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Population and Land Use/Cover Dynamics in the Volta River Basin of Ghana, 1960-2010

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To my wonderful wife Akosua Nyantekyewaah and our lovely children,
Adjoa, Nii Sersah, Nii Ardey and Nii Baah.

ABSTRACT

The Volta River basin is one of the most economically deprived areas in Africa. Rain-fed and some irrigated agriculture is the main economic activity of the majority of the population living in this region. High population growth rates have brought in its wake increasing pressure on land and water resources. Precipitation in the region is characterized by large variability as expressed in periodic droughts. Due to large variability in precipitation patterns, the development and optimum use of (near) surface water resources is the key to improved agricultural production in this region. As a result of the interplay between land/atmosphere, energy, water (vapor) and land use, significant shifts in land use patterns will bring about spatio-temporal changes in weather patterns and rainfall characteristics. There is the need therefore for a sustainable management of the water resources of the Volta River Basin. The Global Change in the Hydrologic Cycle (GLOWA) Volta Project therefore seeks to analyze the physical and socio-economic determinants of hydrological cycles, which will eventually lead to the development of a scientifically sound decision support system for the assessment, sustainable use and development of water resources in the Volta Basin of West Africa.

It is a well-perceived notion that man and his activities are the major drivers behind land use/cover change, and therefore become very central in any land use/cover change analysis. This study was therefore carried out as a sub-project of the GLOWA Volta Project, and it specifically looked at the relationship between population and other socio-economic dynamics, on the one hand, and agricultural and forest land uses on the other, and predicted the effect of changes in population on the two land uses in 2010.

At the general basin level, population data were derived from population census reports of Ghana for 1960, 1970, 1984 and 2000, while forest cover information was derived from land cover and land use maps of 1990/91 and 2000, which were developed using LANDSAT Thematic Mapper (TM) satellite images. Agricultural land use data were obtained from the Ghana Ministry of Food and Agricultural Censuses of 1992 and 2000. Furthermore, a soil suitability map for 90-day maize was remapped into a binary layer of *suitable* and *not suitable* for agriculture, and used to predict the effect of population change on agricultural land use. At the district level, the main source of data was primary. A structured and open-ended questionnaire was administered between November 2001 and March 2002 amongst 252 households in 12 localities in the Kassena-Nankana District, and 252 households in 9 communities in the Ejura-Sekyedumase District. Results show that the Bawku and Bolgatanga-Tongo Urban Councils in the White Volta, and the Kete-Krachi Local Council in the Daka will experience agricultural land shortfalls in the year 2010, as a result of changes in population.

At the district level, years allowed for land to fallow and proportion of major farmers were statistically significant predictors of cropped area in the Kassena-Nankana District in 1984. However, the situation changed in 2000, since land fallow did not only cease to be a statistically significant predictor of cropped area in the Kassena-Nankana District, but also had a negative relationship with cropped area. In 1984, population of the locality was a statistically significant predictor of cropped area in the Ejura-Sekyedumase District. In 2000, distance to farthest farm, off-farm income, and practice of agricultural extensification were predictors of cropped area in the Kassena-Nankana District, while population of the locality again predicted cropped area in the Ejura-

Sekyedumase District. Furthermore, the analysis shows that extra income earned off-farm is not necessarily invested into farming activities. A spatio-temporal analysis of the relationship shows that land tenure arrangement (whether owned or hired), the presence of electricity as a source of household energy, affluence (items and livestock ownership), the use of tractors, inorganic fertilizer and improved seed variety as well as household size did not influence agricultural land use in both districts and in both years.

On the effect of population change on forest cover between 1990 and 2000, predictions show that only the Jaman and Berekum Local/urban Council areas that fall within the Black Volta sub-basin will have depleted forest cover as a result of increases in population density. All the other areas within the sub-basin will have some amount of forest cover in 2010, irrespective of increases in population density that might occur. On the other hand, the Kete-Krachi Local Council in the Daka sub-basin will experience depleted forest cover in 2010 as a result of population density increase, while the Gushiegu-Chereponi, Bimbilla and Salaga Local Councils will have some forest cover in 2010 despite increases in population density. Finally, other indirect demographic factors, namely the farming systems, practices and inputs used, types of crops grown, consumption patterns of fuelwood as energy for cooking and other activities, and extensification of agricultural lands were all shown as indirect demographic causes of deforestation.

Bevölkerungs und Landnutzungdynamik im Voltabecken von Ghana, 1960-2010

KURZFASSUNG

Das Becken des Voltaflusses ist eine der wirtschaftlich am stärksten benachteiligten Regionen in Afrika. Natürlich und zum Teil künstlich bewässerte Landwirtschaft ist die wichtigste wirtschaftliche Aktivität des größten Teils der Bevölkerung in dieser Region. Hohe Wachstumsraten bei der Bevölkerung haben zu einem verstärkten Druck auf Land und Wasserressourcen geführt. Der Niederschlag in der Region ist gekennzeichnet durch eine große Variabilität, die durch periodische Dürren in Erscheinung tritt. Aufgrund der großen Variabilität in den Niederschlagsmustern bilden die Entwicklung und optimale Nutzung von (nahen) Oberflächenwasserressourcen den Schlüssel zur verbesserten landwirtschaftlichen Produktion in dieser Region. Als Folge des Wechselspiels zwischen Land/Atmosphäre, Energie, Wasser (Wasserdampf) und Landnutzung werden wesentliche Verschiebungen in Landnutzungsmustern zu räumlich-zeitlichen Veränderungen in Bezug auf Wettermuster und Niederschlagmerkmale führen. Daher ist ein nachhaltiges Management der Wasserressourcen im Voltabecken erforderlich. Das GLOWA-("Global Change and Water Availability") Volta-Projekt versucht daher die physikalischen und sozioökonomischen Größen von hydrologischen Zyklen zu analysieren, die schließlich zur Entwicklung eines wirtschaftlich soliden ‚Decision Support'-System für die Bewertung, nachhaltige Nutzung und Entwicklung der Wasserressourcen im Voltabecken von West Afrika führen soll.

Es ist allgemein bekannt, dass der Mensch und seine Aktivitäten die treibenden Kräfte für die Veränderungen der Landnutzung/-bedeckung darstellen. Diese spielen daher eine zentrale Rolle in jeder Analyse der Landnutzung-/-bedeckungsveränderungen. Aus diesem Grund wurde die vorliegende Studie als ein Unterprojekt des GLOWA Volta Projektes durchgeführt. Sie untersucht im Besonderen die Beziehung zwischen Bevölkerungsdynamik und anderen sozioökonomischen Vorhersageparametern auf der einen Seite und land- und forstwirtschaftlicher Landnutzung auf der anderen und berechnet die Auswirkung von Veränderungen in der Bevölkerungsentwicklung auf diese beiden Landnutzungen für das Jahr 2010.

Auf der Ebene des Voltabeckens wurden die Bevölkerungsdaten den Erhebungen in Ghana der Jahre 1960, 1970, 1984 und 2000 entnommen, während die Daten der Waldbedeckung aus Landbedeckungs- und Landnutzungskarten aus den Jahren 1990/91 und 2000 stammen. Diese waren auf der Grundlage von LANDSAT Thematic Mapper (TM) Satellitenbildern erstellt worden. Daten zur landwirtschaftlichen Nutzung wurden aus Daten des Ghana Ministerium für Nahrungsmittel sowie aus landwirtschaftlichen Erhebungen der Jahre 1992 und 2000 ermittelt. Außerdem wurde eine Karte der Bodeneignung für 90-Tage-Mais umgesetzt in eine binäre Schicht von für Landwirtschaft *geeignet* und *nicht-geeignet*, um die Auswirkung von Bevölkerungsveränderungen auf landwirtschaftliche Landnutzung vorherzusagen. Auf der Ebene des Distrikts bildeten Primärdaten die Hauptquelle. Befragungen mit einem strukturierten Fragebogen mit offenen Fragen wurden zwischen November 2001 und März 2002 in 252 Haushalten in 12 Dörfern im Kassena-Nankana-Distrikt und 252 Haushalten in 9 Dörfern im Ejura-Sekyedumase-Distrikt durchgeführt.

Die Ergebnisse zeigen, dass die Stadtgemeinden Bawku und Bolgatanga-Tongo im Weißen Volta und in der Kete-Krachi Gemeinde in Daka einen Mangel an landwirtschaftlich nutzbarem Land im Jahre 2010 als Folge von Veränderungen in der Bevölkerungsentwicklung erfahren werden. Auf der Distriktebene zeigten sich die landwirtschaftlichen Brachezeiten sowie der Anteil an hauptberuflichen Farmen als signifikante Vorhersageparameter für die Bestimmung der Entwicklung der angebauten Flächen im Kassena-Nankana-Distrikt im Jahre 1984. Jedoch hatte sich die Situation in 2000 verändert: Die Brache hatte nicht nur aufgehört, ein signifikanter Vorhersageparameter in Bezug auf die angebaute Fläche im Kassena-Nankana-Distrikt darzustellen, vielmehr war die die Beziehung zur angebauten Fläche negativ geworden. 1984 war die Bevölkerung in der betreffenden Gemeinde im Ejura-Sekyedumase-Distrikt ein signifikanter Vorhersageparameter hinsichtlich angebauter Fläche. Im Jahre 2000 waren Entfernung zur am weitesten entfernten Farm, bäuerlicher Nebenverdienst und die Praxis der Ausdehnung der landwirtschaftlichen Flächen entsprechende Vorhersageparameter hinsichtlich angebauter Fläche im Kassena-Nankana-Distrikt, während die Bevölkerungsentwicklung der Gemeinde im Ejura-Sekyedumase-Distrikt wiederum Aussagen zur angebauten Fläche ergab. Außerdem zeigt die Analyse, dass das zusätzliche Einkommen aus dem Nebenverdienst nicht notwendigerweise in landwirtschaftliche Aktivitäten investiert wird. Eine räumlich-zeitliche Analyse der Beziehung zeigte, dass in beiden Distrikten und Jahren Landbesitzformen (ob Eigentum oder gepachtet), das Vorhandensein von Strom als Quelle der häuslichen Energie, Wohlstand (Sachen und Viehbesitz), der Gebrauch von Traktoren, anorganischen Düngemitteln und besseren Saatgutsorten sowie Haushaltsgröße keinen Einfluss auf die landwirtschaftliche Landnutzung hatten.

Hinsichtlich der Auswirkung der Bevölkerungsveränderung auf Waldbedeckung zwischen 1990 und 2000 zeigen die Vorhersagen, dass die lokalen/städtischen Gemeinden von Wa, Bole und Damango und die von Bimbilla und Salaga in den Schwarzen Volta- bzw. Daka-Becken 2010 einen gewissen Anteil von Waldbedeckung, unabhängig von Veränderungen in der Bevölkerungsdichte, aufweisen würden. Alle anderen Gebiete innerhalb der beiden Becken würden einen Abbau ihrer Waldflächen verzeichnen. Schließlich zeigten sich andere indirekte demographische Faktoren, nämlich Anbausysteme, -praktiken und eingesetzte Stoffe (Dünger), Art der angebauten Pflanzen, Verbrauchsmuster hinsichtlich Feuerholz für Kochen und andere Aktivitäten, sowie die Vergrößerung der landwirtschaftlichen Flächen als indirekte demographische Ursachen für die Abnahme der Waldflächen.

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1 INTRODUCTION

1.1 Background of the study

1.1.1 Global change in the hydrologic cycle (GLOWA) Volta project

The Volta River Basin, which covers about 400,000 km^2 and includes six West African countries namely Ghana, Burkina Faso, Togo, La Cote d'Ivoire, Benin, and Mali, is economically one of the most deprived areas in Africa (average annual income in the region is estimated at US$ 800 per year) although precious mineral resources (gold, diamond, manganese, bauxite, etc.) abound. Rain-fed and some irrigated agriculture is the main economic activity of the majority of the population living in this region. Population growth rates are high (over 2.7% per annum) and this has brought in its wake increasing pressure on land and water resources.

Precipitation in the region is characterized by large variability, as expressed in periodic droughts. Unpredictable rainfall is a major factor in the economic feasibility of hydraulic development schemes, as witnessed by the power outages, which plagued Ghana in 1998. Due to large variability in precipitation patterns, the development and optimum use of (near) surface water resources is the key to improved agricultural production in the West African savannah some of which lies in the Volta River Basin. The consequence of these water development programs will impact on downstream water resources availability, specifically those of the Volta River Lake, which supplies most of the urban population of Ghana with its power requirements, and other West African countries such as Benin and Togo to where Ghana exports power.

As a result of the interplay between land/atmosphere, energy, water (vapor) and land use, significant shifts in land use patterns will bring about spatio-temporal changes in weather patterns and rainfall characteristics. Future changes in the West African weather regimes would be affected by global climate change. However, there is only limited understanding of the impact of global changes on regions such as West Africa, and even less knowledge of the feed-back of these effects on factors determining regional weather such as land-cover changes, and the resulting shifts in evaporation and run-off. This feedback, however complex it may be, may have catastrophic consequences for the region and may affect the availability of water and the strategy for managing it.

It is worthy of mention that the residents of the Sahel Region have experienced a lot of hardships as a result of changes in rainfall patterns. In the past, the grave water deficiency during extensive droughts had destructive consequences for the population concerned, and partially caused irreversible ecological damages. The World Meteorological Organization (1985) recorded that in 1984, the drought in the Sahel affected about 250 million people from 22 countries. Several hundred thousand people died as a result of the droughts during the years 1972, 1973, 1977, and between 1982 and 1984. Furthermore, in Druyan's (1989) estimation, millions of people migrated to adjoining areas to save their lives. The large rainfall variability, therefore, makes West Africa a region with permanent climatic problems.

Due to the issues mentioned, there is the need for a sustainable management of the water resources of the Volta River Basin. The Global Change in the Hydrologic Cycle (GLOWA) Project therefore seeks to analyze the physical and socio-economic determinants of hydrological cycles, which will eventually lead to the development of a scientifically sound decision support system for the assessment, sustainable use and development of water resources in the Volta Basin of West Africa. The main scientific challenge of the project is therefore the integration of climatic, ecological and socio-economic factors with respect to the hydrological cycle.

It is envisaged that the decision support system will provide a comprehensive monitoring and simulation framework enabling decision makers to evaluate the impact of manageable (irrigation, primary water use, land use change, power generation, trans-boundary water allocation) and less manageable (climate change, rainfall variability, population pressure) factors on the social, economic, and biological productivity of water resources. Decision makers would thus be able to evaluate alternative development strategies and answer questions including the following:

- Is there a reduction in rainfall and an increase in rainfall variability? What would be the economic and ecological consequences of such a tendency?
- How can the limited available resources be reconciled with the present population increase and which water resource management strategy should be pursued?
- Which feedback loops between land use intensification and reduced rainfall are to be expected?

- What are the returns in terms of productivity and downstream availability of water resources yielded by large-scale irrigation schemes along major rivers or hydraulic development of small valleys in the upper reaches?

- What are the ecological and socio-economic consequences of an increased hydropower production (helping industries around Accra) and/or an improved agricultural productivity through irrigation in the north (reducing rural poverty)?

- What would be the impact of upstream dam building in Burkina Faso on the Volta River? Can win-win management strategies be developed which satisfy both countries?

The decision support system will take the form of a set of models, which can readily interchange information with the correct scale and format, and a shell within which the models can be used. The model will be dynamic, meaning the relations between variables and the rates of change may vary over time and space. As such, the model would do more than extrapolate present trends, by also capturing the functional relationships between different variables.

Integration of climatic, ecological and socio-economic factors and correlations with respect to the hydrologic cycle is the main scientific challenge of the project. The decision support system depends vitally on the input from many different scientific disciplines and the project is interdisciplinary in nature. The challenge for any interdisciplinary research project is on the one hand the development of a meaningful quantitative exchange of information, and on the other hand a synthesis of the different findings, which goes beyond a mere description of the links between social, economic, agronomic, hydrological and meteorological processes.

The means by which the quantitative exchange of information is pursued in the project is a set of dynamic models which capture all first order linkages between relevant processes in atmosphere, soil and water. In fact, it is the main scientific ambition to let the boundaries of the models coincide with physical boundaries of the Volta River watershed and not to depend on ad hoc assumptions about population growth, land use change, rainfall variability or hydropower demand. All models will be embedded in one shell which defines common interfaces and access to information pooled in a common database. With the exception of the interfaces, the models are independent enough to be developed, calibrated, verified and tested individually.

The dynamics in the project are addressed by dividing the research activities over three clusters: atmosphere, land use change, and water use and the definition of interfaces for exchanging information. The research activities within each cluster are undertaken by a small interdisciplinary team. It is expected that by concentrating the information exchange between disciplines in small groups, scientific problems between these disciplines will be addressed and solved at the on-set. Final project integration will take place by connecting the clusters through the well-defined, simply structured interfaces.

Each of the three clusters treats one important water redistribution complex, but between the clusters, the levels of manageability differ. The behavior of the atmosphere can not be managed although it is directly affected by macro-developments world-wide, which are treated as given externalities. Land cover and use, soil surface and vegetation, are managed but usually with the objective to obtain a crop and not with the objective to interfere in the hydrologic cycle. The application of management tools is restricted. Irrigation development, hydro-power dams and groundwater withdrawal are, however, the direct outcome of human intervention in the natural flow of water. Subsequently, the role of the social sciences increases from almost nil in the atmosphere cluster, to supportive in the land use cluster, and to dominant in the water use cluster.

The main variables which are modeled over space and time are:

1.Precipitation

2.Actual evapotranspiration

3. Agricultural production

4. Land use and land cover

5. Population dynamics (including growth and urbanization)

6. River flow

7. Water use

8. Hydro energy

9. Health

10. Technological development and

11. Institutional development

Variables 1 through 8 are endogenous variables, which will be modeled within the project. They are a function of other endogenous variables, and give dynamic feedback. Variables 9 through 11 are exogenous, with 9 being an output variable and 10 and 11 input variables. It is also realized that the three exogenous variables should ideally be produced and treated as endogenous variables but present state of knowledge inhibits such treatment. Consideration of the exogenous variables is a direct result of the project and gives social meaning to the project as a whole. Each sub-project produces output needed either by other sub-projects as variables for further calculation or as a variable for the whole model. Figure 1.1 shows the general structure and correlations between the sub-projects with each arrow representing major information input.

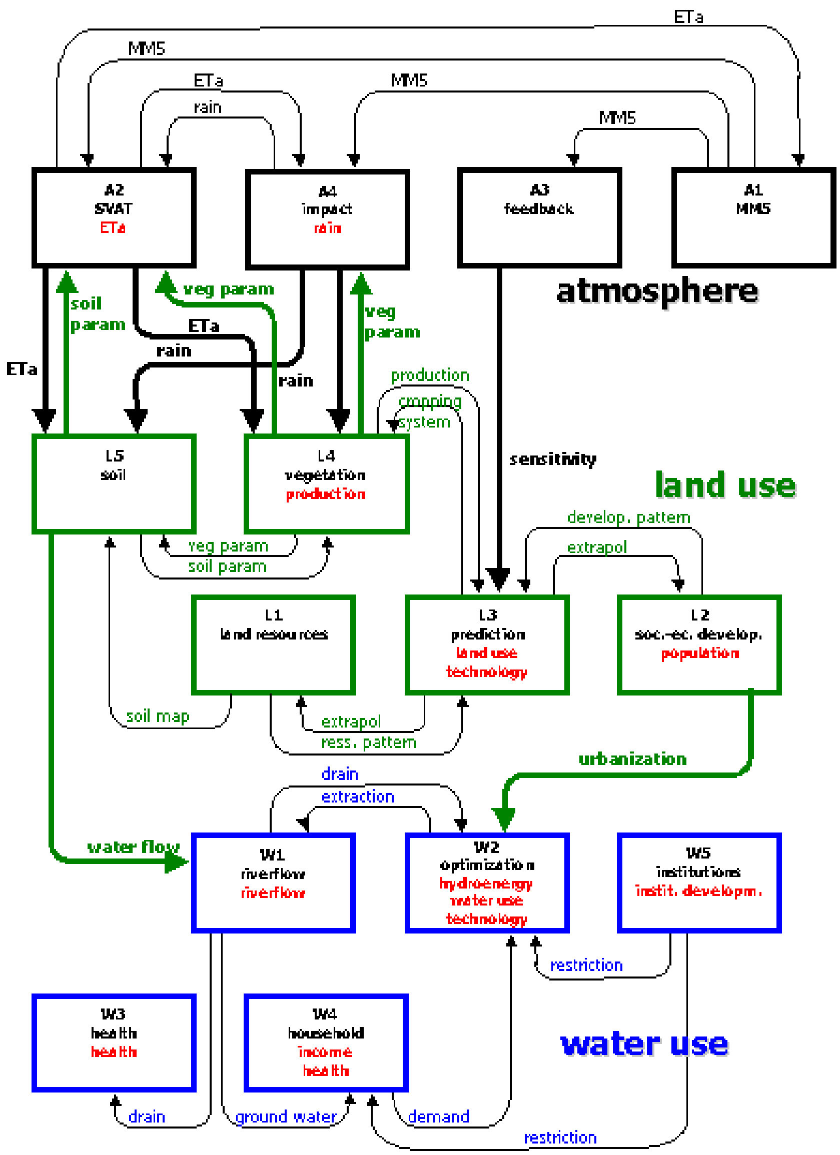

Figure 1.1: General structure of the GLOWA Volta Project

1.1.2 Population and land use/cover sub-project

Land is a very important asset and a means to sustain livelihood. It is the key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage. Land is a fundamental factor of production, and through much of the course of human history, it has been tightly linked to economic growth. It is described as comprising biophysical qualities such as soil, topography, climate, geology, hydrology, biodiversity and political divisions. Land is also defined as consisting of such socio-economic factors as technology and management.

