EVALUATION OF POPULATION CENSUS DATA AND POPULATION GROWTH IN GHANA THROUGH DEMOGRAPHIC ANALYSIS

Daniel Yaw Gbogbo (B. Ed. Mathematics)

A thesis submitted to the Department of Mathematics, Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Industrial Mathematics

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DECLARATION

I, Gbogbo Daniel Yaw, hereby declare that except for references made to people's work and piece of information sourced from the internet, this study which is supervised by Dr. S. K. Amponsah, is the result of my own research. It has neither been presented for another degree in this University or elsewhere.

Daniel Yaw Gbogbo (PG2010108) ....
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Supervisor Signature Date

Certified by:

Mr.K. F. Darkwah ....
Head of Department Signature Date

Certified by:

Prof. I. K. Dontwi ....
Dean, IDL Signature Date

ABSTRACT

Ghana takes a census of its population every 10 years. The census has important ramifications for many aspects of society. The study explores the historical contexts of population census through ancient practices to modern development in population studies. It explores Ghana's population trends over a fifty-year period (1960-2010); examines parameters involved in demographic analysis of the population; explores differences in the results of the same period, using different models; and investigates some limiting factors which inhibit population growth. The research design, the study area, data collection methods and instruments, validation of the instruments, limitations and the procedure for data analysis were discussed. Statistical instruments, Malthus' Exponential model and Verhulst's Logistic model, are most useful in determining population growth. Specifically, in Ghana, births exceed deaths by mean 17.86 per 1000 persons, population grows exponentially at 1.78% on average; each addition to population also produces compounding accelerating effect on population size. From the foregoing discussions, logistic growth model is more reliable than the simplified exponential growth model, but together they provide us with the size and growth of Ghana's population over the study period. To conclude, as the total population continues to rise, there should be corresponding and appropriate methods and sources for calculating population size and growth, which would give a total human population figure at any given time. However, owing to lack of professional demographer, statisticians and seasoned computer analysts, the total population figure should not be taken as the truthful number.

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DEDICATION

This work is wholly dedicated to my, ever-loving and caring mum, Madam Awumeshie Amekuedi for everything she has done for me.

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First of all, I am indebted to my supervisor who has painstakingly read through the work and provided insights and understanding to the models. Without his suggestions and motivation, this present work would not have been accomplished.

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May God bless each of you!

CHAPTER 1

INTRODUCTION

This chapter explores the historical contexts of population census through ancient practices to modern development in population studies.

1.1 Background of the Study

Historically, the oldest incidence of census was said to have taken place in ancient Egypt during the Pharaonic period in 3340 BC and in 3350 BC. Censuses are also associated with ancient Israel, when Moses counted his people, as mentioned in the Bible (Exodus 30:11-16 and Numbers 1-4) in the wilderness of Sinai and in the plains of Moab respectively. King David also conducted a census to know the strength of his army (2 Samuel 24 and 1 Chronicles 2:17). Solomon had the foreigners counted in order to levy them. Furthermore, there were instances of population census in the New Testament too; Jesus was born during Herod's census (Luke 2:1-7 NKJV).

In modern times, during the seventeenth century men became very interested in the study of human population purely from scientific point of view. The first person who undertook the said study was an Englishman called John Graunt (1620-1674). His work was truly standard; he introduced the first life table for the study of population of London in some detail. Many then followed his footsteps in the study of human population, notable among them was Rev. Thomas Malthus. Keyfitz and Flieyer

(1990) were the first to analyse the human population in their work on world population growth and aging. The use of logistic model to study human population was received in 1920 by Pearl and Read. They compared the census figures for the population of United States of America from 1790 to 1910 with the values predicted from logistic models. Over ninety (90) per cent of all countries carry out censuses to count their population and to collect information about the people living in various geographic regions. The uses of census data are varied.

Information on the size, distribution and characteristics of a country's population is essential for describing and assessing its economic, social and demographic circumstances and for developing sound policies and programmes [in such fields as education and literacy, employment and manpower, family planning, housing, maternal and child health, rural development, transportation and highway planning, urbanization and welfare] aimed at fostering the welfare of a country and its population (United Nations, 1998).

Also, the uses of census data in business, industry, labour and research institutions have multiplied. Information technology has radically extended possible uses of population census data beyond the traditional models. As population census data have become more and more pervasive in our lives, so are the calls for increasing their scope, completeness, accuracy and validity, and for improving their national value and international comparability.

The fact is that despite all the meticulous preparations, there is always some degree of errors in coverage and in content. Siegel (2004) recommended a number of methods to evaluate census data, including demographic analysis, the post-enumeration survey (PES) and comparison of census data with administrative statistics and household surveys. The methods differ widely with regard to data requirements, the level of technical sophistication and the quality of the results.

From colonial era, Ghana has conducted several types of censuses; eleven (11) national population censuses in 1891, 1901, 1911, 1921, 1931, 1948, 1960, 1970, 1984 and PHC: 2000 and 2010. Five (5) Ghana Demographic and Health Surveys (GDHS) every five years since 1988 (1988, 1993, 2000, 2005 and 2010); and other various surveys such as the Living Standards Surveys (LSS) and the Multiple Indicators Cluster Survey (MICS).

Censuses have important ramifications for many aspects of society, such as budgeting for the regions and representations in parliament. The method of taking the census and how it is analyzed and has been very hot issues not only in Ghana, but the world over. For example, in the US the Republicans issued legal jurisdiction against the Democrats over the last population census, knowing that a direct head count always undercounts minorities and the poor, who vote predominantly Democratic. The Democrats claimed that the Constitution framers wanted an accurate count of the populace, so that modern statistical methods should be employed. This would naturally give them an advantage in the voting. The Supreme Court came down in the middle pleasing neither party and saying that the Constitution requires a head count, which will be used for allocating Congressional seats and districting, while the more accurate statistical count will be used for apportioning the money for Federal funding. Similarly in Ghana, the New Patriotic Party is accusing the National Democratic Congress (NDC) manipulating the 2010 population figures to favour the NDC government in the 2012 national election (GNA, 2011). Since independence, Ghana has conducted and accumulated large amounts of data at the national level. Among them are four censuses (1960, 1970, 1984 and 2000); four Ghana Demographic and Health Surveys (GDHS), with the fifth (2008) in progress at the time of this study.

It is therefore important to note that accurately predicting these demographic data is important for planning our communities in the future. The quality of the census outputs is a function of the quality of the inputs and throughputs as informed by the strategy.

Lutz et al., (1997) proposed eight measurable dimensions of quality (Quality Assessment Framework) to develop performance indicators in both quantitative and qualitative survey. These dimensions are:

(i) Relevance: The degree to which the data meets the real needs of clients. It is concerned with whether the available information sheds light on the issue of most importance to users.

(ii) Methodological soundness: This refers to the application of international standards, guidelines and other agreed upon practices to produce statistical outputs. Application of these standards fosters national and international comparability.

(iii) Accuracy: The accuracy of statistical information is the degree to which the output correctly describes the phenomena it was designed to measure.

(iv) Timeliness: This refers to the delay between the reference point to which the information pertains, and the date on which the information becomes available.

(v) Accessibility: Accessibility refers to the ease with which information can be obtained from the producers of the information. This includes the ease with which the existence of information can be ascertained, as well as the suitability of the form or media through which the information can be accessed. The cost of the information may also be another aspect for some users.

(vi) Interpretability: The interpretability of information refers to the ease with which users understand statistical information through the provision of metadata.

(vii) Coherence: The coherence of statistical information reflects the degree to which it can be successfully brought together with other statistical information within a broad analytic framework and over time.

(viii) Integrity: Integrity refers to values and related practices that maintain confidence of users in the agency that produces the statistics and ultimately in the statistical products.

These quality dimensions are considered in all phases of the population censuses programme, though certain dimensions are more pronounced in one census than in the other. For example, in the PHCs the focus is more on the environmental conditions of the people than in other surveys. Again, at the base of all these population censuses and surveys, there are future projections and predictions, involving some types of mathematical models. This study, therefore, reviews two mathematical models of population dynamics of human population – Malthusian growth model and Logistic growth model - and explores the varying rates of population growth of the people over a defined period of time (1960-2010).

Apart from scattered census records or figures kept, there seems to be no unified mathematical model of such population figures or data developed with the aid of describing the statistical properties of data related to such population figures or data. Due to ever increasing population growth naturally, it has become absolutely necessary to introduce the most common quantitative approach to population dynamics, taking note of the different theoretical foundations and assumptions to such population. Several authors, including Pearl and Reed (1920 and Meyer et al., (1999) have demonstrated that simple mathematical models can account for growth – increase or decline - in human population. The number of people that the environment can support, called the carrying capacity, gives an interesting background to the population research survey and evaluation of the data. Meyer and Ausubel (1999) stated that, "New technologies affect how resources are consumed." They concluded that "models that employ dynamic carrying capacity are more reflective of the human condition."

1.2 Statement of the Problem

As Ghana's population trends have shown ever increasing growth rates, while government policy has been to keep growth rates in check, the need to understand and model population size and growth becomes more and more pressing. An international population expert, Sai (2011) has bemoaned the

2.4% growth rate of Ghana's population, hinting that it would retard Ghana's development process. He again said, that "Ghana risks doubling its population to 48 million in 28 years time if measures are not taken to forestall it.

Merrit (2001) posited out that "The process of translating a real-life problem into a mathematical form (model) can give a better representation and solution of certain problems, with or without some difficulties. Now, the question is what mathematical model or models could provide the right information about population data and population growth for effective and efficient development agenda? In addition, what demographic factors are more prevalent in Ghana's population growth between the periods 2001 and 2010?

1.3 Objective of the Study

The objectives of the study are to:

(i) explore Ghana population trends over a fifty-year period (1960-2010);

(ii) examine parameters involve in demographic analysis of the population;

(iii) explore differences in the results of the same period, using different models; and

(iv) investigate some limiting factors which inhibit population growth.

1.4 Significance of the Study

Governments have viewed population data, especially, size and growth with serious concern, though they differ in the method of curtailment. At the centre of each method is the future projection and estimation. Islam (2009) justified the use of mathematical models "for the estimation of population projection and estimation. In fact, mathematical model is essentially an endeavour to find the relationship and their dynamic behaviour among the various elements in the Demography." In the present study, the structures of the models are deterministic in that the functional relationship between different variables that take definite values would be explored.

This study is significant in many ways: its perspective is to evaluate social and economic statistics relating to population size and growth over the study period (1960-2010). In this view, the study is aimed at recommending mathematical models, which governments could use for future population projection. Again, to a less extent though, it would help the central and local governments in allocation of social amenities, including education, housing and healthcare for the elderly and children.

Organizations relying solely on census information data to provide social services would use the models herein for their processes. Developed countries also need census data when planning technical and economic assistance to developing countries such as Ghana. Finally, other researchers would use this study as their secondary source of literature.

1.5 Scope of the Study

Generally, the study covers the demographics data of the world's population, with emphasis on the differences in characteristics between developed and developing countries. However, specifically the study focuses on Ghana's demographic trends between 1960 and 2010. We should consider basic components of demographic analysis, giving detailed qualitative examination of population size and growth during the said study period.

We shall put forward two mathematical models - Malthus Growth Model (Exponential model) and Logistics Growth Model in relation to population size and growth from 2001 to 2010. This aspect first explored basic definitions of the models followed by a further examination of the relationship between population growth rate and the population models. We shall conclude with a recommendation of application of theory and practice in future prediction and projection of population.

1.6 Limitations of the Study

This section of the study is to draw readers' attentions to the problems encountered by the researcher during the study. The first problem has to do with collecting census figures in context. Officials in charge of the census data were reluctant to release the figures to me, despite my identification; they suspected political motivation was the main reason. In fact, the present controversies between the government and its political opponents did not help much in this reason. Secondly, the various figures from the Statistical Services and Population Centre were at variance. The researcher had to make a compromise at some points, to get a near accurate figure. Again the figures on the internet were also at variance with the two earlier sources. Thirdly, some of the hospitals visited did not have up-to-date data on ion of the questionnaires distributed to them; on demographic elements such as fertility rates, birth rates and death rates. Fourthly, as full-time tutor in charge of classroom teaching and organization of practical teaching for students, the researcher took much longer time in the collection of data. Finally, the financial obligation involved in collecting data over a six-month period was enormous; the researcher had to travel from Jasikan to Accra all this time.

To conclude, despite the constraints, very reliable results were obtained. However, it is worthy to note that there might be variations when other models are used which might not reflect in some of the findings in this study.

1.7 Organization of the Study

Chapter 1 which is the Introduction includes the background information, the statement of the problem, objectives of the study, research questions, significance of the study, scope of the study and the organization of the chapters. Chapter 2 covers the review of related literature. It examines issues of population evaluation in a developing nation such Ghana and outlines the concept and theories available on mathematical modeling of census data. Chapter 3 deals with methods for collection, presentation and analysis of data. Chapter 4 provides the presentation and analysis of data and discussions on findings. Chapter 5 presents summary, conclusion and recommendations for the study.

1.8 Summary

In this chapter, researcher considered and also enumerated basics to the research work are background of the study, statement of the problem, objective of the study, significance of the study, scope of the study, limitations of the study and organization of the study

In next chapter, researcher puts forward pertinent literature in the field of concept of population size and population growth, history of population censuses in Ghana, history of population censuses in Ghana, population growth, Ghana's population growth, determinants of population growth, demographic analysis, parameters of population growth, mathematical models of population, and methods for overall assessment of census quality

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This Chapter presents relevant literature in the field of census data. This includes the conceptual and theoretical frameworks. This study is based on the results of national censuses and statistical data between 1960 and 2010. The study examines the use of demographic analyses in the presentation population size and growth. Specifically, two mathematical models - Malthusian Growth Model and Logistic Growth Model - will be discussed in relation to the demographic elements.

2.1 Concept of population size and population growth

In a similar study by Ogbeide and Ikpotokin (2000), population growth is a function of rate of fertility, life expectancy, mortality and net immigration and emigration.

Marchetti, Meyer and Ausubel (2001) said "decrease or growth comes from the interplay of death and birth (and locally migration)". In this study, the latter approach would be adopted. Again, the researcher intends to borrow the view of Marchetti, Meyer and Ausubel (2001) who agreed that, "Migration also affects the size of local populations, but we will not consider it here." To justify the use of mathematical models to analyse population, Islam (2009) said, "Mathematical model is very important for the estimation of population projections. In fact, mathematical model is essentially an endeavour to find out structural relationships and their dynamic behaviour among the various elements in demography."

