.994978843	6075244.605	61.68427304
10	0.001030	0.005136	98006.09565	503.3697201	488772.054	0.995806066	5584005.964	56.97610875
15	0.000634	0.003165	97502.72593	308.6378329	486722.1764	0.996577159	5095233.91	52.25734831
20	0.000761	0.003798	97194.0881	369.1447482	485056.204	0.996503322	4608511.734	47.41555607
25	0.000715	0.003568	96824.94335	345.5038793	483360.1185	0.991644312	4123455.53	42.58670738
30	0.003040	0.015101	96479.43947	1456.903839	479321.3124	0.981107386	3640095.411	37.72923466
35	0.004762	0.023567	95022.53563	2239.360492	470265.6798	0.950595414	3160774.099	33.26341565
40	0.015957	0.076884	92783.17514	7133.495806	447032.3985	0.9325097	2690508.419	28.99780499
45	0.010587	0.051528	85649.67933	4413.361438	416862.0479	0.947301604	2243476.021	26.19363012
50	0.012085	0.058744	81236.3179	4772.133922	394894.0868	0.918451766	1826613.973	22.48518914
55	0.022807	0.108180	76464.18397	8271.904075	362691.1714	0.880687479	1431719.886	18.72405892
60	0.027919	0.130774	68192.2799	8917.749598	319417.5734	0.833586105	1069028.715	15.67668241
65	0.045161	0.202865	59274.5303	12024.7377	266262.051	0.79624995	749611.1412	12.64642904
70	0.043011	0.192990	47249.7926	9118.758984	212011.1449	0.84110961	483349.0902	10.22965528
75	0.032520	0.152085	38131.03362	5799.17432	178324.6114	0.451494697	271337.9454	7.115934703
80	0.358025	0.891551	32331.8593	28825.50462	80512.61642	0.134397048	93013.33395	2.876832201
85	0.280492	...	3506.354681	3506.354681	12500.71753	...	12500.71753	3.56516059

Table A53: Kgalagadi South - FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.033426	0.032500	100000	3250.006807	97229.36878	0.966180144	6142500.742	61.42500742
1	0.001168	0.004656	96749.99319	450.5085639	385860.7033	0.995505532	6045271.374	62.48342945
5	0.000481	0.002403	96299.48463	231.4335349	480918.8393	0.997372102	5659410.67	58.7688573
10	0.000571	0.002853	96068.05109	274.0887961	479655.0335	0.997500276	5178491.831	53.90441226
15	0.000653	0.003260	95793.9623	312.3083449	478456.0283	0.92738644	4698836.798	49.05149223
20	0.034826	0.161840	95481.65395	15452.71374	443713.633	0.890077247	4220380.769	44.20096002
25	0.004286	0.021150	80028.94021	1692.597354	394939.409	0.98638706	3776667.136	47.19126764
30	0.002297	0.011423	78336.34286	894.8615535	389563.1227	0.975708126	3381727.727	43.16933372
35	0.008283	0.040655	77441.4813	3148.41806	380099.9043	0.95827937	2992164.605	38.63775014
40	0.007993	0.039187	74293.06324	2911.347235	364241.8967	0.957346989	2612064.7	35.15893122
45	0.009823	0.047987	71381.71601	3425.401702	348705.883	0.941015717	2247822.804	31.49017605
50	0.014620	0.070594	67956.3143	4797.335025	328137.7166	0.9238033	1899116.921	27.94614364
55	0.016129	0.077412	63158.97928	4889.269367	303134.7056	0.935808308	1570979.204	24.87341027
60	0.011186	0.054456	58269.70991	3173.109258	283675.9759	0.913860849	1267844.498	21.75820851
65	0.026738	0.125807	55096.60065	6931.560666	259240.3681	0.863423728	984168.5224	17.8625997
70	0.031008	0.144100	48165.03999	6940.598003	223834.2851	0.828972775	724928.1543	15.05091981
75	0.046784	0.210575	41224.44198	8680.8201	185552.5286	0.708607045	501093.8692	12.15526142
80	0.092593	0.374096	32543.62188	12174.42866	131483.829	0.583307123	315541.3406	9.695950308
85	0.110668	...	20369.19322	20369.19322	184057.5117	...	184057.5117	9.036072742

Table A54: Kgalagadi North - MALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.035556	0.034503	100000	3450.262189	97038.62105	0.964669492	6643179.93	66.4317993
1	0.000956	0.003815	96549.73781	368.3519684	385296.1252	0.995043305	6546141.308	67.80071554
5	0.000803	0.004005	96181.38584	385.1876641	479943.9601	0.995732607	6160845.183	64.0544439
10	0.000908	0.004531	95796.19818	434.0560748	477895.8507	0.99553906	5680901.223	59.30194863
15	0.000947	0.004724	95362.1421	450.5342217	475763.9858	0.992427777	5203005.373	54.5604918
20	0.002141	0.010653	94911.60788	1011.052415	472161.3948	0.990332031	4727241.387	49.80677803
25	0.001802	0.008972	93900.55547	842.5164045	467596.5531	0.979344767	4255079.992	45.31474783
30	0.006816	0.033541	93058.03906	3121.29283	457938.2373	0.972481943	3787483.439	40.70022834
35	0.003861	0.019118	89936.74623	1719.446651	445336.6666	0.977291578	3329545.201	37.02096574
40	0.006188	0.030529	88217.29958	2693.216502	435223.7735	0.938735762	2884208.535	32.69436435
45	0.019374	0.092553	85524.08308	7915.471969	408560.1207	0.921394713	2448984.761	28.6350309
50	0.011682	0.056665	77608.61111	4397.723546	376445.1353	0.946993391	2040424.641	26.29121449
55	0.011268	0.054866	73210.88756	4016.80075	356491.055	0.921037906	1663979.505	22.72857987
60	0.023166	0.109928	69194.08681	7606.373106	328341.7748	0.868275178	1307488.45	18.89595644
65	0.034091	0.157808	61587.71371	9719.01178	285091.013	0.778079782	979146.6757	15.89840922
70	0.066667	0.285109	51868.70193	14788.23695	221823.5531	0.732764183	694055.6627	13.38101084
75	0.055556	0.243531	37080.46498	9030.241999	162544.3547	0.681973686	472232.1096	12.73533409
80	0.100000	0.395187	28050.22298	11085.09727	110850.9727	0.64205568	309687.7549	11.04047391
85	0.085322	...	16965.12571	16965.12571	198836.7822	...	198836.7822	11.72032472

Table A55: Kgalagadi North - FEMALES

AGE	m(x,n)	q(x,n)	l(x)	d(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	0.016129	0.015898	100000	1589.766786	98565.54121	0.978701044	6964069.193	69.64069193
1	0.002921	0.011600	98410.23321	1141.533697	390784.9807	0.991762744	6865503.652	69.76412338
5	0.000844	0.004211	97268.69952	409.5524885	485319.6164	0.995613047	6474718.671	66.56528465
10	0.000915	0.004564	96859.14703	442.0773082	483190.5419	0.995415425	5989399.055	61.83617385
15	0.001133	0.005649	96417.06972	544.705991	480975.3184	0.975350988	5506208.513	57.10823331
20	0.008505	0.041619	95872.36373	3990.083039	469119.7521	0.97699453	5025233.194	52.41586834
25	0.000894	0.004462	91882.28069	409.9528045	458327.4316	0.988959646	4556113.442	49.58642089
30	0.004296	0.021290	91472.32789	1947.442706	453267.3347	0.972044206	4097786.011	44.79809474
35	0.006296	0.030985	89524.88518	2773.951168	440595.8866	0.975049866	3644518.676	40.7095599
40	0.003891	0.019269	86750.93401	1671.607028	429602.9601	0.974410968	3203922.789	36.9324299
45	0.007080	0.034833	85079.32698	2963.609451	418609.8361	0.954942157	2774319.829	32.60862453
50	0.011442	0.055699	82115.71753	4573.77796	399748.1796	0.936497297	2355709.993	28.68768689
55	0.014963	0.072238	77541.93957	5601.442918	374363.0896	0.908574448	1955961.814	25.22456653
60	0.023333	0.110321	71940.49665	7936.523759	340136.7374	0.88930074	1581598.724	21.98481798
65	0.022321	0.105491	64003.9729	6751.871831	302483.8522	0.90512091	1241461.987	19.39663947
70	0.018293	0.087477	57252.10106	5008.252327	273784.4594	0.893386132	938978.1344	16.40076289
75	0.027972	0.130959	52243.84874	6841.824881	244595.2393	0.861460125	665193.675	12.73247839
80	0.033898	0.157321	45402.02386	7142.679488	210709.0454	0.499025608	420598.4357	9.263869757
85	0.182283	...	38259.34437	38259.34437	209889.3903	...	209889.3903	5.485964116

UTILISATION OF GREEN ENERGY AMONG HOUSEHOLDS IN BOTSWANA

By;
Nomazile Chicho[1] and Keneilwe Kgosikoma[2]

EXECUTIVE SUMMARY

There has been an intensive global dependence on fossil fuels and Botswana is not an exception. However, there is a drive towards adoption of environmentally friendly energy sources. Botswana envisages a reduction on its reliance on fossil fuels and targets a 50% proportion of domestic households to generate their electric power from solar and other renewable sources by 2036. This paper aims to establish the main energy sources and provide baseline data on utilisation of green energy by households in Botswana. Primary data from the National Population and Housing Census of 2022 was analysed using SPSS and STATA to establish the extent of use of green energy in the country, categorised across primary uses, lighting, main and alternative cooking sources, heating space and/or water. From the data, descriptive statistics were used to summarise the findings using tables.

The results showed that the predominant energy source for lighting and heating was electricity from the national grid, generated primarily from fossil fuels. LPG was the predominant energy source for cooking, followed by firewood. Renewable, or green energy sources include electricity from solar or solar home system, and biogas, used by at most only about 7% of the total households. There is need for intensive promotion of transition towards green energy sources by raising awareness on the diverse possibilities and opportunities of using green energy sources and providing incentives for the green transition.

INTRODUCTION

There has been an intensive global dependence on fossil fuels and Botswana is not an exception. A drive towards adoption of environmentally friendly energy sources has been on national and international agendas for a long time (African Union Commission, 2015). Botswana envisages a reduction on its reliance on fossil fuels and targets a 50% proportion of domestic households to generate their electric power from solar and other renewable sources by 2036 (GOB, 2016). The country has committed to support and facilitate initiatives targeted at increasing the contribution of solar energy to the total energy supply mix and to explore the potential for wind and facilitate wind power development (GOB, 2009, 2016, NEP, 2021). Notably, the NDP 8, NDP 9 and NDP 10 also emphasised the reduction of dependence on fossil fuels which was noted to be increasing in NDP10 (GOB, 1997,2002, 2009). This is in line with the sustainable development goal 7 and target 7.2 to substantially increase the share of renewable energy in the global energy mix by 2030 (Statistics Botswana, 2018) for sustainable economic development in Botswana (Pillar 1 of Vision 2036).

Globally, countries, Botswana inclusive, have made commitments towards reduction of fossil fuels; thus, transitioning towards green energy and alternative clean energy or renewable sources such as solar, wind and bioenergy which are expected to account for about 15% of total energy mix in Botswana by 2030 (IRENA, 2021). According to the Population and Housing Census of 2011, the proportion of the population primarily

reliant on clean fuels was 64.08% (Statistics Botswana, 2018); however, the main contributor was traditionally biomass which was mostly firewood (GOB, 2022; IRENA, 2021). Despite, such observation, dependence on fossil fuels remains significant in Botswana. Nonetheless, NDP11 indicates efforts through the Integrated Water and Energy Resource Strategy (WERS) to promote efficient and optimal use of energy resources through use of renewable energy. Botswana's intended nationally determined contribution (NDC) on adoption of clean energy may be achieved through ensuring that there are conducive legal frameworks, legislation, policies and strategies that promote and avail technology and resources for using green energy in most aspects of life and economic activities (UNFCC, 2022). Energy sector contributes significantly to climate change due to extensive dependency on fossil fuels; therefore, adoption of clean energy is imperative.

Aim and Objectives

The aim of this study is to determine the extent of use of green energy sources by the local populace and based on this aim, the main objectives are:

- **To establish main energy source(s) utilised by households in Botswana.**
- **To establish green energy sources utilised for various energy uses by households in Botswana.**

Significance of the study

Green energy has always been called for its implementation at national and household levels. Therefore, the findings of this study shall serve as a baseline to establish the milestones reached by Botswana as far as green energy utilisation is concerned in addressing sustainable development goals (Maswabi et al., 2021). With Botswana's intended nationally determined contribution having set its overall greenhouse gas emissions reduction of 15% by 2030 (UNCCC, 2022), utilisation of green or clean energy is indispensable. Therefore, with this report, policy makers and implementers may utilise the finding to inform adoption of green energy across all sectors; thus, meeting the SDGs and Vision 2036 defined objectives on energy (Government of Botswana, 2016; Statistics Botswana and UNFPA, 2018).

Literature Review

This sectioned reviews the literature that informed this article regarding the green energy sources and utilisation among households in Botswana. This will help in establishing if the households are increasingly using the green energy or not. The literature reviewed highlights the global and regional trends of adoption of green energy at industrial and domestic level in various countries.

Green Energy and its Significance

Development of the green energy sub-sector remains a major challenge for the African continent (Hafner, Tagliapietra and de Strasser, 2018) and Botswana is not an exception. Literature indicates that Botswana's total primary energy supply is fossil-based, especially the oil products and coal (IRENA, 2021). It is further noted that these are supplemented by biomass and waste energy. According to IRENA (2021), though remains limitedly exploited, Botswana has potential for intensively adopting renewable energy, particularly, the solar, wind and bioenergy since it receives adequate sunlight, has adequate wind and can produce enough bioenergy inputs, respectively. To achieve this, Botswana has established key actions that would help in energy transition.

Transition to Green Energy Utilisation, a Drive to Zero Emissions

The significance of green energy has been noted by Botswana's set targets for energy transition (IRENA, 2021), among others being:

Promotion and facilitation of the implementation of a clear long-term vision for renewable energy development;

Establishing a grid code that is conducive to variable renewable power;

Support for the growth of solar rooftop and home systems through strong incentives and policy instruments;

Promotion of the role of renewable energy for heating, cooling and cooking;

Defining a clear regulatory framework to manage risks involved in private sector participation;

Performing a location-specific (pre-feasibility) study for renewable energy generation and streamline permitting processes;

Developing a strategy for renewable energy and agriculture;

Developing local human capacities along the project value chain.

These key actions align well with SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all) and 13 (take urgent action to combat climate change and its impacts). Therefore, households may contribute towards green environment through the types of energy they utilise.

It is important to note that most of the places have been connected to the national electricity grid, however, this does not imply that all have access to electricity (Danielsson and Ekman, 2023). Furthermore, this grid is mostly reliant on fossil fuel generated electricity, a move the world is transitioning away from. Therefore, this serves as an opportunity for the new connections, specially, in rural areas, farms and cattle post to enhance utilisation of green energy such as solar, wind and bioenergy.

With reference to national energy use survey of 2022, the national energy consumption by district, locality type and per household indicatively highlighted that households utilised mostly biomass, petrol (gasoline), diesel, paraffin, liquid petroleum gas, coal, and electricity, with urban areas consuming more electricity compared to their counter parts (Department of Energy, 2023) in rural areas.