In the face of a rapidly growing global population, an increase in technological capacity and affluence, the Earth's land cover has been transformed especially in developing countries. At the same time, social organization, attitudes, and values have also undergone profound changes. In contemporary times, issues of sustainable development, pollution prevention, global environmental change and related issues of human-environment interaction have been a major concern of the global scientific community as well as of citizens and policy makers of the world. This concern has largely been sparked by the phenomenon of global warming and its consequences, which are threatening the very existence of humans on the surface of the earth.

In understanding global environmental change, a consideration should be made to the conditions and changes in land cover engendered by changes in land use; the rates of change in the conversion, modification and maintenance processes of use and the human forces and societal conditions that influence the kinds and rates of the processes. The social and economic implications have only recently gained recognition and it must be mentioned that this area of scientific enquiry is currently the focus of a joint international research effort of the International Geosphere-Biosphere Program (IGBP), and the International Human Dimension Program (IHDP) on Global Environmental Change as well as numerous scholars (e.g., Geoghegan et al., 1998; Lambin et al., 1999; Green and Sussman, 1990).

Even though remote sensing is not a new technology, since aerial photographs have been in widespread use for a half-century (Carls, 1947) and satellite images for a quarter-century (Estes et al., 1980), remotely sensed data have been observed to have potential scientific value for the study of human-environment interaction, especially land use/cover changes and have therefore been identified as a useful tool to aid the process of understanding human-environment interaction (Turner II et al., 1993; Dale et al., 1993).

Furthermore, remote sensing and global positioning systems (GPS) have given rise to the advent of more precise and geographically referenced data on cover and use of land, which in turn have created opportunities for improved assessments and analysis. With the aid of these new data, researchers can now start to unravel the processes that drive the cycle of land use change and resource degradation.

In the past, technology and routines of data collection and management of the Earth's surface and atmosphere from planes and satellites have been developed primarily for the earth science community. However, in recent times, the National Aeronautics and Space Administration (NASA) has been paying increased attention to the potential value of remote sensing data for useful social purposes such as making crop forecasts, predicting severe storms, and planning land development.

Despite the apparent usefulness of remotely sensed data for social purposes, Rindfuss and Stern (1998) are of the opinion that remotely sensed images have not been a popular data source for social science research. Their reasons are that, firstly, the variables of greatest interest to many social scientists are not readily measured from the air. Many social scientists find visible human artifacts such as buildings, crop fields, and roads less interesting than the abstract variables that explain their appearance and transformation. Secondly, social science is generally more concerned with why things happen than where they happen. Even areas of social science in which one might expect a spatial orientation are curiously aspatial (Faust et al., 1997).

Despite the potential of the use of combining remote sensing and socio-economic study, a major challenge faces the remote sensing and geographic information systems (GIS) community. The problem is to link people to pixels, and to do so at the appropriate spatial and temporal scales, so that the behavior of individuals, households and communities can be linked to changes in land use/cover and to the population, biophysical and geographical processes that serve to define the landscape in terms of composition and spatial organization and their changes over time and space.

Ghana has a surface area of about 238,533 km^2. In 1921, the country had a population of 2.2 million, which almost doubled within a period of 27 years, reaching 4.1 million in 1948. The population from then increased rapidly between 1948 and 1960, rising to 6.7 million. The 1970 census put the country's population at 8.6 million while in 1984, 12.3 million people were counted in the country. By the year 2000, Ghana's population had reached 18.9 million. The annual growth rate of the population has been recorded to be 2.4% during 1960-1970, 2.6% in 1970-1984 and 2.7% between 1984 and 2000. Ghana's population can therefore be said to have grown at a high rate of

2.6% since 1960 (Ghana Population Census Reports, 1921, 1948, 1960, 1970, 1984 and 2000; Population Impact Project (PIP), 1994; Obeng, 1990).

The current rate of population growth suggests that Ghana's population would double within the next 26 years and there is therefore little or no sign to show that Ghana's population growth rate has declined in recent times. Due to rapid population growth, population density rose from 28 persons per km^2 in 1960 to 39 persons per km^2 in 1970. In 1984 it was 51 persons per km^2 and in 2000 it had reached 79 persons per km^2.

The high rate of population growth has been mainly due to a moderately declining fertility and declining mortality since 1970. Total fertility rate (TFR) has declined from a high of around 7 children per woman in the 1960s (Ghana Statistical Service (GSS), 1980) to 6.4 in 1988. In 1993, TFR was recorded as 5.5, which has further declined to 4.6 in 1998, i.e., a reduction of almost two children per woman within a period of 10 years. Cultural beliefs and practices that encourage large family sizes are mainly responsible for the fertility rates among different population sub-groups in the country. Due to the issues mentioned, the crude birth rate (CBR) has been high at about 45 per 1000 population in the 1960s and 1970s with marked declines observed only during the 1990s.

Mortality trends have also shown some steady improvements over the years. Infant mortality has declined from a level of 77.2 in 1988 to 66.4 and 61.2 per 1000 live births in 1993 and 1998, respectively. Child mortality has similarly declined from 84.0 in 1988 to 56.8 per 1000 live births and 52.4, respectively, in 1993 and 1998. In the same way, overall under-five mortality, which was 154.7 per 1000 live births in 1988, declined to 127.4 in 1993 and 110.4 in 1998 (GSS, 1988, 1993 and 1998). This has all culminated in a steady decline in the crude death rate (CDR). CDR, which stood at about 23 per 1000 population in the 1960s, steadily declined to as low as 8 per 1000 population according to the 1998 Ghana Demographic and Health Survey (GDHS) report. The fertility and mortality situation in the country discussed implies that the natural population increase has shot up following a widening gap between fertility and mortality.

As far as migration is concerned, the trend and pattern in the country during the 1960s was more of rural-rural movements. This was a result of the cocoa *(Theobroma* *cacao)* boom, where most of the forest areas in the Ashanti, Eastern, Western and Brong Ahafo Regions became important receiving areas for migrants mainly for cocoa and other cash crop production. The pattern of internal migration, however, changed in the mid-1970s towards the cities and large towns. According to the 1984 population census, in terms of volume, internal migration has been 35.3% urban-urban, 25.3% urban-rural, 22.9% rural-rural, and 16.6% rural-urban.

On the international migration front, the contribution to Ghana's population growth has not been that much. Cross-border population movements between Ghana and its neighbors, i.e., La Cote d'Ivoire, Togo and Burkina Faso, have constituted the main sources of international migration in Ghana. Another aspect of this phenomenon is the crossing of herdsmen from the neighboring countries, particularly Burkina Faso, into Ghana with a large number of cattle during periods of drought. Finally, a number of refugees from the West African sub-region, particularly from Liberia and Sierra Leone following the civil wars in those countries, have also migrated to Ghana.

Ghana's economy declined in the 1970s and early 1980s resulting in the adoption of the Economic Recovery Program (ERP) and Structural Adjustment Program (SAP) in 1983. The country's economy recorded an average Gross Domestic Product (GDP) growth rate of 5 per cent after the inception of the ERP. In recent times, however, GDP growth has fallen below 5 per cent. For instance in 1998, the GDP growth rate was 4.7 per cent while in 1999, the 2000 Budget and Financial Policy of the Government of Ghana put it at a further reduced rate of 4.4 per cent.

The percentage of the population defined as poor relative to the higher poverty line by the Ghana Living Standards Survey (GLSS) is 31 per cent. This is compared with figures in the 1987/88 and 1988/89 surveys, which were 37 and 42 per cent respectively (GSS 1996). In 1991 and 1992, the incidence of poverty was lowest, and showed one-third of the Ghanaian population being classified as poor relative to the higher poverty line and one-sixth relative to the lowest poverty line. Generally, the poverty rate in Ghana was estimated to be 35.7 per cent in 1998/99.

The rapid population growth rate currently being experienced in Ghana, coupled with the deteriorating economic situation mentioned above, has consequences on land use. This study, a sub-project of GLOWA belongs to the land use cluster, and will look at the relationship between population dynamics and agricultural and forest land uses in the Volta Basin of Ghana, using a combination of remote sensing and geographical information systems (GIS) on the one hand, and socio-economic surveys on the other. The study is connected with other sub-projects shown in Figure 1.1 to attain the broad objectives of the GLOWA Volta Project.

1.2 Statement of the problem

Rapid population growth and low economic standards of living in Ghana have brought in their wake numerous consequences for agricultural land and forest resources. As Benneh and Agyepong (1990) put it, the three factors that have contributed to greater competition for land, hitherto covered by trees and are now devoid of vegetation, include demographic pressures (see also World Bank, 1992). In their opinion, as population increases, so does the need for land, to expand settlement infrastructure and other utilities.

Furthermore, there has been increasing use of fuelwood in both urban and rural areas in Ghana, as it is the cheapest form of energy. Faced with development constraints, including low incomes, shifts from the use of fuelwood to use of cleaner fuel alternatives such as electricity, kerosene, and Liquefied Petroleum Gas (LPG) have not been possible. While large areas continue to be depleted, the trend of fuelwood use has been increasing in Ghana. Between 1966 and 1975, countrywide fuelwood consumption increased at the rate of 5.8 per cent per annum (Ardayfio-Schandorf, 1986).

A 1988 study of charcoal production and use in Ghana indicated that over 500,000 metric tonnes of charcoal is consumed annually (Nketia, et al., 1988). This translates into more than 3.6 million tonnes of wood extracted each year from forests and farmlands for charcoal production. Corresponding estimates for fuelwood consumption indicates that an annual total of 5.83 million tonnes of wood is cleared. Put together, the total amount of wood cleared to meet Ghana's annual fuelwood needs is equivalent to over 650,000 hectares of forest land (ERG Bulletin 1989).

Furthermore, Benneh and Agyepong (1990) estimated an annual domestic consumption of 5,547,200 m^3 of fuelwood and 1,992,400 m^3 of charcoal in Ghana. Alhassan (1993) also found that per capita fuelwood consumption in Ghana in both urban and rural areas was increasing, from 485 kg per capita in 1980 to about 525 kg per capita in 1993. These figures are well above growth of wood stock (Tufour, 1989) and deforestation and energy problems could even get higher with time unless the trend is halted. It was estimated that Ghana's forests were depleting at an alarming rate of 22,000 hectares per annum until the 1980s (Obeng, 1990) which has continued till recent times. In the opinion of Nketia et al., (1988), Ghana's dependence on fuelwood is a large factor behind the deforestation witnessed in recent times.

Due to wasteful and uncontrolled forms of logging in Ghana, the country is increasingly under the threat of desertification. The northwestern section of Upper West Region, the eastern half of Northern Region and parts of Upper East Region are at the highest risk. Furthermore, deforestation has led to increased soil erosion and loss of reliable water supply, all of which has brought about a marked decrease in agricultural productivity and a lowering standard of living among the population.

As a result of rapid population growth, conflicts over land have been rife in Ghana, assuming various dimensions from minor conflicts between individuals and families to large scale ones between ethnic groups. The northern parts of the Volta Basin in Ghana constitute an area plagued with ethnic conflicts. Bloody conflicts, which have brought in their wake devastation of groups of people and in some instances desolation of entire settlements, have raged between Nanumba and Konkomba (1980), Gonja and Vagla (1984), Konkomba and Bimoba (1990) and Nawuri and Gonja (1991).

The loss of lives and property that is associated with such conflicts over land places a great socio-economic burden on the nation's scarce resources and, consequently, hampers development. Finally, migration to urban centers is another effect of rapid population growth.

All the evidence presented makes it worthwhile to investigate the relationship between population and land use. Specifically, to ascertain what role population has played in agricultural and forest land uses in the past and is playing now in contemporary times in the five sub-basins of the Volta River in Ghana (White Volta, Black Volta, Main Volta, Oti and Daka). Furthermore, to predict what effects changes in population would have on the above two land uses in the future. An analysis has also been done at the district level and it considers the effect of demographic and non-demographic factors on agricultural land use. The Kassena Nankana and the Ejura-Sekyedumase Districts representing the upper and southern sections of the Volta basin, respectively, were selected for the district level study because they are two of the three pilot study sites for the entire Volta GLOWA project. The third pilot study site, the Tamale area, was excluded from this study, because it has similar agro-ecological conditions to those of the Kassena-Nankana District. The study will not only add to the knowledge of driving forces behind land use changes at a regional scale, but will ultimately assist in the understanding of global environmental change.

2 LITERATURE REVIEW

Land use and land cover change and the factors that drive them are subjects of global concern as they affect global climate change. They have thus in recent times been the themes of a number of studies (Kummer and Turner, 1994; Skole, et al., 1994). Airborne and satellite remote sensing data have been proven to be one of the best techniques for monitoring forest clearing, shifting cultivation, and land use conversion patterns (Fearnside, 1986; Sader and Joyce, 1988; Sader, 1995; Sader et al., 1990, 1994, 1996; Skole and Tucker, 1993; Ehleringer and Field, 1993; Foody and Curran, 1994; Fox et al., 1995; Michener, 1994; Quattrochi and Goodchild (eds), 1997; Rosswall et al., 1988; M. Turner, 1990; M.Turner et al., 1995; and Woodcock and Strahler, 1987).

It has therefore been identified as a technique that can be partnered with socio-economic surveys on the ground and population censuses, as well as with other biophysical information gathering techniques, to bring about a better understanding of land use/cover dynamics and the factors that bring them about. The following is a review of some of the studies and projects that have been carried out in this new area of scientific enquiry.

2.1 Global situation

Extensive studies on the human dimensions of global change have been undertaken by the Land Use/Cover Change (LUCC) project of the International Geosphere-Biosphere Program and the International Human Dimension Program on Global Environmental Change. These studies have focused largely on indirect linkages between information embedded within spatial imagery and the core themes of the social sciences as highlighted by Behrens et al. (1994); Ehrlich et al. (1997); Fischer and Nijkamp (1993); Martin (1996); Massart et al. (1995); Sample (1994); Frohn et al. (1996); Guyer and Lambin (1993); Wear et al. (1996); Bockstael (1996); Bell and Bockstael (1997); Bawa and Dayanandan (1997); Rahman and Csaplovics (1999).

The Nang Rong District of Thailand has been an area of intense study using remote sensing images and socio-economic analysis. It is a district where major changes in land use have occurred over the past several decades, paralleling social, economic, and demographic change (Siamwalla et al., 1990; Panayotou and Sungsuwan, 1989;

Phantumvanit and Sathirathai, 1988; Tambunlertchai, 1990). Entwisle et al. (1997 and 1998), for example, concluded that population growth has led to an extensification of agriculture in the Nang Rong District and Rindfuss et al. (1996) found out that land fragmentation encouraged out-migration of young adults during 1984 – 1994.

The Amazon Region has also been intensely studied with the combination of data produced by conventional social science methods with satellite-generated information on a particular scene (Brondizio, 1996; Moran et al., 1994; Moran and Brondizio, 1998; Millette et al., 1995; Mausel et al., 1993; Skole and Tucker, 1993 & 1996; Wood and Skole, 1998; Skole, 1992; Behrens et al., 1994).

Skole and Tucker (1993 and 1996), for example, concluded that tropical deforestation increased from 78,268 km^2 in 1978 to 230,324 km^2 in 1988, which implied an annual average rate of deforestation of 15,000 km^2 during the period 1978-1988, while Wood and Skole (1998) found out among other things that an additional person in an already populated area will have less of a marginal impact on land clearing than an additional person in a sparsely populated area. The reason being that land cover change is more related to the number of new arrivals in rural places. Finally, it is important to mention that Behrens et al. (1994) discovered that sendentism and the market opportunities that promote it seem more important factors of land-use intensification and tropical deforestation among contemporary native Amazonians than population growth itself.

The Peten Region of Guatemala is another significant area in which a combination of remote sensing/GIS techniques and a socio-economic survey has been applied in order to study deforestation rates (Canteo, 1996; Sever, 1998; Schwartz, 1990; Sader et al., 1996). Canteo's (1996) study recorded that until 1970, nearly 90 per cent of the Peten Region of Guatemala remained forested. However, over half of the forest has been cut by 1996, and he predicted that if deforestation continued at the rate it was at the time, only two per cent of the Peten's forest would remain by the year 2010. Sever (1998), too revealed that the ratio of clear-cutting to mature forest has been increasing during the period 1986 and 1995, and that the highest forest-cutting ratios were associated with the construction of new roads and increases in migrating settlers. Finally, Schwartz (1990) documented that between 1960 and 1986, the Peten Region experienced a population increase of 1,100% and used satellite imagery to demonstrate that between 1986 and 1995, human migration and deforestation continued to accelerate.

The combination of socio-economic surveys and the use of satellite imagery for land use/cover studies have also been carried out in other parts of the world apart from the regions mentioned. A review by Turner et al. (1995), for example, shows that many researchers have found strong links between the external sector (international commodity prices and exchange rate dynamics, or El Nino/Southern Oscillation phenomena) and changes in land use or land cover, such as forest biomass or cropping schedules.

Perhaps the most extensive studies in Africa as far as socio-economic factors of land use and cover change are concerned are the ones by Guyer and Lambin (1993), Mertens and Lambin (1997) and Mertens et al. (2000). While Guyer and Lambin (1993) combined household and remote sensing data to assess the level of intensification of farming systems in Nigeria and the relative role of two major drivers of land use change, i.e., population pressure and urban market expansion, Mertens and Lambin (1997) identify at least six spatial patterns of land use/cover change in Eastern Cameroon that are indicative of market, subsistence, policy and urbanisation processes. Finally, Mertens et al. (2000) demonstrated that macroeconomic changes affecting Cameroon have played a fundamental role in the way land-use practices influence the forest cover. This is because observations reveal that the beginning of the economic crisis in 1986 is associated in time with a strong increase of the deforestation rate related to population growth, increased marketing of food crops, modification of farming systems, and colonization of new agricultural areas in remote forest zones.

In every area of scientific enquiry, there are bound to be some differences in opinion, and this relatively new area of enquiry has not been an exception. This is borne out of the fact that, whereas some researchers have postulated a straightforward link between population levels (or rates of change) and deforested area (or deforestation rates), but argue that such relationships typically explain no more than 50% of the variance in forest cover across diverse regions, and commonly disappear in place specific analysis (Mather, 1996; Kasperson et al., 1995), others have concluded that population growth and land cover change are strongly correlated (Allen and Barnes, 1985; Rudel, 1989; Reis and Guzman, 1992; Pfaff, 1997).

Finally, Veldkamp and Fresco (1996a) have formulated a dynamic model to simulate Conversion of Land Use and its Effects (CLUE); the model has been applied to Costa Rica (Veldkamp and Fresco, 1996b, 1997a, 1997b), Ecuador (Koning et al., 1999), China (Verburg and Veldkamp, 1997, Verburg et al., 1997 and Verburg et al., 1999a), as well as the island of Java in Indonesia (Verburg et al., 1999b).