Ghana became the third country in Sub-Saharan Africa to adopt an explicit and a comprehensive population policy in 1969 after Mauritius (1958) and Kenya (1967). The policy was meant to affect the growth, structure and distribution of the country's growing Although the 1969 policy was retained by successive governments, very little progress was made during the next two decades in reducing the rate of population growth because political commitment was absent. In 1994 the policy was revised to ensure that Ghana achieves and maintains a level of population growth that is consistent with national development. Furthermore, the government's long term vision (Ghana-vision 2020) for the country is to attain a balanced economy that helps people attain a middle-income status and standard of living by the year 2020. Again, the vision sets a goal to reduce population growth from its present level of around 3% to 2% each year. This would allow real income per capita to increase.

Collecting census data from Africa in general, and in Ghana in particular, is not relatively as accurate as in Europe and America. The reason is largely illiteracy and inaccessibility of some places, especially during the rainy season as a result of the unmotorable nature of our roads. Professional demographers are also a headache. After much effort of successive

Ghanaian governments to oversee credible population census, there are still inconsistencies in population data because most of the figures are projections from previous population figures, which in themselves are far from correct. Hence, various statistical models (not just one) must be used to arrive at the final figures.

2.2 Definitions and Terminologies

2.2.1 Census data

Macmillan English Dictionary (2007 edition) defines census as "an occasion on which government officials count the people who live in a country." Merriam Webster's Third New International Dictionary of the English Language (2002 publication) also defines census as "the procedure of systematically acquiring and recording information about members of a given population." It is a regularly occurring and official count of a particular population. The term is used mostly in connection with national population and housing censuses; other common censuses include agriculture, business, and traffic censuses. In the latter cases the elements of the population are farms, businesses, and so forth, rather than people. The United Nations defines the essential features of population and housing censuses as "individual enumeration, universality within a defined territory, simultaneity and defined periodicity", and recommends that population censuses be taken at least every 10 years.

From the above definitions, census can be contrasted with sampling in which information is obtained only from a subset of a population, sometimes as an intercensal estimate. Census data is commonly used for research, business marketing, and national economic and financial planning, as well as a baseline for sampling surveys. In some countries, census data are used to apportion electoral representations.

2.2.2 History of Population Censuses in Ghana

(i) Pre-independence censuses

Table 2.1 gives the results of pre-independence population censuses. From the table, the first census in Ghana was taken in 1891, and further censuses were taken in each tenth year until the series was interrupted as a result of World War II but was resumed in 1948. Chiefs were asked to carry out the counting which, in accordance with native custom at the time, was done by heads of families placing in a bowl or other receptacle a cowry for each female or a grain of corn for each male member of the family. The cowries and grains were counted and the numbers of each communicated to the District Commissioner by the chief. However, this practice was gradually discontinued in later years.

The 1931 census was the first in which the entire population was individually counted; either by enumerators who counted and recorded village population on a form or by means of forms delivered to households in which the head of the household or occupier inserted particulars of each individual. It is worthy to note the difference in the conduct of the earlier population censuses and the 1931 one; whereas on previous occasions an ad hoc enabling ordinance had been enacted for each census, for the 1931 census a definite ordinance was enacted which was intended to be permanent.

For the 1948 census, a temporary Census Office was formed under the direction of a Census Commissioner from which all forms and instructions were distributed and to which all completed forms were sent after collection for tabulation.

YEAR	TOTAL
1891	764,613
1901	1,549,661
1911	1,503,911
1921	2,486,392
1931	3,457,282
1948	4,501,218

YEAR	POPULATION		
	MALE	FEMALE	TOTAL
1960	3,400,270	3,326,815	6,726,815
1970	4,247,809	4,311,504	8,559,313
1984	6,063848	6,232,233	12,296,081
2000	9,357,382	9,554,697	18,912,079
2010	11,801,661	12,421,770	24,223,431

Table 2.1: Pre-Independence Population of Ghana

Table 2.2:Post-Independence Population of Ghana

(ii) Post-Independence Censuses

Table 2.2 gives the results of post-independence population censuses. The 1960 census was the first to be undertaken since Ghana achieved her independence on March 6, 1957. It was also one of the first censuses taken in Africa as part of the World Population Census proclaimed by the United Nations. The 1960 Ghana Census has since been acclaimed as the first modern census on the African continent and aroused interest not only in Africa but also in several other parts of the world. The second post-independence census was conducted in 1970, with the expectation that a decennial census programme would be maintained. The 1970 Population Census also had all the essential features of a modern population census, as set out in the "Principles and recommendations for the 1970 Population Censuses" issued by the United Nations.

The third post-independence census was conducted in March, 1984. This census data were the first to be captured, processed and stored electronically. Data processing of the census information was undertaken using a Wang VS-80 Main-frame computer which was linked to microcomputers. The fourth census which was expected to have been conducted in March, 1994 was re-scheduled to 2000.

(iii) Population and Housing Census (PHC: 2000)

The 2000 Population and Housing Census was the first time Ghana conducted a Population and Housing census as one operation and reactivated the maintenance of major data collection programmes and provided data required as a basis for the design and development of socio-economic and population policies and programmes. Two major activities undertaken at the planning stage of the 2000 PHC were the preparation of census instruments and the trial census. These instruments, which included the questionnaire, instruction manuals, code lists, and enumeration forms were prepared and tested during the trial census.

2.2.3 Population Growth

Population growth is the change in a population over time, and can be quantified as the change in the number of individuals of any species in a population using "per unit time" for measurement. In biology, the term population growth is likely to refer to any known organism, but in this study it is applicable only to human populations (demography). According to Siegel (2004), population growth is used informally for the more specific term population growth rate, which refers specifically to the growth of the human population of the world. In this study, the terms will be used interchangeably.

Cohen (2001) noted four outstanding changes of world growth rate: first, the agricultural revolution which took place in Southwest Asia and China; second, the global agricultural revolution; third, the fall in death rate which was in the decades after 1950; and finally, the change in fertility rates since the 1980s. It is noteworthy that while the first three changes concern increases in the rate of population growth, the fourth is a decrease in population growth. He further maintained that, “There are enormous concerns about the consequences of human population growth for social, environmental and economic development. Intensifying these problems is population growth.”

The United Nations collaborated the above observation, estimating world population to be 6.2 billion by 2000 (with the poorest areas of the world have the highest population growth rates. For example, out of the about 90 million babies born in the world in 1995, about 85 million were born in developing countries), which would increase to 9.8 billion by 2050.

In addition, the United States Census Bureau’s estimation of the current world population was 6.916165 billion. The Bureau explained that the population experienced continuous growth since the end of the Bubonic Plague around the year 1348-1350. In the next 35 years, 2.5 billion people would be added to the current population. Again, it was revealed

that,

- In low-income countries more than a third of the population is under age 15, while in high-income countries less than a fifth is.
- The world’s population is growing by 200,000 people a day.

- Between 1980 and 2030, the population of low- and middle-income countries will more than double - to 7.0 billion, compared with 1 billion for high-income countries.

Globally, the growth rate of the human population has been declining since 1962 - 1963 at 2.20% per annum. In 2009 for example, the estimated annual growth rate was 1.1%. The CIA Factbook gives the world annual birth rate, mortality rate, and growth rate as 1.915%, 0.812%, and 1.092% respectively. The last one hundred years have seen a rapid increase in population due to medical advances and massive increase in agricultural productivity made possible by the Green Revolution.

The actual annual growth in the number of humans fell from its peak of 88.0 million in 1989 to a low of 73.9 million in 2003, after which it rose again to 75.2 million in 2006. Since then, annual growth has declined. In 2009, the human population increased by 74.6 million, and it is projected to fall steadily to about 41 million per annum in 2050, at which time the population will have increased to about 9.2 billion. Each region of the globe has seen great reductions in growth rate in recent decades, though growth rates remain above 2% in some countries of the Middle East and Sub-Saharan Africa, and also in South Asia, Southeast Asia, and Latin America.

Some countries experience negative population growth, especially in Eastern Europe mainly due to low fertility rates, high death rates and emigration. In Southern Africa, growth is slowing due to the high number of HIV-related deaths. Some Western European countries might also encounter negative population growth. For example, Japan's population began decreasing in 2005. Fig.1 represents the world's percentage growth rate between 1960 and 2000 and projections from 2010 to 2040. In 1960 the growth rate was 1.4%; 2.0% (1970); 1.6% (1980); 1.5% (1990); 1.2% (2000); 1.1% (2010 est.); 1.0% (2020 est.) 0.8% (2030 est.); and 0.6% (2040 est.)

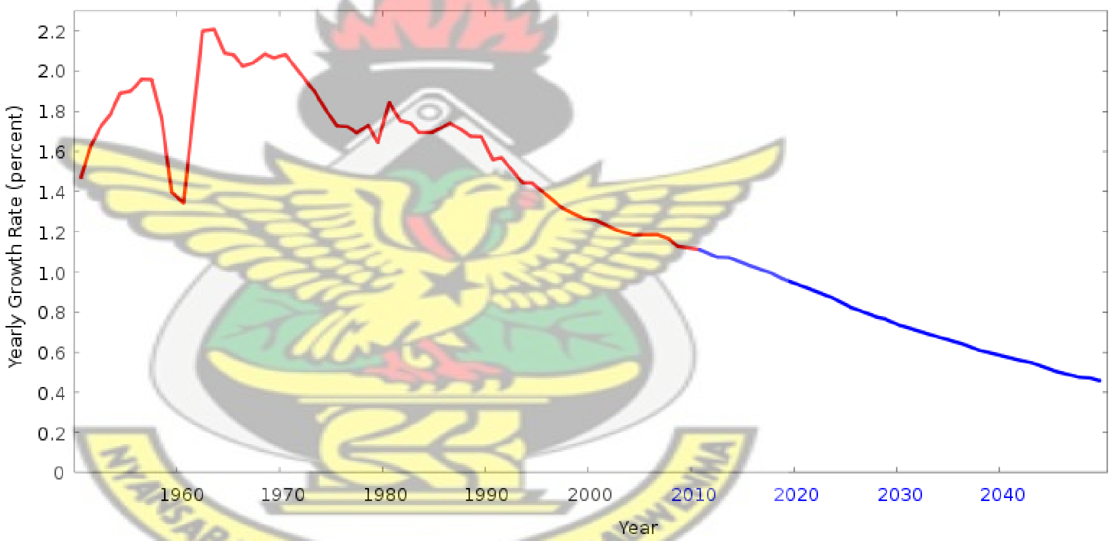


Figure 1 Growth rate of world population (1960-2050)

http://en.wikipedia.org/wiki/Population_growth.

2.2.4 Ghana's Population Growth

In 1921 Ghana's population was just over 2 million which increased to about 6.7 million in 1960 and 8.6million in 1970. The official figure recorded 12.3 million for 1984; 18.9 million for 2000 and a projected value of 24.8m for 2010. It is expected that these figures will further increase to 27 million by 2020. From the foregoing, Ghana's population more than tripled in a short period of nearly fifty years (i.e. 1921- 1970). The average annual growth rates of 1.6 in 1931-1948 and 4.1 per cent in 1948-1960 suggest an acute under-enumeration of the 1948 population. The average annual growth rates of 2.8 per cent between 1921 and 1960 and 2.7 per cent between 1931 and 1960 also confirm the undercount that occurred in 1948. The depression in the 1930s however might have shrunk the immigration stream or even reversed it so that the level of incompleteness might not therefore be as high as portrayed by the results (Kimble 1960:88; Caldwell 1967:113).

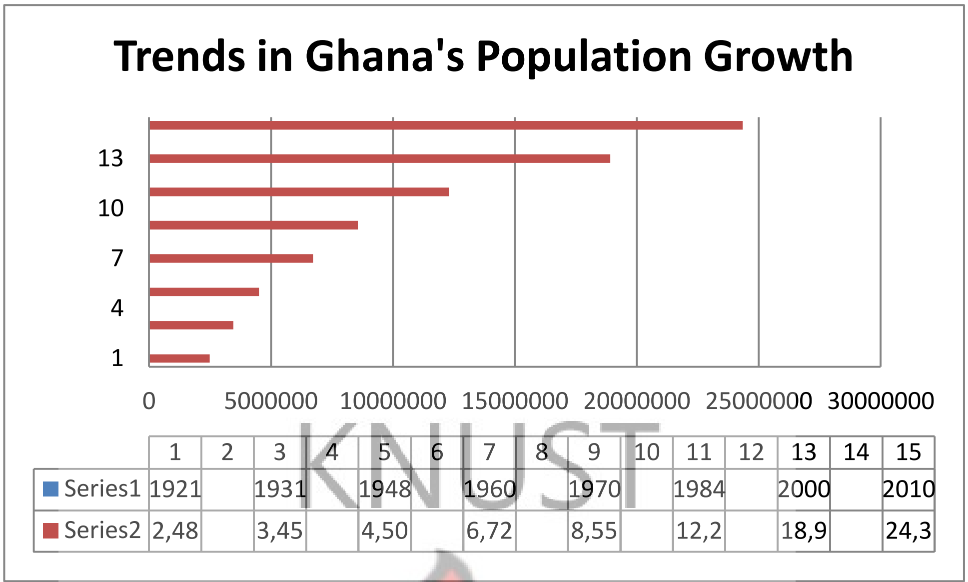


Figure 2: Ghana's Population trend (1921-2010)

Figure 2 depicts a period of 79 years (1921-2000), the population of Ghana more than doubled (from 8.6m to 18.9m). The projected value of 24.8m (2010), shows that the population has doubled between 1984 (12.3m) and 2010. The population growth rate between the 1960s and 2000 that has hovered between 2.4% and 3.0% is described as rapid.

2.2.4.1 Determinants of Population growth

Generally, population growth is determined by four factors, births (**B**), deaths (**D**), immigrants (**I**), and emigrants (**E**). Using a formula expressed as **ΔP≡B-D+I-E**

In other words, the population growth of a period can be calculated in two parts, natural growth of population (B-D) and mechanical growth of population (I-E), in which mechanical growth of population is mainly affected by social factors, e.g. the advanced economies are growing faster while the backward economies are growing slowly even with negative growth.

2.2.4.2 Calculating Population Growth Rate

Population growth rate (PGR) is the increase in a country's population during a period of time, usually one year, expressed as a percentage of the population at the start of that period. It is the fractional rate at which the number of individuals in a population increases, and reflects the number of births and deaths during the period and the number of people migrating to and from a country. This can be written as a formula:

$$\text{Growth rate} = \frac{(\text{population at end of period} \; - \; \text{population at beginning of period})}{\text{population at beginning of period}}$$

The above formula can be expanded as:

Growth rate = crude birth rate - crude death rate + net immigration rate, or

$\Delta P/P = (B/P) - (D/P) + (I/P) - (E/P)$,

The formula above allows for the identification of the source of population growth, whether due to natural increase or an increase in the net immigration rate. Natural increase is an increase in the native-born population, stemming from either a higher birth rate, a lower death rate, or a combination of the two. Net immigration rate is the difference between the number of immigrants and the number of emigrants.