Government Initiatives and Policies Promoting Green Energy

Botswana is making efforts towards development and implementation of legislation and strategies for exploitation of renewable energy. Thus, the development of the Renewable Energy Strategy of Botswana (RESB) and the National Energy Efficiency Strategy (NEES) in 2019 are a testimony for government commitment in achieving clean environment (MMRGTES, 2021. These subsequently informed key aspects for inclusion in the Botswana's Energy Policy where some of the objectives include:

To diversify the national energy mix by promoting renewable energy sources, especially solar and clean coal technologies.

To minimise the impacts of energy supply and consumption on the environment through increase of renewable energy in the supply mix and improved efficiency in energy use.

To ensure equitable access to modern energy forms by the industry, rural communities and the disadvantaged groups.

To establish an effective and sustainable energy research and development platform that encourages innovation and promotes development of local skills.

Botswana is also guided by the National Energy Policy (NEP) which highlights the significance of adoption of renewable energy and energy efficiency measures. For example, the policy emphasises the diversification of the energy mix as well as promoting renewable energy sources (MMRGTES, 2021).

Opportunities and Challenges for Household Green Energy Utilisation

Even though in most cases the initial set up of the green energy systems is costly and requires technical knowhow, it has been noted that these projects usually save costs in the long run, offer energy security and are often environmentally friendly (Danielsson and Ekman, 2023; Asim, et al., 2022). This therefore calls for steady transition to and utilisation of green energy.

METHODOLOGY

Primary data from the National Population and Housing Census (NPHC) of 2022 was analysed using SPSS and STATA to establish the extent of use of green energy in the country, categorized across primary uses, lighting, main or alternative cooking source, heating space and/or water. From the data, descriptive statistics were used to summarize the findings using tables. Notably, trends towards adoption and use of renewable energy sources, particularly solar energy, is anticipated; hence, trend analysis on green energy is presented. With development of technology and exposure to information, it is also expected that there shall be some people utilising biogas and wind power. The analysis utilised chi-test to establish if there were significant differences among the fuels utilised.

FINDINGS AND DISCUSSIONS

This section outlines the results for the main sources of energy, and particularly the green energy sources. Most households have access to electricity, though from various sources, compared to 74% in 2011. The predominant energy source for lighting is electricity from the national grid, generated primarily from fossil fuels, used by 73% of all the households. Green energy still comprises a relatively small proportion of the total energy consumption for lighting at only 7.85% from solar.

The primary energy source for cooking was Liquefied Petroleum Gas (LPG), used by 35% of the total population, followed by firewood (30%) and electricity from the national grid (25%) as shown in **Table 1**. The primary source for cooking from green energy sources was biogas, used by about 7% of the total population. Green energy sources are utilised as an alternative energy source for cooking by about 6% of the total households.

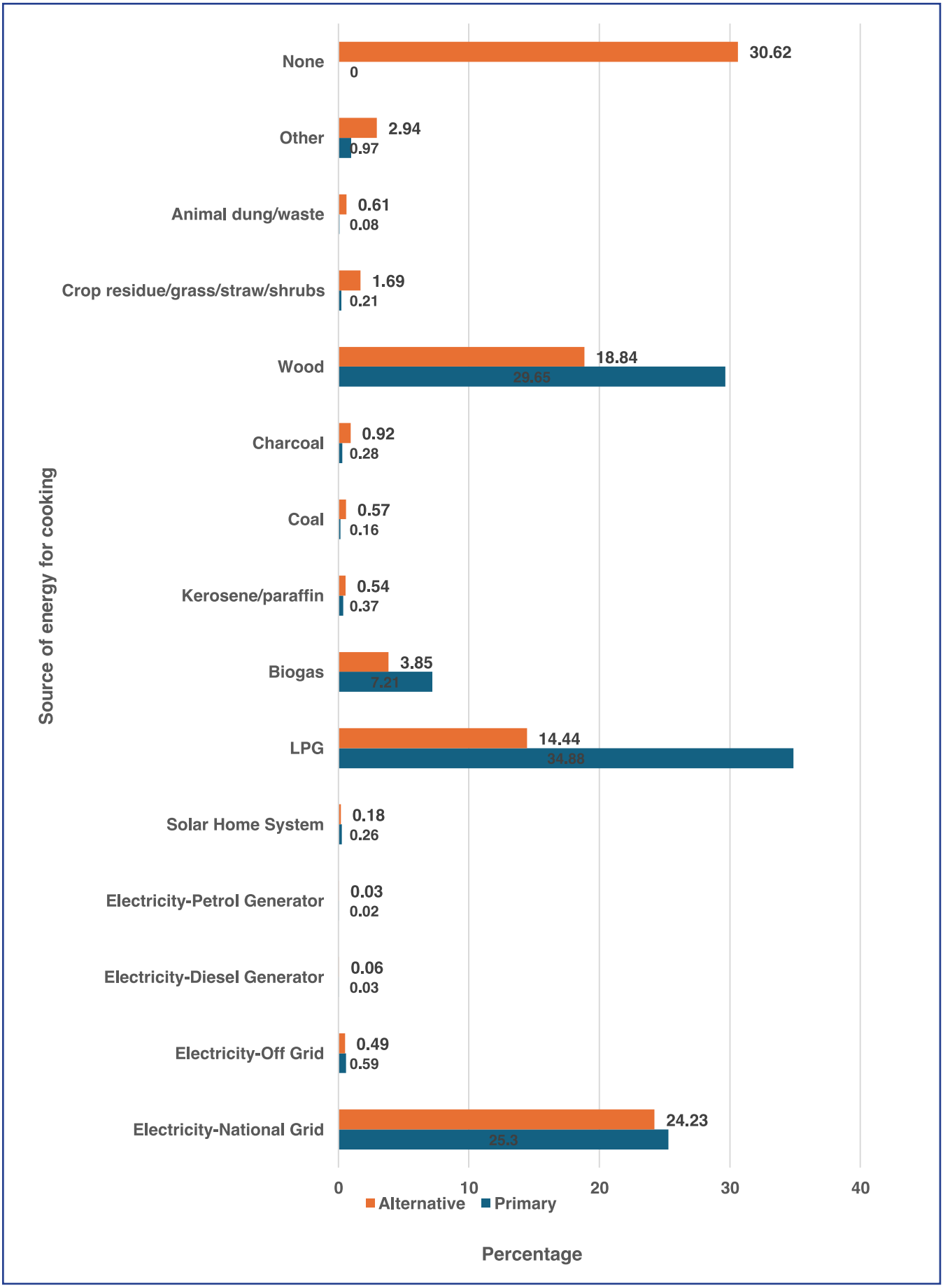
TABLE 1: Principal sources of energy (N = 695, 561)

SOURCE OF ENERGY	LIGHTING	COOKING	ALTERNATIVE COOKING	HEATING SPACE	HEATING WATER
Electricity- national grid	73.47	25.30	24.23	30.00	52.88
Electricity – off grid	0.36	0.59	0.49	0.45	0.49
Electricity Solar	1.10	-	-	-	-
Electricity Battery	0.68	-	-	-	-
Electricity generator	0.08	0.05	0.09	0.03	0.04
Solar home system	2.04	0.26	0.18	0.30	0.62
Solar lantern	4.71	n/a	n/a	n/a	n/a
LPG	0.49	34.88	14.44	1.39	3.80
Candle	8.61	n/a	n/a	n/a	n/a
Kerosene/ Paraffin	5.43	0.37	0.54	0.19	0.13
Firewood	1.06	29.65	18.84	25.24	37.23
Coal/ charcoal	0.02	0.44	1.49	0.65	0.63
Biogas	-	7.21	3.85	0.47	0.99
Crop residue/ grass/ straw/ shrub	-	0.21	1.69	0.10	0.20
Animal dung/ waste	-	0.08	0.61	0.07	0.06
None	-	-	30.62	38.94	2.54
Other	1.95	0.97	2.94	2.17	0.38
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Figure 1 indicates that most of the households (30%) have no alternative energy sources, indicating a possibility of risk for energy poverty among households. The important alternative energy sources for cooking are electricity from the national grid, firewood, and LPG, respectively **(also see Figure 2)**. The most prominent green energy source for cooking is biogas, used by 7.21% of the population as the primary source and by 3.85% as an alternative energy source.

There were significant differences in the means of households using all the green energy sources (solar and biogas) in rural and urban areas (urban and urban village). Generally, there is a higher use of green energy sources in urban areas compared to rural areas. There are households with no alternative cooking sources and/or energy sources for heating spaces, which could be indicative of vulnerability to energy poverty.

FIGURE 1: PRINCIPAL AND ALTERNATIVE SOURCES OF COOKING ENERGY FOR HOUSEHOLDS



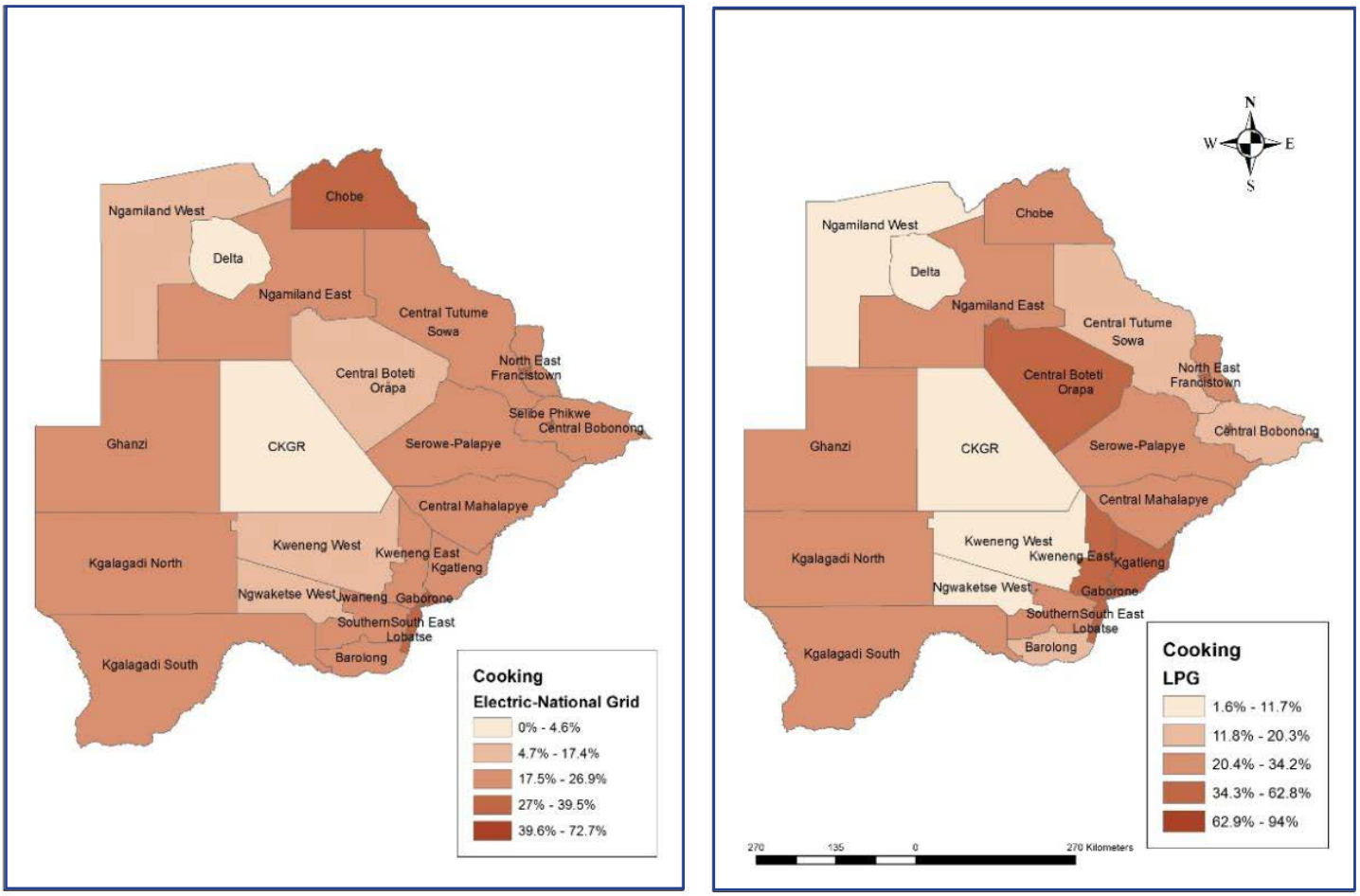
Sources of Renewable Energy for Lighting, Cooking and Heating by Locality at Household Level

Statistics presented in **Table 2** indicates substantial variations existing on sources of green energy used for lighting, cooking and heating across rural-urban continuum. Firewood remains the dominant source of energy for cooking (e.g. town and cities (3.2%); urban villages (15.3%) and rural areas (64.4%); however, promotion of alternative green energies is essential in order to prevent deforestation. Statistics indicatively highlight a relative increase of solar energy in the rural areas as opposed to urban areas. It can also be noted that rural areas still utilise cow dung for cooking and heating, a practice which may reduce reliance on firewood for energy.

TABLE 2: Percentage Distribution of Households by Source of Renewable Energy for Lighting, Cooking and Heating by Locality

			TOWNS AND CITIES	URBAN VILLAGES	RURAL AREAS	TOTAL %
SOLAR HOME SYSTEMS	Lighting		0.3	0.5	5.2	2.1
	Cooking		0.2	0.2	0.4	0.3
	Heating	space	0.3	0.3	0.4	0.3
		water	0.9	0.6	0.5	0.6
SOLAR LANTERN	Lighting		0.5	0.9	12.3	4.7
BIOGAS	Lighting		-	-	-	-
	Cooking		8.9	8.9	3.9	7.2
	Heating	space	0.5	0.6	0.3	0.2
		water	1.0	1.2	0.8	1.0
FIREWOOD	Lighting		0.1	0.3	2.7	1.1
	Cooking		3.2	15.3	64.7	29.7
	Heating	space	4.7	14.6	52.0	25.3
		water	7.7	26.2	70.0	37.3
COW DUNG	Lighting		-	-	-	-
	Cooking		0.0	0.0	0.2	0.1
	Heating	space	0.0	0.0	0.1	0.1
		water	0.0	0.0	0.2	0.1
CROP WASTE	Lighting		-	-	-	-
	Cooking		0.0	0.0	0.6	0.2
	Heating	space	0.0	0.1	0.2	0.1
		water	0.0	0.1	0.5	0.2
TOTAL NO. OF HOUSEHOLDS			150,142	307,268	239,835	

FIGURE 2: SPATIAL DISTRIBUTION FOR MAIN ENERGY SOURCES FOR COOKING IN BOTSWANA



Sources of Household Green Energy for Cooking by District

Further, **Table 3** highlight different green energy utilization for cooking across districts in Botswana. There is overreliance on firewood in the Delta (85.8%) and CKGR (85.7%) region, and this present an opportunity to introduce more energy sources like biogas and solar. Characteristically, urban areas do not utilize cow dung for energy. Ironically, it is noted that some of the enumerated people in Gaborone reported the use of biogas; and this may be allied to the tripartite dwelling system of Batswana who are likely to own a house in town, village, farm and a cattle-post of which one has a biodigester.