The literature reviewed at the global level has resulted in useful lessons that have guided this study and these are discussed below. The first issue to be mentioned is the methodological approach. It became clear from the literature review that merging the satellite and census data into a single data could be the most challenging aspect of the study. Thus, the techniques used by most of the researchers have been noted and adopted for this study. For instance, there is the need to aggregate the land cover data to conform to the boundaries of each district or municipality that would be used; this methodology has been explicitly employed by Skole (1992) and other researchers.

Another issue with regard to the methodology is the fact that most of the studies used multi-temporal remote sensing data as well as time series socio-economic surveys or longitudinal household surveys for the analysis. Even though this methodology could bring out extensive results, since it traces the evolution of the dynamics in the various variables considered in the study, this study considers only two points in time due to resource constraints.

The final issue to be mentioned on methodological lessons learnt from the literature review is the appropriate sample size that could be considered for a study of this nature. Mertens et al. (2000), for instance, used survey data covering 552 households in 33 villages in the east province of Cameroon. Considering the fact that the study by Mertens et al. (2000), was more extensive than this one, the sample size used guided this study, which used survey data covering 504 households in 21 villages.

The next lesson learnt concerns the factors (sometimes described as the driving forces in the literature) that affect land use/cover change. Several factors were mentioned by the researchers, and these include population change including rates of growth and decline, population composition, agricultural technology and practices used, land tenure which could result in land fragmentation, marketing opportunities for farm products, development policies evident in credit and tax incentives, infrastructural development, mining exploration activities, and selective logging. The others are land development or preservation policies, external sector influence in the form of international commodity prices and exchange rate dynamics and macroeconomic policies.

Finally, other physical/natural/environmental factors which influence land use/cover change have been mentioned in the literature. Some of these are climate (sunshine, precipitation, and temperature), geomorphology (altitude, and slope), soil (fertility, drainage, permeability, texture), and geology. However, these physical variables will not be considered in this study as they will form the central variables in other sub-projects of GLOWA. This study will, therefore, only concentrate on the population dynamics and the socio-economic variables that influence land use/cover change in the Volta Basin of Ghana.

2.2 Ghanaian situation

As far as Ghana is concerned, prior to 1901, there were only few survey and mapping activities. The first survey department, the Mines Survey Department, was established in 1901, but the Survey Department itself was set up in 1908 (Abu and Brimah, 1989). Aerial photography can be said to have begun in Ghana in earnest about 1946 with coverage of a small area on the dip slopes of the Kwahu Scarp around Abetifi by the then Royal Air Force.

According to Amatekpor (1999), a land use map of Ghana was not available until 1998. In his opinion, the land use map of Ghana, which was available in 1959, was not only obsolete, but also of little or no value for intensive land use planning. He further mentioned that the development of remote sensing and geographic information systems technology has enabled Ghana to complete in 1998 a detailed land use/cover map of the whole country at a scale of 1:250,000 under the Ghana Environmental Resource Management Program (GERMP).

Until 1956, only small areas (south-western coast, Nsaba cocoa growing area and parts of Mamprusi) were covered mainly for specific investigation such as oil exploration, agricultural census and land use planning. However, since 1972, satellite remote sensing coverage of Ghana has been available (Agyepong, 1989), and remote sensing technology has been applied to a great deal of natural resource management research in Ghana.

Some of these are soil resources inventory (Asiamah, 1989, Asiamah and Senayah, 1989, Agyili, 1989); water resources research (Amuzu, 1989); forest inventory (Agurgo, 1989); disaster management (Kyem, 1989); land use inventory and mapping (Yankson, 1989, Allotey, 1989, Kufogbe, 1999, Duadze et al., 1999, Alhassan, 1999); environmental monitoring (Amamoo-Otchere, 1989); vegetation survey (Titriku and Anku, 1989, Blankson, 1989); geological problems (Adjei, 1989); rainfall calibration (Kakane and Hooijer, 1999); road map updating (Mensah and Nyamekye, 1999); and groundwater exploration (Banoeng-Yakubu, 1999).

Although this began later, Ghana has also benefited from the combination of remote sensing/GIS technology and socio-economic studies. For example, Benneh and Agyepong (1990) used a combination of the two methods to conclude that population increase, development policies, urbanization and settlement expansion, logging, agricultural land use including fuelwood demands, have among others contributed to greater competition for land, leaving areas formerly covered by trees devoid of vegetation and subsequently leading to fuelwood scarcity.

Kufogbe (1999) on his part carried out a digital analysis of time sequential SPOT-XS images and the Makov chain model to assess the changes in the land use/cover over the period 1988 and 1994 in the Afram plains of Ghana. His results indicate that the dominant land cover comprises wooded savanna and transition forest. According to him, deforestation in the plains is indicated by various stages of forest re-growth, which have been associated with decline in cocoa cultivation from the beginning of the 1980s. Finally, Allotey (2000) concluded that there was evidence of changes in the agricultural land use in the Akwapim South District during the period 1972/74 to 1991.

It can be seen from the literature review of Ghana, that remote sensing techniques and the use of satellite imagery for scientific studies started quite late in Ghana. However, despite this setback, it has been shown that remote sensing has been used extensively in Ghana for various studies. A closer assessment of the situation in Ghana shows that very few studies combining remote sensing/GIS techniques and socio-economic surveys to study land use/land cover changes, which is the methodological approach of this study, have been conducted in the country. Even more, only one study, i.e., the one by Benneh and Agyepong (1990), considered the role population dynamics play in the land use/cover changes in the study areas, the central theme of this study. They found out that population increase among other factors contributed to greater competition for land, and subsequently loss of vegetative cover in some parts of the country.

Moreover, as far as the spatial coverage is concerned, the study by Benneh and Agyepong (1990) covered the entire country. However, the literature review showed that it is important to concentrate on smaller areas in studies of this nature in order to bring out the complex interactions that exist between population and socio-economic and land use/cover dynamics, and this is the methodology adopted by this study. This study concentrates on a study area each from the transitional ecological zone, namely the Ejura-Sekyedumase District and the Northern Savanna zone, the Kassena-Nankana District.

The studies by Benneh and Agyepong (1990) considered one specific point in time and did not take into account the temporal dimension of the problem. From the extensive literature review conducted, it has clearly emerged that population and land use variables are very dynamic, and most of the studies have therefore considered different periods in the analyses in order to trace the evolution of these variables. This study will, therefore, give an added advantage to the situation in Ghana due to the fact that it considers two different periods.

3 POPULATION AND ENVIRONMENT NEXUS: THEORETICAL AND CONCEPTUAL ISSUES

3.1 Land use and land cover definitions

Land is a very important asset and has been defined as a means to sustain livelihood. Blum (1998) is of the opinion that land has at least six functions. These are production of biomass food, fodder and renewable energy upon which the very existence of human life depends, filtration, buffering and transformation capacity (of the soil) between the atmosphere, biosphere and hydrosphere, biological habitat, and gene reserve (protection). The other functions are spatial-based for technical and industrial structures and social infrastructure necessary for development, source of raw materials (e.g., clay, minerals such as gold, bauxite and diamond), as a source of energy (petroleum hydrocarbons), and reservation of cultural heritage concealing paleontological and archaeological treasures.

Land use has been defined to be the predominant purpose for which an area is employed (United States Department of Agriculture (USDA), Forest Service, 1989), the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Di Gregorio and Jansen, 1997; Jansen and Di Gregorio, 1998), the way in which, and the purposes for which, humans employ the land and its resources (Meyer, 1995; Mather, 1989), and the purpose to which land is put by humans (e.g., protected areas, forestry for timber products, plantations, row-crop agriculture, pastures, or human settlements) as reported by Turner and Meyer (1994).

Land cover on the other hand has also been given several definitions by researchers and institutions. Some of these include that which overlays or currently covers the ground, especially vegetation; permanent snow and ice fields; water bodies or structures (USDA Forest Service, 1989); the observed (bio) physical cover on the Earth's surface (Di Gregorio and Jansen, 1997, 1998, Jansen and Di Gregorio, 1998); and the ecological state and physical appearance of the land surface, e.g., closed forests, open forests, or grasslands (Turner and Meyer, 1994).

3.2 Population and environment nexus: Theories.

Human activities that make use of, and hence change or maintain attributes of land cover, are considered to be the proximate sources of change (Turner et al., 1993; Skole & Tucker, 1993). They range from the initial conversion of natural forest into cropland to on-going grassland management. Such actions arise as a consequence of a very wide range of social objectives, including the need for food, fibre, living space, and recreation. They therefore cannot be understood independent of the underlying driving forces that motivate and constrain production and consumption.

Some of these, such as property rights and the structures of power from the local to the international level, influence access to or control over land resources. Others, such as population density and the level of socio-economic development, affect the demands that will be placed on the land, while technology influences the intensity of exploitation that is possible. Still others, such as agricultural pricing policies, shape land-use decisions by creating the incentives that motivate individual decision-making.

Due to the increasing realization of the importance of land, the biophysical and economic drivers of land use change as well as societal responses to changes in land cover have been the subject of numerous studies in the past few years (Veldkamp and Fresco 1996a & 1996b; Archard et al., 1998; Moran et al., 1998; Fischer et al., 1996).

Models that link population and environment can broadly be classified into five, namely, the linear, multiplicative, mediating, development-dependency and complex systems perspectives.

3.2.1 Linear perspectives

The Malthusian and Boserupian views could be described as the linear views and they emphasize the reciprocal, linear, and direct relationships, which exist between population and the environment.

3.2.1.1 Malthusian view

This view analyses population growth as a threat to the inherent limit of arable land to provide food, shelter and sustenance. It argues that food production could only grow at an arithmetic rate compared to population that grows geometrically. Thus, population growth would ultimately outstrip the capability of any economy to meet the demand for food, owing to the ecological constraints imposed by natural resources. It perceives that if preventive measures or checks are not put in place, poverty, disease, famine and war, which are social checks, would automatically place a check on population growth (Malthus, 1960; Brown et al., 1976; Ehrlich, 1968; Ehrlich et al., 1977; Eckholm, 1976; Hardin, 1968; Meadows et al., 1972 and 1992; De Sherbinin, 1993; Gilbert, 1999). It suggests that population demands thus place direct limits on the availability of resources and that resources, in turn, place a direct restriction on population growth. The Malthusian theory, formulated before the agricultural revolution, presumes that the productivity of environmental resources such as land is fixed.

In an extension of the Malthusian theory, Mortimore (1993) stated that increase in population density brings about a corresponding increase in the frequency of cultivation, and the shortening of the fallow period that is needed to rejuvenate soil fertility. As fallow length is reduced, soil fertility is bound to decline, and this leads to declining yields. Falling output is experienced, which eventually culminates in food scarcity. The problem of food scarcity subsequently leads to further increases in cultivation, leading to accelerated degradation, soil erosion and eventually causing environmental degradation. Farmers may migrate to work on marginal lands as a result of a decrease in arable land (Figure 3.1).

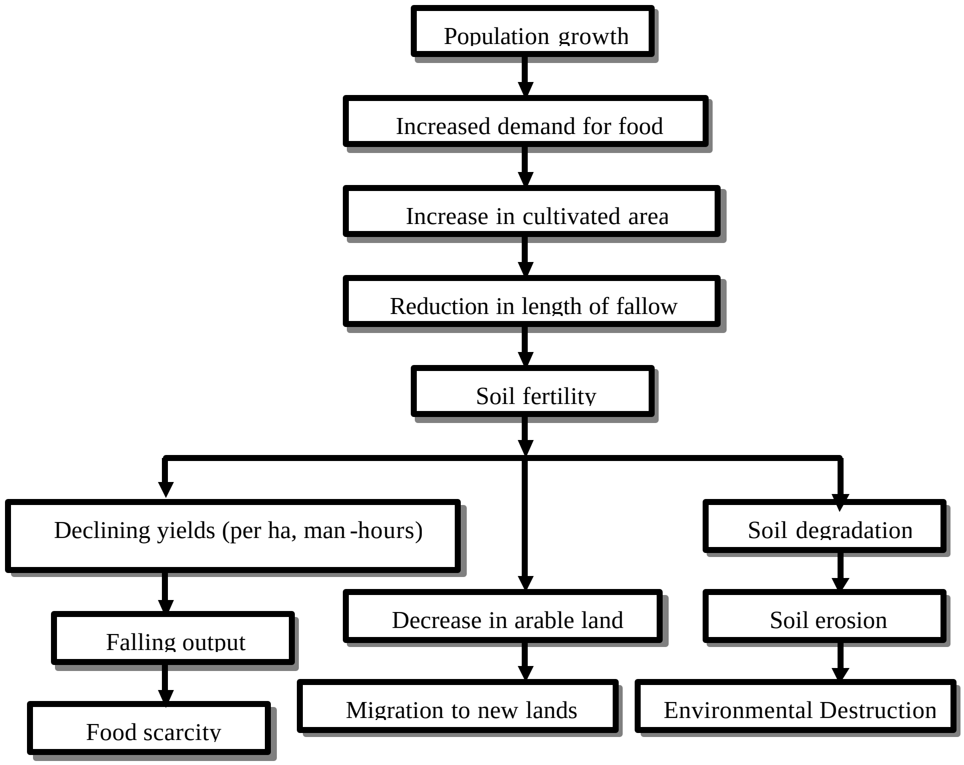

Figure 3.1: A Malthusian view of the link between population growth and environmental degradation

Source: Modified from Mortimore, 1993

3.2.1.2 Boserupian view

The Malthusian view did not foresee the important technological advances that have accompanied modernization. Writing after the agricultural and industrial revolutions, Boserup (1965, 1976 and 1981) takes this technological change into account. She suggests that increasing population pressure mostly leads to an increase in land use intensity. Thus, every population through technological innovations adapts itself to the best fitting land use system according to population density.

In her view, so long as an area has low population density, there will be room for long fallow periods, and required outputs for agriculture can be obtained without the investment of additional capital. However, in highly populated areas, there will be the need to sustain a large growing population, and this will culminate in the adoption of more intensive farming methods, which will require additional labour input per unit area. On the whole, even though this scenario will bring about a diminishing return on the labour and capital that have been invested, on the other side of the coin, it will bring about an increase in the total agricultural output.

Summarizing the Boserupian model, Lambin (1994) states that firstly, technological change (use of fertilizers, plough, terracing and multiple cropping) is impelled by increases in population. Secondly, intensive farming is characterized by low labor efficiency compared to extensive systems since increase in agricultural intensity (determined by increase in population density) leads to more than a proportionate increase in the amount of required labor.

Boserup's thesis has some critical limitations. First, it assumes, at least implicitly, that the farmers' objective is to maximise leisure (by maximising labour productivity) under the constraint that they meet their subsistence needs ("the law of least effort"). This is not always true, as many farmers in developing countries have exhibited profit-maximising behaviour.

Secondly, the scope of agricultural intensification in some systems can be very limited owing to intrinsic ecological constraints (Mortimore, 1993). This is the case for fragile soils of West Africa and Ghana for that matter, i.e., Leptosols and Plinthosols that are intensely leached. When there is no known feasible technology that the population can adopt, the carrying capacity of the ecosystem is outstripped and a Malthusian limit is reached. Apart from this, inefficient markets characteristic of the West African Region and lagged responses to population growth have exacerbated land degradation in the region. For instance, artificially low producer prices for agricultural products and lack of property rights in many countries in Africa have been identified as a disincentive for land resources conservation (Lele, 1989). Some of the empirical tests of Boserup thesis can be seen in Guyer and Lambin (1993); Turner et al. (1993); Pingali et al. (1987); and Simon (1981 & 1990).

Other factors that can impede Boserup's responses (land intensification process) in the face of increased population density include macroeconomic policies that discriminate against agriculture and distort market prices, land tenure systems which concentrate land ownership/access in certain groups, poor credit markets and lack of appropriate technology suited for tropical agriculture (Jolly and Torrey, 1993).

Both the Malthusian and Boserupian perspectives imply linear relationships between population and the environment. Social and natural scientists have, however, also introduced other non-linear ways of thinking about population-environment interrelationships. These non-linear views may consider the "multiplicative" effects between population and other factors (consumption or technology) in producing environmental impacts or, alternatively, the "mediating" effect that other factors (socio-economic, institutional and cultural) may have on population-environment relationships.

Population ecology and human ecology, which deal with questions of environmental carrying capacity, equilibrium and optimum population size, also reflect this perspective (Hawley, 1986; Drummond, 1975). The concept of carrying capacity presumes that there are critical levels of population that any given land area can support (Higgins et al., 1982; Cohen 1995 and Lutz 1991). This level or "carrying capacity" is determined by soil and climatic conditions and technological inputs (e.g., fertilizer and irrigation).

Critiques of the concept of carrying capacity have pointed out that it does not adequately account for the potential impact of technological change, aspirations for higher standards of living, possibilities for and effects of international trade, and institutional, social, economic and political constraints on land use and production (Mahar, 1985; Blaikie and Brookfield, 1987; de Sherbinin, 1993; Leff, 1993). Boserup (1965), in emphasizing the impact of technological change, also offered an implicit criticism of carrying capacity.

However, in response to those criticisms, Hogan (1992 and 1993) asserted that the concept of carrying capacity continues to have relevance as a heuristic device, and that recent attempts to calculate carrying capacities have more effectively taken into account variations in institutional and socio-economic factors. Hogan and Burian (1993) carried out a review of existing concepts of carrying capacity. They concluded that the concept represented an important tool for considering the relationship between population and sustainable development, if it can be extended to include other basic needs besides food (e.g., access to water) as well as access factors other than the natural distribution of resources (e.g., social, cultural and political constraints).

3.2.2 "Multiplicative" perspectives

Multiplicative perspectives present the view that population (size, growth, density and distribution) interacts in multiplicative ways with other factors, such as levels of consumption and technology, having impacts on the environment. One of the most frequently used multiplier approaches, is the "IPAT" equation. Total environmental impacts (I) are seen as a product of population size (P), the level of affluence or per capita consumption (A), and the level of technology (T) (Ehrlich and Holdren, 1971 and 1974; Harrison, 1992; Commoner, 1991 and 1992).

The IPAT equation implies that although population, consumption or technology might be considered as independent causes of environmental impact, it is their combined effect that is of most interest. The "IPAT" approach has been criticized on the basis that "P", "A" and "T" are, in fact, not independent as the equation implies, and that important political and institutional variables affecting resource use, for example, the distribution of land, are not accounted for (Shaw, 1993).

Shaw has proposed an alternative multiplicative conceptual scheme. In doing so, he distinguished between "ultimate causes," or the driving forces behind environmental impacts, and "aggravating factors." In the case of environmental degradation, ultimate causes are polluting technologies, high consumption levels, warfare, land and urban mismanagement policies, socio-economic institutions, and poverty (Shaw, 1989; Hogan, 1992). Population, in contrast, is viewed not as a cause but, rather, as an aggravating factor that multiplies the scale at which the ultimate causes of environmental degradation (polluting technologies, etc.) operate.

3.2.3 "Mediating" perspectives

Mediating perspectives emphasize that social, cultural and institutional factors play a mediating role in determining population-environment relationships. Social scientists are inclined to consider the impact of social, cultural and institutional factors on population-environment relationships, and much recent research implicitly or explicitly reflects this viewpoint. Blaikie and Brookfield (1987) and Bilsborrow (1987, 1992a and 1992b) emphasize the mediating role played by social, economic and institutional factors, in particular, that of policy and the state. The influence of those factors on population-environment relationships is viewed as multilevel so that layers of mediating variables at the household, community, national and international levels must be considered.

3.2.4 Development-dependency perspectives

Another perspective collapses all social, cultural and institutional factors that mediate population-environment relationships into the larger concept of 'development' and focuses on the way in which development processes mediate population and the environment relations. Emphasis is particularly placed on development trends, which have kept the south 'dependent' on the north, e.g., mercantile exploitation and export of natural resources towards manufacturing centers in the north.

This "dependency perspective" (Jolly 1991) stresses the overwhelming role that common international political and economic forces play in shaping both demographic factors such as population growth and environmental outcomes such as degradation in developing countries. This approach further suggests that even major global environmental problems (depletion of ozone, greenhouse effects, toxic waste accumulation and loss of biodiversity) are the direct results of the prevailing model of development (Martine 1992 and 1993). Duplication of this model in rapidly growing developing countries, as is the current tendency, is seen as compounding negative environmental impacts.