The most common way to express population growth is as a ratio, not as a rate. The change in population over a unit time period is expressed as a percentage of the population at the beginning of the time period. That is:

Growth ratio = Growth rate x 100%

From the foregoing, it is worthy to note that, a positive growth ratio (or rate) indicates that the population is increasing, while a negative growth ratio indicates the population is decreasing. A growth ratio of zero indicates that the number of people is the same at the two times - net difference between births, deaths and migration is zero. However, a growth rate may be zero even when there are significant changes in the birth rates, death rates, immigration rates, and age distribution between the two times. Equivalently, percent death rate = the average number of deaths in a year for every 100 people in the total population.

A related measure is the net reproduction rate. In the absence of migration, a net reproduction rate of more than one indicates that the population of women is increasing, while a net reproduction rate less than one (sub-replacement fertility) indicates that the population of women is decreasing.

2.5 Demographic analysis

According to Griffith Feeney (2003) (a *Senior Fellow in demography at The East-West Center in Honolulu*), demography is the study of population change in human societies, “of the life cycle events that generate this change, and of the various factors and circumstances that influence these events." The strength of this definition lies in the fact that it addresses the following questions: How long do we live? How many children do we have? How do demographic conditions today compare with those of our ancestors? How does our society compare with the rest of the world? What explains differences between societies and change over time? How do life span and family size influence population growth? How fast is the population of the world growing? What are the prospects for future growth? Why are human populations growing older and what are the social and economic consequences of this aging? From the above, demography deals with statistical analysis of births, deaths, migrations, disease, fertility, growth and economic issues, as illustrating the conditions of life in communities.

According to Shryock et al. (1976) demographic analysis is an important tool for evaluating census data. However, a weakness in the demographic analysis is that it generally does not provide enough information to separate errors of coverage from errors in content. Moreover, demographic methods require reliable data on the components of population such as fertility, mortality and migration. These records are often unavailable in Ghana, largely because of illiteracy, not keeping correct records, and heavy informal sector.

However, Lewis (2006) recommends a number of methods of demographic analysis – cohort component analysis, trend analysis and cohort survival regression; they differ with regard to data requirements, the quality of the results and the technical sophistication required to use them.

2.5.1 Cohort component analysis

The cohort component method of demographic analysis uses data from two successive censuses as well as life-table survival rates, age-specific fertility rates and estimated levels of international migration between censuses. The results of a census are compared with data from other demographic systems, such as vital registration of births and deaths and net migration, if such data are available. The population enumerated in the first census is projected forward to the reference date of the second census, based on estimated levels and age schedules of fertility, mortality and migration, and the "expected" population is compared with the enumerated population in the second census. In some developing countries where this method has been used, indirect estimates of fertility and mortality must be derived, Shryock et al. (1976).

The present researcher does not propose to use this method firstly because the time schedule for the study would not suffice for the collection of cohort components – rates of fertility, life expectancy, birth, death, immigration and emigration, etc. Secondly, the detailed documents probably are not available or the officers in charge are not willing to release them for fear of reprisal from senior officers or politicians.

2.5.2 Trend analysis

Another method of demographic analysis is the trend analysis which involves comparing age distributions of successive censuses. In a population closed to migration, this method is widely used because it requires little data other than information from two censuses. Its usefulness increases significantly when data from more than two censuses are available, Shryock et al. (1976). The present study will employ this method in analysis of data in chapter four; demographic information derived from models will be compared over successive years in order to examine the effectiveness of the models.

2.5.3 Cohort survival regression

A final method, the cohort survival regression analysis uses population counts by age from two censuses and deaths by age during the intercensal period to assess the relative completeness of coverage, Shryock et al. (1976). Partly, this type of analysis will also form the basis of our study; age structure will be qualitatively examined in chapter four.

It is worthwhile to state here that in developed countries, census organizations employ qualified demographers and statisticians (data processing experts, cartographers, GIS experts and demographic statisticians), who have the expertise to undertake demographic analysis. Census questions are designed to collect adequate information for demographic analysis, Shryock et al. (1976). Moreover, the integrity of actual census responses should not be compromised in the processing stage. However, in Ghana, as in other developing nations, lack of funds has led to delays in processing or to tabulating only a sample of census returns as in the case of the 2010 housing and population census. This could have adverse effects on the use of demographic methods in the evaluation of census data.

2.6 Parameters of population growth

2.6.1 Fertility rate

One indicator that is used to explore trends in population growth is fertility rate. Ghana Demography Health Surveys revealed overall decline in fertility in Ghana; from 6.4 births per woman in 1988 to 4.4 per woman in 1998, and 3.95 in 2000. Birth stabilized at that level until 2003, and then declined to 3.4 in 2008. In 2010 it is estimated at 3.57.

However, fertility trends differed in urban and rural areas; urban fertility declined from 5.3 in 1988 to 3.0 births per woman in 1998 and remained at that level throughout. In rural areas, the decline in fertility continues through the present day, falling from 7.0 births per woman in 1988 to 5.6 in 2003 to 4.9 in 2008 (Ghana Statistical Service report 2010).

2.6.2 Median of first marriage

Related to fertility rate is the median age at first marriage; that is the age by which 50% of the women in a group were married for the first time. *Trends in Ghana* (2010:11) reported that in Ghana, the median age at first marriage for women age 25-49 was 18.1 years between 1979 and 1988, but increased to 18.8 years by 1993, and 19.8 years by 2008.

2.6.3 Education

Another important significant of the indicators of population growth is the educational level of the population; education, especially for women is closely associated with other demographic factors such as fertility, mortality, childbearing etc. Surveys have shown tremendous improvements in the education levels since independence. In 1993, 74% males and 62% females aged 6 were attending school. The 2010 PHC estimated figures were 74% males and 62% females.

2.6.4 Rural-Urban distribution

According to Trends (2010 p.3), while Ghana's population is predominantly rural, urbanization grew between 1960 and 2000 to become one of the most significant demographic trends; the proportion of the population living in urban areas has grown gradually, from twenty-three percent (23%) at the 1960 census to forty-four percent (44%) at the 2000 PHC.

2.6.5 Dependency ratio

The broad base structure of Ghana's population shows the youthful nature of the population, with about 41% being under 15 years for both sexes. Those in the working age of range between 25 and 64 years carry the burden of caring for themselves and the non-working groups. This gives a dependency ratio of about 87% and the population 65 year and above takes about 6% for the 2000 PHC. The age-sex structure of Ghana depicts that of a developing country.

2.6.6 Economy

The economy is mixed, consisting of a large traditional agric sector, including small scale-scale farmers, small capital intensive mining concessions, a few manufacturing establishments, a growing informal small-scale businessmen, artisans and technicians. The agricultural sector takes care of three-fifths of the country's labour force and accounts for 34% of the GDP (GSS 2000). The service sector which is growing at 10% rate (the fastest growing sector of the economy) also contributes one-third towards the country's GDP, while the industrial sector contributes a little over one-quarter (26%).

2.6.7 Population density

The Ghana Statistical Service has released figures for population density. It has increased from 79 in 2000 to 102 in 2010 i.e. 23.71% in ten years.

2.7 Mathematical Models of Population

In population study, there are so many ways of projecting future population of a given country. We will then turn our attention to some of them presently. Basically, all these cannot be done without demography method or process. The mathematical way of modeling and statistical analysis of population is known as demography. A mathematical model is therefore, a description of a system using mathematical language.

Islam (2009) justified Mathematical models for the estimation of population projections and estimations thus: "In fact, mathematical model is essentially an endeavour to find out structural relationship and their dynamic behaviour among the various elements in Demography." He further added that, the structure of mathematical models of population is mostly two types: non-deterministic or stochastic and deterministic. The variables in the stochastic models are in the form of probability distribution. On the other hand, deterministic models are used to explain the relationship between variables that take definite values. Furthermore, deterministic models are classified into two classes – stationary population and time serial population models.

In this study two mathematical models will be discussed in relation to Ghana's population growth: Malthusian (Exponential) model and Logistic model, which are deterministic, using time series to compare population size and growth rates over a fifty-year period.

2.7.1 Malthusian (Exponential) Growth Model ($N = N_o e^{rt}$)

The first growth model we will examine in this study is the Malthus model, also commonly called the natural growth model or exponential growth model. This simple model of population growth was proposed by the British social scientist Reverend Thomas Robert Malthus. In 1798, in his work *An Essay on the Principle of Population*, Thomas Malthus maintained that the growth of the human population is fundamentally different from the growth of the food supply to feed that population. He wrote that the human population was growing geometrically [i.e. exponentially] while the food supply was growing arithmetically [i.e. linearly]. He argued that "the geometrical growth of the human population would soon outwit the arithmetical progression of the world, leaving the world's population in dire strait". Malthus believed that population would go on increasing until it was checked by famine, disease, pestilence or war. He also believed that while human instinct for reproduction (for sex) could not be subjected to conscious control, food supply would never keep up with population growth. Thus, he concluded that left unchecked, it would only be a matter of time before the world's population would be too large to feed itself and the inevitable consequence of human population growth are famine, pestilence and war.

Although a few “evolutionary biologists” notably, Charles Darwin and Alfred Russel Wallace, and later “neo-Malthusian” intellectuals including Stanford University biologist Paul Ehrling, author of *The Population Bomb* and Lester Brown, president of World watch Institute share Malthus’ pessimistic prognosis. Ehrling (1968) stated that the rate of population growth was outstripping agricultural growth and the capacity for renewal of Earth's resources. Given current rates of natural increase, demographic disaster will be in response to eventual food shortages and disease. Industrialized regions such North America and Europe will be required to undertake "mild" food rationing as starvation spread across the developing worlds of Asia, Latin America, and Africa. In a worst case scenario, lack of food security in the developing world will set into motion several geopolitical crises that can result in thermonuclear war. (*The Population Bomb* p. 10).

One of the greatest dangers of the planet Earth is that of over-population by humans. Since the beginning of human history our population has been growing exponentially (actually a little faster than exponentially). However, there is now little additional land that can be put into use for food production and our wastes are rapidly polluting the environment. Unless major technological breakthroughs are made, we are close to the Earth's carrying capacity.

In support of the above, Small and Keyfitz (1977) added that, compounding the problem is the fact that our average birth rate is still very high (greater than 2.0). It is possible we will overshoot the Earth's carrying capacity and for the first time in recorded history have massive population decline brought on by disease and starvation. You have seen how sensitive a population's growth is to its birth rate. The decrease in birth rate needed to avert a disaster is not large, but it is one that everyone needs to work on together to achieve.

2.7.1.1 Population growth shown as a geometric progression

A geometric progression is a simplified way to show exponential population growth. For example, starting with one couple, assume that every female has 4 children (2 boys and 2 girls). The following table compares the population growth in 7 generations. The original couple has 4 children, two of which are girls which give rise to 8 children (2 x 4). Four of the 8 children are girls which give rise to 16 children (4 x 4), etc. This is an exponential increase in which the population doubles each generation.

The 7th generation has a population of 2^7 or 128.

Table 2.3: Geometric progression

Number	2	4	8	16	32	64	128
2^x	(1)	(2)	(3)	(4)	(5)	(6)	(7)

2.7.1.2 Doubling Time: 70/n years

Exponential growth means that some quantity grows by a fixed percentage rate from one year to the next. A handy formula for calculating the doubling time for exponential growth is:

Exponential Growth

- **Percentage change in something each year**
- **always blows up in the long run**
- **much, much faster than linear increase**

$$e^{\lambda t}; \lambda = growth \quad rate; t = time$$

$$e^{\lambda t_d} = 2; t_d = doubling \quad time$$

$$e^x = y; lny = x$$

$$ln2 = .693$$

$$\lambda t_d = .693$$

$$t_d = .693/\lambda$$

Example: For $\lambda = 0.10$ (10 % per year) $t_d = .693/.1$ $= 6.93 = 7$ years

Supposing the table 2.4 shows a survey about the optimal size for growth of an area. We can conclude that by year 7, the population has doubled, about 10,000 new residents have moved to the area. However, the general population can not equate 10% growth rate with 7 year doubling time. (70/n years; n =% growth rate; where “n” is the percentage growth rate). Thus, if the growth rate is say 5%, the doubling time would be 14 years. In exponential growth, the rate of growth may well change, but the growth is still exponential.

So

- for n = 1% the doubling time is 70/1 = 70 years.
- for n =2% the doubling time is 70/2 = 35 years
- for n =5% the doubling time is 70/5 = 14 years
- for n = 35% the doubling time is 70/35 = 2 years

Table 2.4: Demonstration of doubling time

Year	1	2	3	4	5	6	7	8
Pop	60,000	66,000	72,600	79860	87846	96630	106294	116923

In describing the character of human population growth Malthus said that a thousand millions are just as easily doubled every 25 years by the power of population as a thousand. But the food to support the increase from the greater number will by no means be obtained with the same facility. (*An Essay on the Principle of Population*, (ibid p.73)).

Here, Malthus is claiming that, for a population undergoing exponential growth, the time it takes to double is independent of the size of the population.

Furthermore, in plotting this graph for Table 2.4, one can clearly see that no matter what the growth rate is, exponential growth starts out being in a period of slow growth and then quickly changes over to rapid growth with a characteristic J-shape as below.

Furthermore, this model has many applications besides population growth. Clearly, exponential rates of growth have significance in that they are an integral part of the planning process. Different aspects of a growing population have different exponential growth rates and these need to be considered. For instance, suppose our example above is an urban area is growing at the rate of 5% a year, the planner must consider some of the following:

- Number of extra road miles that need to be built;
- Number of extra schools that need to be built;
- Price and affordability of housing in the area;
- Zoning regulations;
- Growth and efficiency of utility services;
- Growth and efficiency of security services (police and fire services);
- Growth of sanitary and hospital services; and
- Reservations for parks and environmental facilities

2.7.1.3 Exponential growth rate

For the Exponential model we assume that the population grows at a rate that is proportional to itself. It is important to note that taking the natural logarithm of the ratio of the final value to the initial value and dividing by the time period in years gives the average annual growth rate. For example, to find Ghana's growth rate for 2010 from 2000 figures, gives:

- initial value (1992) = 18,912,079
- final value (2000) = 24,339,838
- ratio of final/initial = 1.29
- natural log (ln) 1.29 = x
- over 10 years, growth rate is then x/10 = y% per year
- doubling time is 70/x = w years (and the sample has doubled x from 18,912,079 to 24,339,838 in w years of self-consistent)

2.7.1.4 Exponential growth curve

The difference between linear growth (constant number of units growth per year) and exponential growth (constant percentage increase) is difficult to see initially, if the exponential growth rate is small. However, to model population data and population growth, we assume that the population grows at a rate that is proportional to itself. For example, If P represents such population, then the assumption of natural growth can be written symbolically as

$$\mathbf{dP/dt = k\,P}$$, where **k** is a positive constant.