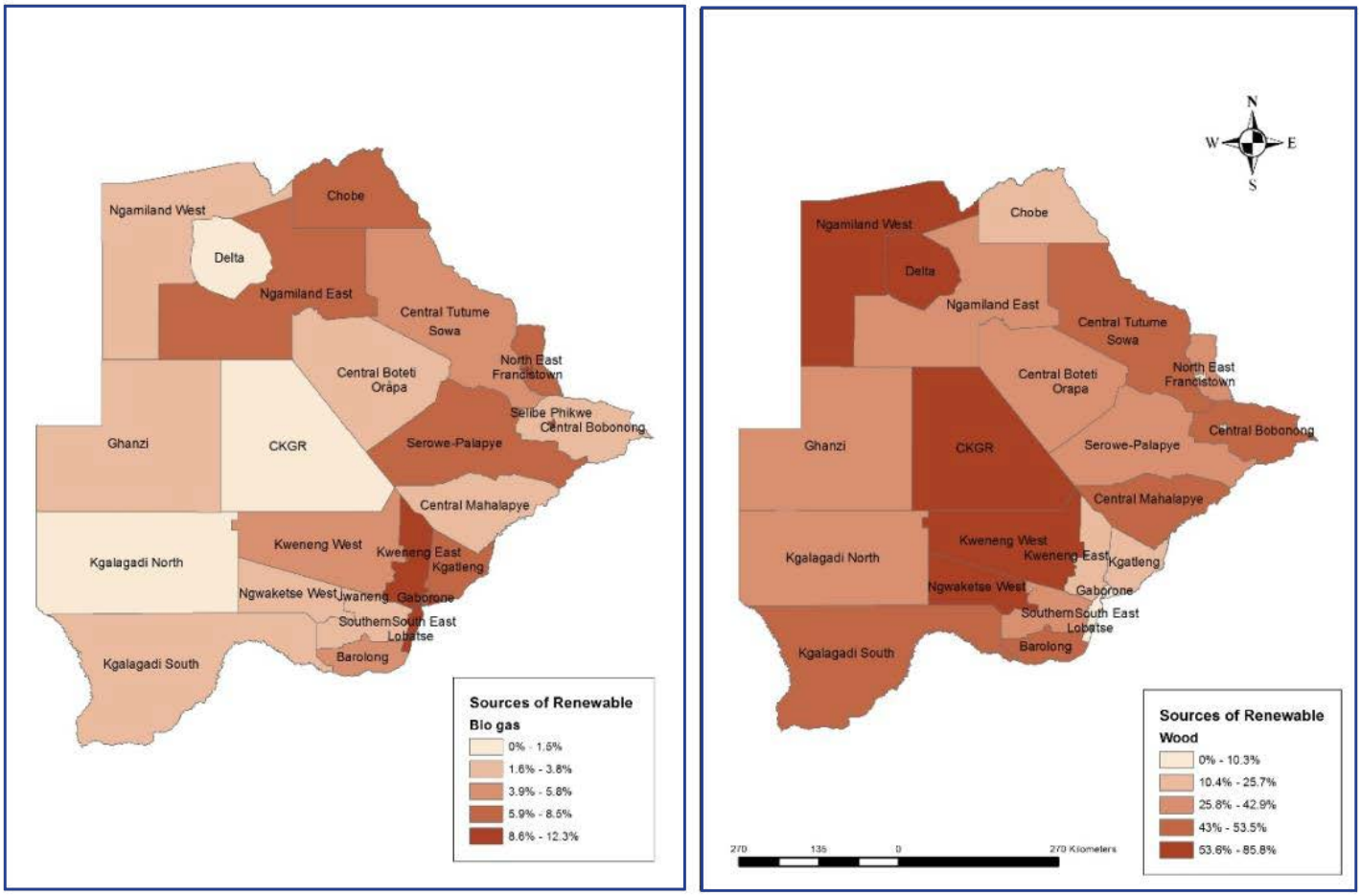
TABLE 9: Percentage Distribution of Households Source of Green Energy for Cooking by District

DISTRICT NAME	SOURCES OF RENEWABLE HOUSEHOLD ENERGY FOR COOKING					TOTAL HOUSEHOLDS
	SOLAR HOME SYSTEM	BIOGAS	WOOD	CROP RESIDUE/ GRASS/ STRAW/ SHRUBS	ANIMAL DUNG/ WASTE	
Gaborone	0.2	8.5	0.9	0	0	**82,421**
Francistown	0.2	12.3	6.4	0	0	**33,811**
Lobatse	0.1	7.3	4.2	0	0	**9,839**
Selibe Phikwe	0.2	10.5	10.3	0	0	**13,330**
Orapa	0.1	0.3	0	0	0	**3,049**
Jwaneng	0.1	1.4	1.2	0	0	**6,586**
Sowa	0.1	0.7	2.4	0	0	**1,106**
Southern	0.3	3.8	36.6	0.2	0.1	**37,806**
Barolong	0.1	4.6	50.3	0.6	0.4	**16,498**
Ngwaketse West	0.3	3.5	68.5	0.7	0.1	**6,588**
South East	0.2	9.5	7.7	0	0.1	**36,327**
Kweneng East	0.3	12	17.8	0.1	0.1	**100,751**
Kweneng West	0.2	4.9	69.4	1.1	0.4	**15,920**
Kgatleng (Wards)	0.2	8.3	25.7	0.1	0	**36,538**
Central Serowe -Palapye	0.2	7.5	39.6	0.3	0.1	**56,992**
Central Mahalapye	0.2	2.9	49.8	0.3	0.1	**36,683**
Central Bobonong	0.2	3.8	52.8	0.3	0.1	**22,212**
Central Boteti	0.6	2.9	38.5	0.8	0.1	**21,259**
Central Tutume	0.2	5.8	53.5	0.2	0.1	**46,626**
North East	0.2	6.5	39.9	0.2	0	**2,0912**

Sources of Household Green Energy for Cooking by District

Findings indicate that firewood remains the dominant source of green energy for heating water and space in various districts **(see Appendix 1)**. For example, Borolong (47.6%), Ngwaketse West (61.3%), Delta (86.3%), and CKGR (85.7%) just to mention a few. It is however important to note that other renewable energies, that were historically not so common, like solar and biogas are gaining traction in various districts such as Kweneng East (0.8%) and Kgatleng (0.8%) who use it for heating space **(see Figure 3)**. The same form of green energy has been utilised for heating water in South East (1.0%), Kweneng East (1.6%), Kweneng West (1.2%) and Central Tutume (1.2%) districts.

FIGURE 3: SPATIAL DISTRIBUTION OF UTILISATION OF BIOGAS AND WOOD FOR ENERGY SOURCES



Trends on Green Energy Utilization

Despite reported utilization of green energy by households, the relative use and adoption remains insignificant. Objectively, green energy consists of solar, biogas, solar energy, biomass (firewood), wind energy, hydropower and geothermal just to note a few. Notably, SDG 7 put an emphasis on increasing the share of renewable energy on the total final energy consumption in Botswana; an effort which may be achieved if there is an emphasis on the adoption of the same by households. With firewood subject to debates due to the capacity of communities to sustainably manage its availability; it however remains the main source of energy for cooking. This is also shown in previous statistics on energy (CSO, 2007); nevertheless, a trend shows a decline in the use of firewood for food preparation from 45.7% in 2001 to 29.7% in 2022 as shown in **Table 4**. Overall, the households utilizing firewood for various purposes has been reportedly declining between 1981, 1991 and 2001 population census reports. With solar uptake indicated to be gradually increasing and statistics shows that explicitly the increase is in rural areas who accounted for 73% in 2003, and these are likely to be less connected to the national electricity grid; hence, relatively higher proportions.

Notwithstanding lower adoption of green or renewable energy in Botswana, the penetration of the same must be appreciated. For example, the statistics from energy use survey indicate that there are 29,256 households using Solar Photovoltaic Systems in the country, 11,777 uses solar water heating system while 216 have biogas digesters. Nevertheless, the visibility of all these green energy systems remains higher in the rural villages. Regarding biogas digesters, all reportedly found in rural areas.

TABLE 10: National Energy Source Trends Among Households (%) For Lighting, Cooking And Heating – 1981 To 2022

HOUSEHOLD ENERGY SOURCE		1981	1991	2001	2011	2022
Solar Systems	**Lighting**	-	-	0.2	0.5	6.8
	Cooking	-	-	0.2	0.1	0.3
	Heating	-	-	-	0.1	0.3
Biogas	**Lighting**	-	-	0.1	--	--
	Cooking	-	-	0.6	0.9	7.2
	Heating	-	-	-	0.1	0.5
Wood	**Lighting**	-	-	5.6	3.6	1.1
	Cooking	85.8	63.3	45.7	41.2	29.7
	Heating	-	-	-	47.7	25.3
Cow dung	**Lighting**	-	-	-	-	-
	Cooking	-	-	0.1	0.1	--
	Heating	-	-	-	-	0.2[1]
Crop waste	**Lighting**	-	-	-	-	-
	Cooking	-	-	0.1	-	0.2
Other	**Lighting**	-	-	6.7	0.4	2
	Cooking	-	-	0.2	0.1	1.3
	Heating	-	-	-	33.6	39

[1] For heating purpose, the value includes animal dung, crop waste, gra0.5ss, shrubs and straws
NB: No data available (-); Zeros (--)
Some data from: Statistics Botswana, 2014

Policy Implications

The majority of households are reliant on fossil fuel-based electricity sources, predominantly coal-generated electricity from the national grid, but also from other sources such as LPG, petrol and diesel generators. There is need to make transition from non-renewable to renewable energy sources to supply the national electricity grid to reduce the country's carbon footprint and ensure sustainability of the environment. To ensure that Botswana aligns and achieve the Sustainable Development Goal 7 on clean energy, there should be developmental consideration in safeguarding that Vision 2036, National Development Plans, Botswana Energy Policy, Renewable Energy Strategy, Integrated Resource Plans, Climate Change Strategy and Action Plan and other policies do not only promote green energy but rather plans, budget for and allocate funds for development of infrastructures (physical and services) that cement adoption of the same. With this report indicating a relatively lower levels of green/renewable energy adoption, it is imperative to set targets and incentivize green technologies adoption, utilization and implementation policy initiatives. The benefits of renewable sources on the environment and household economies remain significant; therefore, this calls for urgent intensification of the same, both at urban and rural areas. This will help Botswana achieve the set target of increasing the share of renewable energy in the national energy mix.

Conclusions and Recommendations

Most of the households are highly reliant on fossil fuel energy sources. There is need to develop renewable energy sources to supply the national electricity grid. With noted minimal utiliatsion of green energy at household level nationwide, the enhancement of climatepreneurship approaches in the energy sector is imperative. This is because the energy utilisation contributes significantly to climate change; hence, turning these challenges into entrepreneurship opportunities is indispensable. Therefore, this recommends the following:

There should be intensive stakeholder engagement so that both the public and private sector engage in promoting adoptive measures for green energies through collaborative researches and joint funding. Relevant department to intensively raise awareness on green energy opportunities through entry points at grassroot levels such as kgotla meetings where the local communities are likely to be engaged.

Communities employ possible green energies at household levels.

The country invests in renewable energy infrastructure that are likely to be limited.

The country to offer subsidies or tax incentives for communities to adopt green energies, for example, people should find a motive to use biogas, only if the prices are affordable.

The municipalities and government bodies or energy utilistion related departments to intensively promote employment of green energies such as solar and biogas energy sources.

Capacity building on available avenues for green energy at household level and corporate organisations. Offer financial capital (grants and loans) for projects geared towards use or adoption of renewable energy technologies.

Also, offer incentives for individual households for using renewable energy sources like solar panels or biogas.

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APPENDICES

APPENDIX 1: Percentage Distribution of Households Source of Renewable Household Energy for Heating Space and Water

DISTRICT NAME	SOURCES OF HOUSEHOLD RENEWABLE ENERGY FOR HEATING SPACE					SOURCES OF HOUSEHOLD RENEWABLE ENERGY FOR HEATING WATER					TOTAL HOUSEHOLDS
	Solar home System	Biogas	Wood	Crop residue/ grass/ straw/ shrubs	Animal dung/waste	Solar home System	Biogas	Wood	Crop residue/ grass/straw/ shrubs	Animal dung/waste	
Gaborone	0.3	0.5	2.2	0	0	1	1	3.4	0	0	**82,421**
Francistown	0.3	0.6	6.3	0	0	0.5	1	12.5	0	0	**33,811**
Lobatse	0	0.5	8.1	0	0	0.1	1.8	12.5	0	0	**9,839**
Selibe Phikwe	0	0.2	10.2	0.1	0	0.6	0.7	20.3	0	0	**13,330**
Orapa	3.3	0	0.1	0	0	5.7	0	0	0	0	**3,049**
Jwaneng	0.4	0.2	3	0	0	1.6	0.3	5.5	0	0	**6,586**
Sowa	0	0	1.7	0	0	0.2	0.1	16.1	0	0	**1,106**
Southern	0.2	0.3	32.3	0.1	0.1	0.3	0.6	52.7	0.5	0.1	**37,806**
Barolong	0.1	0.2	47.6	0	0.2	0.1	0.7	62.4	0.1	0.2	**16,498**
Ngwaketse West	0.2	0.2	61.3	0.2	0.1	0.7	0.6	73.2	0.9	0.5	**6,588**
South East	0.2	0.6	12.2	0.1	0	0.8	1	17.4	0.1	0	**36,327**
Kweneng East	0.3	0.8	18.8	0.1	0.1	0.4	1.6	28.6	0.1	0.1	**100,751**
Kweneng West	0.2	0.6	68.3	0.2	0.2	0.3	1.2	72.9	0.5	0.4	**15,920**
Kgatleng (Wards)	0.3	0.8	23.1	0	0	0.5	1.3	38.7	0.1	0.1	**36,538**
Central Serowe -Palapye	0.1	0.5	32.7	0.1	0.1	0.3	1.1	47.8	0.2	0.1	**56,992**
Central Mahalapye	0.3	0.3	41.1	0.3	0.1	0.4	0.7	57.5	0.5	0.1	**36,683**
Central Bobonong	0.1	0.1	39.7	0.1	0	0.7	0.4	62.3	0.4	0	**22,212**
Central Boteti	0.2	0.2	33.7	0.2	0.3	0.6	0.5	43.7	0.4	0.1	**21,259**
Central Tutume	0.4	0.6	36.9	0.1	0	0.5	1.2	59	0.3	0	**46,626**
North East	0.1	0.2	34.6	0.1	0.1	0.4	0.6	47.8	0.1	0	**20,912**
Ngamiland East	0.3	0.3	24.5	0.1	0.1	0.5	0.8	39.1	0.1	0.1	**31,591**
Ngamiland West	0.4	0.1	39.2	0.3	0.2	1.3	0.4	64.5	0.3	0.1	**17,921**
Chobe	0.9	0.5	12.8	0	0.1	1.6	0.9	30	0	0	**10,124**
Delta	1.1	0.5	86.3	0.5	0	1.1	0	86.8	0.5	0	**192**
Ghanzi	0.6	0.2	35.4	0.1	0	1.6	0.7	50.5	0.2	0	**15,158**
CKGR	1.2	0	85.7	0	0	3.6	0	86.9	0	0	**84**
Kgalagadi South	0.3	0.2	43.3	0.3	0.2	0.3	0.4	51.4	0.8	0.1	**9,749**
Kgalagadi North	0.3	0.1	41.6	0.1	0	0.5	0.2	49.4	0.1	0	**7,172**
Total	**0.3**	**0.5**	**25.3**	**0.1**	**0.1**	**0.6**	**1**	**37.3**	**0.2**	**0.1**	**697,245**

PATTERNS AND TRENDS FOR HOUSEHOLD ENERGY USE FOR LIGHTING, COOKING, AND HEATING I

By;

Enock Ngome , Nomazile Chicho , Khumo & Connoh Mogaetsho

ABSTRACT

Introduction: This study aims to analyse household energy consumption practices in Botswana to achieve its long-term vision of 2036. Access to affordable and sustainable energy is crucial for socio-economic development. Understanding patterns and trends in energy use is essential for improving quality of life, economic transformation, and growth. The study aims to inform policy-making and strategic decision-making in the energy sector.