3.2.5 Complex system and adaptive strategy perspectives

An additional approach considers mediating factors as well as environment and population in a structured way or as a complex of interrelated systems. This approach aims to understand how ecological and human-driven systems (socio-cultural, demographic, and economic) dialectically interact and interconnect to form larger "socio-ecological systems" (Gallopin et al., 1988) within which population and environment relationships are embedded. Studies using this approach have addressed situations in which large-scale structural changes due to economic development processes have caused radical shifts in the existing relationships between human populations and ecological systems (Tudela , 1989).

Population ecology, human ecology and ecological anthropology, sub-disciplines within anthropology, have also drawn on ecological systems models in studying the interfaces between human-demographic, socio-economic, and natural systems (Ellen 1982, Hawley 1986, Lee and De Vore, 1976, Moran, 1982, Rappaport, 1968). Cultural ecology, another sub-discipline within anthropology, has focused more on micro-level (community and household-level) interfaces between human demographic dynamics, socio-economic organization, and natural systems in specific settings drawing on the biological concepts of niche and adaptation (Barth 1956; Bennett 1969; Fricke 1993; Netting 1968, 1981, 1986 and 1993; Scudder 1962; Stewart 1955; Wolfe 1966; Wilk 1991; Viazzo 1989). Figure 3.2 shows some conceptual approaches to the study of the population-environment linkage.

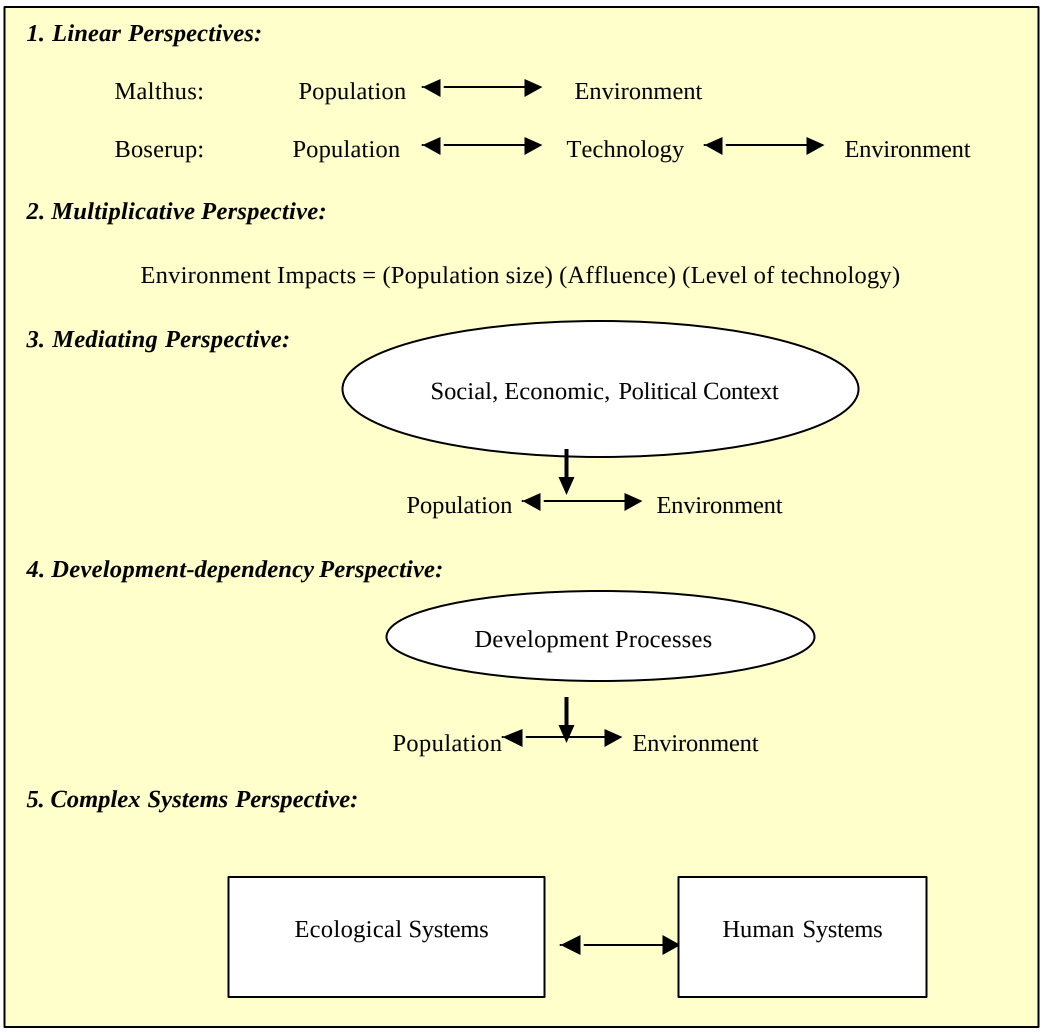

Figure 3.2: Some conceptual approaches to the population-environment nexus

Source: Marquette & Bilsborrow, 1997

3.3 Conceptual framework for the study

Based on the theoretical formulations and the literature review, the study adopts concepts from a combination of the linear, multiplicative, and mediating perspectives of the population and environment relationship. At the basin level, the underlying concept is to identify a direct linear relationship between three population variables, namely population size, population density and population growth rate on the one hand and the environment on the other, in this instance agricultural and forestry land uses (see Figure 3.3). The idea is to assess what specific role population plays in the two environments, assuming that all other factors affecting the environment remain constant. The reverse scenario, which is the effect of changes in the environment on population, was however not considered in this study.

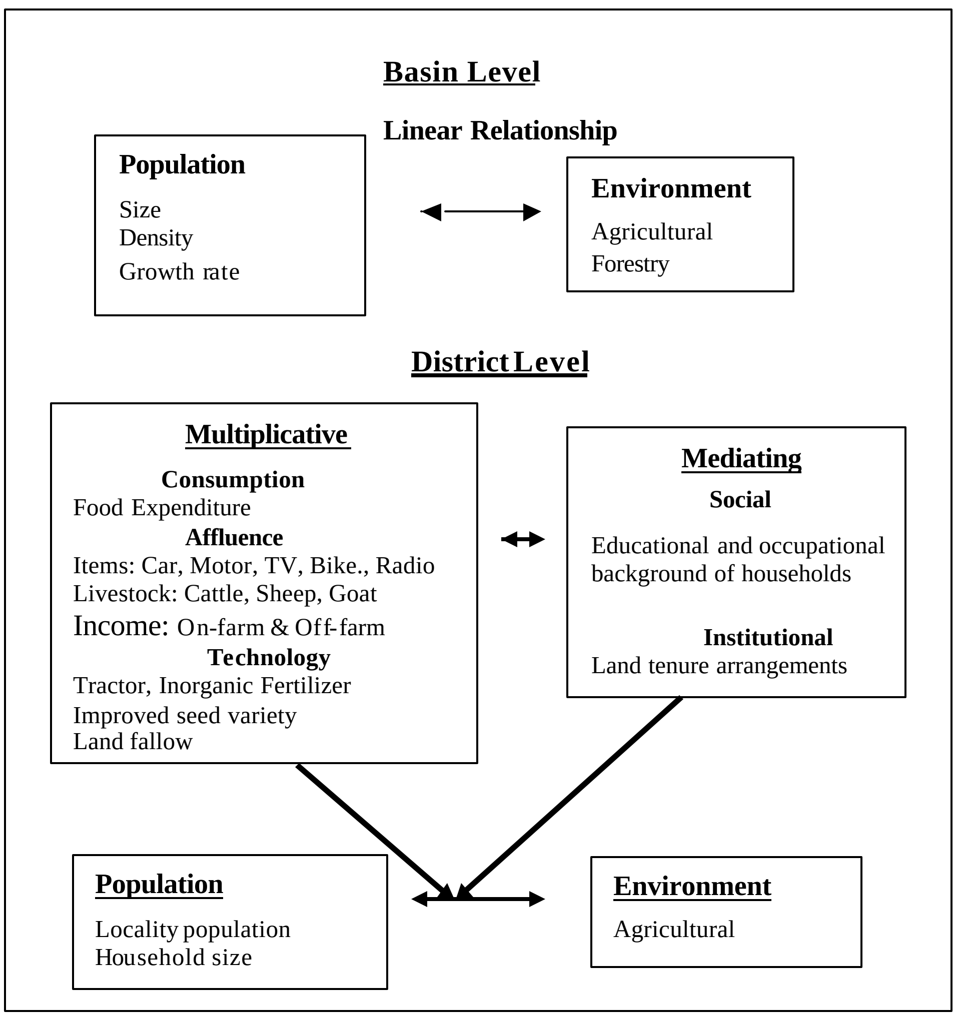

Figure 3.3: Conceptual framework for the study (Author's construct)

At the district level of analysis, the study incorporates concepts from the multiplicative and mediating perspectives to achieve a holistic understanding of the population and environment relationship. Firstly, the population in terms of its size in the locality as well as in the household was used for the study. It was conceptualized to interact with other factors, including levels of consumption (in the form of household expenditure on food), affluence (measured by ownership of certain household items like car, motorcycle, bicycle, television, and radio), income, in the form of monthly household off-farm income, defined as income from non-farm activities, as well as income from the sale of farm produce, and ownership of livestock, (namely, cattle, sheep and goat). It also interacts with the level of technology, which was measured by the use of advanced forms of agricultural inputs such as tractor, inorganic fertilizer and improved seed variety.

The study also employs the social and institutional concepts in the mediating perspectives in the study. The educational and occupational backgrounds of the household members who were considered, are viewed as social issues that interact with other factors in the population-environment relationship. Land tenure arrangements were considered as institutional issues embedded in the mediating view.

3.4 Objectives, goals and hypotheses

Based on the observations made in the literature review and taking into account the conceptual framework adopted, the study has five main objectives, which are to:

- assess the trend and pattern of three demographic variables (population size, population density and annual population growth rate) between 1960 and 2000, as well as their projections for 2010, in the five sub-basins of the Volta River in Ghana,
- assess agricultural land use in 1992 and 2000 and forest cover in 1990 and 2000 in the sub-basins,
- examine the relationship between the demographic variables and agricultural and forest land uses in the sub-basins between 1990 and 2000,
- predict the effect of changes in the demographic variables on agricultural land use and forest cover in 2010, and

- examine the effect of dynamics in population as well as certain socio-economic factors on agricultural land use in two districts (Kassena-Nankana and Ejura-Sekyedumase) of the Volta River basin in Ghana between 1984 and 2000.

These objectives were formulated as an increase in population could result in households having a lot of people to feed and thereby being compelled to either put more land under cultivation, thus increasing total cropped area or to practise agricultural intensification especially in areas where the growth in population also increases pressure on arable land resources.

On the other hand, a decrease in population will not bring pressure on land, and therefore, total cropped areas of households may be maintained or even decrease. Secondly, the quality of the population with respect to its educational attainment could also affect the size of the cropped area. It is envisaged that in areas where the population is well educated and has opportunities to work in more skilled forms of occupations, they may not take to farming, thus total cropped areas may not increase. This situation could arise even in the face of increased population growth.

With regard to the socio-economic factors, it is expected that households earning more from the sale of farm products may invest more into their farms and thereby increase the size of their farm holdings, while the opposite is expected of households with less income from farm products. This scenario could arise in areas where farmers practice subsistence farming, and sometimes do not grow enough food to feed themselves, and have to supplement with the purchase of food on the market. In such a situation, very little or sometimes no income may accrue from the sale of farm products to be reinvested in the farms to increase the cropped area. Furthermore, households with members who work in non-farming activities as primary or secondary occupations may earn additional income that might be used to support the farming activities of the household; an increase in total cropped area is thus envisaged in such households.

In addition, it is expected that households which use more modernized forms of agricultural tools, practices and implements may increase their yield and therefore increase the size of their cropped areas when compared to their counterparts who continue to use traditional tools and practices. Land tenure systems are also related to total cropped area in that in communities where the tenure system makes land accessibility very easy and flexible, there is a greater tendency to increase the cropped area than in areas where accessibility to land is difficult.

The study formulates the following hypotheses:

i. There is a positive correlation between population size and agricultural land use in all the sub-basins.

ii. The use of technologically advanced forms of farm inputs like tractor, inorganic fertilizer and improved seed variety has increased the amount of cropped area in the two study districts.

iii. Population is inversely related to forest cover in all the sub-basin.

4 MATERIALS, METHODOLOGY AND STUDY AREA

4.1 Sources and method of data collection

4.1.1 Basin level

4.1.1.1 Population data

The main sources of data for determining the size of the population in the sub-basins, and their subsequent projection are derived from the Population Census Reports of Ghana for 1960, 1970, 1984 and 2000. The Census Reports present information on population at the national, regional and local council levels. The Census districts (local/urban councils prior to 2000 and districts in 2000) therefore do not have common boundaries with those of the river sub-basins. The problem that confronted this study was how to aggregate a number of local/urban councils or districts to represent one river sub-basin, since the boundaries of the river sub-basins cut across a number of local councils or districts.

A map of the local councils of Ghana was superimposed on the river sub-basins map, to determine which local councils fall within each of the river sub-basins. The population of major settlements (urban settlements with population 5,000 or more as at 1984) was added to the sub-basin in which they are spatially located. Thus, having taken these major settlements and added them to sub-basins to which they are physically located, a uniform distribution of each local council's population was assumed and the relative proportions of its population calculated and added to the sub-basin in which it is located. On the other hand, the population of local councils that fully fall into one river sub-basin was added wholly to the river sub-basin in question without determining any proportions.

By using this methodology, the population of each river sub-basin according to the 1960, 1970, 1984 and 2000 Population Censuses was estimated to form the basis for projecting into the future. To achieve this objective, the proportion of the population of each local council or district falling into each river sub-basin was estimated. Then, the population growth rate for 1984-2000 in respect of each local council was assumed to remain relatively constant throughout the projection period (1984-2010). The population of each local council estimated to fall within each river sub-basin was projected using the population growth rate for the particular local council for 1984-

2000, and the total aggregated to form the total population for each river sub-basin at each point in time during the projection period.

Population projections were carried out for 1992, 2005 and 2010, using the annual inter-censal growth rate between 1984 and 2000. The inter-censal growth rate (r) between 1984 and 2000 was calculated as

$$r = 1/t \ln(P_2/P_1) \quad (1)$$

where P_1 is the population in the year 1984, P_2 the population in the year 2000 and t the time interval. Population estimates for 1992 were then derived using

$$P_{1992} = P_{1984} \cdot e^{tr} \quad (2)$$

The same procedure was used for deriving 2005 and 2010 population.

With the areas of the local councils known, the same procedure was adopted to determine the size of each river sub-basin in square kilometers. This facilitated the estimation of the population density for each river sub-basin relative to each local council during the projection periods.

4.1.1.2 Determination of forest cover using remote sensing

The forest cover information used in this study was derived from land cover and land use maps of 1990/91 and 2000, which were developed using Landsat Thematic Mapper (TM) satellite images (Agyepong et al., 1999 and Duadze et al., 2001). A visual interpretation by on-screen digitizing was employed for the 1990/91 land use/cover classification, while a supervised classification technique, which requires the selection of training areas for use as the basis for classification, was used for 2000. The Maximum Likelihood method was then used to determine if a specific pixel qualifies as a class member.

The entire Oti sub-basin, and about 50% of the local/urban councils that fall within the Main Volta sub-basin, were excluded from the analysis due to unreliability and unavailability of data, respectively. Furthermore, forest cover in this study is defined as areas with closed forest (more than 60% canopy covered), open forest (less than 60% canopy covered), riverine vegetation (luxurious vegetation found along river beds), as well as closed savannah woodland (more than 150 trees per hectare of land). Closed savannah woodland has been included as forest because, specifically speaking, there is very little forest found in the upper sections of the Volta River in Ghana. These areas are mainly in the dry savannah agro-ecological zone of Ghana.

The study did not differentiate between reserved forests (traditional groves, conservation and wildlife areas) and open-access forests. Neither did it differentiate between primary and secondary forest. All these categories were considered as forest. Riverine vegetation has also been classified as forests, because they have the characteristics of forests, only that they are mainly found along river courses.

4.1.1.3 Agricultural census data

Agricultural land use at the general basin level was measured by the total cropped area (hectares) of the major crops in the various sub-basins, namely maize *(Zea mays)*, rice *(Oryza sativa),* cassava *(Manihot esculenta),* yam (*Dioscorea spp.),* cocoyam *(Xanthosoma sagittifolium)*, plantain *(Musa x paradisiaca),* sorghum *(Sorghum bicolar),* millet *(Panicum colonum),* groundnut *(Arachis hypogaea),* okro *(Hibiscus esculentus)*, pepper *(Capsicum baccatum)* and tomato *(Lycopersicon esculentum)*. The data were derived from the Ghana Ministry of Food and Agricultural (MOFA) Censuses of 1992 and 2000.

4.1.2 Study district level

The main source of data for the study at the district level is primary. A structured and open-ended questionnaire was employed by the study and the administration of the questionnaires was by direct interview with the respondents. This technique was employed because the majority of the respondents had no formal education. Information collected included quantitative as well as qualitative data, since provision was made in the questionnaire for information relating to beliefs, values, and attitudes of respondents. According to McDowell (1996), quantitative approaches uncover trends and reveal relationships, and this will be very instrumental in assessing land use change. On the other hand, qualitative data help reveal the processes, values, and reasons of the patterns underlying the actions of human beings observed using other techniques.

The enumerators who undertook the exercise comprised males and females between the ages of 26 years and 35 years. They were made up of students of the University of Ghana, Legon, who were on vacation, and extension workers of the

Ministry of Food and Agriculture, Ghana. The extension officers were chosen because they have a lot of experience in the administration of questionnaires, and by the nature of their work, interacted on a daily basis with the respondents at all levels. The enumeration was preceded by a three-day orientation seminar and pre-test of the questionnaire, which was done in selected farming communities in the Greater Accra Region. The actual survey was carried out in November-December, 2001, in the Kassena Nankana District and February-March, 2002, in the Ejura-Sekyedumase District.

Enumerators visited households that had been captured in the sample sometimes on numerous occasions until universal coverage was made. During the entire duration of the enumeration, enumerators were tasked to probe for accurate information, most especially on total cropped area and socio-economic characteristics of household members. Where there were doubts on the responses given, enumerators were tasked to probe for items that could authenticate or validate the responses given. Some of these items included birth and baptismal certificates, voter identification cards as well as family records, which were instrumental in determining the accurate ages of household members. In situations where all the above-mentioned records were not available, enumerators were to help respondents in coming out with estimates, which might be close to the realistic ages of the respondents, using significant local and national events and the dates these events occurred.

4.2 Sampling procedure

An important component of determining the sample size of any study is how representative the sample size would be with regard to the total population being studied. Thus, a careful consideration was made in determining the sample size of the study. Due consideration was also given to the time available for the study, which was limited, and the resources for the study which were certainly not limitless.

According to the Ghana Population Census of 1984, about 70% and 80% of the population of the Kassena-Nankana and the Ejura-Sekyedumase Districts, respectively, were classified as working in the agriculture and hunting sector. Coupled with the fact that the study targets a very homogenous area, i.e., farming communities, it was assumed that 80% of the households in both study areas are farming households (i.e., households with the major occupation of the majority of adult members being farming). The overriding issue therefore was what the required sample size given a minimum required level of precision of the estimate should be.

Carletto (1999) stated that the level of precision sought could only be achieved within an acceptable margin of error and with a given level of confidence. The confidence level, as expressed in percentage terms, must be converted into the normal deviate, indicating the number of standard deviations defining the confidence interval. Table 4.1, provides the most commonly used conversion values from confidence interval to normal deviate. This also takes into account whether the analysis is being done with a one-sided or a two-sided interval.

Table 4.1: Normal deviates for confidence intervals

Confidence level (%)		***Normal deviate***
Two-sided interval	One-sided interval	K
80	90	1.28
90	95	1.64
95	97.5	1.96
98	99	2.33
99	99.5	2.58

The formula below portrays the practical requirements needed for the calculation of the sample size. These are the variability of variable within the population, the acceptable margin of error of the estimate, the degree of confidence, and the sample design:

$$n = \frac{d \times K^2 \times \sigma^2}{M^2}$$

where n is total sample size, d is the design effect, K is the normal deviate, σ is the estimated variance of the indicator in the population, and M is the allowed margin of error.