This model assumes that a population is N_t individuals at time *t*, where *t* is measured in years. Suppose that the number of births in a year is a fraction β and the number of deaths in a year is a fraction γ of the total population. We can write down an expression for N_{t+1} in terms of N_t, β and γ and, without using calculus, obtain an expression for N_t given that $N_t = N_0$ at $t = 0$.

Suppose N = Population at time t.

In a small time interval Δt, the population size will change because of

$$(1)\ \text{births} = \beta \qquad (2)\ \text{deaths} = \gamma$$

Assume the number of births and deaths depend on

(1) size of Δt
(2) size of population

$$\therefore \text{number of births} = \beta \times \mathrm{N_t} \times \Delta t$$
$$\text{number of deaths} = \gamma \times \mathrm{N_t} \times \Delta t$$

$$\text{so}\begin{Bmatrix}\text{The increase in}\\ \text{population in}\\ \text{time } \Delta \text{t}\end{Bmatrix} = \begin{Bmatrix}\text{Number of}\\ \text{Births}\end{Bmatrix} - \begin{Bmatrix}\text{Number of}\\ \text{Deaths}\end{Bmatrix}$$

$$N_t(t+\Delta t) - N_t(t) = \beta \cdot N_t \cdot \Delta t - \gamma \cdot N_t \cdot \Delta t$$

putting $\Delta \mathrm{t} = 1$ (i.e 1 year) we form a difference equation

$$\mathrm{N_t}(t+1) = N_t(t)[1+\beta-\gamma]$$

Using suffix notation we have

$$N_{t+1} = N_t[1+\beta-\gamma]$$

Now using given condition $N_t = N_0$ at t = 0 we get

$$N_1 = N_0[1+\beta-\gamma]$$

$$N_2 = N_1[1+\beta-\gamma]$$

$$= N_0[1+\beta-\gamma][1+\beta-\gamma]$$

. . . .

. . . .

$$\underline{N_t = N_0[1+\beta-\gamma]^t}$$

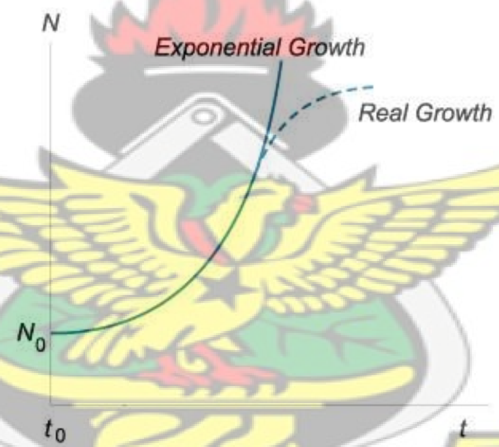


Figure 3: Diagram showing exponential growth of population

Turchin (2001, 2003) and Trefil (2002) supported the usefulness of the above model, referring to it as Exponential Growth Law. However, they agreed that the model describes the initial phase of growth when population is far from its limits. They argued that the accuracy of the exponential model drops at a later stage due to saturation or other nonlinear effects, such as when population density is high. Cohen (1995) posits that, "The simplicity of the model makes it useful for very short-term predictions and of not much use for predictions beyond 10 or 20 years." Although Rowland (2007) agrees that it is a useful model for population growth, he also asserts that it would be appropriate for modeling the effect of natural disasters or the lack of resources in a country.

Furthermore, the importance of the Malthus Growth model lies in the fact that it reflects

exponential growth of population and can be described by the differential equation.

$$\frac{dN}{dt} = aN,$$

where a is the growth rate (Malthus Parameter). Solution of this equation is the exponential function.

$$N(t) = N_0 e^{at},$$

where N_0 is the initial population and t = time.

Alternatively, Cohen (2001) provides us with the following calculation for growth rate:

Let P(t) be the population size at time t and a(t) be the concentration of the rate-limiting

substrate, we have

$$dP/dt = k(a)P(t) \qquad (1)$$

where k(a) is the specific growth rate of population.

Integrating both sides of the equation with constant k, gives

$$\int^{a}_{Po} {}^{dP}/_{P} = \int^{t}_{o} kdt \qquad (2)$$

$$\log [P]^{P}_{Po} = kt$$

$$P - \log Po = at$$

$$\text{Log}\,(P/Po) = kt$$

$$P/Po = e^{kt}$$

$$P = Poe^{kt}$$

Where k is the fertility rate, the constant ratio of growth rate to population Po is the population at whatever time is considered to be t = 0.

2.7.2 Logistics (Verhulst) Growth Model

A slightly more realistic and largely used population growth model is the Logistic Growth Model proposed by Belgian scientist, Pierre Francois Verhulst in 1838. According to him, population growth depends not only on population size, but also on the effect of a "carrying capacity" that would limit growth, Verhulst (1846). A simple logistic function may be defined by the formula

$$\mathrm{N(t)} = \frac{1}{1 + e^{-t}}$$

where e^{-t} is exponential function, the variable *P* the population and the variable *t* is the time. For values of t might be shown in the range of real numbers from −∞ to +∞. The weakness in this formula is that it does not show the limiting factors to population growth.

From the foregoing, Rubinon (1975) offered another formula in the form of a differential equation:

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

where K is the maximum size of the population. The right-hand side of this equation can be presented as:

$$\mathrm{rN} - \frac{rN^2}{K}$$

Notice that the first term is responsible for growth of population and the second term limits this growth due to lack of available resources or other reasons.

In this version of the logistic model, the size of the population exerts negative feedback on its growth rate. As population size increases, the rate of increase declines, leading eventually to an equilibrium population size known as the carrying capacity. The time course of this model is the familiar S-shaped growth that is generally associated with resource limitation. Glesne (1999) supported this alternative equation in which the logistic model has only two parameters: r (the intrinsic growth rate) and K (the land carrying capacity). The rate of increase in the population declines as a linear function of population size. In symbols:

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

K is the maximum population which can be sustained and r is the intrinsic growth rate.

We can solve this equation for N, assuming $N = N_0$ at $t = 0$.

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

Let $x = \frac{N}{K}$ ie. $N = Kx$

$$K\frac{dx}{dt} = rKx(1 - x)$$

$$\frac{dx}{dt} = rx(1 - x)$$

$$\frac{dx}{x(1 - x)} = rdt$$

that is $\left[\frac{1}{x} + \frac{1}{1 - x}\right]dx = rdt$

Integrating both sides we get

$$\ln\left|\frac{x}{1 - x}\right| = rt + c$$

Applyingboundary conditions we have

$$t = 0, \quad x = x_0 \quad \left(= \frac{N_0}{K} \right)$$

$$\therefore \quad \ln\left|\frac{x}{1-x} \cdot \frac{1-x_0}{x_0}\right| = rt$$

taking natural antilogarithms of both sides

$$\frac{x}{1-x} \cdot \frac{1-x_0}{x_0} = e^{rt}$$

$$x\left(\frac{1}{x_0} - 1\right) = (1-x)e^{rt}$$

$$\frac{x}{x_0} - x = (1-x)e^{rt}$$

$$0 = \frac{x}{x_0} - (1-x)e^{rt} - x$$

$$0 = x\left(\frac{1}{x_0} + e^{rt} - 1\right) - e^{rt}$$

$$\therefore x = \frac{e^{rt}}{\left(\frac{1}{x_0} + e^{rt} - 1\right)}$$

to tidy up expression multiply both sides by e^{-rt}

$$e^{-rt}x = \frac{1}{\left(\frac{1}{x_0} + e^{rt} - 1\right)}$$

$$x = \frac{1}{1 + \left(\frac{1}{x_0} - 1\right)e^{-rt}}$$

Now putting $x = \frac{N}{K}$ and $x_0 = \frac{N_0}{K}$ back into the above expression, we get

$$\frac{N}{K} = \frac{1}{1+\left(\frac{K}{N_0}-1\right)e^{-rt}}$$

$$\therefore N = \frac{K}{1+\left(\frac{K}{N_0}-1\right)e^{-rt}}$$

A sketch can illustrate this result.

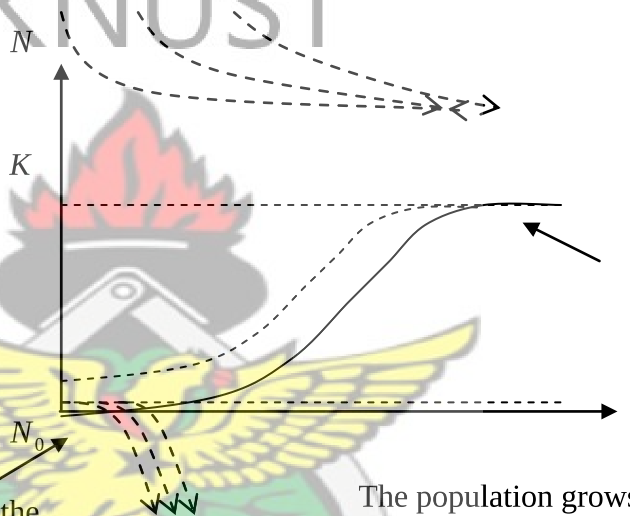


Figure 4: Diagram showing Logistics growth model of population

It is important to realize that when the population size is very small (i.e., when N is close to zero), the term in the parentheses is approximately one and population growth is approximately exponential. When population size is close to the carrying capacity (i.e. $N \approx K$), the term in parentheses approaches zero, and population growth ceases. It is straightforward to integrate this equation by partial fractions and show that resulting solution is indeed an S-shaped, or sigmoid, curve.

According to Pearl and Reed (1920), the Logistics growth model shows how changes in mortality, fertility, and agricultural productivity actually all have distinct effects on the population growth rate, and equilibrium. They further claimed that analysis of the logistic model would yield the following results:

- Increasing agricultural productivity or the amount of time spent working on agricultural production increases the food ratio, while keeping the population growth rate largely unchanged
- Increasing baseline survival increases the food ratio but decreases the population growth rate
- Decreasing fertility only decreases the growth rate – the food ratio remains unchanged

One major problem with the logistics model is that it fails to consider mechanisms of population regulation; when population density increases, the model is indifferent to birth rates and death rates. Thus, the r parameter in the logistic model is simply the difference in the gross birth and death rates when there are no nonspecific present. In general, when the birth rate exceeds the death rate, population increases. The linear decrease in r with increasing population size presumably can come about by either the birth rate decreasing or the death rate increasing. Therefore, logistic model is indifferent to the specific cause of slowing; it just stops increasing when $N = K$.

Another major problem with the logistic model is that there is no structure - all individuals are identical in terms of their effect on and contribution to population growth. Human vital rates vary predictably and substantially by age, sex, geographic region, urban vs. rural residence, etc. In addition, there is the issue of unequal resource distribution. Pearl and Reed (1920), claimed that "all individuals in a population are hardly equal in their consumption" or production, and so we should hardly expect each person to exert an identical force on population growth.

Following from the above, Lee and Tuljapurkar (2008) introduced an alternative version of the logistics model called Logistic Differential Model in which "as food gets scarce and scarce, mortality increases and fertility decreases." The model has equilibrium where birth and death rates balance.

The logistic differential model has exact solution as the logistic model as derived below.

$$\frac{dN}{dt} = aN\left(1 - \frac{N}{M}\right), \quad \Rightarrow \int \frac{dN}{N\left(1 - \frac{N}{M}\right)} = \int a\,dt.$$

The integrand in the left integral can be found using the partial fraction decomposition method:

$$\frac{1}{N\left(1-\frac{N}{M}\right)}=\frac{A}{N}+\frac{B}{1-\frac{N}{M}}, \quad \Rightarrow \frac{1}{N\left(1-\frac{N}{M}\right)}=\frac{A\left(1-\frac{N}{M}\right)+BN}{N\left(1-\frac{N}{M}\right)}, \quad \Rightarrow 1 \equiv A-A\frac{N}{M}+BN, \quad \Rightarrow \begin{cases} A=1 \\ B=\frac{1}{M} \end{cases}.$$

Then the integral in the left side is

$$\int\frac{dN}{N\left(1-\frac{N}{M}\right)}=\int\left(\frac{1}{N}+\frac{{}^{1}\!/_{M}}{1-\frac{N}{M}}\right)dN=\int\frac{dN}{N}+\int\frac{d\left(\frac{N}{M}\right)}{1-\frac{N}{M}}=\ln|N|-\ln\left|1-\frac{N}{M}\right|=\ln\left|\frac{N}{1-\frac{N}{M}}\right|=\ln\frac{N}{1-\frac{N}{M}}.$$

Thus, the general solution of the logistic differential equation is given by

$$\ln\frac{N}{1-\frac{N}{M}}=at+\ln C, \quad \Rightarrow \ln\frac{N}{1-\frac{N}{M}}=\ln e^{at}+\ln C, \quad \Rightarrow \ln\frac{N}{1-\frac{N}{M}}=\ln Ce^{at}, \quad \text{or} \quad \frac{N}{1-\frac{N}{M}}=Ce^{at}.$$

The last algebraic equation can be solved for *N*:

$$N=Ce^{at}-\frac{N}{M}Ce^{at}, \quad \Rightarrow N\left(1+\frac{1}{M}Ce^{at}\right)=Ce^{at}, \quad \Rightarrow N=\frac{Ce^{at}}{1+\frac{1}{M}Ce^{at}}=\frac{CMe^{at}}{M+Ce^{at}}.$$

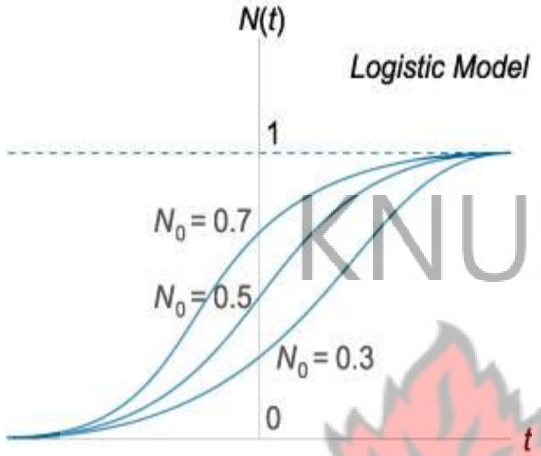
The constant C can be determined from the initial condition $N(t=0)=N_0$, so that

$$N_0=\frac{CM\cdot 1}{M+C}, \quad \Rightarrow CM=N_0M+CN_0, \quad \Rightarrow C=\frac{N_0M}{M-N_0}.$$

Substituting this value for C into the general solution, we obtain:

$$N(t)=\frac{\frac{N_0M^2e^{at}}{M-N_0}}{M+\frac{N_0M}{M-N_0}e^{at}}=\frac{N_0M^2e^{at}}{M^2-N_0M+N_0Me^{at}}=\frac{N_0Me^{at}}{M-N_0+N_0e^{at}}=\frac{N_0M}{N_0+(M-N_0)e^{-at}}.$$

Figure 5 shows a few logistic curves at different values of N_0, and Figure. 6 shows how the shape of the curve changes depending on the growth rate a.