Methodology: This study uses data from the 2022 Botswana Population and Housing Census (PHC) and secondary sources from Statistics Botswana. The research examines households' energy usage for lighting, cooking, heating space, and water, focusing on various types of energy sources. The data is cross tabulated with census districts and localities, analysing 697,245 households in 28 districts.

Results: The 2010 Revised National Population Policy (RNPP) set ambitious energy targets for Botswana, including doubling the access to electricity for lighting from 26.8 percent in 2003 to 53.6 percent by 2020. By 2011, approximately 53 percent of households used electricity for lighting, and this figure has since risen to 73.4%, far exceeding the original target. This progress aligns with Botswana's Vision 2036 goals of sustainable development and economic diversification. The National Development Plan continues to focus on expanding electrification and enhancing access to modern energy services.

The RNPP also aimed to halve the number of households using paraffin for lighting from 53.2 percent in 2003 to 26.6 percent by 2020. By 2011, 30 percent of households used paraffin for lighting, and by 2022, this figure had dropped to 5.4%. Additionally, only 8.6% of households used candles for lighting by 2022. The RNPP sought to reduce the percentage of households using wood as the main source of fuel from 46 percent in 2001 to less than 23% by 2020. The proportion was 41.1% by 2011. By 2022, the use of wood for lighting had significantly decreased to 1.1% of households. However, 29.7% used wood for cooking, 25.3% for heating space, and 37.3% for heating water. The RNPP also aimed to reduce the use of wood fuel for cooking in rural households from 81 percent in 2003 to 30 percent by 2020. Although this reliance had decreased to 77 percent by 2011, rural areas still showed a higher dependency on wood for cooking (64.7%) by 2022, compared to urban areas (3.2%) and urban villages (15.3%).

Renewable energy solutions like solar systems are increasing, accounting for 6.8% of households in 2022. This aligns with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) and Africa Agenda 2063's aspirations for sustainable development and environmental sustainability. Differences in energy access and usage patterns across different localities highlight the need for targeted interventions. Policies aimed at improving infrastructure and access to modern energy services are crucial, especially in rural areas where traditional energy sources remain high. Increasing the usage of LPG (Light Petroleum Gas) is also essential for achieving Botswana's development objectives and meeting SDG targets related to clean energy and sustainable cities and communities.

Conclusions and Policy Implications: Botswana should promote renewable energy adoption, rural electrification, and clean cooking technologies to reduce reliance on traditional biomass. Policy interventions should include subsidies, tax breaks, and financial incentives. Diversifying heating solutions, monitoring energy access, and aligning energy policies with the Sustainable Development Goals and Africa Agenda 2063 are crucial for effective policy implementation.

INTRODUCTION

This report analyses the data gathered by the Statistics Botswana for the 2022 population census with special emphasis on establishing the patterns and trends for household energy use (both conventional and traditional energy sources) for lighting, cooking and heating in Botswana. This section explores the extent at which households reported the utilization of specific energy sources in comparison with previous data sources noted and present a holistic view on energy consumption trends across Botswana from 1971 to 2022. The significance of this report shall be noteworthy to the policymakers, energy suppliers/providers, environmental lobbyists, law enforcers and the general populace in ensuring energy efficiency practices as well as establishing a foundation for informed policy-making and strategic decision-making in the energy sector. Therefore, these findings support evidence-based decision-making and the implementation of policies and programs that contribute to sustainable development, energy security, improved living standards, and environmental preservation in Botswana.

BACKGROUND

Botswana has been predominantly dependent on fossil fuels sources for main energy supply and use among the households and industries, especially for industrial processes, transportation, lighting, cooking and heating (Arntzen, and Kgathi, 1984; Hiemstra-van der and Hovorka, 2008; Government of Botswana, 2016). With fossil fuels playing a significant role in contributing to greenhouse gases globally (Siddik et al., 2021), Botswana's efforts on environmental sustainability and energy efficiency are paramount, therefore; understanding the dynamics of household energy utilization is imperative for management approaches. Furthermore, to achieve prosperity for all citizens through the national Vision 2036 pillar three on environmental sustainability as well as the Sustainable Development Goals goal 7(Ensure access to affordable, reliable, sustainable and modern energy for all) and Goal 12 (Ensure sustainable consumption and production patterns), examining and understanding how energy is consumed at the household level is indispensable for Botswana's fuelwood use status (Government of Botswana, 2016; Statistics Botswana, 2023).

Aim and Objectives

The aim of this study is to examine the existing trends and patterns on the energy utilized for lighting, cooking and heating in Botswana. Based on this aim, the main objectives of the study are:

- **To determine percentage of households by principal sources of energy for lighting, cooking, heating space and heating water in Botswana.**
- **To establish existing trends in use of principal source of energy for lighting, cooking, heating space and heating water in Botswana.**
- **To discern policy implications targeting household energy efficiency and propose recommendations to enhance the adoption of modern energy sources for lighting, cooking, and heating space and water in Botswana.**

Significance of the study

This report contributes directly to the realization of the national and regional initiatives and development frameworks by focusing on the patterns and trends of household energy use for lighting, cooking and heating in Botswana. Through this comprehensive assessment of the energy sources, technologies employed, consumption patterns, and efficiency practices, critical insights for policymakers and stakeholders to address energy-related challenges and harness opportunities for green energy may be uncovered. This study significantly contributes to availing analytical discussions central for measurement of SDGs and Vision 2036 target achievements.

LITERATURE REVIEW

Historical trends on energy consumption

Access to affordable, sufficient, clean and sustainable energy is crucial for the socio-economic development of nations (Barnes & Samad, 2019). Energy is an imperative asset in economic development due to its great potential to enable improvement in the quality of life, economic transformation, and economic growth (Maswabi, Chun and Chung, 2021). To indicate the trends in snippets of specific energy sources, previous studies revealed that paraffin was the primary source of energy for household lighting in Botswana in 2001 (Singh and Dwivedi, 2011), however, with increasing electrification in the country, electricity overtook it in urban areas in 2011; nevertheless, paraffin remained dominant overall. Literature also indicated that wood and gas were used for cooking in both urban and rural areas in both 2001 and 2011, with fuel wood dominating at the national and rural levels (Statistics Botswana, 2012). Precisely, wood was the dominant energy source used for space heating in 2001 and 2011, followed by electricity (Fagbenle, 2001; CSO, 2002; Makonese, Ifegbesan and Rampedi, 2018). Subsequently, the detailed statistical presentations shall be indicated in Table of figures. Similar patterns were noted from a study done among seven selected SADC countries where firewood was the main source fuels for cooking (66.7%) followed by liquefied petroleum gas with 8.8%, then electricity (8.6%) and charcoal accounting for 7.4% (Makonese, Ifegbesan and Rampedi, 2018; IRENA, 2021).

Policy implications on energy utilization

The 2010 Revised National Population Policy (RNPP) was designed to address key energy challenges in Botswana by setting ambitious targets to improve energy access and promote sustainable development. One of the primary goals was to double the proportion of households using electricity for lighting from 26.8% in 2003 to 53.6% by 2020. Remarkably, by 2011, this figure had already reached 53%. Additionally, the RNPP aimed to halve the number of households using paraffin for lighting from 53.2% in 2003 to 26.6% by 2020. By 2011, 30% of households used paraffin for lighting. The policy also sought to reduce the percentage of households using wood as the main source of fuel from 46% in 2001 to less than 23% by 2020. By 2011, the proportion was 41.1%. For rural households, the RNPP aimed to reduce the use of wood fuel for cooking from 81% in 2003 to 30% by 2020. This reliance had decreased to 77% by 2011.

Botswana Energy Master Plan (BEMP) on the other hand; has been a key instrument is guiding development regarding the energy sector prior to the development of the National Energy policy (Ministry of Mineral Resources, Green Technology and Energy Security (MMGTES), 2021). This provided guidelines regarding production and consumption of energy by all sectors and stakeholders. Also, this notes the need for establishment of green and safer energy sources for local consumption and export if opportunity avails. The need for energy efficiency, social equity on energy access as well as environmental quality and sustainability was also noted to be key policy objectives (Fagbenle, 2001), which their achievement need detailed exploration of how energy is utilized at national and household levels. A call which advantages the country and households alike (MMGTES, 2021). Contrasting policy efforts remains a challenge, especially where the Botswana National Energy Policy emphasizes optimal electricity generation, self-sufficiency, adequate distribution infrastructure, universal access and balancing the interests of the investors, consumers and the environment (MMGTES, 2021) while at the same time the Sustainable Development Goals promotes reduction of greenhouse gases through reduction of fossil fuel utilization of which is where the bulk of Botswana electricity emanates from (Statistics Botswana, 2023; IRENA, 2021). Notably, with efforts on the ground for acceleration of electrification across the country noted in NDP 8 and subsequent National Development Plans, this is evidence for a push towards the use of electricity as the main energy source in the country (GOB,1997; Botswana Government, 2017)

To counteract all these potential impacts, the policy also commits Government to the development of off-grid solar, exploring wind power, ensuring efficient use of firewood and embarking on initiatives promoting production and use of energy derived from biodegradable resources to protect the environment and offset the country's carbon footprint; thus, employment of green energy (Maswabi et al., 2021). The analytical synthesis of the statistics on energy utilization patterns and trends shall help explore how Botswana is integrating, contextualizing, operationalizing and domesticating Botswana Vision 2036, the Transitional National Development Plan, the Sustainable Development Goals, and the Africa Agenda 2063 to address energy sector challenges while tapping on available opportunities therein (Government of Botswana, 2016; Statistics Botswana, 2023). Thus, ensuring that these findings contribute towards reforms in the energy sector geared towards cleaner energy use at household and national levels. For example, National Development Plan 11 indicatively highlighted the need to half the percentage of households using fuelwood for various energy needs. (Botswana Government, 2017).

Energy challenges presenting opportunities for Batswana.

Despite challenges faced in the energy sector, this presents itself as an opportunity for Batswana who may convert these challenges into economic opportunities. This may be noted from Ghana who are currently actively turning climate challenges into opportunities such as intensifying transition to clean energy as well as realizing new opportunities for managing forest resource as an asset for climate resilience, including for carbon sinks focusing on reversing deforestation and promoting cleaner cooking (Fosu, 2022). This is in line with efforts in place to ensure private entities participate in green energy and supply to national electricity grid through projects like Rooftop energy projects.

METHODOLOGY

This study utilized the data from 2022 Botswana Population and Housing Census (PHC) and secondary data from various sources published by Statistics Botswana. With the first population census being conducted in 1971, this study will therefore use five population census data bases being 1981, 1991, 2001, 2011 and 2022. In some instances where data is scanty, secondary data from the 2017 Botswana Demographic Survey (BDS) is utilized to examine trends. The study, as guided by the objectives explores the extent to which households utilise specific energy sources for lighting, cooking, heating space, heating water and establishes the trends therein. The dependent variable were the various types of energy sources which were cross tabulated with census districts and localities. There are a total of 697,245 households that were enumerated during the 2022 PHC in a total of 28 census districts. Localities are categorised as Towns and Cities, Urban Villages and Rural areas. Towns and Cities include Gaborone, Francistown, Lobatse, Selibe Phikwe, Orapa Jwaneng and Sowa.

RESULTS

Source of Household Energy for Lighting

Trends in Source of Household Energy for Lighting

Figure 1 presents the percentage distribution of households by principal source of energy for lighting. The figure shows that the majority of households in Botswana (73.4%) rely on electricity from the national grid for lighting. Next in line are candles, representing 8.6% of households, succeeded by paraffin at 5.4% and solar lanterns at 4.7%. Moreover, 2.1% of households depend on solar home systems, while other sources collectively make up the remaining 5.8%.

Table 1 presents trends in the percentage distribution of households by source of energy for lighting 1981, 1991, 2001, 2011, 2017 bds and 2022. The trends demonstrate a significant shift towards electricity as the primary lighting source. In 1981, only 5.4% of households relied on electricity from the national grid for lighting, but this proportion steadily increased over the decades, reaching 73.4% by 2022. This transition reflects substantial improvements in electrification infrastructure and accessibility over the years.

6 This includes crop waste, grass, straw, shrubs, animal waste and dung.

Furthermore, the adoption of alternative energy sources for lighting has also seen notable changes. Solar systems emerged as a marginal contributor in 2001, representing only 0.2% of households, but experienced substantial growth, reaching 6.8% in 2022. This trend indicates increasing interest and investment in renewable energy solutions for lighting.

Conversely, traditional sources such as paraffin and candles have witnessed a decline in usage. Paraffin, which once dominated as the primary lighting source in 1991 with 53.4% usage, dwindled to 5.4% by 2022. Similarly, candle usage decreased from 16.3% in 1991 to 8.6% in 2022. These declines likely stem from the expanding availability and affordability of electricity, coupled with efforts to transition away from less efficient and environmentally harmful lighting options. A declined is also noticed with the use of wood as the source of energy for lighting.

FIGURE 1: PERCENTAGE DISTRIBUTION OF HOUSEHOLDS BY PRINCIPAL SOURCE OF ENERGY

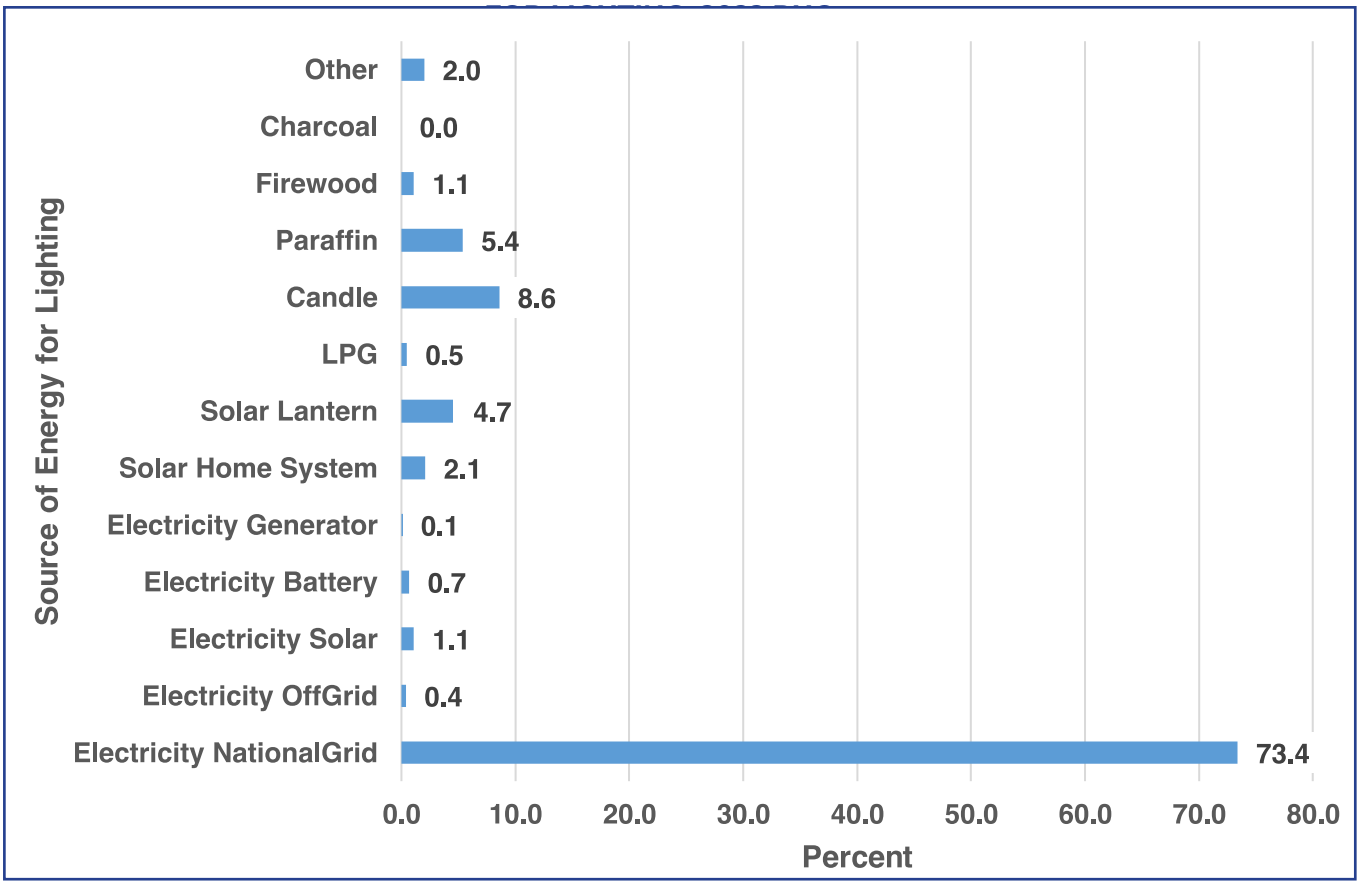


TABLE 1: Trends in the Percentage Distribution of Households by Source of Energy for Lighting 1981, 1991, 2001, 2011, 2017 BDS and 2022.