An assumption that 80% of the households were farming households, and estimation of the value (is being done) with a margin of error of plus or minus 5 per cent with a 95% confidence level was made. The first issue to be considered is to convert the set confidence level into the corresponding value of the normal deviate. From Table 4.1, the value of the normal deviate for a two-sided interval at 95%

confidence level equals 1.96. For an assumed 80% farming households in the study areas, then p(1-p) where p is proportion of farming households is 0.8 and M is 0.05. These figures are substituted into the equation to give

$$n = \frac{(1.96)^2 \times [0.8(1-0.8)]}{(0.05 \times 0.05)}$$

The value of "n" is therefore 246. The calculated value of "n" denotes that at least 246 households should be interviewed in each of the two study areas to get a representation of the sampled areas.

As mentioned in the introduction, the Kassena Nankana and the Ejura-Sekyedumase Districts were selected for the district level study. The pilot sites were selected after the application of several data processing techniques (e.g., NDVI differences, comparison of classifications, triangular method also used by Lambin et al., 1997) to detect the most prominent changes of land use and land cover, which were then compared with expert opinion. These areas were identified as "hot spots", i.e., areas where significant land use and land cover changes have taken place.

The 1984 Ghana population census report on localities was used for the selection of the settlements in the study areas, because it was by then the current information available. Even though preliminary results of the 2000 Population and Housing Census of Ghana had been released, the one on settlements had not yet been processed.

The Kassena-Nankana District, which in 1984 comprised the Chiana-Paga and Navrongo Local Councils had 368 localities, while the Ejura-Sekyedumase District had 378 localities. Most of the localities were very small in size as far as their populations were concerned. For instance, 16% and 6% of the settlements in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively, had less than 50 houses. The situation in the Ejura-Sekyedumase area was more pronounced, as 51% of the localities enumerated in the 1984 Population Census had only one house.

Taking into consideration the available resources (both in terms of logistics and finances), a criterion (localities with 90 houses or more) was used to select the localities in the two districts. Twelve localities in the Kassena-Nankana District and nine in the

Ejura-Sekyedumase District qualified, and were therefore selected for the study. The localities selected, the number of enumerated houses in the 1984 Population Census for the two districts, and the number of respondents are shown in Table 4.2.

Table 4.2: Sampled areas, number of houses in 1984 and respondents in the study areas

Kassena-Nankana			Ejura-Sekyedumase		
Locality	**No. of houses (1984)**	**No. of respndts.**	**Locality**	**No. of houses (1984)**	**No. of respndts.**
Telania	98	155	Sekyedumase	567	243
Navrongo	1817	135	Ejura	1212	345
Bonia	128	139	Anyinasu	272	197
Kanania	97	157	Aframso	153	209
Atibaabisi	154	175	Hiawoanwu	251	268
Yuwa Afarig.	94	134	Dromankuma	264	213
Nabango	120	135	Afrante	196	173
Paga	637	132	Kasee	133	195
Mirigu	104	187	Bonyun	99	191
Badania	123	114			
Manyoro	106	111			
Janania	98	129			
Total		**1703**	**Total**		**2034**

To meet the threshold level of 246 households, calculated by the normal deviate method, 21 households were randomly selected from each of the 12 localities to obtain a total sample size of 252 in the Kassena-Nankana District. As far as the Ejura-Sekyedumase District is concerned, since only nine localities qualified for selection, 28 households were selected to meet the threshold level. Due to the homogeneity in the sample, the random sample procedure was used to select the houses where the interviews were undertaken.

4.3 Method of analysis

Several methodologies have been used to study the spatio-temporal interaction between land use change and its biophysical, institutional and economic drivers. These include bio-economic modeling techniques such as production function analysis, village-level social accounting matrix models, technical coefficient generator model, cost-benefit and multi-criteria/multi-agent analysis, multiple goal linear programming, multi-market model and optimal control models.

There are also methods based on the theory of spatial diffusion, which has developed largely from the logistic function S-shaped curves. The logistic function is useful in the modeling of stabilization in land use patterns in a resource-limited environment. Other techniques include the use of Markov chain and similar stochastic techniques to estimate future land use patterns based on apriori information (Burnham, 1973; Aaviksoo, 1993; Ogneva-Himmelberger, 1996). A comprehensive review of these techniques has been carried out by several works, e.g., Baker (1989); Lambin (1994); Bockstael (1996). This study, however, employed the use of simple and multiple regression models.

4.3.1 Simple and multiple regression models

The techniques employed for the analysis included descriptive statistics, inferential statistics, as well as bivariate and multivariate analysis. Descriptive statistics were used to assess the proportions of certain relationships as well as measures of central tendency and dispersion. The Pearson's correlation method was adopted to calculate the correlation coefficient, as well as the coefficient of determination ("R^2") for the population size, population density and population growth rate on the one hand, and agricultural land use on the other for 1992 and 2000, and forest cover for 1990 and 2000, for the five sub-basins.

While the analysis of the correlation coefficients gave a lot of insight as to the relationship existing between the three demographic variables and agricultural and forest land uses, the coefficient of determination, which is the square of the correlation, revealed how good the variations in the demographic variables explain the variation in agricultural and forest land uses.

Simple regression models were used to predict the effect of population (size) change on agricultural land use in the White Volta and Daka sub-basin in 2010:

$$y = 0.29x + 6690.7 \qquad \text{White Volta}$$

$$y = 0.15x + 1327.7 \qquad \text{Daka}$$

as well as the effect of population density change on forest cover in the Black Volta and Daka sub-basins in 2010:

$$y = -1.38x + 110.52 \qquad \text{Black Volta}$$

$$y = -1.32x + 72.78 \qquad \text{Daka}$$

At the study district level, the multiple regression model stated below was used in the study. Table 4.3 gives the description of the variables and methods of aggregation.

$$CA_{ij} = \alpha + \beta_1 E_{ij} + \beta_2 MF_{ij} + \beta_3 EL_{ij} + \beta_4 OF_{ij} + \beta_5 ON_{ij} + \beta_6 F_{ij} + \ldots + \beta_n P_{ij}$$

Table 4.3: Description of variables and aggregation method used in the model

Abbrev.	Description	Aggregation method
CA	Household total cropped area (in acres) – Dependent variable	Mean
E	Educational level of household	Mean
MF	Proportion of major farmers in household	Mean
EL	Presence or otherwise of electricity in household	Mode
OF	Household income from off-farm activities	Mean
ON	Household income from farm activities	Mean
F	Household expenditure on food	Mean
A	Affluence (car, motorcycle, bicycle, TV & radio)	Mean
AL	Affluence (ownership of livestock)	Mean
LT	Land tenure system in households	Mode
T	Household members who use tractor on their farms	Mean
I	Household members who use inorganic fertilizer	Mean
S	Household members who use improved seed variety	Mean
LF	Years allowed for land to fallow in household	Mean
D	Household distance traveled to farthest farm	Mean
EX	Recent extended farm lands (in acres) (Extensification)	Mean
HS	Household size	Mean
P	Population of locality	Size
i	Locality	
j	Years (1984 & 2000)	

The multiple regression model was adopted since it not only offers the best linear prediction but also controls for other confounding variables, thus allowing a fuller evaluation of the contribution of specific variables that explain cropped area differences.

Various methods such as forward, backward and stepwise selection may be used in entering variables in a multiple regression model. Forward selection begins with no independent variable in the model and is sequentially entered, and backward selection begins with all variables in the model and is sequentially eliminated. As far as this analysis is concerned, the stepwise method is used. It allows for the addition of independent variables, one at a time, starting with those variables that show the strongest relationship to the independent variable. At each stage of the analysis, a variable is eliminated, if the variable already included in the model declines to a statistically non-significant level. The selection therefore ends when the contribution of a variable is not statistically significant. The selection of the independent variables in the stepwise model was based on the strength of the bivariate relationships as well as on theoretical relevance.

Furthermore, the conditions underlying the use of multiple regression models requires that the variables be measured on an interval or ratio scale. However, in certain situations, nominal variations can be entered into the regression process by transforming non-linear variables to dummy variables. For instance, the measure of land tenure was transformed into a set of dummy variables with those who had customary, individual, and family ownership of land being classified under one umbrella i.e., "self-ownership" of land, and was used as a reference category against which respondents who rented land for farming could be compared.

Series of checks were also carried out in the modeling process to detect and eliminate positive errors and biases such as multicollinearity, measurement error in the independent and dependent variables, and the omission or otherwise of a relevant independent variable. According to Gujarati (1992), rules of thumb, or indicators that provide some clue about the existence of multicollinearity include high correlation coefficients of determination but few significant "t" ratios, high pair-wise correlations among explanatory variables, examination of partial correlations and subsidiary, or auxiliary regressions.

This study adopted the latter method, where each independent variable was regressed on the other independent variables. The bivariate correlation matrix revealed that just one correlation, i.e., the use of tractor and inorganic fertilizer on farms, was of the magnitude of 0.8, giving an indication that multicollinearity is not a major problem. This is due to the fact that multicollinearity is not considered a problem when the correlation coefficients are less than 0.9.

4.3.2 Population density analysis

Due to the fact that the study area had numerous local/urban councils with very low population densities, a criterion which identified areas with 1-50 people per km^2 as low density, between 51-100 as medium density, and more than 100 as high density was used. Geographical Information System (GIS) techniques were used to map the results.

4.3.3 Agricultural land suitability analysis

A soil suitability map (Ghana Soil Research Institute, 1999) for 90-day maize *(Zea Mays)* of the study area was remapped into a binary layer of *suitable* and *not suitable* for agriculture using GIS techniques. The classification considered intrinsic properties of the soil such as soil texture, fertility, water holding capacity, cation exchange capacity, and organic matter content. While further subdivision of degrees of soil suitability would have provided more information on the agricultural potential of the land, such classification is not of interest to the study.

In other words, it was assumed that all parcels suitable for agriculture have the same probability of being converted for such use. This assumption is justifiable, as tenure arrangement markedly limits access to land in densely populated areas. A district map was overlain on the resulting soil suitability map, to determine the proportion of land area suitable for agriculture within each district, using a weighted average index. It must be mentioned that 90-day maize was used for the study, because it is grown in all the study areas.

4.3.4 Determining agricultural land availability status - 2010

In determining the agricultural land availability status of the local/urban councils in the two sub-basins for 2010, the equal interval classification technique, which is useful in revealing the distribution patterns of phenomena, since it determines the number of features in each category, was used (By de, 2001). The first stage identified all negative values as areas that will be experiencing agricultural land shortfall as a result of population change. At the second stage, the minimum and maximum values, (V_{min} and V_{max}) of the classification parameters were determined as 21% and 96%, respectively. The (constant) interval size for each category was then calculated to be 25%, using the formula, $(V_{max}-V_{min})/n$, where n is the number of classes chosen, in this instance 3. The classes were then assigned land availability statuses ranging from Low to High.

4.3.5 Determining forest cover availability status – 2010

In determining the forest cover availability in 2010 for the two sub-basins, the difference between the forest cover available in 2000 and the predicted forest cover in 2010, which would occur as a result of changes in population density, were ascertained. It was determined that local/urban councils with negative values were those that would experience forest depletion in 2010 as a result of changes in population density, and the positive values were areas that would have some amount of forest cover available in 2010.

4.4 Problems of research design and data collection

Even though the exercise can be generally described as a success, a few problems were encountered during both the data collection and analysis stage. Some of the problems are discussed below.

Long introductions and sometimes long explanations that were made when the enumerators visited the households delayed the exercise. Even though in all the study areas visited, the chief, assemblyman or an opinion leader was as custom demands contacted for an announcement concerning the exercise to be made, delays occurred when the enumerators were introduced. Secondly, the questions had to be translated from English into the local languages "Kassin" and "Nankan" in the Kassena-Nankana District and "Twi" in the Ejura-Sekyedumase District. This also slowed down the exercise.

The problem that confronted the study at the analysis stage was how to aggregate a number of local councils or districts to represent one river sub-basin, since boundaries of the river sub-basins cut across a number of local councils or districts. Reconciling the local/urban councils used for the 1960, 1970 and 1984 Population Censuses with the districts in 2000 was another problem. It was observed that some of the local councils maintained their boundaries and names. Furthermore, but for the names that were changed, some of the local/urban councils were maintained as districts. Other local/urban councils were integrated into new districts, others were merged to form new districts and, finally, some local/urban councils even changed regions. Assistance was provided by the Regional Population Officers of the National Population Council, who gave useful suggestions as to how to merge the local councils with the districts.

4.5 Organization of the study

The study is organized in eight chapters. The first chapter is the introductory chapter and discusses the background to the study, statement of the problem, objectives, and statement of hypotheses. Chapter 2 considers a literature review of the theme of the study, while Chapter 3 deals with theoretical issues in the population-environment nexus as well as a conceptual framework for the study.

Chapter 4 concentrates on the materials and methods used for the study and a description of the study areas. Chapter 5 assesses the effect of changes in three demographic variables, namely population size, population density and annual population growth rate on agricultural land use in the five sub-basins between 1992 and 2000, and predicts the effect in 2010. Chapter 6 looks at the effect of changes in demographic and indirect demographic factors on agricultural land use in the two selected study districts Kassena-Nakana and Ejura-Sekyedumase. Chapter 7 assesses the effect of changes in the three demographic variables on forest cover between 1990 and 2000, and concludes with a prediction for 2010. The study has a concluding Chapter 8, which also entails some recommendations as well as further research.

4.6 Study area

4.6.1 Volta River basin

As mentioned in the introduction, the Volta River Basin covers about 400,000 km^2. The largest portions of the basin are located in Burkina Faso and Ghana. For instance, about 67% and 64% of the land area of Burkina Faso and Ghana are respectively located in the Volta River Basin. Togo is the next with about 47%, followed by Benin and Mali, which have 14% and 1% of their land area respectively located in the basin. Figure 4.1 shows the Volta River Basin.

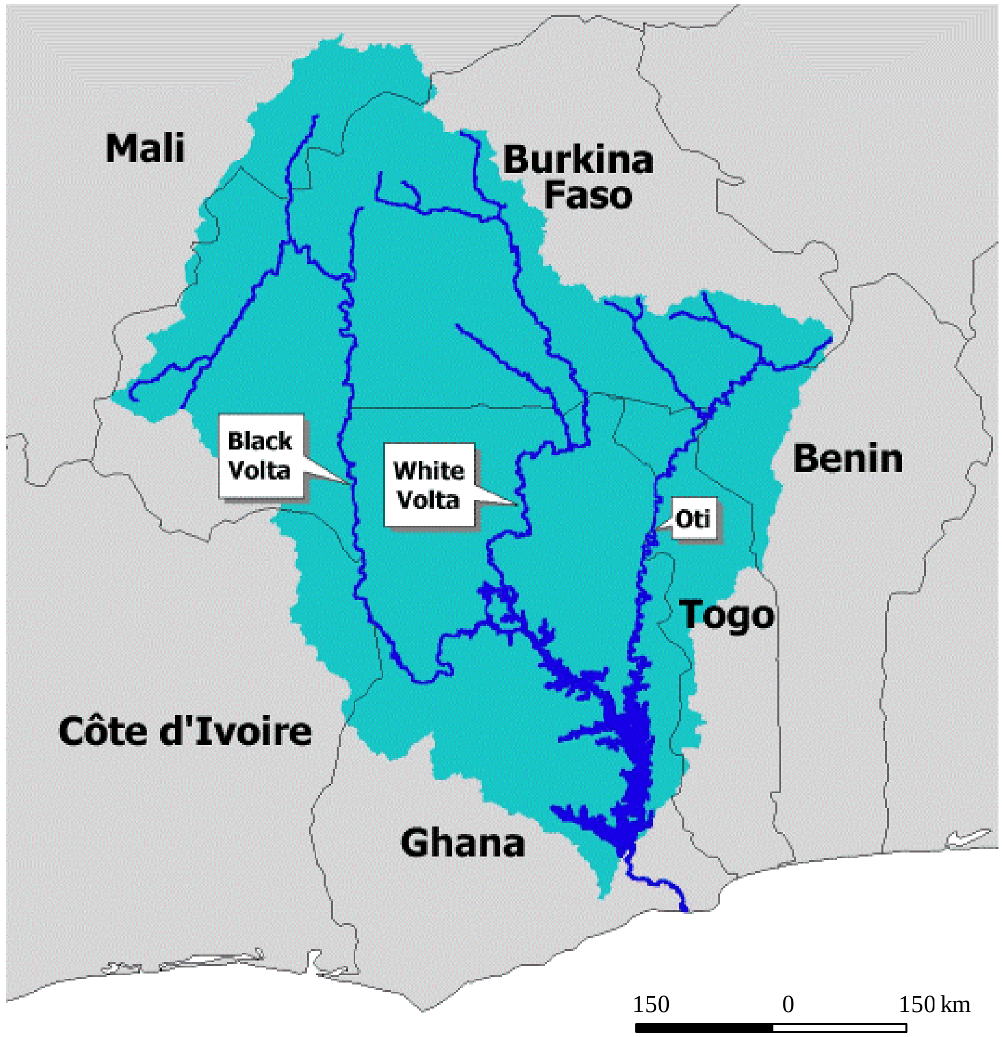

Figure 4.1: Volta River Basin

Source: GLOWA Volta Project Proposal, 1999

4.6.1.1 Volta River sub-basins in Ghana

Since this study concentrates on the Volta River Basin in Ghana, the discussions from here solely concern the basin in Ghana. Five sub-basins can be identified in Ghana. They are the White, Black and Main Volta sub-basins, as well as the Daka and Oti sub-basins (see Figure 4.2). The boundaries of the basin cut across the local/urban councils. An attempt has therefore been made in Figure 4.2 to give a description of the various sub-basins. The White Volta sub-basin is located to the north of Ghana, extending southwards to about latitude 8^0 30' N. It covers all local councils in the Upper

East Region and also includes sections of Wa Urban Council, Tumu, Lawra-Jirapa, and Nadawli-Funsi Local Councils in the Upper West Region. In the Northern Region, parts of Bole, Damongo, Savelugu, Gushiegu-Chereponi, Nalerigu and the whole of Walewale Local Councils fall within the White Volta sub-basin.

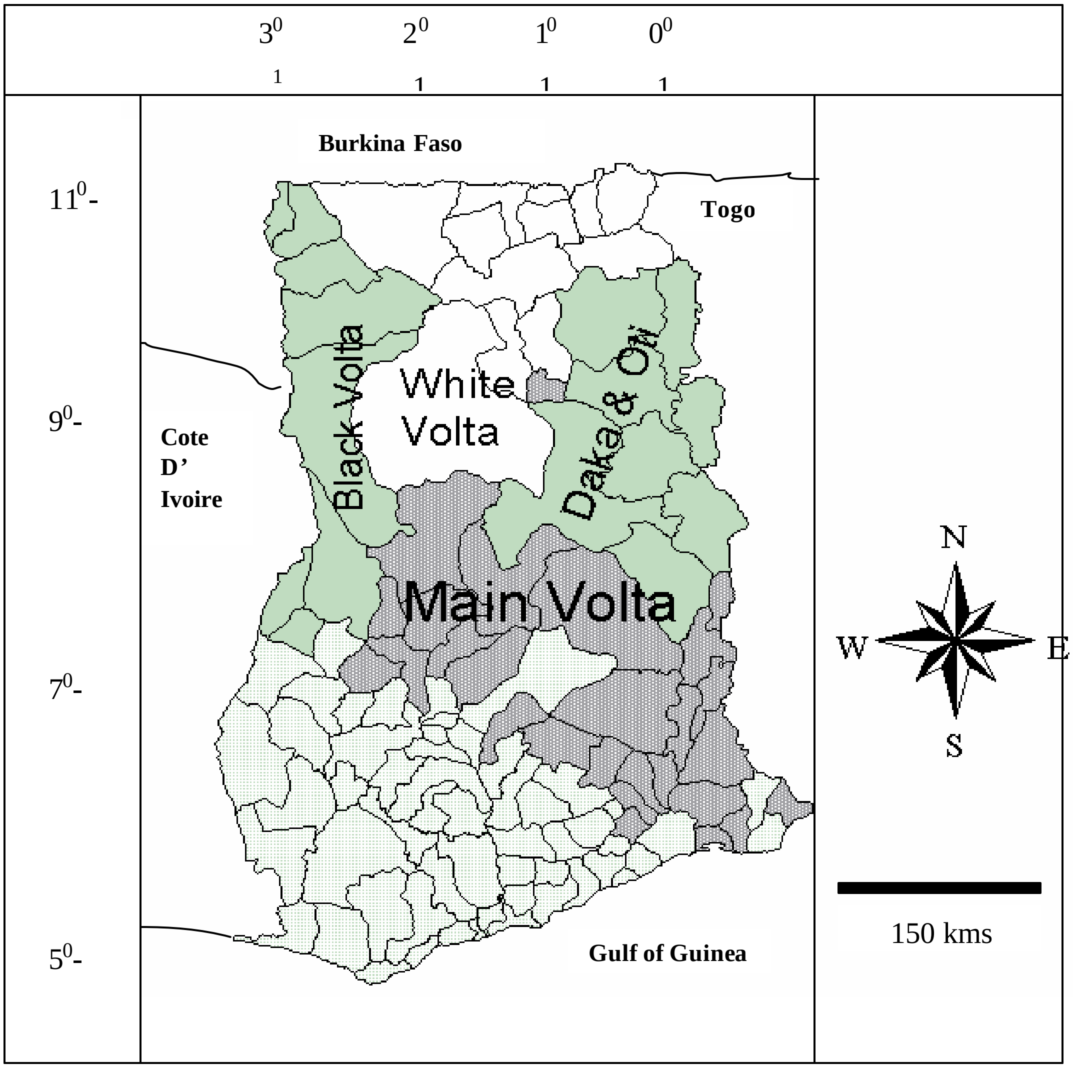

Figure 4.2: Map of Ghana showing the sub-basins

The Black Volta sub-basin, on the other hand, extends narrowly from the northwest of Ghana southward across the middle belt up to about 7^0 45' N and 10^0 W as its eastern most spatial extension. It covers parts of the Upper West, Northern and Brong Ahafo Regions. The local councils in this sub-basin are parts of Tumu, Lawra-

Jirapa, Nadawli-Funsi and Wa in the Upper West Region; parts of Bole and Damongo Local Councils in the Northern Region; Atebubu, Nkoranza, Wenchi, Berekum and Jaman in the Brong Ahafo Region.