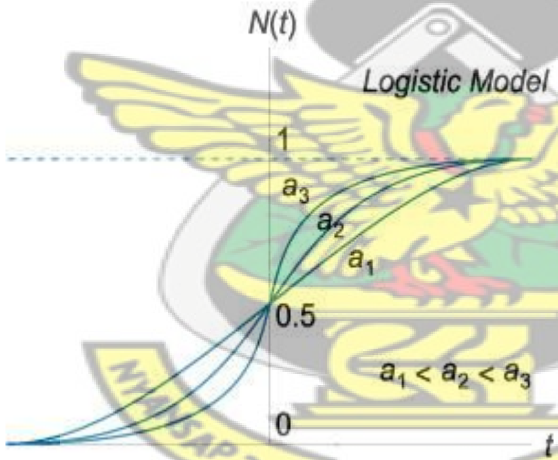


Figure 5 Figure 6

From the diagram 6 above, we see that the family of logistic curves on the segment $t > 0$ can describe nonlinear population growth with saturation, when the maximum allowed value has a limit.

Finally, it is necessary to note that the range of models will offer different values for Ghana's population size and growth for the period of 2001 to 2010. While the simple model offers only time as the variable factor affecting population growth, the Lee and Tuljapurkar's model is useful for this study, but its emphasis lays in the possibility of increasing the death rate and decreasing the birth rate might. As a country that thrives on cheap labour, especially in the Agricultural sector, the model might not reveal the true state of affairs. In between the two extremes is the Rubinon's model which emphasizes two parameters - the intrinsic growth rate and the land carrying capacity. The limiting effects of food production as well as time as a function of growth would be discussed. In view of these various reasons, the researcher prefers Rubinon's model over the two extreme models - the Simple Logistic Model and Lee and Tuljapurkar's model.

2.8 Methods for overall assessment of census quality

2.8.1 Methods of evaluating coverage error

Coverage errors refer to under- or over-enumeration.

The most intensive methods of evaluating coverage error are done with regard to age-sex groups or age cohorts. They are as follows:

- Graphical analysis of age-sex distribution (age-sex pyramid). According to Shryock et al. (1976), this technique has become a standard method in the evaluation of all population censuses.

- Summary indices of age-sex data, including age-sex ratios and age-sex accuracy indices are used. Arriaga et al. (1994) proposed other smoothing techniques
- Stable population analysis compares reported age-sex distribution with a stable or quasi-stable population model. This requires that both fertility and mortality have been constant in the past, while quasi-stable models are applicable when mortality decline has been under way for a known duration.

2.8.2 Methods of evaluating content error

Content errors refer to response quality of specific questions. Several methods of evaluation involve comparative analyses of data from successive censuses. Fosu (2001) has proposed four major methods of content error evaluation. These are as follows:

- Comparison of census with other sources of data. The estimate of the population based on the most recent census can be compared with data from other demographic systems, such as vital statistics of births and deaths and net migration between censuses.

- Cohort component method. Population projections derived from the previous census data and fertility, mortality and migration statistics can be compared with new census results. Several developing countries have used this method. Since registration data are usually deficient and satisfactory adjustment is usually not feasible, indirect estimates of fertility and mortality levels are usually derived from two censuses.
- Comparison of age distributions of two censuses based on intercensal cohort survival rates. The size of birth cohorts enumerated in successive censuses is compared. In a population closed to migration, the variations in the number of persons in a birth cohort between two successive censuses will be due to mortality. Hence, the ratio of size of the birth cohort in the first census to that of the second census should approximate the expected survival rate based on prevailing conditions of mortality.
- Cohort survival regression method. This method derives estimates of coverage correction factors to make age data from two censuses mutually consistent. When this is combined with data on the number of deaths during the intercensal period from vital registration or a life table, it makes the population in each cohort in the second census

consistent with the size of the cohort in the first census and the implied mortality in the intercensal period.

2.9 Summary

Population dynamics is the study of the marginal and long term changes in the number of individuals, sex and weight and age composition in a particular location. Several factors which include the individual biological and environmental processes influence the changes in the population. These changes, according to Ibrahim and Lewis (2006), result in addition or reduction of members of the population. In addition, strategic planning gives an interesting background to the population research survey and evaluation of the data with the aid of mathematical models. McFalls (1995) posits that,

The study of population dynamics must begin with fertility because population refers to a number of people that the environment can support which is called the carrying capacity.

2.10 Conclusion

Spiegel (2004) recommended demographic analysis as "an important tool for evaluating census data, particularly in countries where independent sources of data, such as vital registration and sample surveys, are lacking or where a post-enumeration survey (PES) is not conducted." In the case of Ghana, reliable registration systems are lacking, hence demographic analysis is the basic methodological option for the evaluation of census data, as well as population growth, and it should be used because PES is non-existent. As required, the use of stable population models requires that both fertility and mortality have been constant in the past, as presented in this study between 2001 and 2010.

CHAPTER 3

METHODOLOGY

3.0 Introduction

This chapter discusses the research design, the study area, data collection methods and instruments, validation of the instruments, limitations and the procedure for data analysis.

3.1 Research design

This study will basically apply a library research method, specifically the survey method. The researcher would collect population data over a fifty-year period (1960 – 2010) from the Ghana Statistical Service Department and Ghana National Population Council for analysis, and modeling 2020 projections.

3.2 Sample Design

Sample Design is a definite plan for obtaining a sample from a given population. It refers to the technique or the procedure the researcher would adapt to select units for the sample (Alhassan, (2006)).

Purposeful sampling, which seeks information cases that can be studied in depth, is the dominant strategy in qualitative research. Patton (1990) identifies and describes types of purposeful sampling. Among all, it is the intention of the present researcher to use the maximum variation sampling, which “aims to capture and describe the central [principal outcomes] that cut across a great deal of participant or program variation” (Patton 1990: 172). In my particular case, maximum variation sampling will yield detailed descriptions of each census data, the trend of growth in Ghana’s population and in addition, identify shared patterns (parameters) that cut across the two mathematical models (Malthus growth model and logistical growth model) being used.

3.3 Data Collection

According to Masters and Ela (2008), there are two methods of data collection: direct and indirect. Direct data come from vital statistics registries that track all parameters of population; births, changes in marriage, divorce, and migration. In developed countries with good registration systems (such as the United States and Europe), registry statistics are the best method for data collection. However, in developing nations such as Ghana, full data are not available. Therefore, one technique that is prevalent is where researchers can then indirectly estimate birth or death rates for the entire population.

There are a variety of demographic methods for modeling population processes, including models of mortality, fertility and marriage models, population projections and population momentum methods. This study will focus on collection of population census data between 1960 and 2010. We shall, analyse the trend of growth over the fifty-year period, using the longitudinal survey method.

Finally, the method of collection will be contextual interviews; semi-structured interviews will be used to gather data about Ghana's population census from 1960-2010. The government departments which will be involved are Ghana Statistical Service Department, Ghana National Population Council and some government hospitals. Moreover, hypothetical situation will be used as a tool to initiate mathematical modeling of population, using the exponential and logistical methods.

3.4 Data analysis

3.4.1 Trend Analysis

Glesne (1999) defines data analysis as "working with the data you describe, create explanations, pose hypotheses, and develop theories. LeCompte (2000) identifies four categories of data analysis strategies, which was useful in the present study. The four process are:

1. *Data Management:* the researcher will accumulate interview notes, transcripts and documents, and categorize/organize the data into file folders as tangible texts.

2. *Description:* using data from multiple sources - Ghana Statistical Services, Population Studies Center and some hospital - the present researcher will articulate a rich description of contexts under investigation.

3. Analysis: the researcher will manipulate the data by creating and applying abstract categories and then use those categories to compare, contrast, sort, and refine distinguishable trends in Ghana's population growth.

4. Interpretation: informed by descriptions and analysis, the researcher will make inferences by connecting the data with the theoretical structure that frames the study. The goal will be to create descriptive, multi-dimensional categories, which form a preliminary framework for analysis. These categories will further be gradually modified during the subsequent stages of analysis that follow.

3.4.2 Longitudinal Analysis

The researcher is interested in the changes in the population over the fifty-year period and will attempt to describe and/or explain these changes in terms of quality and quantity. The main type of longitudinal survey that would be used is trend analysis (see 2. for explanation).

3.5 Validity and Reliability

Raymond Pearl, a professor at Johns Hopkins University and founder of the Society for Human Biology and the International Union for the Scientific Study of Population (IUSSP) fit the logistic model to the populations of Algeria and the United States (1790-1930). He described the validity and reliability of modeling population census data and population growth in his book, *The Biology of Population Growth*, thus said that … human populations grow according to the same law as do the experimental populations of lower organisms, and in turn as do individual plants and animals in body size. This is demonstrated in two ways: first by showing as was done in my former book "Studies in Human Biology," that in a great variety of countries all of the recorded census history which exists is accurately described by the same general mathematical equation as that which describes the growth of experimental populations.

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

4.0 Introduction

This chapter presents demographic analysis and models relating to Ghana's population census data and population growth between 1960 and 2010. The presentation of data is in two parts: preliminary analysis, with its evaluation, and further analysis with related mathematical modeling. The preliminary analysis is more of descriptive and exploratory presentation of Ghana's demographic population data, while the further analysis seeks to establish some mathematical inferences; i.e. the relationships between the parameters and descriptive variables presented in this study, using mathematical, analytical procedures. SPSS or Excel software is used in all analyses.

4.1 Study Area

The Republic of Ghana is bounded on the north by Burkina Faso, on the east by Togo, on the west by Cote d'Ivoire and on the south by the Gulf of Guinea. The total land area is 92,100 square miles (238,537) square kilometers. The country can be roughly divided into three vegetation zones, namely coastal Savannah characterized by shrubs and mangrove swamps, a forest belt that gradually thins out into a dry Savannah as one moves northwards. Ghana has ten administrative regions: Greater Accra, Eastern, Western, Ashanti Central, Brong-Ahafo, Northern, Volta, Upper East and

Upper West Regions, which are further divided into 110 districts. These form the basic units of political administration, with the capital town as Accra. In addition, the Ghanaian population is made up of many ethnic groups, as discussed in chapter two.

Figure 7: Study Area

4.2 Preliminary analyses

Analyses done here are expected to present description of demographic data of Ghana’s population census data and population growth between 1960 and 2010. In all, ten main variables (demographic trends) are of critical concern to the researcher: age structure, sex distribution, literacy, ethnicity, urban vs. rural dwelling, employment vs. unemployment, housing conditions, water/sanitation, sources of fuel for cooking, and religion. Frequency distributions cross tabulations and quantitative mean comparisons were used in analyzing these variables.

Table 4.1 Percentage distribution of Ghana's age-sex structure (1960-2000)

Age group	1960			1970			1984			2000		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**
0-4	18.89	19.67	19.28	18.32	18.21	18.27	16.74	16.29	16.51	14.74	14.54	14.57
5-9	15.16	15.12	15.14	17.14	16.74	16.94	16.70	15.87	16.28	14.86	14.49	14.67
10-14	10.52	9.72	10.13	12.11	11.32	11.71	12.78	11.69	12.23	12.30	11.63	11.96
15-19	8.10	7.98	8.04	9.39	8.79	9.09	10.50	9.78	10.14	10.27	9.66	9.96
20-24	7.89	9.70	8.78	7.19	8.71	7.96	7.98	9.18	8.59	8.15	8.77	8.46
25-29	8.19	9.21	8.70	6.83	7.92	7.38	7.15	8.21	7.69	7.43	8.29	7.86
30-34	7.13	7.39	7.26	6.21	6.89	6.55	5.80	6.28	6.04	6.05	6.70	6.38
35-39	5.83	5.39	5.61	5.21	5.03	5.12	4.66	4.84	4.75	5.25	5.64	5.45
40-44	4.88	4.38	4.63	4.11	4.07	4.09	3.73	3.97	3.85	4.74	4.64	4.69
45-49	3.61	2.87	3.25	3.39	2.97	3.18	3.58	3.39	3.48	4.03	3.59	3.81
50-54	2.85	2.46	2.65	2.82	2.59	2.70	2.86	2.88	2.87	2.99	3.02	3.01
55-59	1.74	1.46	1.60	1.80	1.53	1.67	1.77	1.70	1.73	1.95	1.81	1.88
60-64	1.87	1.46	1.75	1.77	1.53	1.71	1.78	1.89	1.84	1.90	1.98	1.94
65-69	0.95	0.86	0.91	1.12	1.06	1.10	1.16	1.20	1.18	1.38	1.36	1.37
70-74	0.88	0.80	0.84	0.99	0.94	0.96	1.05	1.04	1.05	1.14	1.24	1.19
75-79	0.48	0.44	0.46	0.51	0.48	0.49	0.37	0.37	0.58	0.79	0.74	0.77
80+	1.02	0.90	0.96	1.09	1.08	1.08	1.23	1.23	1.20	2.01	1.91	1.96
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Number	3,399,908	3,326,907	6,726,815	4,212,883	4,349,430	8,559,313	6,063,526	6,232,555	12,296,081	9,357,382	9,554,697	18,912,079

Source: CIA World Factbook 2000

Table 4.1 shows Ghana's population distribution between 1960 and 2000 as well as that period's percentage age-sex structure. Ghana's first post-independence population census in 1960 counted about 6.7 million inhabitants. By 1970 the national census registered 8.5 million people, about a twenty-seven percent (27%) increase, while the official census in 1984 recorded a figure of 12.3 million; almost double of the 1960 figure. The nation's population was estimated to have increased to about 15 million in 1990 and to an estimated 17.2 million in mid-1994. With an annual growth rate of two percent (2.2%) for the period between 1965 and

1980, a 3.4 percent growth rate for 1981 through 1989, and a 1992 growth rate of 3.2 percent, the country's population was 18.9 million in the year 2000. According to Trends (2010:1) “Ghana’s pop is growing rapidly, estimated at a rate of 1.9%; the pop size is 23.9 million in 2008 (CIA 2010). The young age of the pop 39% is less than 15 years and only 4% is age 65 and above – is a result of high rate of pop growth.”