HOUSEHOLD ENERGY SOURCE	1981	1991	2001	2011	2017 BDS	2022
Electricity – (National grid)	5.4	10.1	24.8	53.2	67.4	73.4
Solar System	..	..	0.2	0.5	2.6	6.8
LPG	..	..	0.2	0.5	0.1	0.5
Biogas	..	..	0.1	-	-	-
Wood	..	..	5.6	3.6	1.8	1.1
Paraffin			53.4	30.0	3.0	5.4
Candle			10.9	16.3	10.4	8.6
Other	..	..	6.7	0.4	2.8	2.0

The data also show fluctuations in the usage of other sources, such as LPG, albeit at lower percentages. Overall, the trends reflect Botswana's journey towards modernizing its lighting infrastructure, embracing renewable energy alternatives, and reducing reliance on traditional and often less sustainable lighting sources over the past four decades.

Households by Source of Energy for Lighting House by District

The distribution of households by their primary energy source for lighting in Botswana's census districts reveals significant variations. Urban districts like Gaborone, Francistown, and Jwaneng heavily rely on electricity from the national grid, ranging from 90.0% to 93.1%, with minimal usage of alternative sources like candles and paraffin. Lobatse and Selibe Phikwe also demonstrate substantial dependence on grid electricity, at 81.0% and 89.5% respectively, while also incorporating other sources such as paraffin and solar lanterns.

Conversely, Orapa and Sowa stand out with a remarkable preference for grid electricity, utilized by 99.3% and 99.9% of households respectively, while showing negligible reliance on traditional sources like candles and paraffin. Rural districts like Barolong, Ngwaketse West, Kweneng West and Central Mahalapye exhibit a notable dependency on traditional energy sources such as firewood and paraffin, ranging from 10.9% to 11.7%, indicative of limited access to electricity infrastructure. These regions also demonstrate higher adoption rates of solar home systems compared to urban areas, emphasizing the significance of off-grid solutions in remote locales.

There's a notable proportion of households relying on candles for lighting in certain districts, particularly in rural areas. For instance, Kgalagadi South, Ngamiland West Barolong, Ngwaketse West, Kweneng West, Kgalagadi North and Ghanzi demonstrate relatively higher usage of candles, reflecting proportions ranging from 15.5% and 24.4%. These statistics highlight the continued reliance on traditional energy sources in some rural districts, where access to modern energy infrastructure remains limited. Urban districts showcase a greater reliance on grid electricity, whereas rural districts exhibit a more diverse energy mix, reflecting disparities in infrastructure and access to modern energy services across Botswana.
Households by Source of Energy for Lighting by Locality

The percentage distribution of households by the source of energy for lighting varies significantly across different localities, reflecting diverse energy access and usage patterns **(See Table **)**. Urban areas demonstrate a higher reliance on modern energy sources, with urban and urban village localities localities showing substantial proportions of households using electricity from the national grid, ranging from 89.1% to 91.4%. These areas also exhibit minimal usage of traditional sources such as firewood and paraffin, highlighting the prevalence of electrification and access to modern energy infrastructure in urban settings.

Furthermore, the analysis reveals a growing trend towards the adoption of renewable energy sources in both urban and rural areas. Solar home systems and solar lanterns are increasingly being utilized, particularly in rural localities where access to the national grid is limited. In rural areas, the proportion of households using solar home systems is 5.2%, while solar lantern usage is 12.3%. This trend underscores the importance of off-grid solutions in providing reliable and sustainable energy access to remote communities.

[5]This category includes both the solar lantern light and the solar power systems.

Conversely, the use of traditional sources such as candles remains prevalent in rural localities, with 15.8% of households using candles for lighting. This indicates continued reliance on traditional lighting methods, particularly in areas with limited access to modern energy infrastructure.

Source of Household Energy for Cooking

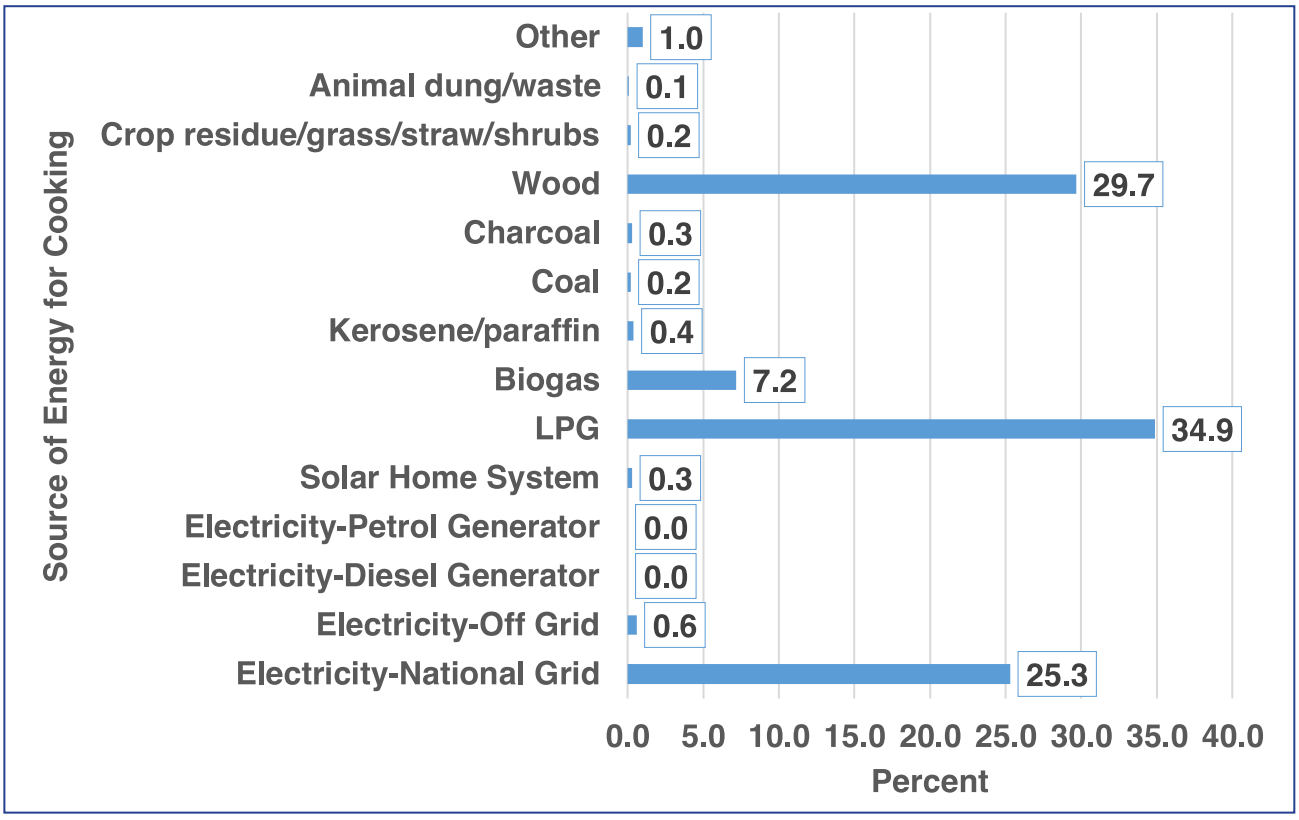
Trends in Source of Household Energy for Cooking

Figure 2 shows the percentage distribution of households based on their primary energy sources for cooking in Botswana. The table reveals a diverse energy landscape. Electricity from the national grid constitutes 25.3% of households, indicating significant electrification efforts. LPG (liquefied petroleum gas) emerges as the most common primary energy source, accounting for 34.9% of households, highlighting the widespread use of clean and efficient cooking technologies. Wood remains a prevalent energy source, utilized by 29.7% of households, particularly in rural areas where access to modern energy infrastructure is limited. Biogas, derived from organic waste, is utilized by 7.2% of households, reflecting a growing trend towards sustainable energy solutions. Other energy sources such as solar home systems, kerosene/paraffin, coal, charcoal, and agricultural residues contribute to a smaller proportion of households, collectively accounting for 2.5% of the surveyed population. Overall, the statistics underscore the importance of addressing energy access challenges and promoting clean and sustainable cooking technologies to improve livelihoods and environmental sustainability in Botswana.

Table 2 presents trends in the sources of energy for cooking in households in Botswana from 1981 to 2022 reveal significant transformations in energy usage patterns. In 1981, wood was overwhelmingly dominant, constituting 85.8% of households, while electricity from the national grid accounted for only 1.8%. Over the decades, there has been a remarkable transition towards cleaner and more modern energy sources. By 2022, the proportion of households using electricity from the national grid increased substantially to 25.3%, reflecting efforts to expand electrification and enhance access to modern energy services.

Concurrently, there has been a notable surge in the adoption of LPG (liquefied petroleum gas) as a primary energy source for cooking. LPG usage escalated from 5.4% in 1981 to 40.6% in 2001, although it experienced a slight decline to 34.9% by 2022. This shift towards LPG underscores the country's efforts to promote cleaner cooking technologies and improve indoor air quality.

FIGURE 2: PERCENTAGE DISTRIBUTION OF HOUSEHOLDS BY PRINCIPAL SOURCE OF ENERGY FOR COOKING: 2022 PHC.



Moreover, the emergence of alternative energy sources such as biogas has become increasingly apparent over the years. While biogas accounted for only 0.6% of households in 2001, it rose significantly to 7.2% by 2022, highlighting a growing interest in sustainable energy solutions and environmental conservation.

Conversely, the proportion of households relying on traditional energy sources like wood and paraffin/kerosene has gradually decreased over time. Wood usage declined from 85.8% in 1981 to 29.7% in 2022, reflecting a shift towards cleaner and more sustainable alternatives. Similarly, the use of paraffin/kerosene decreased from 7.5% in 2001 to 0.4% by 2022, indicative of efforts to transition away from polluting and inefficient energy sources for cooking.

TABLE 2: Trends in the Percentage Distribution of Households by Source of Household Energy for Cooking: 1971, 1981, 1991, 2001, 2011 and 2022.

HOUSEHOLD ENERGY SOURCE	1981	1991	2001	2011	2017 BDS	2022
Electricity – (National grid)	1.8	2.7	4.9	17.8	24.8	25.3
Solar System	..	..	0.2	0.1	-	0.3
LPG	5.4	21.6	40.6	37.9	40.6	34.9
Biogas	..	..	0.6	0.9	0.1	7.2
Wood	85.8	64.3	45.7	41.2	33.9	29.7
Paraffin/Kerosene	..	..	7.5	1.7	0.3	0.4
Cow Dung	..	..	0.1	0.1	0.1	-
Coal	..	..	0.1	-	-	0.2
Crop Waste	..	..	0.1	-	0.1	-
Charcoal	..	..	-	0.1	-	0.3
Other	..	..	0.2	0.1	0.1	1.3

NB: (..) represents data not available; (-) represents zeros.

Source of Household Energy for Cooking by District

Table 6 presents the percentage distribution of households by the source of energy for cooking across districts in Botswana and it reveals significant differences between districts. Gaborone, Francistown and Selibe Phikwe exhibit relatively high reliance on electricity from the national grid, with percentages at 36.2%, 33.4% and 30.7% respectively, while districts like Orapa and Sowa Town demonstrate exceptionally low reliance, with percentages at 4.6%. This indicates disparities in access to electricity infrastructure and grid connectivity across districts.

Districts such as Central Bobonong, Central Tutume, Ngwaketse West, Kweneng West, Ngamiland West and the Delta display lower usage of LPG, with percentages ranging from 19.6% and 1.6% respectively, compared to Gaborone, Lobatse, Orapa and Jwaneng districts where LPG usage is notably highest, with percentages at 51.9%, 62.8% 94% and 73.6% respectively. These variations may reflect differences in the availability and affordability of LPG cylinders and distribution networks.

Rural districts like Central Bobonong, Central Tutume, Ngwaketse West, Kweneng West, Ngamiland West, Barolong, CKGR and the Delta demonstrate a higher dependency on wood for cooking, with percentages ranging from 50.3% to 85.8%, compared to urban centres like Gaborone and Francistown, where wood usage is relatively lower, with percentages at 0.9% and 6.4% respectively. This suggests the influence of socio-economic factors and traditional cooking practices in rural areas.

While the overall usage of solar home systems is relatively low across districts, districts like Kgalagadi South, Ghanzi, Central Boteti, CKGR and the Delta show higher adoption rates, with percentages ranging from 0.4% to 1.6%. This may be attributed to initiatives promoting renewable energy adoption in remote areas with limited access to the national grid.

Some districts exhibit unique patterns of energy usage. For instance, the Delta and the CKGR districts rely predominantly on wood (85.8% and 85.7% respectively), reflecting traditional lifestyles and limited access to modern energy sources.

Source of Household Energy for Cooking by Locality

Table 7 shows the percentage distribution of households by the source of energy for cooking across different localities in Botswana and results reveal significant differences by localities. Urban areas show a higher reliance on electricity from the national grid compared to urban villages and rural areas. For instance, in the urban locality, the percentage is 33.2%, while in urban villages and rural areas, it's 31.1% and 12.8% respectively. This indicates disparities in access to electricity infrastructure and grid connectivity between urban and rural settings. Urban villages exhibit a slightly higher usage of LPG compared to urban areas and rural settings. For instance, in urban villages, the percentage is 42.3%, while in urban areas and rural settings, it's 52.4% and 14.4% respectively. This could be attributed to differences in economic status and access to LPG distribution networks.

Rural areas demonstrate a significantly higher dependency on wood for cooking compared to urban areas and urban villages. For instance, in rural areas, the percentage is 64.7%, while in urban areas and urban villages, it's 3.2% and 15.3% respectively. This reflects traditional cooking practices and the availability of biomass resources in rural environments.

Urban and urban village localities show a negligible usage of solar home systems compared to rural areas. This suggests that rural areas may have a higher adoption rate of renewable energy solutions due to factors like limited access to the national grid and initiatives promoting renewable energy in remote regions.

Urban areas exhibit a slightly higher usage of other sources like kerosene/paraffin and coal compared to urban villages and rural areas. This may be due to factors such as availability and affordability of alternative fuels and appliances in urban settings.