The Main Volta sub-basin is the largest of the sub-basins of the Volta River stretching over a greater part of Central and Eastern Ghana. Local councils from six regions, namely Northern, Brong Ahafo, Ashanti, Volta, Eastern and Greater Accra, constitute the Main Volta sub-basin.

The Oti sub-basin is found along the eastern fringes of the Northern Region across the middle belt to the northern part of the Volta Region. Latitudinally, it extends from about 10^0 50'N to around 7^0 30'N and covers parts of Nalerigu, Gushiegu-Chereponi, Yendi, Bimbilla, Salaga and the whole of the Saboba-Zabzugu Local Council in the Northern Region. The total area of the sub-basin is 17,942 km^2. The Daka sub-basin is also located mainly in the Northern Region. It stretches narrowly across the middle belt from about latitude 10^0 15' N and shares borders with the Main Volta sub-basin to the north. It is made up of parts of the Gushiegu-Chereponi, Yendi, Salaga, Bimbilla Local Councils in the Northern Region and a small proportion of the Kete-Krachi Local Council in the Volta Region.

4.6.2 Study districts

The Kassena-Nankana District in the Upper East Region, and the Ejura-Sekyedumase District in the Ashanti Region of Ghana are the two study areas. The Kassena-Nankana District is bounded by Burkina Faso to the north, Builsa District to the south, Bongo and Bolgatanga Districts to the east, and Tumu District to the west. The Ejura-Sekyedumase District is bounded by the Atebubu District to the north, Afigya-Sekyere District to the south, Sekyere West District to the east and Offinso and Nkoranza Districts to the west. The district map in Figure 4.3 shows the locations of the two study districts.

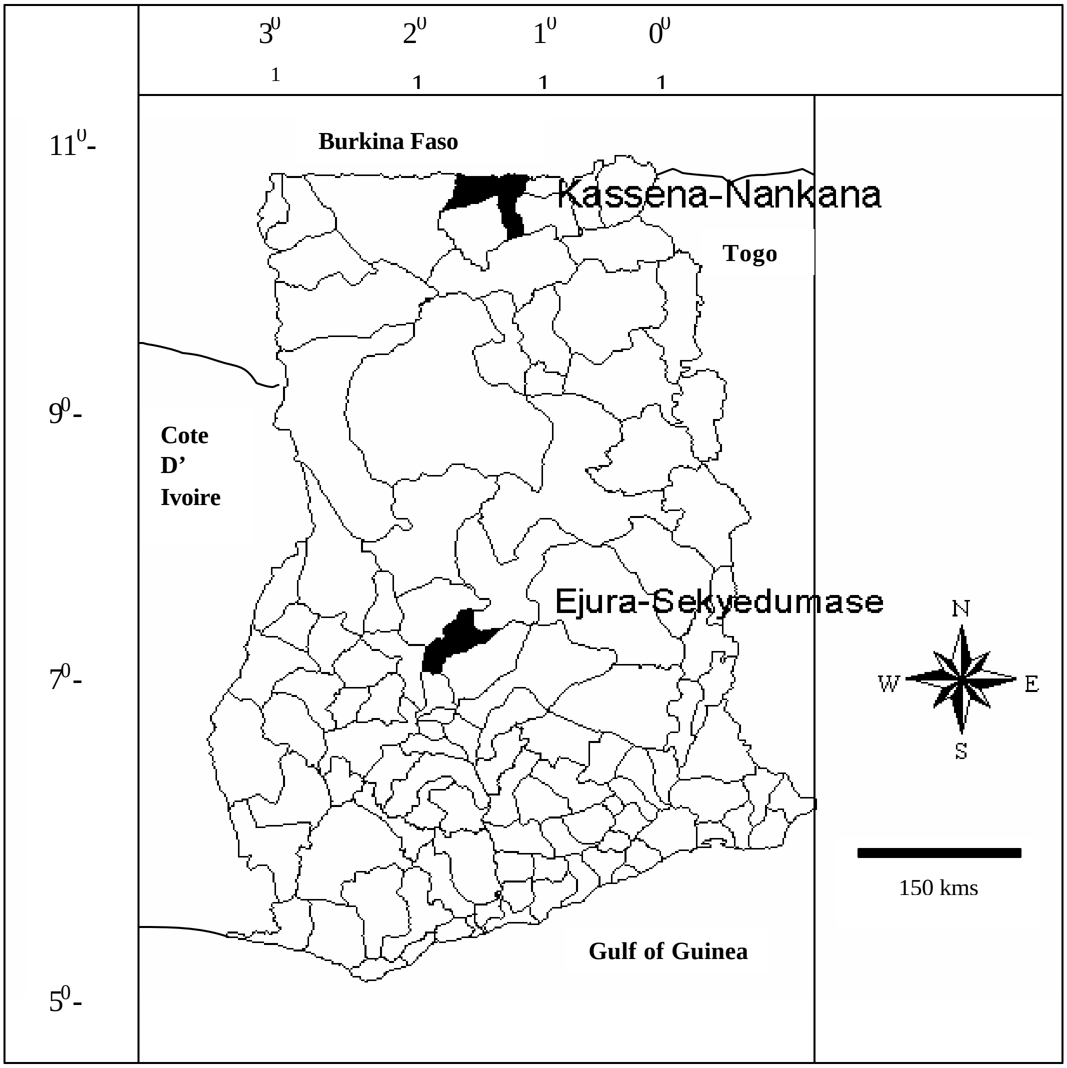

Figure 4.3: Districts map of Ghana showing the two study districts

4.6.2.1 Relief

The Kassena-Nankana District falls within the savannah high plains with the most widespread rocks being granite. Due to the fact that much of the erosion in this district is caused by sheet flooding, the topography is more gently rolling (Dickson and Benneh, 1995). The average altitude in the district is between 180 and 300 metres above sea level. Small rounded hills or inselbergs, of a type of rock formation in Ghana, termed Birrimian rocks are scattered all over the district. The Ejura-Sekyedumase District on the other hand, lies in the Voltaian sandstone basin. The area is generally characterised by gently dipping or flat-bedded sandstones, shales, and mudstones, which, generally speaking, are easily eroded. This has resulted in an almost flat and extensive plain, which is between 60 and 300 metres above sea level.

4.6.2.2 Rainfall

The Kassena-Nankana District lies within the geographical area of Ghana with a single maximum rainfall regime. Areas within this rainfall regime, experience only one rainy season from about May to August, when the sun is overhead or almost so, on the Tropic of Cancer in the northern hemisphere, followed by a long dry season. The district experiences a mean annual rainfall of 115 centimetres as shown in Figure 4.4.

The Ejura-Sekyedumase District, however, experiences a double maxima rainfall regime, where there are two rainy or wet seasons. The two wet periods occur from May to August and from September to October, with a mean annual rainfall of 143 centimetres. The differences in the rainfall regimes have implications for agricultural production in the two study areas; this is shown in Chapter 6 of this study.

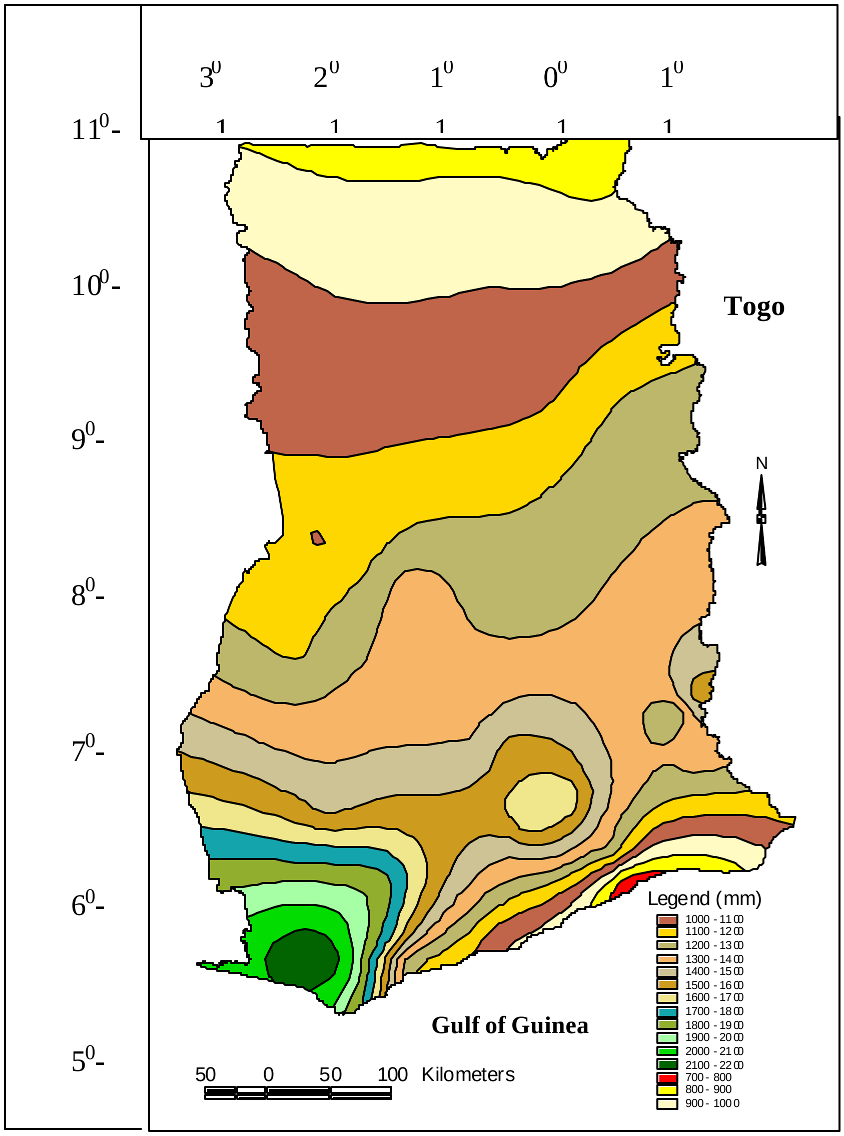

Figure 4.4: Map of Ghana showing mean annual rainfall

Source: Center for Remote Sensing and Geographical Information Systems (CERSGIS), Ghana

4.6.2.3 Temperature and humidity

The Kassena-Nankana District lies within the tropical continental or interior savannah, with mean monthly temperatures varying from about 36^0 C in March to about 27^0 C in August. Relative humidity is high during the rainy season (about 70% to 90%) but falls to as low as 20% during the dry season. The Ejura-Sekyedumase District falls within the wet semi-equatorial climatic zone of Ghana. The mean monthly temperatures are low, ranging from about 30^0 C in March to about 24^0 C in August. Relative humidity is higher, varying from about 90% to 95% in the rainy seasons to 75% to 80% in the dry seasons.

4.6.2.4 Vegetation

Figure 4.5 shows that the Kassena-Nankana District belongs to the mid-dry savannah vegetation type in Ghana. The district is characterised by few and scattered trees such as the baobab *(Adansonia digitata)*, locust bean tree *(Parkia biglobosa)*, acacias *(Acacia spp.)* and the sheanut tree *(Butyrospermum parkii)*, which have adapted to the environment. Grasses grow in tussocks and can reach a height of 3 metres or even more. Marked changes in the plant life of the district are experienced during different seasons of the year. During the rainy season, the vegetation in the district is very green. Trees blossom and grasses shoot up very quickly. However, immediately after the rains recede, leaves begin to change colour from green to yellow and trees begin to shed their leaves. Regular burning, the grazing of livestock and cultivation have left only few trees still standing and rendered the vegetation to be open and dominated by short grasses.

The vegetation in the Ejura-Sekyedumase District can be described as wet savannah and is composed of short branching trees, many less than 15 meters high, which do not usually form a closed canopy and are often widely scattered. The ground flora consists of apparently continuous layers of grass, some species of which reach a height of about 4 meters.

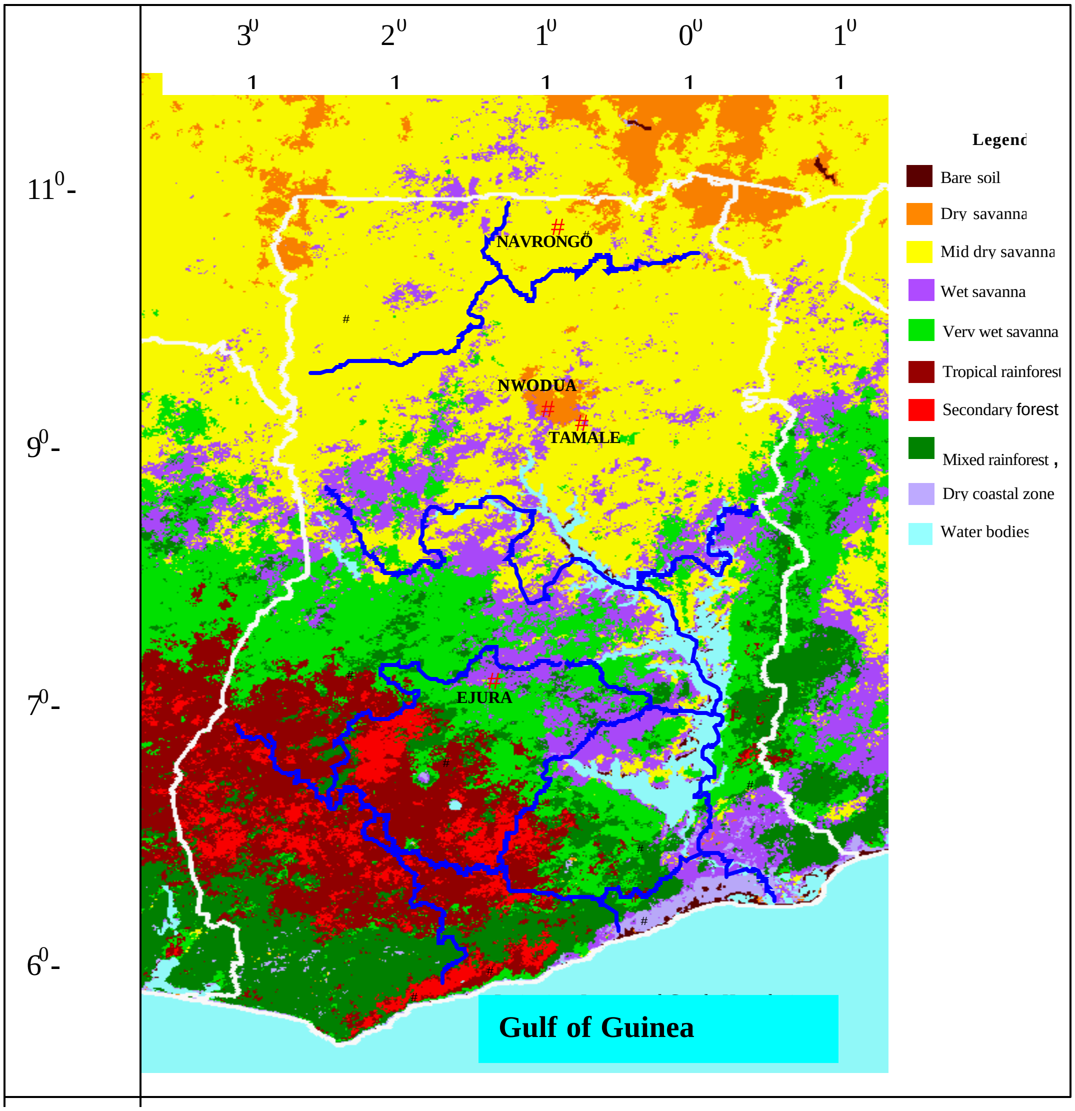

Figure 4.5: Map of Ghana showing vegetation

Source: Remote Sensing Research Group (RSRG),Geography Institute, University of Bonn, Germany

4.6.2.5 Soils

Lixisols are soil types found in both the Kassena-Nankana and Ejura-Sekyedumase Districts. In the Ejura-Sekyedumase District, the normal profile consists of about 30 cm of dark brown to brown, fine sandy loam overlying, from 30-152 cm, reddish brown to reddish yellow, fine sandy loam to fine sandy clay loam. They are moderately well supplied with organic matter and nutrients. Moisture holding capacity is moderately good and the soils are easily tilled by machines and by hand. They are mainly utilized for the production of yams *(Dioscorea divaricata)*, maize (*Zea mays)*, cassava *(Manihot esculenta)*, groundnut *(Arachis hypogaea)*, cowpea *(Vigna unguiculata)*, tobacco *(Nicotiana andicola)*, cotton *(Geossypium herbaceum)* and vegetables but are, however, subject to moderate erosion (Adu and Mensah-Ansah 1995).

The Ejura-Sekyedumase District also has patches of Plinthosols. It has poor humus fine sandy loam topsoil approximately 12 cm or less in thickness, over brown to light yellowish brown fine sandy loam containing abundant ironstone concretions and large boulders or iron pan. The soils are poorly drained and medium to light textured and subject to seasonal water logging or flooding for varying periods, but generally become thoroughly dry during dry seasons. The Kassena-Nankana District also has patc hes of Leptosols, which consist of about 10 cm of brown slightly humus sandy loam topsoil overlying hard massive rock. Frequently, ferruginized rock brash and fragments of stones are incorporated in the topsoil. It has little agricultural value. Figure 4.6 shows a soil map of Ghana.