4.2.2 Factors responsible for population distribution in Ghana

4.2.2.1 North vs. South

By contrast, a large part of the Volta Basin is sparsely populated. The presence of tsetse flies, the relative infertility of the soil, and, above all, the scarcity of water in the area during the harmattan season affect habitation. The far north, on the other hand, is heavily populated. The eighty-seven persons to a square kilometer recorded in the 1984 census for the Upper East Region, for example, was well above the national average. This may be explained in part by the somewhat better soil found in some areas and the general absence of the tsetse fly; however, onchocerciasis, or river blindness, a fly-borne disease, is common in the north, causing abandonment of some land. With the improvement of the water supply through well-drilling and the introduction of intensive agricultural extension services as part of the Global 2000 program since the mid-1980s, demographic figures for the far north could be markedly different by the next census.

4.2.2.2 External factors

Another factor affecting Ghana's demography is the influx of refugees. At the end of 1994, approximately 110,000 refugees resided in Ghana. About 90,000 were Togolese who had fled political violence in their homeland beginning in early 1993. Most Togolese had settled in Volta Region among their ethnic kinsmen. About 20,000 Liberians were also found in Ghana, having fled the civil war in their country. Many were long-term residents. As a result of ethnic fighting in north-eastern Ghana in early 1994, at least 20,000 Ghanaians out of an original group of 150,000 were still internally displaced at the end of the year. About 5,000 had taken up residence in Togo because of the strife.

4.2.3 Demographic trends of Ghana (1960 - 2000)

Table 4.2: Demographic features

	DEMOGRAPHIC FEATURES	
1	Age structure	*
2	Sex distribution	*
3	Life expectancy	*
4	Fertility rate	*
5	Population density	*
6	Urban-rural distribution	*
7	Ethnicity	*
8	Religion	
9	Education	
10	Net migration	
11	Dependency ratio	*
12	Housing conditions	
13	Growth rate	*
14	Median age	
15	Sex ratio	
16	Birth rate	*

17	Death rate	*
18	Infant mortality	

* The demographic features under study.

4.2.3.1 Age structure

Total census figures have one significant demographic element, national age distribution. Table 1 reveals a pre-dominantly large dependency group made up of people below the age of twenty-five (<25) and above sixty-five years of age (>65). In 1960 Ghana's population was 6,726,815. About sixty-one point four percent (61.4%) fall below age 25. In 1984 approximately, seven million (7,000,000) people were represented in this category, about 4 million (4,000,000) of them under the age of ten (<10 years). The large population of young people represents economically unproductive individuals.

Again, in the 1984 total census figures of 12,296,081, approximately seven million (7,000,000) people were represented in the below 25category; about 4 million (4,000,000) of them above under the age of ten (<10 years). Besides, 3.5% were in the above sixty-five (> 65) age group. In addition, the large population of young, economically unproductive individuals appeared to be growing rapidly. In the early 1990s, about half of Ghana's population was under age fifteen. In the 2000 PHC fifty-nine point six (59.6%) represent below age twenty-five and five point three percent (5.3%) represents above sixty-five age group. We need to emphasize here that the under-twenty-five group and those above the age of sixty-five are regarded as the dependent group. Since these groups are dominant and saw much increase as far as in the population growth is concerned, the social, political, and economic implications for the 2000s and beyond are as grave for Ghana as they are during the 1990s.

4.2.3.2 Sex distribution/ratio

From Table 4.2 the gender ratio of the population, 97.3 males to 100 females, was reflected in the 1984 figures of 6,063,848 males to 6,232,233 females. This was slightly below the 1970 figure of 98 males to 100 females, but a reversal of the 1960 ratio of 102.2 males to 100 females. The fall in the proportion of males to females may be partly attributed to the fact that during the 1980s a large number of Ghanaians (mostly men) left the country in pursuit of greener pastures in neighbouring Nigeria and far away Libya. However, in the 2000 PHC the male figure was 9,357,382 to 9,554,697 females, representing a ratio of 87 males to 100 females.

4.2.3.3 Life expectancy

Table 4.3 shows Life expectancy and fertility rates between 1960 and 2000. Between 1960 and 1984, a constant 45 percent of the nation's total female population was of childbearing age. The crude birth rate of 47 per 1,000 populations recorded for 1965 dropped to 44 per 1,000 populations in 1992. Also, the crude death rate of 18 per 1,000 populations in 1965 fell to 13 per

1,000 populations in 1992, while life expectancy rose from an average of forty-two years for men and forty-five years for women between a 1970 – 1975, to fifty-two and fifty-six years, respectively, in 1992. The 1965 infant mortality rate of 120 per 1,000 live births also improved to 86 per 1,000 live births in 1992. Currently, the average life expectancy at birth in Ghana is 60 years (CIA, 2010) which was raised from 45 in 1957. Life expectancy is heavily influenced by the rates of infant mortality rate. In 2008, these rates were estimated at 50 and 80 deaths per 1000 live births respectively. The relatively high child mortality in Ghana is due to an amalgam of factors, especially the lack of protection from preventable diseases. To address this issue, the MOH has pursued a policy of to achieve universal immunization. (Trends p.2)

4.2.3.4 Fertility rate

With the fertility rate averaging about seven children per adult female and expected to fall only to five children per adult female by the year 2000, the population projection of 35 million in 2025 becomes more credible. A number of factors, including improved vaccination against common diseases, and nutritional education through village and community health-care systems, contributed to the expanding population. The rise in the nation's population generated a corresponding rise in the demand for schools, health facilities, and urban housing.

4.2.3.5 Population density

Population density increased steadily from thirty-six per square kilometer ($36km^{-2}$) in 1970 to fifty-two per square kilometer ($52km^{-2}$) in 1984; in 1990 sixty-three persons per square kilometer ($63km^{-2}$) was the estimate for Ghana's overall population density. These averages, naturally, did not reflect variations in population distribution. For example, while the Northern Region had a density of seventeen persons per square kilometer ($17km^{-2}$) in 1984, in the same year Greater Accra Region recorded nine times the national average of fifty-two per square ($52km^{-2}$) kilometer. As was the case in the 1960 and 1970 figures, the greatest concentration of population in 1984 was to the south of the Kwahu Plateau. The highest concentration of habitation continued to be within the Accra-Kumasi-Takoradi triangle, largely because of the economic productivity of the region. In fact, all of the country's mining centers, timber-producing deciduous forests, and cocoa-growing lands lie to the south of the Kwahu Plateau. The Accra-Kumasi-Takoradi triangle also is conveniently linked to the coast by rail and road systems - making this area an important magnet for investment and labourr.

4.2.3.6 Urban-rural disparities

Table: 4.3 Percentage Distribution of Urban /Rural Population by Sex (1960-2000)

Sex	1960		1970		1984		2000	
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Male	11.9	38.7	14.4	35.2	15.6	33.7	21.4	28.1
Female	11.2	38.2	14.5	35.9	16.4	34.3	22.4	28.1
Total	**23.1**	**76.9**	**28.9**	**71.1**	**32.0**	**68.0**	**43.8**	**56.2**

Table 4.3 shows percentage distribution of urban and rural population. Localities of 5,000 persons and above have been classified as urban since 1960. On this basis, the 1960 urban population totaled 1,551,174 persons, i.e. twenty-three point one percent (23.1%) of the total population. By 1970, the percentage of the country's population residing in urban centers had increased to twenty-eight point nine percent (28.9%). That percentage rose again to 32 percent (32%) in 1984, and was estimated at forty-three point eight percent (43.8%) for 2000.

The rate of urbanization varied from one administrative region to another. While the Greater Accra Region showed an eighty-three percent (83%) urban residency, the Ashanti Region matched the national average of 32% percent in 1984. The Upper West Region of the country recorded only 10% percent of its population in urban centers that year, which reflected internal migration to the south and the pattern of development that favored the south, with its minerals and forest resources, over the north. Urban areas in Ghana have customarily been supplied with more amenities than rural locations. Consequently, Kumasi, Accra, and many towns within the southern economic belt attracted more people than the savanna regions of the north; only Tamale in the north has been an exception. The linkage of the national electricity grid to the northern areas of the country in the late 1980s may help to stabilize the north-to-south flow of internal migration.

The growth of urban population notwithstanding, Ghana continued to be a nation of rural communities. The 1984 enumeration showed that six of the country's ten regions had rural populations of 5 percent or more above the national average of 68 percent. Rural residency was estimated to be 67 percent of the population in 1992. These figures, though reflecting a trend toward urban residency, were not very different from the 1970s when about 72 percent of the nation's population lived in rural areas.

In an attempt to perpetuate this pattern of rural-urban residency and thereby to lessen the consequent socioeconomic impact on urban development, the "Rural Manifesto", which assessed the causes of rural underdevelopment, was introduced in April, 1984. Development strategies were evaluated, and some were implemented to make rural residency more attractive. As a result, the Bank of Ghana established more than 120 rural banks to support rural entrepreneurs, and the rural electrification program was intensified in the late 1980s. The government, moreover, presented its plans for district assemblies as a component of its strategy for rural improvement through decentralized administration, a program designed to allow local people to become more involved in planning development programs to meet local needs.

4.2.3.7 Religion

According the 2000 census, Christians made up 68.8% of the population; Pentecostal/Charismatic 24.1%, Protestant 18.6%, Catholic 15.1%, other 11%. The census also noted that Muslims made up 15% of the population, however other sources suggested the Moslems number might be 30%. Other religions including African Traditional Religions and the Eastern sects took up the rest 2%.

4.2.3.8 Ethnicity

According to (*Trends* 2010) Ghana has about 35 ethnic groups. From the 2000 census the results were follows: Akan 45.3%, Mole-Dagbon 15.2%, Ewe 11.7%, Ga-Dangme 7.3%, Guan 4%, Gurma 3.6%, Gurunsi 2.6%, Mandé-Busanga 1%, other tribes (Hausa, Yoruba, Fulani) 1.4%, others (among them whites of mostly British descent) 7.8%.

4.3 Modeling Ghana's population growth (2001 - 2010)

The demography of Ghana describes the condition and overview of Ghana's peoples. This present study aims at discussing demographic features of Ghana's population over a fifty-year period (1960-2010), including population density, ethnicity, education level, health of the populace, economic status and other aspects of the population. The preliminary analysis has dealt with qualitative description of population trend over the study period. Now we will turn our attention quantitative analysis; mathematical modeling of 2010 PHC. Unfortunately, the provisional figure released by the Ghana Statistical Services for the 2010 Population and Housing Census are at variance with the one released by the Ghana National Population Council; 24,223,431 and 24,339,838 respectively.

4.3.1 Exponential Population growth: $N = N_0.e^{tr}$

The main source of data for determining the projections of population size and growth for 2010 are the population census for 2000 (CIA Factbook). The intrinsic natural increase, also called the Malthus parameter (r) can be calculated from doubling time thus: Doubling time = 70/annual growth rate

Alternatively, under a simplified condition such as a constant environment and with no net immigration, the change in population size (N) through time (t) will depend on the difference between individual birth rate (b_0) and death rate (d_0) i.e. subtracting the death from birth during one year, converted into a percentage. This is given by:

$$dN/dt = (b_0 - d_0) / N_0 \quad (1)$$

where:

b_0= instantaneous birth rate; births per individual per time period (t)

d_0 = instantaneous death rate; deaths births per individual per

time period (t)

N_0 = current population size

The foregoing calculations are shown in the following table.

Table 4.4 shows the number of births and deaths per 1000 from 2001 and 2010.

Year	Births/1000 (b_0)	Deaths/1000 (d_0)	Growth Rate ($dN/dt = b_0 - d_0/N_0$)
2001	28.95	10.26	1.869
2002	28.08	10.31	1.777
2003	25.84	10.53	1.531
2004	24.90	10.67	1.423
2005	23.97	10.84	1.313
2006	30.52	9.72	2.080
2007	29.85	9.55	2.030
2008	29.22	9.39	1.983
2009	28.58	9.24	1.934
2010	28.09	8.93	1.916
Total	**278.00**	**99.44**	**17.813**

Table 4.4 above shows the theoretical number of individuals added to the population during the various years between 2001 and 2010, including the number of births and deaths per 1000 population and the percentage change in total population. From the table, at the end of 2010 the total population

would have increased by 1.8%; the mean birth rate at the end of the ten years being 27.8%, mean death rate 9.94% and growth rate 1.78%. Comparatively, the median births are 28.34%, median deaths 9.99% and growth rate 1.87%. It is important to point out the fact that the difference between the mean and median figures of each component is less than 1.

The projections of population size and growth for 2001 - 2010 can be calculated from the change in population size (N) through time (t) and growth rate (r), using Exponential model given by the formula:

$$N = N_0.e^{tr} \qquad (2)$$

where (N_0) is the initial population, and (e) constant, which is valued at 100 with a natural log of 2.718. The following table shows the population size and growth for ten years.

Table 4.5: Growth of Ghana's population (2001-2010) by Exponential model

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Growth (r)	1.87%	1.78%	1.53%	1.42%	1.31%	2.08%	2.03%	1.98%	1.93%	1.92%
Pop (N)	19,255,543	19,605,254	19,901,508	20,182,060	20,446,112	20,879,975	21,301,734	21,732,013	22,148,825	22,596,214

Table 4.5 represents the population growth of Ghana between 2001 and 2010, using the Exponential model. In 2001 the population size is 19,255,543, an increase of 343,464 over the 2000 figure, representing 1.87%. With an annual growth of 1.78% the population reaches 19,605.254

in 2002 which further increases to 19,901.508, representing 1.53% in 2003. The population growth in 2004 is 1.42% giving us a total population of 20,182,060 and a further increase of 1.31% will give us a total population size of 20,446,112 in 2005. Again, the 2006 population is 20,879,975, representing 2.08% which further increases by 2.03% to give 21,301,734 in 2007. The annual growth of population in 2008 is 1.98% and the total population is 21,732,013, increasing by 1.93% in 2009 to reach a total population of 22,148,825. Finally, in 2010 the annual growth rate is 1.92% and a total population of 22,596,214.