Source of Household Energy for Heating Space

Trends in Sources of Household Energy for Heating Space

Figure 3 shows the primary energy sources used for heating space in households surveyed during the Botswana's 2022 census. The majority, 39.0%, reported using no specific energy source for heating. The most common source of energy for heating space is electricity from the national grid, accounting for 29.9%. Wood is also a significant source, utilized by 25.3% of households. Other notable sources include LPG (1.4%), charcoal (0.4%), and other miscellaneous sources (2.2%). The remaining energy sources, such as biogas, kerosene/paraffin, coal, and animal waste, are used by a smaller percentage of households, each ranging from 0.1% to 0.5%.

FIGURE 3:PERCENTAGE DISTRIBUTION OF HOUSEHOLDS BY PRINCIPAL SOURCE OF ENERGY FOR HEATING SPACE: 2022 PHC.

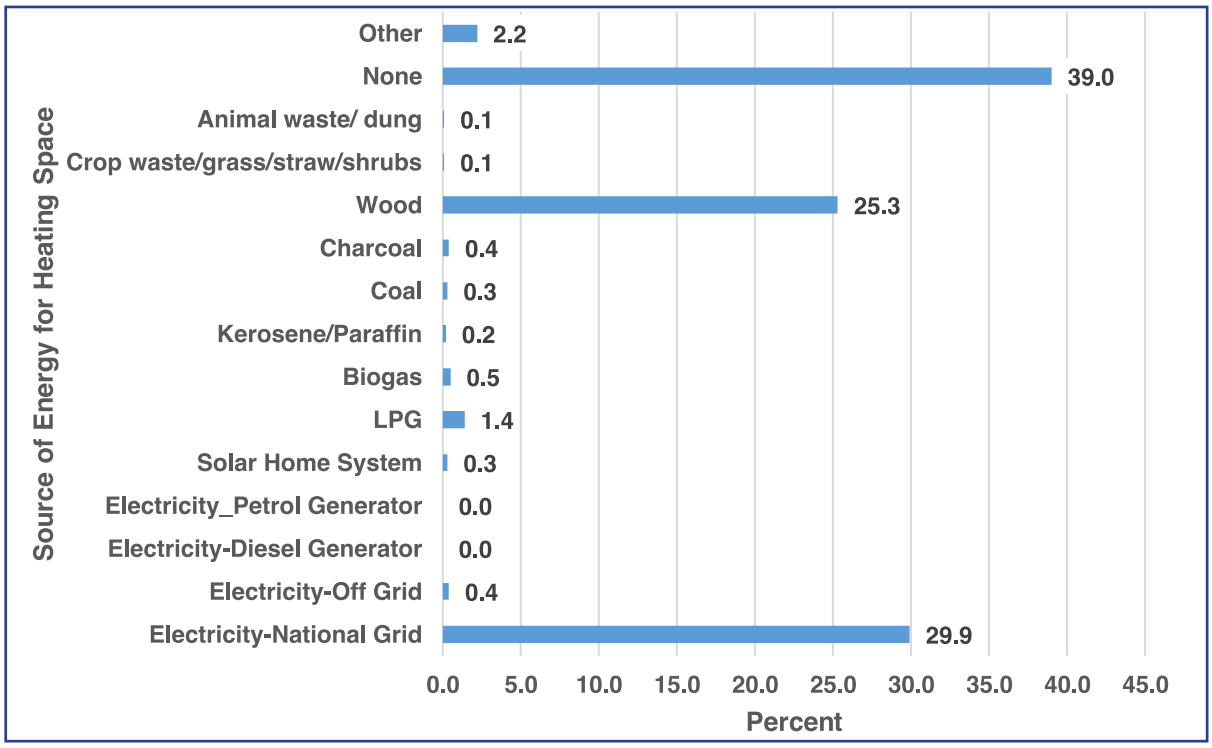


Table 3 shows trends in the sources of energy for heating space in households in Botswana from 2011 to 2022 and they exhibit several notable shifts. Firstly, there has been a noticeable increase in the use of electricity from the national grid for heating purposes. In 2011, electricity accounted for 16.8% of households, which rose to 20.6% in 2017 and substantially increased to 29.9% in 2022. This upward trend suggests a growing reliance on electricity as a primary source of energy for heating space.

Another emerging trend is the gradual adoption of alternative energy sources for heating, such as LPG, biogas, and solar energy. While their usage remains relatively low compared to electricity and traditional biomass, there has been a steady increase over the years. For instance, LPG usage rose from 0.1% in 2011 to 1.4% in 2022, indicating a growing preference for cleaner and more efficient heating options.

In contrast, the use of traditional biomass, particularly wood, has shown a declining trend. Wood, which was the predominant source of energy for heating space in 2011 (47.7%), decreased to 27.2% in 2017 and further dropped to 25.3% in 2022. This decline suggests a shift away from traditional biomass towards more modern and sustainable energy sources.

Interestingly, there has been an increase in the percentage of households using no specific energy source for heating space, indicated as "None." While it decreased from 33.6% in 2011 to 50.6% in 2017, it decreased again to 39.0% in 2022. This fluctuation may reflect changes in household energy access and affordability over the years.

[6] This includes crop waste, grass, straw, shrubs, animal waste and dung.

TABLE 3: Trends in the Percentage Distribution of Households by Sources of Household Energy for Heating Space: 2011, 2017 BDS and 2022.

HOUSEHOLD ENERGY SOURCE	2011	2017 BDS	2022
Electricity – (National grid)	16.8	20.6	29.9
Solar	0.1	0.1	0.3
LPG	0.1	0.8	1.4
Biogas	0.1	..	0.5
Kerosene/paraffin	0.3	0.2	0.2
Coal	0.1	-	0.3
Charcoal	0.2	0.1	0.4
Wood	47.7	27.2	25.3
Cow dung	-	-	0.2
Other	0.1	0.4	2.2
None	33.6	50.6	39.0

Sources of Household Energy for Heating Space by District

Table 8 presents percentage distribution of households by the source of energy for heating space across districts in Botswana. Significant differences exist in the sources of energy for heating space across districts. We focus on identifying districts that have outliers or extreme percentages of households by source of energy for heating space. For example, Orapa has the highest percentage (88.0%) of households using electricity from the national grid for heating space, followed by Jwaneng (64.1%) and Gaborone (51.7%). These districts exhibit a higher level of electrification compared to others. Orapa, the Delta and CKGR have notable percentages of households using solar energy (3.3%, 1.1 and 1.2%, respectively), indicating a growing adoption of renewable energy sources in these areas.

Lobatse stands out with the highest percentage (3.3%) of households using LPG, followed by Kweneng East (3.0%) and Kgalagadi South (2.4%). These districts may have better access to LPG infrastructure or higher affordability.

Ngwaketse West has the highest percentage (61.3%) of households using wood for heating space, suggesting a reliance on traditional biomass, while Francistown (6.3%) and Southern (32.3%) also have significant usage. Francistown stands out with the highest percentage (52.3%) of households using other energy sources, followed by Selibe Phikwe (50.1%). These "other" sources may include alternative fuels or unconventional heating methods.

Selibe Phikwe and Central Boteti has the highest percentage (5.5% and 4.3% respectively) of households using no specific energy source, indicating potential energy access challenges or affordability issues.

Sources of Household Energy for Heating Space by Locality

Table 9 in the appendix indicates significant differences exist in the sources of energy for heating space across localities. Electricity from the national grid is the dominant heating source in urban areas (towns & cities: 46.7%, urban villages: 35.3%), highlighting greater electrification levels compared to rural areas (12.5%).

Wood remains the primary heating source in rural areas (52.0%), signifying a dependence on traditional biomass. Conversely, urban areas display significantly lower usage (towns & cities: 4.2%, urban villages: 14.6%), suggesting access to alternative conventional energy options.

Rural households exhibit a slightly higher reliance on solar energy (0.4%) for space heating compared to urban counterparts (towns & cities: 0.3%, urban villages: 0.2%), potentially indicating an inclination towards off-grid renewable solutions.

LPG use is concentrated in urban and peri-urban areas, with urban villages having the highest percentage (1.9%) compared to towns & cities (1.4%) and rural areas (0.7%). This likely reflects better access to LPG infrastructure in these locations.

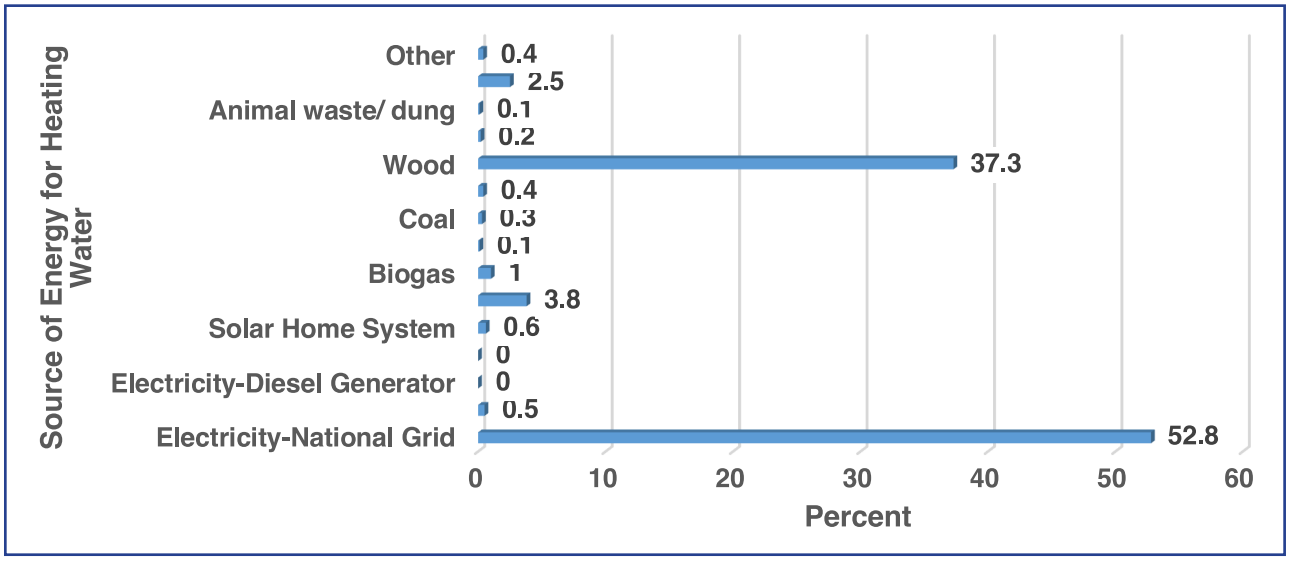
The "other energy sources" category exhibits the highest prevalence in urban villages (43.8%) compared to towns & cities (43.1%) and rural areas (30.2%). This category potentially encompasses various unconventional heating methods not captured in the table.

Source of Household Energy for Heating Water

Current Sources of Household Energy for Heating Water

The primary energy source for heating water in Botswana is electricity from the national grid, accounting for 52.8% of households **(See Figure 4)**. Traditional fuels like wood remain significant, with 37.3% of households depending on it. This suggests a continued reliance on conventional methods for heating water, likely due to factors such as accessibility and cost. LPG (3.8%), biogas (1.0%) and solar home systems (0.6%) demonstrate a growing adoption but still less common. Kerosene, paraffin, coal, charcoal, and crop residue/grass/straw/shrubs are all used by a small percentage of households (less than 1% each). Notably, 2.5% of households reported not using any primary energy source for heating water. We could not provide trends for heating water within household since data were not collected in heating water during the previous censuses and surveys.

FIGURE 4: Percentage Distribution of Households by Principal Source of Energy for Heating Space: 2022 PHC.



Current Sources of Household Energy for Heating Water by District

Table presents percentage distribution of households by the source of energy for heating water across districts. The results highlight significant differences in the use of energy source by districts. Orapa has the highest percentage (90.9%) of households using electricity from the national grid for heating water, followed by Gaborone (86.2%), Jwaneng (83.4%) and Francistown (80.4%). Urban districts such as Sowa, Selibe Phikwe and Lobatse had households using electricity for heating water exceeding 70%. Rural districts like Ngwaketse West (15.6%) and Kweneng West (16.7%) have notably lower percentages, indicating limited access to grid electricity in these areas. It should be noted that census districts such as the Delta and CKGR had almost none of the households using electricity for heating water.

Ngwaketse West (73.2%) and Kweneng West (72.9%) have the highest percentages of households using wood for water heating, reflecting reliance on traditional biomass in rural areas. Urban districts like Gaborone (3.4%) and Francistown (12.5%) show much lower percentages, indicating access to alternative energy sources.

Lobatse stands out with a relatively high percentage (10.6%) of households using LPG for water heating, followed by Selibe Phikwe (2.2%) and Francistown (2.9%). Rural districts generally have lower LPG usage, with some exceptions like Central Bobonong (2.0%) and Central Mahalapye (2.5%).

Orapa has a significantly higher percentage (5.7%) of households using solar energy for heating water compared to other districts. This may be due to specific initiatives or geographic conditions favoring solar energy adoption. Urban districts like Gaborone (1.0%) and Francistown (0.5%) also show some usage of solar energy, albeit at lower percentages.

The Southern district has the highest percentage (52.7%) of households using no specific energy source for water heating, followed by Ngwaketse West (47.8%) and North East (47.8%). This suggests potential energy access challenges or affordability issues in these areas.

Current Sources of Household Energy for Heating Water by Locality

Table 11 shows the percentage distribution of households by the source of energy for heating water across localities. The table highlights notable differences in the use of different sources of energy for heating water by localities. Towns and Cities have the highest percentage (82.7%) of households using electricity from the national grid for heating water, followed by Urban Villages (63.9%) and Rural Areas (20.0%). This indicates a significant disparity in access to grid electricity for water heating, with rural areas having the lowest percentage.

Rural Areas stand out with the highest percentage (70.0%) of households using wood for water heating, followed by Urban Villages (26.2%) and Towns and Cities (7.7%). This highlights a significant reliance on traditional biomass for water heating in rural areas, likely due to limited access to modern energy sources. Interestingly, Towns and Cities show a relatively higher usage of solar energy (0.9%) for heating water compared to Urban Villages (0.6%) and Rural Areas (0.5%). This suggests a slight inclination towards solar energy adoption in urban settings for heating water, possibly due to better awareness or affordability.

U|rban Villages have the highest percentage (4.5%) of households using LPG for water heating, followed by Towns and Cities (4.8%) and Rural Areas (2.2%). Urban Villages exhibit a higher usage of LPG, potentially due to greater availability and infrastructure compared to rural areas.

Rural Areas have a notably higher percentage (3.6%) of households using no specific energy source for water heating compared to Urban Villages (2.2%) and Towns and Cities (1.7%). This suggests potential energy access challenges or affordability issues in rural areas, leading to a higher proportion of households without a specific heating source.

CONCLUSIONS

The 2010 Revised National Population Policy (RNPP) set ambitious targets to improve energy access in Botswana, including doubling the proportion of households using electricity for lighting from 26.8% in 2003 to 53.6% by 2020. By 2011, this figure had already reached 53%, and by 2022, it rose to 73.4%, far exceeding the target. This progress aligns with Botswana's Vision 2036 goals of sustainable development and economic diversification, as well as the National Development Plan's objectives of expanding electrification and enhancing access to modern energy services.