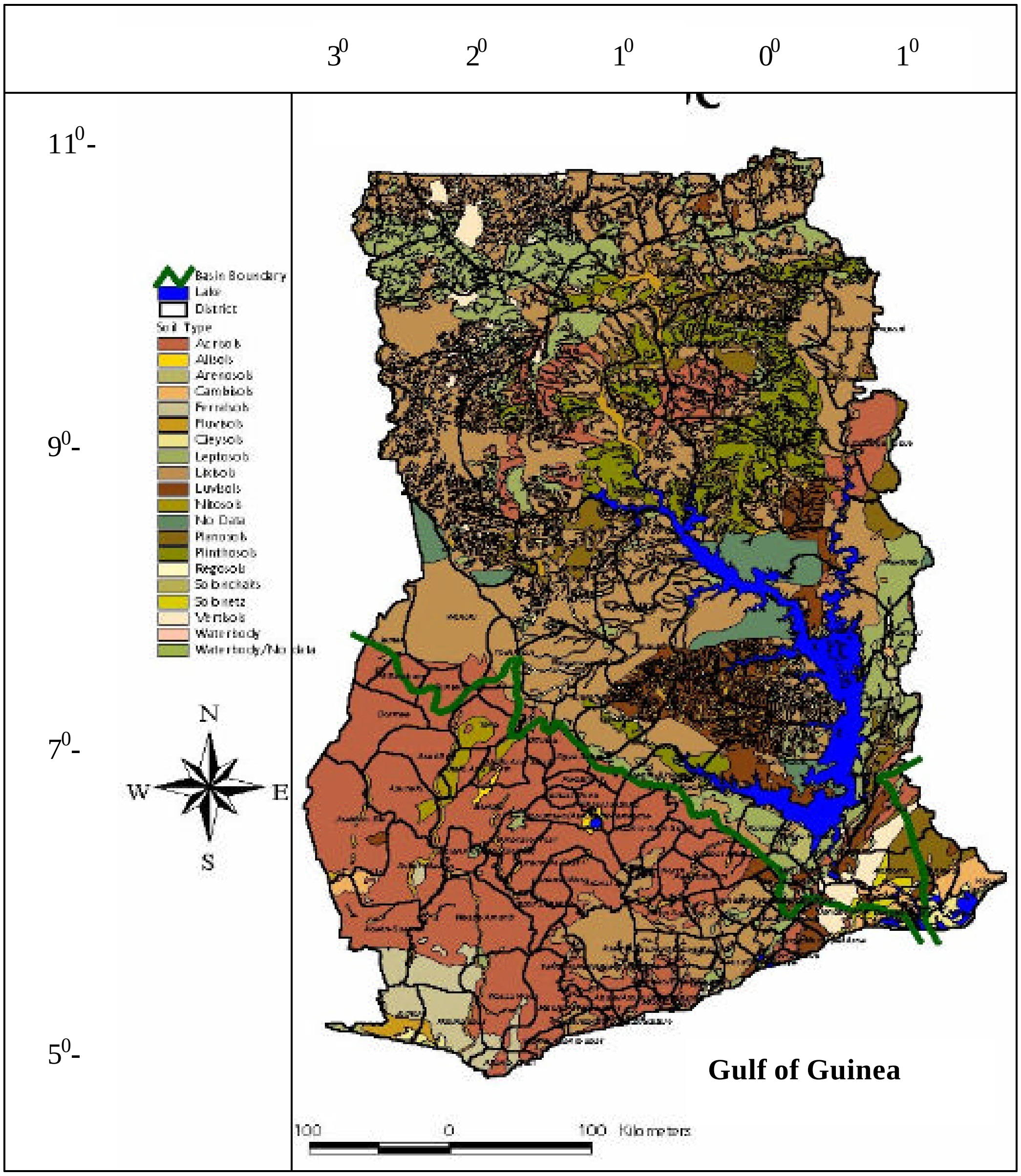

Figure 4.6: Map of Ghana showing soils

Source: Ghana Soil Research Institute

5 POPULATION AND AGRICULTURAL LAND USE IN THE VOLTA BASIN OF GHANA

This chapter assesses the trend and pattern of three demographic variables, namely, population size, population density and annual population growth rate from 1960 to 2000, as well as projections for 2010, within five sub-basins of the Volta River Basin in Ghana (White Volta, Black Volta, Main Volta, Daka and Oti). Furthermore, it assesses the pattern of agricultural land use within the various sub-basins for 1992 and 2000, and concludes with a correlation of the three demographic variables on the one hand, and agricultural land use on the other in 1992 and 2000, to ascertain whether any of the three variables has played a significant role in agricultural land utilization both spatially and/or temporally.

Predictions of cropped area that would be required as a result of changes in population size have been computed for the year 2010 for two of the sub-basins, namely, the White Volta and Daka, based on simple regression models and the projected populations of the two areas. The two sub-basins were used due to the fact that they showed strong correlations of determination between population size and agricultural land use in 2000. It was therefore determined that variations in population size, unlike the other two variables, best explain variations in agricultural land use.

The required cropped areas have been matched with actual arable areas that are available, based on a soil suitability analysis. A land availability status table and map were generated to give an indication of the amount of agricultural land area that would be available to local/urban councils, and those districts that would experience shortfalls in agricultural lands in the two sub-basins in the year 2010 as a result of changes in population size. The analysis was done for the five sub-basins as well as for the two study areas, the Kassena-Nankana and Ejura-Sekyedumase Districts.

5.1 Population of the sub-basins

As shown in Table 5.1, the White Volta sub-basin had a population of 518,569 in 1960, which grew to 1,616,895 in 2000. The period between 1960 and 1970 experienced a 69% increase in the population, compared to a 46% increase in 1970-84. On the other hand, the period 1984-2000 registered a 26% increase in population. The population of the sub-basin more than doubled within a period of 24 years (1960-1984). Using an inter-censal growth rate of 1.5% (see Appendix 4) during the period 1984-2000, the population of the sub-basin has been projected to reach 1,933,687 in 2010, representing a 20% increase on the basis of the 2000 Ghana Population and Housing Census Report. The analysis further shows that the population of the White Volta sub-basin would experience a 273% increase, i.e., almost quadrupling within half a century (1960-2010).

Table 5.1: Population of the Volta sub-basins, 1960 – 2010

Sub/basin	**Population**						
	1960	**1970**	**1984**	**1992***	**2000**	**2005***	**2010***
White Volta	518569	877037	1280660	1440219	1616895	1740017	1933687
Black Volta	277011	388099	607372	669319	736722	782826	921154
Main Volta	876146	1416432	2052555	2501014	3032857	3431550	4268927
Oti basin	106423	227632	350480	385877	557910	646523	771533
Daka basin	48079	91429	127439	159688	198851	228959	260761

Source: 1984 Population Census of Ghana, Special Report on Localities by Local Authority and 2000 Population and Housing Census, Summary Report of Final Results (GSS 2002b)

**Projected Figures*

Considering the differential growth of the local/urban councils within the sub-basin (Appendix 4), the Wa Urban Council experienced the highest growth rate of 5.3% during 1984-2000, while the Navrongo, Chiana-Paga and the Damango Local Councils had negative growth rates of –0.01 within the same period. Wa experienced the highest growth rate, because it is the administrative capital of the Upper West Region, and might have attracted migrants. On the other hand, despite the fact that the Navrongo Local Council is an important market centre in the sub-basin, and the Chiana-Paga Local Council is located on the border between Ghana and Burkina Faso, therefore serving as an important transit point for travellers between the two countries, the two towns experienced population declines between 1984 and 2000. This may be due to high out-migration rates of the population to the cocoa-growing areas in the Brong-Ahafo and Western Regions of Ghana, the mining areas, as well as to the important commercial and urban cities of Accra and Kumasi.

The Black Volta sub-basin showed a steadily rising population from a low of 277,011 in 1960 to as high as 736,722 in 2000. Between 1960 and 1970, it also experienced a 40% increase in the population, compared to a 57% increase in 1970-84. A 21% increase was registered in the population from 1984-2000, and its population more than doubled within a period of 24 years (1960-1984). Even more, the annual inter-censal growth rate of the Black Volta sub-basin during the period 1984-2000 was 1.2%, which means that the projected population for 2010 is 921,154. The projections further show that the population of the Black Volta sub-basin would experience a 233% increase, i.e., more than tripling within half a century (1960-2010).

The Jaman Local Council in the Brong-Ahafo Region's section of the sub-basin experienced the highest growth rate of 3.3% in 1984-2000 (Appendix 4). This is due to the fact that it is located in the cocoa-growing areas of the Brong-Ahafo Region, and therefore attracts a lot of seasonal as well as permanent migrants, mainly farmers, who migrate from the Northern Regions of Ghana to work on cocoa and other cash crop farms. The Nadawli-Funsi Local Council in the Upper West portions of the sub-basin on the other hand, experienced the lowest growth rate of 0.1% during the same period, probably as a result of out-migration.

As far as the Main Volta sub-basin is concerned, its population of 876,146 in 1960 rose sharply to 3,032,857 in 2000. It also recorded an increase of 62% in the population between 1960 and 1970, compared to a 45% increase in 1970-1984; the period 1984-2000 experienced a 48% increase in population. The population of the Main Volta sub-basin more than doubled between 1960 and 1984, a period of 24 years, and has been projected to reach 4,268,927 in 2010, based on an annual inter-censal growth rate of 2.5% during the period 1984-2000. Furthermore, the population of the Main Volta sub-basin is expected to experience a 387% increase, i.e., almost quintupling within half a century. Like the other sub-basins, the populations of the Oti and Daka sub-basins have increased over the years and have been projected which indicates an increase in future (see Table 5.1).

5.1.1 Trends in population growth of the sub-basins

Figure 5.1 shows the population trend for the five sub-basins. For all the periods the study considers, namely, 1960-1970, 1970-1984 and 1984-2000, there were relatively steady increases in population for the White and Black Volta sub-basins compared to the Main, Oti and Daka sub-basins. The Oti and Daka sub-basins have been projected to experience a higher population increase between 2000 and 2010 than the other three sub-basins.

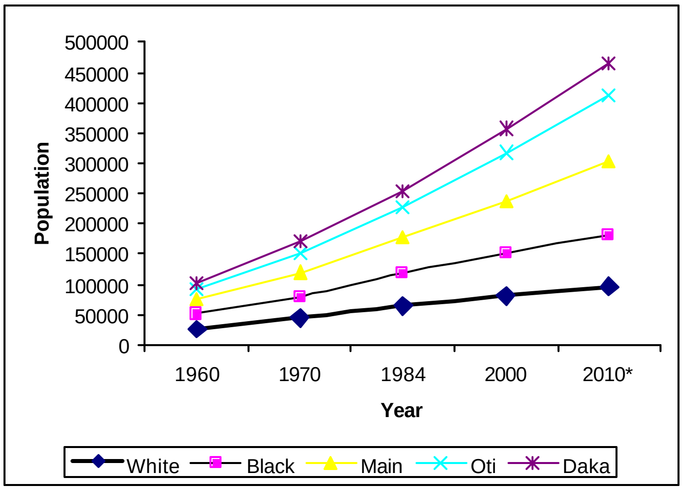

Figure 5.1: Trends in population growth by sub-basins, 1960-2010

5.1.2 Explanations for the observed population patterns in the sub-basins

Several reasons can be stated to have accounted for the observed population patterns in the sub-basins of the Volta River in Ghana. This study, however, concentrates on the few prominent ones. One important factor that has affected the population of the White Volta sub-basin is the Onchocerciasis or river blindness disease. In addition to causing blindness, it is a major obstacle to socio-economic development. In 1974, when the World Health Organization (WHO) and World Bank sponsored Oncho Control Program in West Africa started, more than one million people were suffering from Onchocerciasis and at least 100,000 persons were blind or had seriously impaired eyesight. Furthermore, large areas of fertile, riverain land had been abandoned due to the heavy toll of the disease on the inhabitants of the Oncho-infested areas (Ghana

Government, 1991). Even though Onchocerciasis has been eradicated in Ghana, people are afraid to migrate back to these areas for fear of re-infection.

Secondly, the Tono irrigation project near Navrongo in the Upper East Region has also played a role in the distribution of the population of the White Volta sub-basin. The Tono project was started in 1975 and completed in 1985. The dam was constructed over the Tono River and disrupted the lives of several villages in the sub-basin. The entire project area covers 3,860 hectares, of which 2,500 were developed for irrigation affecting eight settlements.

Finally, seasonal flooding when some of the areas in the north, particularly in the West Mamprusi District, are cut off from the rest of the country, has resulted in massive out-migration from these areas. These areas are therefore termed “the overseas” areas. These floods and massive bush fires, which raged in the country in 1983, have had an effect on the distribution of the population of not only the White Volta sub-basin, but also of the other sub-basins in the northern areas of the Volta Basin in Ghana. The bush fires, which were particularly felt in the northern parts of the Volta basin, destroyed a third of all farms, and it is on record that most farmers moved to other parts of the country from the hard hit areas (Ghana Statistical Service (G.S.S), 1995).

One important characteristic of the population of the Main Volta sub-basin is the mass movement to frontier agricultural areas. One significant area that comes to mind is the Afram Local Council. Situated north of the Kwahu Scarp, the favourable and suitable topography, climate, vegetation and reasonably rich soils allow for large-scale agricultural development both under manual and mechanized farming practices. Added to this is the government’s policy of encouraging the exploitation of the high food and industrial crop potentials of the plains through the provision of tractors, bulldozers and other implements, which has resulted in the large influx of migrants into the area.

It is on record that the population of the Afram Plains in the Main Volta sub-basin grew from 10,660 in 1960 to 31,486 in 1970, and to 82,725 in 1984. This gave an inter-censal population change of 195.4% between 1960 and 1970 and 162.7% between 1970 and 1984. This was the highest percentage increase for all local council areas in the whole country between 1970 and 1984. The very large increase in population between 1970 and 1984 was largely due to migration (GSS, 1995).

Furthermore, the dam on the Volta River created the largest man-made lake in the world. For example, about 2,725 km^2 i.e., 47.4% of the total area of 5,754 km^2 of the Afram Local Council, is under the water of the Volta Lake. The creation of the dam necessitated the resettlement of 80,000 people, who were displaced from 739 villages comprising more than nine ethnic groups, since their lands, homes and farms were inundated. Most of these settlements were in the Main Volta sub-basin and the people were resettled in other parts of the sub-basin as well as in other sub-basins.

Finally, the construction of the Kpong hydroelectric project in the southern part of the Main Volta sub-basin has also played a role in the distribution of the population within the sub-basin. Located downstream from the Akosombo Dam and powerhouse, the Kpong hydroelectric project involved the construction of a dam, powerhouse spillway and dykes, which created a head-pond covering an area of about 3,500 hectares. Five ethnic groups were affected by this project and six main settlement areas of nearly 7,000 people were displaced.

An important factor that has affected the population distribution of the Oti sub-basin is ethnic conflicts. Even though ethnic conflicts can be said to be a phenomenon that is predominant in the northern areas of the Volta Basin in Ghana, it could be argued to have prevailed more in the Oti sub-basin. Bloody ethnic conflicts, which have brought in their wake devastation of groups of people and in some instances desolation of entire settlements, have raged between the Nanumba and Konkomba (1980), Gonja and Vagla (1984), Konkomba and Bimoba (1990) and Nawuri and Gonja (1991). Even though, the immediate causes of these conflicts may vary, the remote causes have always been a struggle for agricultural land resources, and these conflicts have had tremendous impacts on the population and environment of the sub-basin.

5.2 Population density of the sub-basins

The next demographic variable this study considered is population density. As shown in Table 5.2, it increased from 1960 to 2000 in all five sub-basins, and has been projected which indicates an increase in future. Figures 5.2 and 5.3 show the trend in population density in 1960, 1970, 1984 and 2000, as well as the projected population density of 2010. Analysis shows that in 1960, only the Tamale Urban Council in the Main Volta sub-basin had a high population density. However, a few local/urban councils had high population densities in the White and Main Volta sub-basins in 1970. Similar trends continued in 1984 through 2000, and it has been projected that all the sub-basins will have at least one local/urban council with high population density of over 100 people per km^2 in 2010.

Table 5.2: Population density by sub-basins, 1960 – 2010

Sub/basin	**Area (km2)**	**Population Density**						
		1960	**1970**	**1984**	**1992***	**2000**	**2005***	**2010***
White Volta	43830	12.4	20.6	29.6	32.9	36.9	39.6	44.1
Black Volta	30582	9.1	12.7	20.0	21.9	24.1	25.6	30.1
Main Volta	59486	14.7	23.8	34.5	42.0	51.0	57.7	71.8
Oti basin	17942	5.9	12.7	19.5	21.5	31.1	36.1	43.0
Daka basin	8124	5.9	11.3	15.7	19.7	24.5	28.2	32.1

Source: 1984 Population Census of Ghana, Special Report on Localities by Local Authority and 2000 Population and Housing Census, Summary Report of Final Results (GSS 2002b)

**Projected Figures*

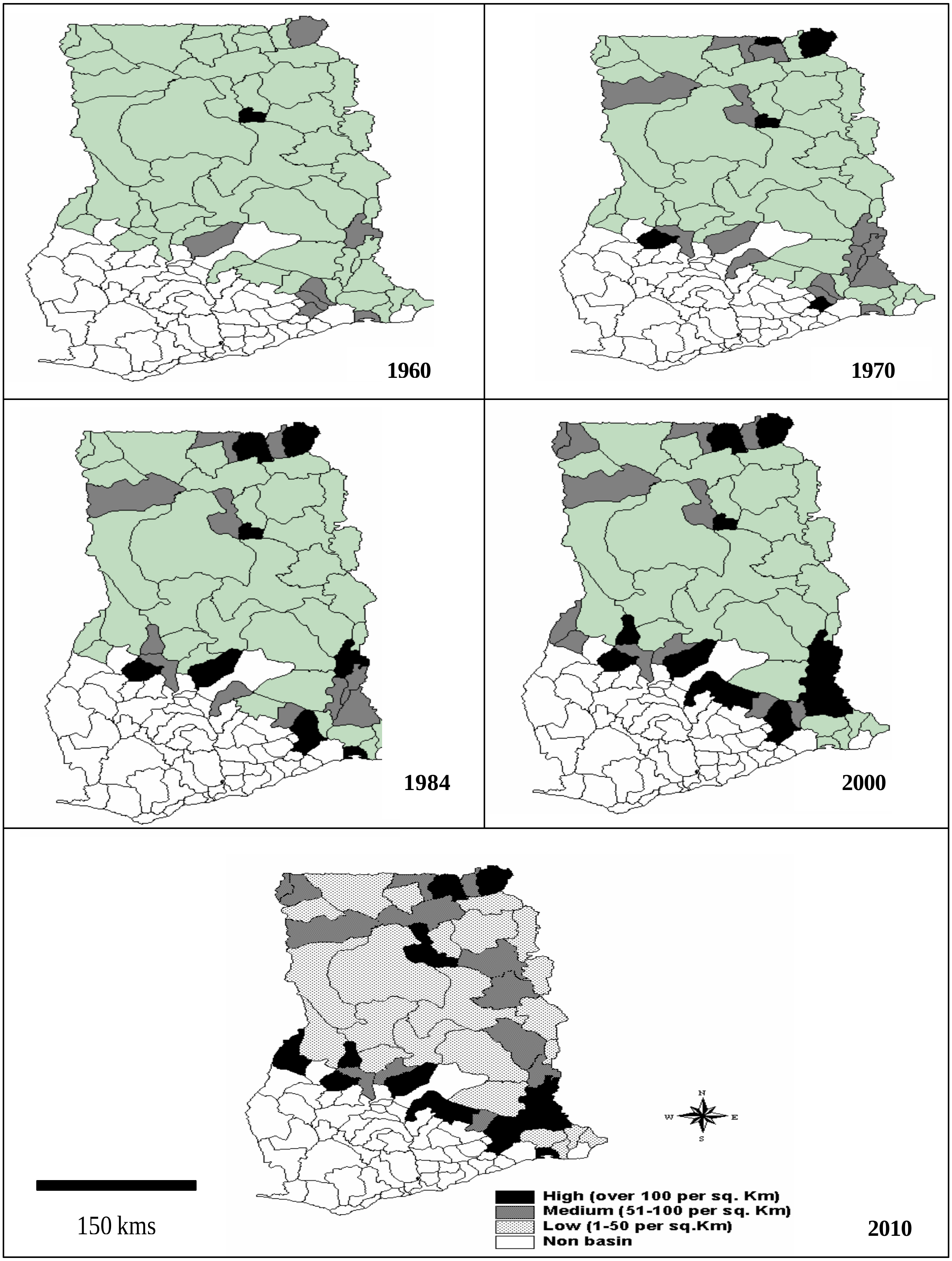

Figure 5.2: Population density for Volta Sub-basins by Districts, 1960-2010

Source: Constructed from Ghana Population Census Reports 1960, 1970, 1984 & 2000

5.3 Annual population growth rate

The third demographic variable that was analyzed regarding its role in affecting agricultural land use, is the annual population growth rate. Results of the annual population growth rate in the various sub-basins in three periods, namely, 1960-1970, 1970-1984 and 1984-2000, are shown in Table 5.3. Figure 5.4 depicts the trends in the annual population growth rate.