Alternatively, fitting (2),

$$N = N_0.e^{tr}$$

$$\ln(N) = \ln(N_0.e^{tr})$$

$$\ln(N) = \ln N_0 + tr \ln e$$

$$\ln(N) = \ln(N_0) + tr,$$

using t = 10 (i.e. 2001-2010); r = 0.018 (i.e. 1.8% the mean growth); and $N_0 = 18{,}912{,}079$, the total population in 2010 is **22,641,497.**

Importantly, the foregoing means that at the end of 2010, the total population will be **22,596,214**, using annual growth rates. However, using the intercensal growth rate for the ten-year period gives a total population of **22,641,497.**

Note that these total population figures do not include net migration which is difficult to ascertain because there is no documents on immigrants like Fulani herdsmen from Burkina Faso, Nigeria, Benin, Cote d'Ivoire and Togo who troop into the country daily on business missions and those who have fled post-election violence from neighboring countries such as Togo, Cote d'Ivoire. Again, our borders are widely open, with corrupt officers in charge (Ref, Ghana Business News of May 5, 2009 reported in a headline: "CEPS officials aid smugglers defraud Ghana of millions in revenue"). In view of the above, the provisional total population figure of 24,223,431 and 24,339,838 provided by the Ghana Statistical Service and Ghana National Population Council respectively are reasonable.

4.3.2 Exponential growth curve

Transforming the equation to natural logarithms (ln), the exponential curve becomes linear, as in Fig. 8 below:

$$\ln(N) = \ln(N_0) + \ln(e)rt \quad (3)$$

$$r = [\ln(N) - \ln(N_0)]/t \quad (4)$$

where ln(e) = 1.

GRAPH SHOWING EXPONENTIAL GROWTH CURVE FOR 2001-2010

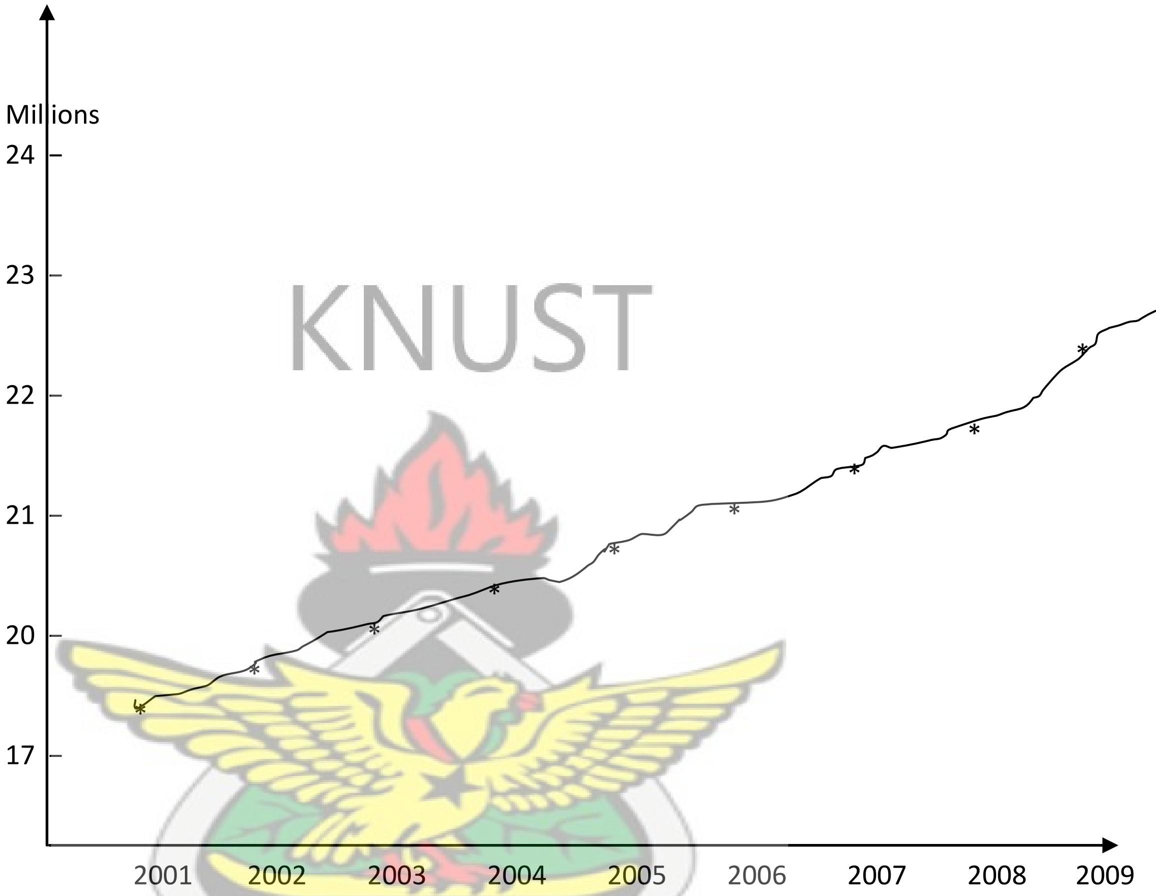


Figure 8: Exponential growth curve

Interpretation

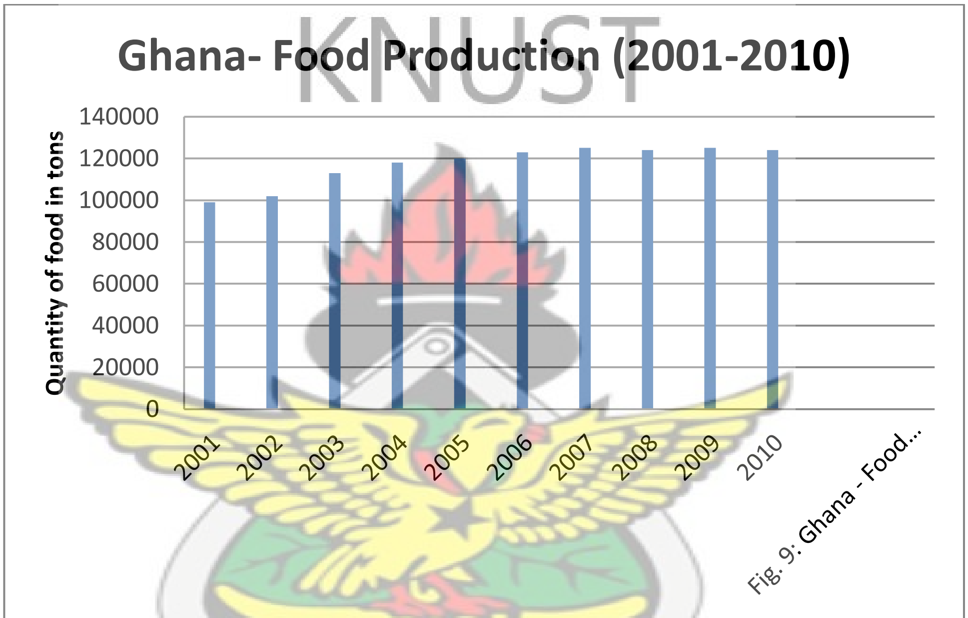
The exponential model describes population growth in an idealized, unlimited environment. In this study, it is used to investigate the principles of Ghana's population growth between 2001 and 2010. It is important to note that population change in size over time, basically, is as a result of natural increases birth and death. Though immigration and emigration are important in some populations, for the sake of simplicity we have ignored them.

In Figure 8 the graph curves upwards, as approaching a J-shape when the population size is plotted over time. Although the intrinsic rate of increase is constant, the population accumulates more new individuals per unit of time. As a result, the curve gets steeper over time. It is worthwhile to note that, in our present case, the intrinsic rate of population is not high (1.87) hence the increase does not grow as fast as compared to one with a high rate of increase, say 3% or 4%..

4.3.3 Logistic Population growth: I = rN(K - N / K)

The growth of natural populations is more accurately depicted by the logistic growth equation rather than the exponential growth equation (Meyer et al, 199). In logistic population growth, the rapid increase in number peaks when the population reaches the carrying capacity. The equation for this type of growth contains the factor for carrying capacity (K), which may be defined as the maximum number of people that can live at [a place] without dangerously threatening its future (International Environmental Forum (2006).

According to Lotka (1925), a static carrying capacity does not reflect the current human condition. In calculating the carrying capacity, the researcher followed the FAO convention which posits, “Use of food production or livestock data alone will suffice to estimate carrying capacity values." In a similar study, Rusell Hopfenberg of Duke University, Durham, North Carolina (USA) stated, "Although livestock are indeed a human food resource, these data are omitted." The food production for the study period is presented in Fig 9 below.



Source: World Development Indicator

Figure 9: Ghana- Food Production (2001 – 2010)

To organize the food production data for each year, the food production index was converted to carrying capacity values. This follows the recommendation of Rusell Hopfenberg (2000) thus:

1. Each year of harvest was assigned a (t+1) value; this was to allow for the time required for gestation of food crops.

2. As food production was reported based upon setting the average to 100, all values were multiplied by the constant 2.28 which was derived by dividing the 2010 population data by FAO Food Production data for 2001.
3. The resultant converted food indices were then multiplied by 2.487 to generate a good fit with actual population data.
4. Finally, the growth rate for the equation: $I = rN(K - N / K)$ was held at 1.87% (the median growth rate).

Table 4.6: Growth of Ghana's population (2001-2010) by Logistic model

Year	**Population (Exponential)**	**Food Production (tons)**	**Carrying Capacity**	**Population (Logistic) I=rN(1-N/K)**
2001	19,255,543	99,000*	578,376.72	16,144,962
2002	19,605,254	102,000*	640,750.68	19,255,543
2003	19,901,508	113,000*	669,102.48	19,605,254
2004	20,182,060	118,000*	680,443.20	19,901,508
2005	20,446,112	120,000*	697,454.28	20,182,061
2006	20,879,975	123,000*	708,795.00	20,445,112
2007	21,301,734	125,000*	703,124.64	20,879,975
2008	21,732,013	124,000*	708,795.00	21,301,734
2009	22,148,825	125,000*	703,124.64	21,732,013
2010	22,596,214	124,000*	720,135.72**	22,148,825

Source: * World Development Indicator (2010) /Field data (2011)

Table 4.6 shows the effects of a limiting factor such the land carrying capacity; let N represents population size and *t* represent time, this model is formalized by the differential equation:

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right) \qquad (1)$$

where the constant r defines the growth rate (1.87) and K is the carrying capacity. The value of r represents the proportional increase of the population *P* in one unit of time. In the equation, the early, unimpeded growth rate is modeled by the first term rN. Later, as the population grows, the second term, which multiplied out is $-rN^2/K$, becomes larger than the first as some members of the population *P* interfere with each other by competing for food.

Dividing both sides of the equation by K gives

$$\frac{dN}{dt}\frac{N}{K} = r\frac{N}{K}\left(1 - \frac{N}{K}\right) \qquad (2)$$

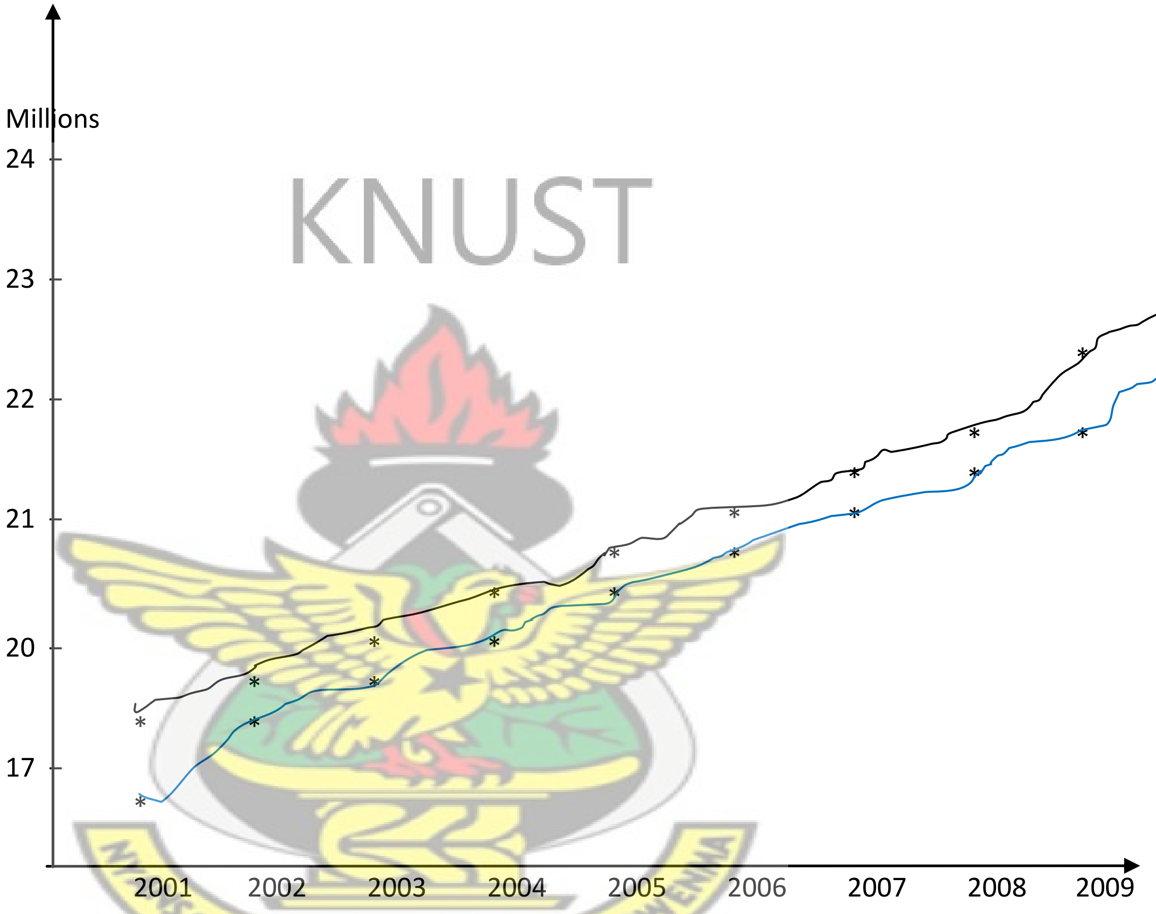
Now setting $x = N / K$ gives the differential equation

$$\frac{dx}{dt} = rx(1 - x). \qquad (3)$$

4.3.4 Logistic Growth Curve

GRAPH SHOWING EXPONENTIAL AND LOGISTIC CURVES

(2001-2010)



Key: Exponential growth Exp. Logistic growth Log.