The RNPP also aimed to halve the number of households using paraffin for lighting from 53.2% in 2003 to 26.6% by 2020. By 2011, 30% of households used paraffin for lighting, and by 2022, this figure had dropped to 5.4%. Additionally, only 8.6% of households used candles for lighting by 2022. In terms of fuel sources, the RNPP sought to reduce the percentage of households using wood as the main source of fuel from 46% in 2001 to less than 23% by 2020. By 2011, the proportion was 41.1%, and by 2022, the use of wood for lighting had significantly decreased to 1.1% of households. However, wood remains a prevalent source for cooking (29.7%), heating space (25.3%), and heating water (37.3%). The RNPP aimed to reduce the use of wood fuel for cooking in rural households from 81% in 2003 to 30% by 2020. By 2011, this reliance had decreased to 77%, and by 2022, it was still high at 64.7%, compared to 3.2% in urban areas and 15.3% in urban villages.

Most households in Botswana now primarily rely on electricity from the national grid for lighting, reflecting substantial modernization of lighting infrastructure. This trend corresponds with the National Development Plan's objectives and aligns with the domesticated Sustainable Development Goals (SDGs) and Africa 2063 agenda, particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). Additionally, 6.8% of households used renewable energy solutions like solar systems in 2022, showcasing Botswana's commitment to environmentally friendly practices.

Disparities in energy access and usage across different localities underscore the need for targeted interventions in line with Botswana's development frameworks and the RNPP. Improving infrastructure and enhancing access to modern energy services, particularly in rural areas where reliance on traditional energy sources remains high, is crucial. For cooking, electricity from the national grid is used by 25.3% of households, while traditional biomass like wood remains prevalent in rural areas (52%). Promoting clean cooking technologies aligns with Vision 2036 goals and SDG targets, such as SDG 3 (Good Health and Well-being) and SDG 7.

Similar trends are observed in energy sources for heating space and water, with electricity from the national grid dominant in urban areas and wood significant in rural areas. Addressing disparities in access to clean and efficient heating technologies is essential for achieving Botswana's development objectives and meeting SDG targets related to clean energy and sustainable cities and communities.
In conclusion, the 2022 census findings highlight the importance of ongoing efforts to improve energy access, promote renewable energy adoption, and address disparities in energy usage across Botswana. These efforts are vital for advancing sustainable development, achieving Vision 2036 goals, and contributing to the attainment of SDGs and Africa Agenda 2063 aspirations.

Policy Implications and Recommendations:

Promoting Renewable Energy Adoption: Given the increasing usage of renewable energy solutions like solar systems, it is crucial for Botswana to continue promoting the adoption of such technologies. Policy measures should focus on incentivizing households to invest in solar energy systems through subsidies, tax breaks, or other financial mechanisms. Additionally, government initiatives to facilitate access to affordable financing for renewable energy installations can further accelerate the transition towards clean energy.

Enhancing Rural Electrification: The disparities in energy access and usage patterns across different districts and localities highlight the need for targeted interventions, particularly in rural areas. Policy efforts should prioritize enhancing rural electrification through infrastructure development and grid expansion projects. Special attention should be given to remote and underserved communities to ensure equitable access to modern energy services, aligning with Botswana's Development Frameworks and Revised National Population Policy.

Promoting Clean Cooking Technologies: To reduce reliance on traditional biomass like wood for cooking purposes, Botswana should prioritize promoting access to clean cooking technologies. This can be achieved through initiatives such as subsidy programs for clean cooking stoves, awareness campaigns on the health and environmental benefits of clean cooking, and capacity-building programs for local communities on the use of alternative cooking fuels. Aligning these efforts with Botswana's Vision 2036 goals of improving health outcomes and achieving sustainable development is imperative.

Diversifying Heating Solutions: Addressing disparities in access to clean and efficient heating technologies requires a multifaceted approach. Botswana should explore diversifying heating solutions beyond electricity and wood, such as promoting the adoption of LPG, biogas, and solar water heating systems. Policy interventions should focus on providing incentives for the uptake of these technologies, conducting targeted awareness campaigns, and facilitating partnerships with private sector stakeholders to drive innovation and investment in clean heating solutions.

Strengthening Data Collection and Monitoring: Continuous monitoring and evaluation of energy access and usage patterns are essential for informed policymaking and effective implementation of energy initiatives. Botswana should invest in strengthening its data collection mechanisms, including regular surveys and assessments, to track progress towards energy access goals and identify areas requiring intervention. Collaborating with relevant stakeholders, including research institutions and international organizations, can enhance data quality and facilitate knowledge sharing and best practices dissemination.

Integration with Sustainable Development Goals (SDGs) and Africa Agenda 2063: Aligning energy policies and interventions with the SDGs and Africa Agenda 2063 aspirations is critical for maximizing impact and ensuring coherence with global and regional development agendas. Botswana should integrate energy-related targets and indicators from the SDGs and Africa Agenda 2063 into its national development planning frameworks, thereby demonstrating its commitment to sustainable development and international cooperation. These may include setting targets for green energy on National development plans, energy strategies, policies and action plans. This alignment can facilitate resource mobilization, promote policy coherence, and enhance coordination among stakeholders towards common energy access objectives. This is because setting objective alone is inadequate; therefore, implementation is indispensable. This then calls for inclusion of energy development in the national financial plans, budgets and actual financial allocations to energy infrastructures development.

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APPENDICES:

TABLE 4 : Percentage Distribution of Households by Source of Energy for Lighting by District

CENSUS DISTRICT	SOURCE OF HOUSEHOLD ENERGY FOR LIGHTING													TOTAL HOUSEHOLDS
	Electricity – (National grid)	Electricity-(Off Grid)	Electricity-(Battery)	Electricity – (Diesel Generator)	Electricity – (Petrol Generator)	Solar Home System	Solar lantern	LPG	Candle	Paraffin	Firewood	Charcoal	Other	
Gaborone	93.1	0.2	0.1	0.1	0.0	0.2	0.5	0.5	3.5	1.3	0.0	0.0	0.3	**82,421**
Francistown	90.0	0.1	0.2	0.2	0.0	0.5	0.7	0.4	5.8	1.5	0.1	0.0	0.4	**33,811**
Lobatse	81.0	0.1	0.2	0.4	0.0	0.4	0.7	0.5	11.8	4.6	0.1	0.0	0.2	**9,839**
Selibe Phikwe	89.5	0.1	0.1	0.4	0.0	0.3	0.5	0.4	4.7	3.4	0.1	0.0	0.3	**13,330**
Orapa	99.3	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.1	**3,049**
Jwaneng	91.2	0.0	0.2	0.4	0.0	0.4	0.5	0.7	3.8	2.5	0.0	0.0	0.3	**6,586**
Sowa	99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	**1,106**
Southern	66.0	0.1	1.1	0.8	0.0	3.1	6.4	0.4	10.8	9.0	1.0	0.0	1.3	**37,806**
Barolong	57.2	1.0	1.0	0.5	0.1	1.9	6.2	0.3	18.5	11.1	1.2	0.0	1.1	**16,498**
Ngwaketse West	34.9	0.7	4.3	1.4	0.1	4.1	13.9	0.7	18.6	11.6	2.9	0.0	6.9	**6,588**
South East	90.8	0.1	0.5	0.2	0.0	0.9	1.2	0.3	3.4	2.0	0.2	0.0	0.3	**36,327**
Kweneng East	79.6	0.6	1.2	0.4	0.0	1.8	2.8	0.6	5.8	5.6	0.7	0.0	0.7	**100,751**
Kweneng West	34.6	0.1	2.1	1.1	0.1	3.8	17.9	0.3	16.1	10.9	6.0	0.0	7.2	**15,920**
Kgatleng (Wards)	75.2	0.2	1.4	0.9	0.1	3.1	5.4	0.3	6.2	6.1	0.5	0.0	0.7	**36,538**
Central Serowe -Palapye	69.2	0.4	1.3	1.2	0.1	2.8	4.9	0.7	8.2	6.9	1.6	0.0	2.7	**56,992**
Central Mahalapye	61.1	0.5	1.4	1.4	0.1	2.8	7.1	0.2	9.1	11.7	1.9	0.0	2.7	**36,683**
Central Bobonong	63.9	0.3	1.6	1.0	0.1	4.0	6.6	0.3	10.7	7.7	0.8	0.0	3.0	**22,212**
Central Boteti	63.2	0.8	1.7	1.4	0.2	2.8	8.9	0.6	11.2	3.1	2.9	0.0	3.2	**21,259**
Central Tutume	64.3	0.3	1.7	1.1	0.1	3.0	6.6	0.3	11.7	5.9	1.7	0.0	3.2	**46,626**
North East	80.2	0.1	1.1	0.3	0.1	2.3	1.8	0.2	9.2	3.0	0.5	0.0	1.2	**20,912**
Ngamiland East	69.3	0.2	1.5	0.6	0.1	2.7	7.1	0.7	7.8	6.2	1.1	0.0	2.8	**31,591**
Ngamiland West	41.5	1.1	1.3	1.4	0.2	3.2	15.7	2.0	21.2	2.4	2.4	0.0	7.5	**17,921**
Chobe	80.3	0.4	2.1	0.4	0.8	1.9	3.9	0.2	7.1	1.0	0.4	0.0	1.5	**10,124**
Delta	0.0	0.0	3.1	0.0	0.0	3.7	22.0	2.6	27.7	17.8	15.2	0.0	7.9	**192**
Ghanzi	53.1	1.1	2.0	1.2	0.2	2.3	6.0	0.5	15.5	8.8	2.1	0.1	7.2	**15,158**
CKGR	0.0	0.0	1.2	0.0	10.7	0.0	0.0	0.0	0.0	0.0	84.5	1.2	2.4	**84**
Kgalagadi South	57.0	0.1	1.7	0.5	0.1	1.7	4.5	0.3	24.4	5.9	0.7	0.0	3.2	**9,749**
Kgalagadi North	60.9	0.2	0.6	0.5	0.1	1.5	9.0	0.2	16.5	5.8	0.7	0.0	3.8	**7,172**
TOTAL	73.4	0.4	1.1	0.7	0.1	2.1	4.7	0.5	8.6	5.4	1.1	0.0	2.0	**697,245**

TABLE 5:Percentage Distribution of Households by Source of Energy for Lighting by Locality

LOCALITY	SOURCE OF HOUSEHOLD ENERGY FOR LIGHTING													TOTAL HOUSEHOLDS
	Electricity – (National Grid)	Electricity- (Off Grid)	Electricity- (Battery)	Electricity – (Diesel Generator)	Electricity – (Petrol Generator)	Solar Home System	Solar Lantern	LPG	Candle	Paraffin	Firewood	Charcoal	Other	
Towns and Cities	91.4	0.2	0.2	0.2	0.0	0.3	0.5	0.5	4.6	1.8	0.1	0.0	0.3	**150,142**
Urban Villages	89.1	0.4	0.3	0.2	0.0	0.5	0.9	0.4	5.0	2.5	0.3	0.0	0.5	**307,268**
Rural Areas	42.1	0.5	2.7	1.6	0.2	5.2	12.3	0.6	15.8	11.5	2.7	0.0	4.9	**239,835**
TOTAL	73.4	0.4	1.1	0.7	0.1	2.1	4.7	0.5	8.6	5.4	1.1	0.0	2.0	**697,245**

TABLE 6: Percentage Distribution of Households Source of Household Energy for Cooking by District

DISTRICT NAME	SOURCES OF HOUSEHOLD ENERGY FOR COOKING														TOTAL HOUSEHOLDS
	Electricity – National Grid	Electricity – Off-Grid	Electricity– Diesel Generator	Electricity – Petrol Generator	Solar home System	LPG	Biogas	Kerosene/paraffin	Coal	Charcoal	Wood	Crop residue/ grass/ straw/shrubs	Animal d ung/waste	Other	
Gaborone	36.2	0.9	0.0	0.0	0.2	51.9	8.5	0.2	0.0	0.0	0.9	0.0	0.0	1.2	**82,421**
Francistown	33.4	0.6	0.0	0.0	0.2	45.7	12.3	0.4	0.1	0.1	6.4	0.0	0.0	0.9	**33,811**
Lobatse	23.1	0.2	0.0	0.0	0.1	62.8	7.3	1.0	0.0	0.0	4.2	0.0	0.0	1.2	**9,839**
Selibe Phikwe	30.7	0.2	0.0	0.0	0.2	47.5	10.5	0.0	0.1	0.1	10.3	0.0	0.0	0.4	**13,330**
Orapa	4.6	0.1	0.0	0.0	0.1	94.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	**3,049**
Jwaneng	23.1	0.1	0.0	0.0	0.1	73.6	1.4	0.1	0.0	0.0	1.2	0.0	0.0	0.4	**6,586**
Sowa	72.7	0.1	0.0	0.0	0.1	23.9	0.7	0.0	0.0	0.0	2.4	0.0	0.0	0.1	**1,106**
Southern	23.2	0.3	0.0	0.0	0.3	34.2	3.8	0.2	0.1	0.3	36.6	0.2	0.1	0.6	**37,806**
Barolong	21.4	0.5	0.0	0.0	0.1	20.3	4.6	0.8	0.1	0.1	50.3	0.6	0.4	0.9	**16,498**
Ngwaketse West	11.0	0.6	0.0	0.0	0.3	11.7	3.5	0.2	0.1	0.4	68.5	0.7	0.1	2.9	**6,588**
South East	33.7	0.6	0.0	0.0	0.2	47.3	9.5	0.2	0.1	0.2	7.7	0.0	0.1	0.5	**36,327**
Kweneng East	22.9	1.1	0.0	0.0	0.3	43.8	12.0	0.5	0.2	0.2	17.8	0.1	0.1	1.1	**100,751**
Kweneng West	9.5	0.2	0.0	0.0	0.2	11.2	4.9	0.6	0.2	0.6	69.4	1.1	0.4	1.6	**15,920**
Kgatleng (Wards)	26.6	0.3	0.0	0.0	0.2	37.5	8.3	0.4	0.1	0.3	25.7	0.1	0.0	0.5	**36,538**
Central Serowe -Palapye	23.6	0.3	0.0	0.0	0.2	26.3	7.5	0.3	0.4	0.4	39.6	0.3	0.1	1.0	**56,992**
Central Mahalapye	18.8	0.3	0.0	0.0	0.2	25.9	2.9	0.4	0.2	0.3	49.8	0.3	0.1	0.7	**36,683**
Central Bobonong	21.6	0.1	0.0	0.0	0.2	19.6	3.8	0.2	0.2	0.5	52.8	0.3	0.1	0.6	**22,212**
Central Boteti	15.0	1.1	0.0	0.0	0.6	38.4	2.9	0.2	0.3	0.3	38.5	0.8	0.1	1.7	**21,259**
Central Tutume	20.8	0.4	0.0	0.0	0.2	16.4	5.8	0.9	0.3	0.5	53.5	0.2	0.1	0.9	**46,626**
North East	26.9	0.3	0.0	0.0	0.2	24.7	6.5	0.2	0.1	0.3	39.9	0.2	0.0	0.7	**20,912**
Ngamiland East	26.1	0.9	0.0	0.0	0.3	27.2	6.7	0.3	0.2	0.5	36.3	0.1	0.0	1.3	**31,591**
Ngamiland West	17.4	0.8	0.0	0.0	0.3	7.2	2.8	0.4	0.2	0.7	67.4	0.8	0.1	1.8	**17,921**
Chobe	39.5	0.5	0.3	0.0	0.3	25.5	7.0	0.5	0.1	0.3	25.3	0.0	0.0	0.6	**10,124**
Delta	0.0	0.0	0.0	0.0	1.6	1.6	0.0	0.5	0.0	2.6	85.8	0.5	0.5	6.8	**192**
Ghanzi	23.8	0.6	0.0	0.0	0.5	25.8	3.3	0.5	0.2	0.7	42.9	0.3	0.1	1.2	**15,158**
CKGR	0.0	0.0	0.0	0.0	1.2	10.7	0.0	0.0	2.4	0.0	85.7	0.0	0.0	0.0	**84**
Kgalagadi South	21.9	0.2	0.1	0.0	0.4	25.2	2.6	0.2	0.2	0.3	47.3	0.4	0.3	1.0	**9,749**
Kgalagadi North	26.3	0.3	0.0	0.0	0.2	26.7	1.5	0.2	0.2	0.6	42.5	0.1	0.0	1.3	**7,172**
TOTAL	**25.3**	**0.6**	**0.0**	**0.0**	**0.3**	**34.9**	**7.2**	**0.4**	**0.2**	**0.3**	**29.7**	**0.2**	**0.1**	**1.0**	**697,245**