Source: Field data 2011

Figure 10: Exponential and Logistic growth curves

Interpretation

Superimposing the logistic equation on the Exponential curves produces some interesting features; first the total population depicted by the Logistic curve falls under the Exponential curve throughout its entire length. Possibly, this the effect of the carrying capacity that set a limiting boundary to population increases in the Logistic model. Secondly, the Logistic curve shows values that are equal to the Exponential values of the preceding year. For example, population size for 2002 on the Logistic curve is equal to population size for 2001 on the Exponential curve (i.e. 19,255,543 for each). Probably, this is the result of the allowance made for the gestation period in food production i.e. (t+1) value. However, 2005 Logistic curve value is greater than the 2004 Exponential value by one. The reason could be the rounding off effects in the carrying capacity food production value for the period of 2005.

Other features to note in the Logistic curve are:

- The carrying capacity for 2006 and 2008 are the same, yet they do not the initial population of the two time frame are different, their food production values are not the same and the resultant population size and growth they produce are at variant. To explain the above feature, other demographic elements such as growth rates (Ref. 2.1% for 2006 and 2.0% for 2008),

- Food production for 2007 and 2009; and 2008 and 2010 are the same respectively, though they produce different carrying capacity and eventually different population sizes and growth.

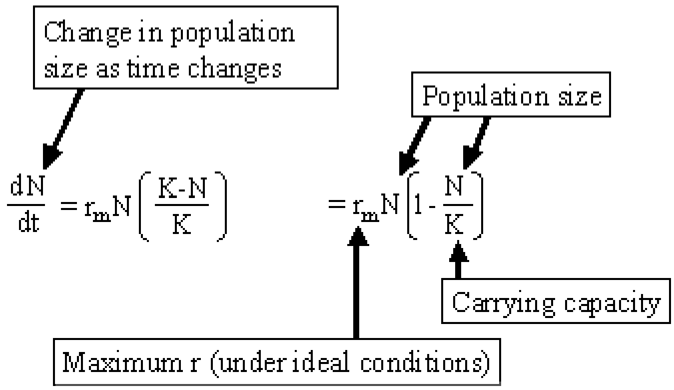
Most importantly, the value of r used in this equation is the maximum growth rate that the population can achieve under optimal conditions. It is called the intrinsic rate of increase. Due to (K-N)/K, the actual growth rate, r (the per capita rate of increase) will be less than r_m.

If this term is multiplied by the equation for exponential growth (equation 2), growth will be slowed down as population size increases and will become zero when N=K.

$$\frac{dN}{dt} = r_m N \left(\frac{K-N}{K} \right) \qquad (4)$$

The logistic equation can be rearranged to produce the following:

$$\frac{dN}{dt} = r_m N \left(1 - \frac{N}{K} \right)$$



The term N/K is the **environmental resistance**. The equation shows that the growth rate slows down as N increases. Due to (K-N)/K, the actual growth rate, r (the per capita rate of increase) will be less than rmax (the intrinsic rate of increase). As N increases, r decreases. At the carrying capacity (K), r = 0. Above the carrying capacity, r becomes negative and below the carrying capacity r is positive.

where K is the carrying capacity, the maximum sustainable population size N, then K-N is the number of additional individuals the environment can accommodate and (K-N)/K is the fraction of K that is still available for population growth. By multiplying the intrinsic rate of increase rmax by (K-N)/K, we modify the growth rate of the population as N increases:

$$dN/dt = rmaxN[(K-N)/K] \qquad (5)$$

When N is small compared to K, the term (K-N)/K is large and the per capita rate of increase is close to the intrinsic rate of increase. However, when N is large and approaches K, resources are limiting.

In this case, the term (K-N)/K is small and so is the rate of population growth. Population growth is greatest when the population is approximately half of the carrying capacity. At this population size, there are many reproducing individuals, and the per capita rate of increase remains relatively high.

Although Ghana's population has a tremendous capacity for growth, however, unlimited population increase does not occur [indefinitely in nature] (Cohen, 2006). Typically, resources are limited. As population density increases, each individual has access to an increasingly smaller share of available resources. Ultimately, there is a limit to the number of individuals that can occupy an environment. Ecologists define the maximum stable population size that a particular environment can support as carrying capacity (K). Again, International Environmental Forum (2006) defined human carrying capacity as "how many organisms can live sustainably in a particular environment without destroying its resources." The Forum established that, "Many things can be limiting factors, such as food or water supply, amount of shelter, capacity to absorb wastes, or predation, and different factors can be the limit that determines carrying capacity at different times and places."

It is difficult to estimate Ghana's carrying capacity, since this depends on the technologies available, our efficiency in the use of resources, and the acceptable standard of living. However, given rapid population growth in

Ghana coupled with our present inability to meet even the basic needs such as food clothing and shelter, human carrying capacity is of prime importance. The idea of carrying capacity relates closely to that of sustainable development. In Ghana, we cut down forests faster than they can grow back; intensified and traditional methods agriculture rob the soil of its fertility; and we make profligate use of non-renewable resources such as minerals and fossil fuels.

There are signs that Ghana is exceeding the carrying capacity; the logistic curve falls under the exponential curve (Fig. 9). Some of the worst political and humanitarian crises since the 1900s are the underlying causes behind high and rapidly increasing density of population, extreme poverty, and a shortage of essential environmental resources, and in particular, a drop in per capita food production in Ghana. The increase in environmental refugees such as Malians who leave their homes because local resources can no longer support them is another symptom of this exceeding the environmental capacity of a country like Ghana (Mathews, 1994; Atwood, 1994).

Rusell Hopfenberg (2001) maintained that "simple mathematical models have illustrated the relationship between human carrying capacity and population growth." In this study, food supply is proposed as the variable which best accounts for the human carrying capacity. The logistic equation, using food supply data as a variable carrying capacity, yields population estimates which are in accord with actual population numbers. That food supply data adequately fits the logistic model of human population dynamics and provides evidence that human population increases are a function of increased food availability.

4.4 Conclusion

The logistic curve produces an exponential growth at its initial stage (Ref. to the steep slope (2001-2002) in Fig 9) when N is plotted over time. This means that new individuals are added to the population rapidly at population sizes, when there are resources such as food, space and other resources in the population. Moreover, the logistic model assumes that regardless of population density, an individual added to the population has the same negative effect on population growth rate. One reason for this Allee effect in Ghana is that women marry very late, coupled with the fact that the rate of literacy among women is very high.

Finally, the logistic population growth model provides a basis from which we can consider how real populations grow and can construct more complex models such as the Matrix Population model.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This is the final chapter of the study comprising the under listed: Summary of the study, Summary of findings, Conclusion and Recommendations.

5.1 Summary of the Findings

Every year new total population figures and growth rates are published for Ghana by the Ghana Statistical Services and Ghana National Population Council. These figures are taken in trust. But are the numbers accurate enough or are the sources for the population figures accurate and up to date? The important issue to remember with this figure is that they are estimates, for "it is impossible to have a true population figure due to the fact that every second the population number changes, which is mostly a rise in numbers. Thus when a census is taken or population data is combined the number of counted human beings within the figures has changed (CIA World Fact book 2010). These study modeled population projection from 2001 to 2010 specifically using The Malthusian Exponential Growth Model and Verhaulst's Logistic Growth Model. The main difference their parameters is the carrying capacity which limits the increases and growth in population over time.

From Table 4.7 Ghana's growth rate has been reduced substantially through decreasing the fertility rate in women, which is the main indicator of growth rate is relatively stable between 2001 and 2010. The results from the study definitely are lower that the statutory published ones; the median growth rate of 1.87% while that of the government's statistician is 2.4%. Furthermore, the median age at first marriage is 19.8 years on average between 2001 and 2010 (Trends p.11).

Another important indicators of population growth, educational level of the population has shown tremendous improvements over 1960-2000 trends; 74% males and 62% females aged 6 were attending school. According to Trends (2010 p 3), the urban areas have grown from forty-four percent (43.8%) at the 2000 PHC to an estimation of forty-eight 48% percent in 2010.

Finally, Apenteng (2009) commented that, the social, economic and demographic structure of Ghana has not changed much since independence. The primary sector continues to dominate the economy, in terms of its contribution to output, employment, revenue generation, and foreign exchange earnings. Agriculture is the main economic activity and currently accounts for about fifty-one percent (41%) of the GDP and about fifty-four (54%) of the labour force. The social structure remains predominant traditional, rural and informal, with close family links, while the population remains young, with relatively high but declining fertility and lo mortality levels

5.2 Conclusions

Having gone through all the analysis and considering the critical points of concern regarding the topic of interest from the research analysis and interviews it has come to light that human populations have become the subject of change in number and structure. Generally, these changes normally take place through the followings processes of birth, deaths and the counter balance between immigration and emigration. Various statistical instruments, including Malthus' Exponential model and Verhulst's Logistic model are most useful in determining population growth. Basically, survival and fertility assumptions of projection of population growth were attributed to as the independent variable and time as the dependent variable.

Specifically, in Ghana, births exceed deaths by mean 17.86 per 1000 persons, population grows exponentially at 1.78% on average; each addition to population also produces compounding accelerating effect on population size. Characteristic of population is density-independent; i.e. mortality rates are unaffected by population density.

However, the logistic growth model incorporates the land carrying capacity of Ghana which is a density-dependent check on population growth. As total population increases the carrying capacity becomes smaller, hence population growth rates slow down, and hence it stays under the

Exponential curve throughout its length. From the foregoing discussions, logistic growth model is more reliable than the simplified exponential growth model, but together they provide us with the size and growth of Ghana's population over the study period.

It is the aim of every political leader to maintain population stability, which may be achieved in one of the two configurations:

Zero population growth = High birth rates - High death rates.

Zero population growth = Low birth rates - Low death rates.

The movement from the first toward the second state is called the demographic transition. After 1950, mortality rates declined rapidly in most developing countries such as Ghana, as against are nearing equilibrium in the developed nations (Meyer et al, 2001). A unique feature of human population growth is the ability to control it with family planning and voluntary contraception. Reduced family size is the key to the demographic transition. Delayed marriage and reproduction help to decrease population growth rates and move a society toward zero population growth. Another important demographic variable is a country's age structure. Age structure diagrams can predict a population's growth trends and can point to future social conditions.

To conclude, as the total population continues to rise, there should be corresponding and appropriate methods and sources for calculating population size and growth, which would give a total human population figure at any given time. However, lack of professional demographer, statisticians, seasoned computer analysts, and others like them the total population figure should not be taken as the truthful number.

5.3 Recommendations

In view of the findings, the following recommendations are made;

1. Rapid population growth has had serious detrimental effects on development and quality of life in Ghana. To lend a voice to Prof. Fred T. Sai's obsession, government must show commitment to reducing growth rate (Daily Graphic, 23rd April 2009). The place to begin is reducing fertility rate as observed by Raymond Pearl (1977) in *The Biology of Population Growth*. Monetary rewards could be an attractive package for any man or woman (between the sexually active ages) who voluntarily offers himself or herself for family planning practices.

2. In this study, as in true life situations, the total population figures are estimated, combined figures from various sources, including population censuses, registration systems, sample surveys and assumptions. Colleen Clark (2006) maintained that "at any given time it is impossible to calculate total population figures, due to the huge gap for errors when taking data from various sources and even more so when making assumptions." He added that "it is not possible to eliminate all errors" but they can be minimized. Hence, effective and efficient Management

Systems (instead of scattered papers) which employed qualified personnel would be valuable assets for retrieval of values of factors that affect the demography.

3. Most of the problems of population enrolment are content-based. Most enumerators are engaged ad hoc, and they are most relatives of personnel from Ghana National Population Council. Again most those engage do not have any prior knowledge, but are moved by monetary considerations to apply for the enrolment exercise. Though we can say there is training for them, it is scanty (professional demographers attend refreshers courses now and then, how much less can a novice be trained for only two weeks). Formerly, teachers were used during vacations, and when the exercise was extended over time, the teacher concerned had to lobby between the classroom and the demographic area. In some cases, the distance between these two places are so vast that it was economically suicidal for the enumerator to commute. The result was that the process was only guesswork, not fieldwork. Another case in hand is that even after the 2010 population results were declared and gazette, people claimed they were not contacted at their work place or at their residents. In view of these, professional demographers are needed for these types of exercises.
4. The four universities are offering population studies, in addition to the Geography department of the University of Ghana offering the same

course. For that matter it should be too hard for Ghana to obtain manpower in that direction. However, the course is too academically theoretical that it does not benefit the learners nor they provide the needed manpower base. The researcher's own experience was that though the students were aware of components such as carrying capacity, they could not determine in formula. The researcher would therefore recommend practical lessons with the Ghana Statistical Service and Ghana National Population Council, though they are sensitive veins of the government.

5. Over the ten-year period (2001 and 2010) both models showed similarities and differences. Using only one or the other model would put limitation to the results. Also each model emphasizes a particular demographic feature. For example, the Exponential Growth Model emphasizes birth and death rates and probably net emigration, whereas the Logistic Growth Model emphasizes the limits to which population can grow over time, depicted by the land carrying capacity. In view of these, the combination of different approaches such as the Exponential Model, Logistic Model and Matrix Model would be a healthy exercise in modeling Ghana's population size and growth.

6. Ghana is a primary producing nation, like any other developing country. Since, the carrying capacity sets limit to population growth, it also sets limit to National Parity Per Capita, to say the least. We need to move away from agriculture into aggressive industrialization, which is the

only way to increase and harness our numerous natural resources and endowment in the land.

7. Finally, most politicians across the divide make mountains out population figures to score cheap political points. They should realize that be ready also to provide alternative models to generate population size and population growth over time. More importantly they should be in a position to justify their choice. Stephen Moore in "The Inaccuracy of Human Population Figures" justified some minimal errors in population figures.

On the other hand, there was the claim in political arena that government did not have any control over the population known figures because of a corrupt government and political system. Valentine S. (2010) supports this claim when he maintained that "most population figures are based on past historical statistics and surveys." Governments should therefore enforce creditable population census all the time.

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APPENDICES

APPENDIX A

Dear Sir/Madam,

I am conducting a study on the topic: "Evaluation of Population Census Data and Population Growth in Ghana through Demographic Analysis" for the award of Masters of Science in Industrial Mathematics. It would be appreciated if you could give your candid responses to this interview schedule.

Confidentiality in respect of whatever information you offer is fully assured.

Thank you for your cooperation

APPENDIX B

Interview Schedule

PART A

1. Name of Respondent

....

2. Gender Male [ ] Female [ ]

3. Age: 20 – 30 [ ] 31 – 45 [ ] 46 – 60 [ ] above 60 [ ]

4. Highest level of education: ....

5. Name of institution you work for..

PART B

1. What parameters does Ghana use in population censuses? Give reasons for the choice.

2a. Does demographic analysis reduce high incidence of unreliability in population data?

2b. If yes, why? If no, why not?

3. How effective could a mathematical model be used to predict and project future population size and growth of Ghana?

4. What limiting factors affect population size and growth of Ghana over the years?