TABLE 7: Percentage Distribution of Households by Source of Household Energy for Cooking by Locality

DISTRICT NAME	SOURCES OF HOUSEHOLD ENERGY FOR COOKING														
	Electricity – National Grid	Electricity – Off-Grid	Electricity– Diesel Generator	Electricity – Petrol Generator	Solar home System	LPG	Biogas	Kerosene/paraffin	Coal	Charcoal	Wood	Crop residue/ grass/ straw/ shrubs	Animal dung/waste	Other	Total Households
Towns and Cities	33.2	0.6	0.0	0.0	0.2	52.4	8.9	0.3	0.0	0.1	3.2	0.0	0.0	1.0	**15,0142**
Urban Villages	31.1	0.8	0.0	0.0	0.2	42.3	8.9	0.2	0.1	0.2	15.3	0.0	0.0	0.7	**307,268**
Rural Areas	12.8	0.3	0.0	0.0	0.4	14.4	3.9	0.6	0.3	0.6	64.7	0.6	0.2	1.3	**239,835**
TOTAL	**25.3**	**0.6**	**0.0**	**0.0**	**0.3**	**34.9**	**7.2**	**0.4**	**0.2**	**0.3**	**29.7**	**0.2**	**0.1**	**1.0**	**697,245**

TABLE 8: Percentage Distribution of Households by Sources of Household Energy for Heating Space by District

DISTRICT NAME	SOURCE OF HOUSEHOLD ENERGY FOR HEATING SPACE															Total Households
	Electricity – National Grid	Electricity – Off-Grid	Electricity – Diesel Generator	Electricity – Petrol Generator	Solar Home System	Lpg	Biogas	Kerosene/ Paraffin	Coal	Charcoal	Wood	Crop Residue/Grass/ Straw/Shrubs	Animal Dung/Waste	Other	None	
Gaborone	51.7	0.7	0.0	0.0	0.3	1.6	0.5	0.1	0.1	0.1	2.2	0.0	0.0	39.9	2.7	**82,421**
Francistown	36.1	0.3	0.0	0.0	0.3	0.7	0.6	0.2	0.3	0.2	6.3	0.0	0.0	52.3	2.7	**33,811**
Lobatse	36.3	0.1	0.0	0.0	0.0	3.3	0.5	0.1	0.3	0.1	8.1	0.0	0.0	48.6	2.6	**9,839**
Selibe Phikwe	32.6	0.3	0.0	0.0	0.0	0.5	0.2	0.0	0.1	0.3	10.2	0.1	0.0	50.1	5.5	**13,330**
Orapa	88.0	0.1	0.0	0.0	3.3	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	7.6	0.5	**3,049**
Jwaneng	64.1	0.0	0.0	0.0	0.4	1.7	0.2	0.0	0.1	0.0	3.0	0.0	0.0	29.2	1.2	**6,586**
Sowa	50.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	46.4	1.0	**1,106**
Southern	22.6	0.2	0.0	0.0	0.2	1.8	0.3	0.3	0.2	0.4	32.3	0.1	0.1	39.9	1.6	**37,806**
Barolong	19.5	0.3	0.0	0.0	0.1	1.0	0.2	0.3	0.2	0.2	47.6	0.0	0.2	28.5	1.9	**16,498**
Ngwaketse West	9.7	0.1	0.0	0.0	0.2	0.6	0.2	0.1	0.2	0.4	61.3	0.2	0.1	24.8	2.2	**6,588**
South East	40.2	0.6	0.0	0.0	0.2	1.6	0.6	0.0	0.1	0.5	12.2	0.1	0.0	42.2	1.6	**36,327**
Kweneng East	33.8	1.0	0.0	0.0	0.3	3.0	0.8	0.2	0.4	0.2	18.8	0.1	0.1	39.7	1.6	**100,751**
Kweneng West	11.6	0.1	0.0	0.0	0.2	0.8	0.6	0.1	0.2	0.5	68.3	0.2	0.2	16.0	1.2	**15,920**
Kgatleng (Wards)	30.4	0.3	0.0	0.0	0.3	0.7	0.8	0.2	0.2	0.4	23.1	0.0	0.0	42.0	1.5	**36,538**
Central Serowe -Palapye	25.7	0.2	0.0	0.0	0.1	1.0	0.5	0.2	0.4	0.3	32.7	0.1	0.1	36.0	2.6	**56,992**
Central Mahalapye	20.1	0.4	0.0	0.0	0.3	1.0	0.3	0.3	0.3	0.5	41.1	0.3	0.1	33.7	1.5	**36,683**
Central Bobonong	19.8	0.1	0.0	0.0	0.1	0.7	0.1	0.3	0.2	0.4	39.7	0.1	0.0	36.5	1.8	**22,212**
Central Boteti	21.6	0.9	0.0	0.0	0.2	1.3	0.2	0.1	0.3	0.5	33.7	0.2	0.3	36.3	4.3	**21,259**
Central Tutume	19.1	0.3	0.0	0.0	0.4	0.8	0.6	0.4	0.6	0.6	36.9	0.1	0.0	38.6	1.4	**46,626**
North East	22.9	0.1	0.0	0.0	0.1	0.6	0.2	0.1	0.1	0.5	34.6	0.1	0.1	37.2	3.4	**20,912**
Ngamiland East	25.1	0.5	0.0	0.0	0.3	1.0	0.3	0.1	0.2	0.2	24.5	0.1	0.1	45.1	2.5	**31,591**
Ngamiland West	9.5	0.3	0.0	0.0	0.4	0.2	0.1	0.4	0.3	0.5	39.2	0.3	0.2	45.7	2.9	**17,921**
Chobe	34.0	0.5	0.1	0.0	0.9	0.8	0.5	0.1	0.3	0.5	12.8	0.0	0.1	46.9	2.5	**10,124**
Delta	0.0	0.0	0.0	0.0	1.1	0.0	0.5	0.0	0.0	0.0	86.3	0.5	0.0	11.6	0.0	**192**
Ghanzi	16.8	0.2	0.1	0.0	0.6	0.7	0.2	0.1	0.6	1.4	35.4	0.1	0.0	40.6	3.0	**15,158**
CKGR	0.0	0.0	3.6	0.0	1.2	0.0	0.0	0.0	1.2	0.0	85.7	0.0	0.0	8.3	0.0	**84**
Kgalagadi South	24.5	0.1	0.1	0.0	0.3	2.4	0.2	0.2	0.1	0.3	43.3	0.3	0.2	27.2	0.9	**9,749**
Kgalagadi North	26.1	0.2	0.0	0.0	0.3	0.6	0.1	0.0	0.3	0.8	41.6	0.1	0.0	28.3	1.5	**7,172**
TOTAL	**29.9**	**0.4**	**0.0**	**0.0**	**0.3**	**1.4**	**0.5**	**0.2**	**0.3**	**0.4**	**25.3**	**0.1**	**0.1**	**39.0**	**2.2**	**697,245**

TABLE 9: Percentage Distribution of Households by Sources of Household Energy for Heating Space by Locality

LOCALITY	SOURCE OF HOUSEHOLD ENERGY FOR HEATING SPACE															Total Households
	Electricity – National Grid	Electricity – Off-Grid	Electricity – Diesel Generator	Electricity – Petrol Generator	Solar Home System	LPG	Biogas	Kerosene/ Paraffin	Coal	Charcoal	Wood	Crop Residue/Grass/ Straw/Shrubs	Animal Dung/Waste	Other	None	
Towns and Cities	46.7	0.5	0.0	0.0	0.3	1.4	0.5	0.1	0.2	0.1	4.2	0.0	0.0	43.1	2.8	**150,142**
Urban Villages	35.3	0.7	0.0	0.0	0.2	1.9	0.6	0.1	0.2	0.3	14.6	0.1	0.0	43.8	2.1	**307,268**
Rural Areas	12.5	0.2	0.0	0.0	0.4	0.7	0.3	0.3	0.4	0.6	52.0	0.2	0.1	30.2	1.9	**239,835**
TOTAL	**29.9**	**0.4**	**0.0**	**0.0**	**0.3**	**1.4**	**0.5**	**0.2**	**0.3**	**0.4**	**25.3**	**0.1**	**0.1**	**39.0**	**2.2**	**697,245**

TABLE 10: Percentage Distribution of Households by Sources of Household Energy for Heating Water by District

DISTRICT NAME	SOURCE OF HOUSEHOLD ENERGY FOR HEATING SPACE															Total Households
	Electricity – National Grid	Electricity – Off-Grid	Electricity – Diesel Generator	Electricity – Petrol Generator	Solar Home System	Lpg	Biogas	Kerosene/ Paraffin	Coal	Charcoal	Wood	Crop Residue/Grass/ Straw/Shrubs	Animal Dung/Waste	Other	None	
Gaborone	51.7	0.7	0.0	0.0	0.3	1.6	0.5	0.1	0.1	0.1	2.2	0.0	0.0	39.9	2.7	**82,421**
Francistown	36.1	0.3	0.0	0.0	0.3	0.7	0.6	0.2	0.3	0.2	6.3	0.0	0.0	52.3	2.7	**33,811**
Lobatse	36.3	0.1	0.0	0.0	0.0	3.3	0.5	0.1	0.3	0.1	8.1	0.0	0.0	48.6	2.6	**9,839**
Selibe Phikwe	32.6	0.3	0.0	0.0	0.0	0.5	0.2	0.0	0.1	0.3	10.2	0.1	0.0	50.1	5.5	**13,330**
Orapa	88.0	0.1	0.0	0.0	3.3	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	7.6	0.5	**3,049**
Jwaneng	64.1	0.0	0.0	0.0	0.4	1.7	0.2	0.0	0.1	0.0	3.0	0.0	0.0	29.2	1.2	**6,586**
Sowa	50.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	46.4	1.0	**1,106**
Southern	22.6	0.2	0.0	0.0	0.2	1.8	0.3	0.3	0.2	0.4	32.3	0.1	0.1	39.9	1.6	**37,806**
Barolong	19.5	0.3	0.0	0.0	0.1	1.0	0.2	0.3	0.2	0.2	47.6	0.0	0.2	28.5	1.9	**16,498**
Ngwaketse West	9.7	0.1	0.0	0.0	0.2	0.6	0.2	0.1	0.2	0.4	61.3	0.2	0.1	24.8	2.2	**6,588**
South East	40.2	0.6	0.0	0.0	0.2	1.6	0.6	0.0	0.1	0.5	12.2	0.1	0.0	42.2	1.6	**36,327**
Kweneng East	33.8	1.0	0.0	0.0	0.3	3.0	0.8	0.2	0.4	0.2	18.8	0.1	0.1	39.7	1.6	**100,751**
Kweneng West	11.6	0.1	0.0	0.0	0.2	0.8	0.6	0.1	0.2	0.5	68.3	0.2	0.2	16.0	1.2	**15,920**
Kgatleng (Wards)	30.4	0.3	0.0	0.0	0.3	0.7	0.8	0.2	0.2	0.4	23.1	0.0	0.0	42.0	1.5	**36,538**
Central Serowe -Palapye	25.7	0.2	0.0	0.0	0.1	1.0	0.5	0.2	0.4	0.3	32.7	0.1	0.1	36.0	2.6	**56,992**
Central Mahalapye	20.1	0.4	0.0	0.0	0.3	1.0	0.3	0.3	0.3	0.5	41.1	0.3	0.1	33.7	1.5	**36,683**
Central Bobonong	19.8	0.1	0.0	0.0	0.1	0.7	0.1	0.3	0.2	0.4	39.7	0.1	0.0	36.5	1.8	**22,212**
Central Boteti	21.6	0.9	0.0	0.0	0.2	1.3	0.2	0.1	0.3	0.5	33.7	0.2	0.3	36.3	4.3	**21,259**
Central Tutume	19.1	0.3	0.0	0.0	0.4	0.8	0.6	0.4	0.6	0.6	36.9	0.1	0.0	38.6	1.4	**46,626**
North East	22.9	0.1	0.0	0.0	0.1	0.6	0.2	0.1	0.1	0.5	34.6	0.1	0.1	37.2	3.4	**20,912**
Ngamiland East	25.1	0.5	0.0	0.0	0.3	1.0	0.3	0.1	0.2	0.2	24.5	0.1	0.1	45.1	2.5	**31,591**
Ngamiland West	9.5	0.3	0.0	0.0	0.4	0.2	0.1	0.4	0.3	0.5	39.2	0.3	0.2	45.7	2.9	**17,921**
Chobe	34.0	0.5	0.1	0.0	0.9	0.8	0.5	0.1	0.3	0.5	12.8	0.0	0.1	46.9	2.5	**10,124**
Delta	0.0	0.0	0.0	0.0	1.1	0.0	0.5	0.0	0.0	0.0	86.3	0.5	0.0	11.6	0.0	**192**
Ghanzi	16.8	0.2	0.1	0.0	0.6	0.7	0.2	0.1	0.6	1.4	35.4	0.1	0.0	40.6	3.0	**15,158**
CKGR	0.0	0.0	3.6	0.0	1.2	0.0	0.0	0.0	1.2	0.0	85.7	0.0	0.0	8.3	0.0	**84**
Kgalagadi South	24.5	0.1	0.1	0.0	0.3	2.4	0.2	0.2	0.1	0.3	43.3	0.3	0.2	27.2	0.9	**9,749**
Kgalagadi North	26.1	0.2	0.0	0.0	0.3	0.6	0.1	0.0	0.3	0.8	41.6	0.1	0.0	28.3	1.5	**7,172**
TOTAL	**29.9**	**0.4**	**0.0**	**0.0**	**0.3**	**1.4**	**0.5**	**0.2**	**0.3**	**0.4**	**25.3**	**0.1**	**0.1**	**39.0**	**2.2**	**697,245**

TABLE 11: Percentage Distribution of Households by Sources of Household Energy for Heating Water by Locality

DISTRICT NAME	SOURCE OF HOUSEHOLD ENERGY FOR HEATING SPACE															Total Households
	Electricity – National Grid	Electricity – Off-Grid	Electricity – Diesel Generator	Electricity – Petrol Generator	Solar home System	LPG	Biogas	Kerosene/ paraffin	Coal	Charcoal	Wood	Crop residue/grass/ straw/shrubs	Animal dung/waste	Other	None	
Towns and Cities	82.7	0.6	0.0	0.0	0.9	4.8	1.0	0.1	0.1	0.1	7.7	0.0	0.0	1.7	0.3	**150,142**
Urban Villages	63.9	0.6	0.0	0.0	0.6	4.5	1.2	0.1	0.2	0.2	26.2	0.1	0.0	2.2	0.2	**307,268**
Rural Areas	20.0	0.3	0.0	0.0	0.5	2.2	0.8	0.2	0.5	0.7	70.0	0.5	0.2	3.6	0.6	**239,835**
Total	**52.8**	**0.5**	**0.0**	**0.0**	**0.6**	**3.8**	**1.0**	**0.1**	**0.3**	**0.4**	**37.3**	**0.2**	**0.1**	**2.5**	**0.4**	**697,245**

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