Table 5.3: Annual population growth rate by sub-basins, 1960 – 2000

Sub/basin	**Annual Population Growth Rate**		
	1960-1970	**1970-1984**	**1984-2000**
White Volta	5.4	2.7	1.5
Black Volta	3.4	3.3	1.2
Main Volta	4.9	2.7	2.5
Oti basin	7.9	3.1	3.0
Daka basin	6.6	2.4	2.8

Source: 1984 Population Census of Ghana, Special Report on Localities by Local Authority and 2000 Population and Housing Census, Summary Report of Final Results (GSS 2002b)

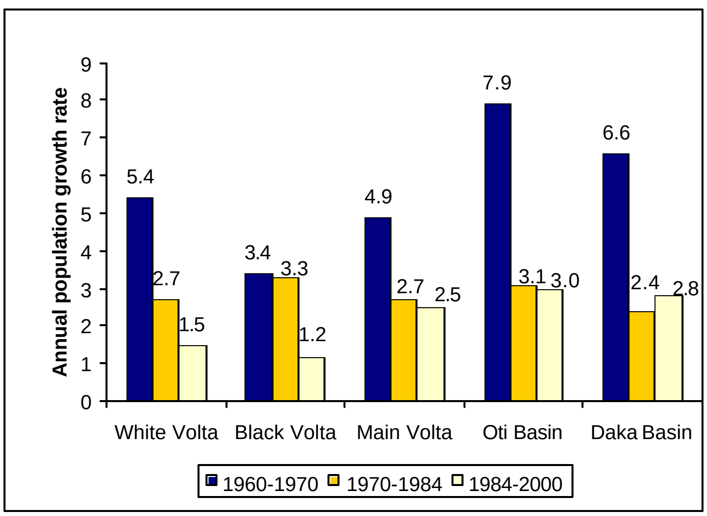

Figure 5.4: Annual percent population growth rates by sub-basins, 1960-2000

The annual population growth rate decreased for all three periods in all sub-basins, the only exception being the Daka sub-basin, where it increased from 2.4% between 1970-1984 to 2.8% in 1984-2000. Annual population growth rates were very much higher between 1960-1970 compared to other periods in all the sub-basins.

5.4 Agricultural land use in the sub-basins

Agricultural land use for 1992 and 2000 in the Volta River sub-basins, as shown in Figure 5.5, was characterised by a mixture of increases and decreases. While there were increases in the White, Black and Main Volta sub-basins during the period, the Oti and Daka sub-basins experienced declines. Appendix 5 shows that more than half of the local councils that constitute the Oti sub-basin experienced declines in agricultural land use between 1992 and 2000, and apart from the Kete-Krachi and Yendi Local Councils that recorded increases in agricultural land use, the other three local councils of the Daka sub-basin experienced declines in agricultural land use.

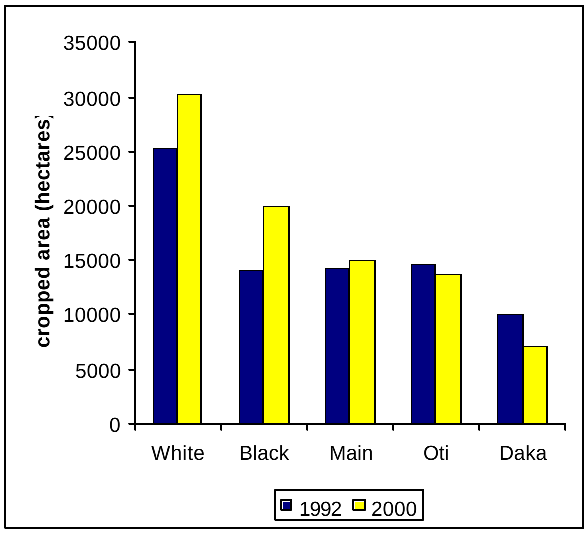

Figure 5.5: Average cropped area by sub-basins, 1992 & 2000

Source: Ministry of Food and Agriculture, Ghana, 2001

The highest annual increase (89.9%) in agricultural land use in the White Volta sub-basin is recorded in the Lawra-Jirapa Local Council, and the lowest a 0.3% increase in the Walewale Local Council. With respect to the decreases in agricultural land use, the Bole Local Council recorded the highest of –6.9%. Four of the 11 local councils in the Black Volta sub-basin, namely, the Bole, Berekum, Wenchi and Nkoranza Local Councils, experienced declines in cropped area between 1992 and 2000 (Appendix 5).

5.5 Relationship between population size, population density, population growth rate and agricultural land use in the sub-basins

The correlation coefficients in Table 5.4 show very weak non-significant positive relationships, portrayed in "r" values ranging from 0.20 to 0.42 and 0.22 to 0.41, between population density and population growth rate on the one hand and cropped area on the other, respectively, in all sub-basins for the year 2000. In fact, in the Main Volta and Daka sub-basins, there are very weak non-significant negative correlations of –0.05 and –0.15 between population density and cropped area, and in the Black and Daka sub-basins, there are also non-significant negative correlations of -0.52 and –0.01 between annual population growth rate and cropped area. This could be interpreted to mean that population density and annual population growth rates do not have strong associations with agricultural land use. The scenario is almost the same in the year 1992. In 1992, the Oti sub-basin had a moderate positive correlation of 0.50 between population density and cropped area. Such a correlation is, however, not statistically significant so it cannot be concluded that dynamics in population density is playing a role in agricultural land utilization.

Table 5.4: Correlation coefficients (r) of cropped area (hectares) on the one hand and population size, population density and population growth rate on the other in the sub-basins of the Volta River, 1992 and 2000

Sub-basin	Population		Population Density		Annual Growth Rate (%)	
	1992	2000	1992	2000	1992	2000
White Volta	0.56*	0.75**	0.13	0.20	0.18	0.41
Black Volta	0.79**	0.43	0.14	0.42	-0.35	-0.52
Main Volta	0.64**	0.57**	0.04	-0.05	0.35	0.24
Oti	0.75	0.65	0.50	0.33	0.07	0.22
Daka	0.99**	0.91*	0.29	-0.15	-0.28	-0.01

** Correlation is significant at the 0.05 level (2-tailed)*
*** Correlation is significant at the 0.01 level (2-tailed)*

The statistically non-significant relationship that exist for population density and annual population growth rate with cropped area, in all the study areas and for the two study years, could be interpreted to mean that changes in population density and growth rate do not necessarily affect agricultural land utilization.

The next stage of the analysis concentrated on the relationship between population size and agricultural land use. As shown in the other column of Table 5.4, there are moderate to strong significant correlations between population size and agricultural land use in all but the Oti sub-basin in both years, and the Black Volta in 2000. The Daka sub-basin has a very high positive significant correlation, i.e., an almost perfect correlation of 0.99 and 0.91 for 1992 and 2000, respectively. It can be deduced from the table that population size is positively correlated to agricultural land use in all of the five sub-basins. This conforms to the hypothesis and it is therefore accepted.

The results further show that there have been only slight changes in the correlation coefficients for both 1992 and 2000 for the White (0.56 to 0.75), Main Volta (0.64 to 0.57), Oti (0.75 to 0.65), and Daka, (0.99 to 0.91) sub-basins indicating that temporally, the relationship between population size and agricultural land use has basically remained the same between 1992 and 2000 in the four sub-basins mentioned above. However, the only exception is the Black Volta sub-basin, where there was a strong significant positive correlation of 0.79 in 1992, but that relationship was reduced to a weak non-significant correlation of 0.43 in the year 2000.

To further assess the relationship between the two variables in a temporal dimension, the extent of change in each variable for the two years was computed, and the results correlated. It could be seen that only the Oti sub-basin has a moderate correlation coefficient of 0.56, which can be interpreted to mean that changes in population growth have to some extent kept pace with changes in agricultural land use. Finally, the White and Main Volta sub-basins had very weak correlations of 0.17 and 0.10, respectively, a scenario which can be described as the direct opposite to the situation in the Oti sub-basin.

The results of the coefficient of determination *(R^2)* between population and agricultural land use for the year 2000 revealed a moderate positive relationship of 0.56 for the White Volta sub-basin, and a strong relationship of 0.83 for the Daka sub-basin. These results and the simple regression models used for the prediction are shown in Figures 5.5 and 5.6. However, with the rest of the sub-basins, very weak relationships were observed between the two variables as reflected in weak coefficient of determination figures of 0.19, 0.32 and 0.43 for the Black Volta, Main Volta and Oti sub-basins, respectively (Appendix 1).

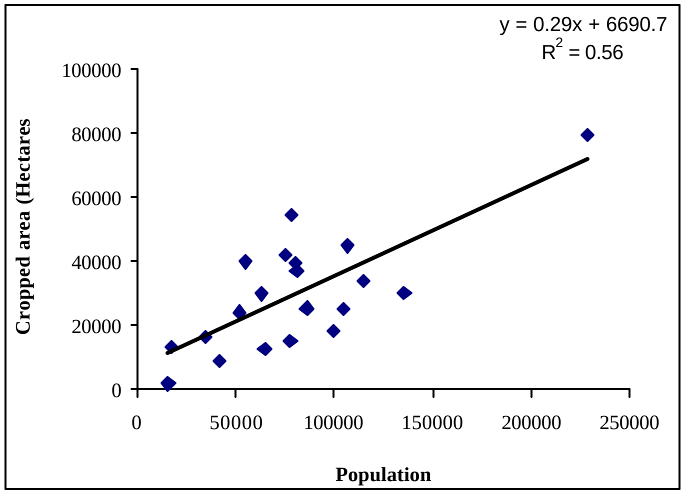

Figure 5.6: Scattergram showing relationship between population and cropped area in the White Volta sub-basin, 2000

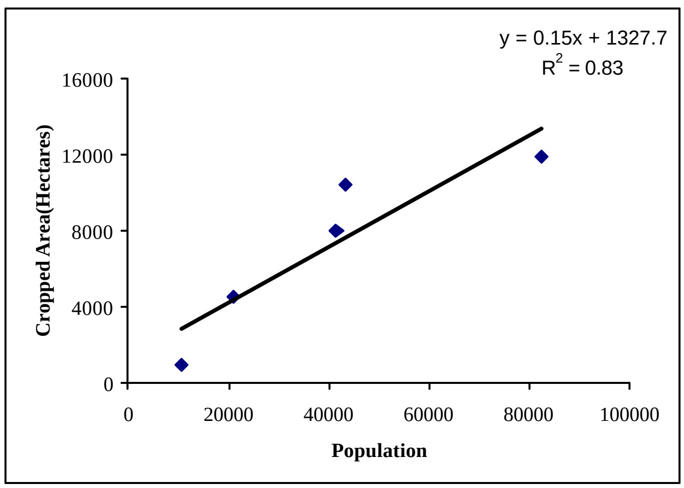

Figure 5.7: Scattergram showing relationship between population and cropped area in the Daka sub-basin, 2000

It can be seen from the Figures 5.6 and 5.7, that a unit increase in population would cause a corresponding increase of 0.3 unit in cultivable land in the White Volta sub-basin, and a 0.2 unit increase in the Daka sub-basin. This shows that, population is slightly stronger in determining agricultural land use in the White Volta compared to the Daka sub-basin. Even though there may be some degree of intensification, the results suggest that agricultural extensification is the major land use change process in both sub-basins.

5.6 Agricultural land suitability

Figure 5.8 is a soil suitability map (Ghana Soil Research Institute, 1999) for 90-day maize of the study area. It shows areas suitable and those not suitable for agriculture. The methodology used is explained in Chapter 4 and the areas suitable for agriculture in the local/urban councils in the White Volta and Daka basins are shown in Tables 5.5 and 5.6. The analysis shows that the Damango local council had the largest area (501,300 hectares) suitable for agriculture in the White Volta basin, while the Salaga local council had the largest area (111,100 hectares) suitable for agriculture in the Daka sub-basin.

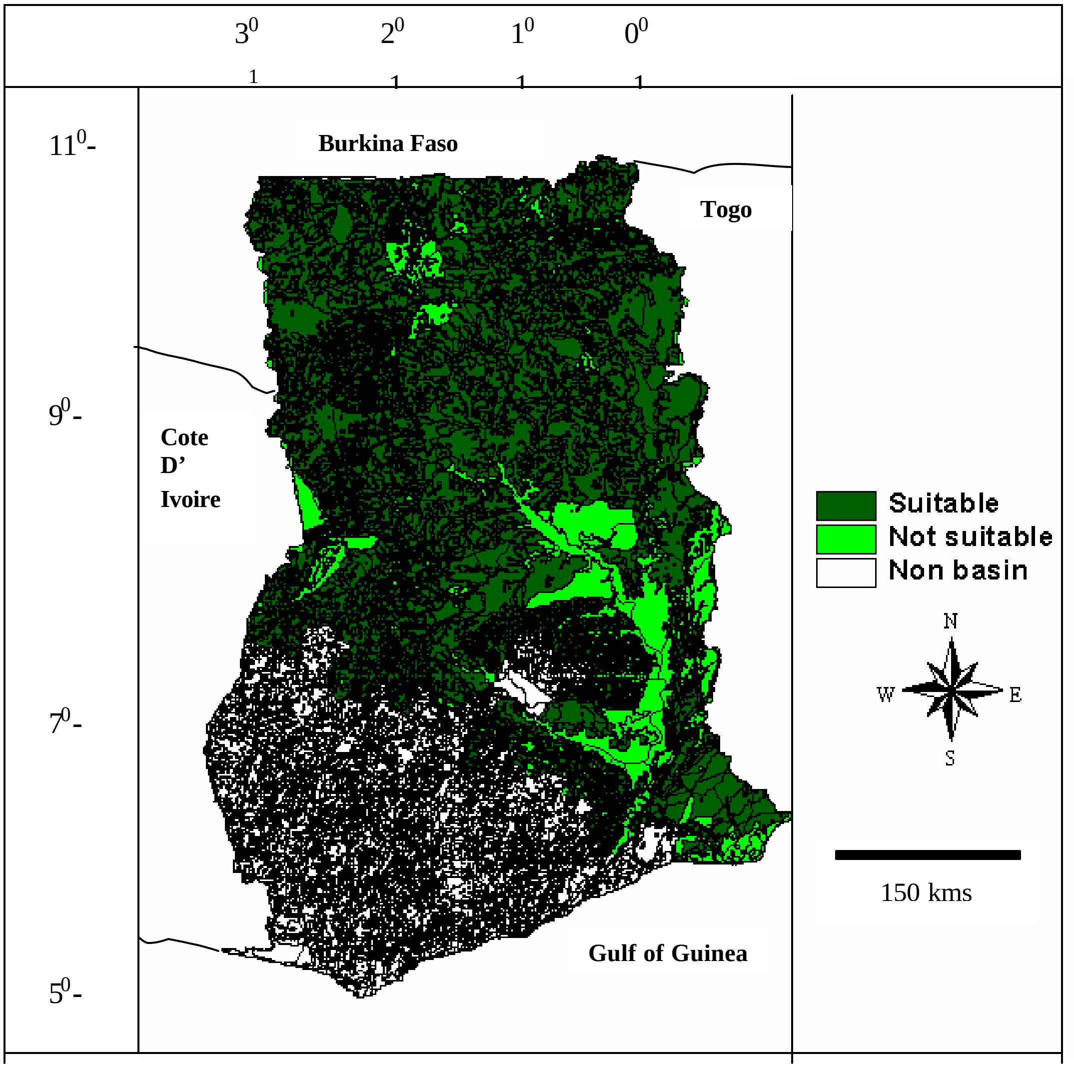

Figure 5.7: Map of Volta basin showing areas suitable and not-suitable for agriculture

Source: Data generated from Ghana Environmental Resources Management Project (GERMP), Ghana Soil Research Institute, 1999

5.7 Population and agricultural land availability in the sub-basins - 2010

As a result of the strong and moderate positive coefficient of determination between population size and cropped area in the Daka and White Volta sub-basins, respectively, in 2000, predictions of change in cropped area, which would occur as a result of population change, were computed for the year 2010, based on a simple regression model and the projected populations of the two sub-basins for the year 2010. These were matched with actual arable area that would be available, based on the soil suitability analysis discussed in Section 5.6, to produce an agricultural land availability status map of 2010 for the two sub-basins.

The predictions have been done for the year 2010, because the predictive abilities of the equations derived do not effectively go beyond that year. Also, the three other sub-basins were not considered for the prediction, because of the weak correlation coefficients obtained between population size and agricultural land use. The analysis was done under the assumption that all other factors affecting agricultural land use would remain constant, and population growth would remain the same for the projection years 1984-2010. Also, it was assumed that the only option that would be available to farmers would be the practice of agricultural extensification.

According to the classification used, the results of the agricultural land availability status in Tables 5.5 and 5.6 and Figures 5.9 and 5.10, show that three local/urban council areas in the White Volta sub-basin, namely the Bolgatanga-Tongo and Bawku Urban Councils as well as the Pusiga-Pulikam Local Council, will experience agricultural land shortfalls in the year 2010 as a result of population change. The Bolgatanga-Tongo Urban Council hosts the Bolgatanga town, which is the administrative capital of the entire Upper East Region of Ghana. It has therefore attracted a larger number of migrants. As far as the Bawku Urban Council is concerned, it has the Bawku Township as its capital, and is a commercial border town between Ghana and Burkina Faso. Due to this, there has been an influx of migrants to the town over the years.

Secondly, the Bawku Urban Council has maintained a large population as a result of the discovery of new mining areas in the 1980s. These mines have attracted many migrants, who are mainly small-scale miners, practicing what is called "g*alampsey*" in the local parlance. The activities of these small-scale miners in these already densely populated areas have resulted in high soil degradation, an issue that has been a major concern for the government. For example, lands, which were hitherto used for agricultural production, have been converted to mining and this scenario is expected to continue (GSS, 1995).

In the Daka sub-basin, one local council area, Kete-Krachi, will experience agricultural land shortfall in 2010. The only reason that could be attributed to this occurrence is the fact that most of the local council area is already under water, since it was inundated when the Akosombo Dam was built. This limits the land area suitable for agriculture. Population has, however, increased over the years, and projections show an increase in the future, since the area is important both commercially and agriculturally.

Another significant finding is that the Bongo-Nabdam Local Council in the White Volta sub-basin will have low agricultural land availability, and about five other local councils (Lawra-Jirapa, Tolon, Kusanaba-Zebilla, Tempane-Garu and Chiana-Paga) will have moderate agricultural land availability in the year 2010. This gives an indication that it may not be too long before the sub-basin experiences pressure on agricultural land as a result of population increase.

Finally, almost all the local councils in the Daka sub-basin, and quite a substantial number of local councils in the White Volta sub-basin (Sandema, Navrongo, Nalerigu, Wa, Nadawli-Funsi, Bole, Damango, Savelugu, Gushiegu-Chereponi, Tumu and Walewale), will have high agricultural land availability to support any form of population growth.

Table 5.5: Agricultural land availability status for 2010, White Volta

Local/Urban Council	*Projected Population 2010*	*Agric. suitability Area (00's hectares)*	*Predicted Cropped Area*	*Difference*	*Percent*	*Avail. Status 2010*
Sandema	81650	1066	300	766	72	HLA
Navrongo	63258	576	247	329	57	HLA
Nalerigu	119736	1658	408	1250	75	HLA
Wa	133639	952	448	504	53	HLA
Nadawli-Funsi	55590	2273	226	2047	90	HLA
Bole	20455	709	125	584	82	HLA
Damango	51905	5013	215	4798	96	HLA
Savelugu	33177	1413	162	1251	89	HLA
Gushiegu-Chereponi	47557	1223	203	1020	83	HLA
Tumu	102571	3504	359	3145	90	HLA
Walewale	175882	1754	569	1185	68	HLA
Lawra-Jirapa	17390	189	117	72	38	MLA
Tolon	129132	680	435	245	36	MLA
Kusanaba-Zebilla	93569	490	334	156	32	MLA
Tempane-Garu	121892	633	415	218	34	MLA
Chiana-Paga	86115	491	313	178	36	MLA
Bongo-Nabdam	68727	331	263	68	21	LLA
Bolgatanga-Tongo	303332	748	932	-184	-25	ALS
Bawku	154359	423	507	-84	-20	ALS
Pusiga-Pulikam	73751	182	277	-95	-52	ALS

Table 5.6: Agricultural land availability status for 2010, Daka

Local/Urban Council	*Projected Population 2010*	*Agric. suitability Area (00's hectares)*	*Predicted Cropped Area*	*Difference*	*Percent*	*Avail. Status, 2010*
Gushiegu-Chereponi	23850	612	48	564	92	HLA
Yendi	77577	984	127	857	87	HLA
Salaga	42652	1111	76	1035	93	HLA
Bimbila	100263	873	161	712	82	HLA
Kete-Krachi	16420	33	37	-4	-12	ALS

ALS - Agricultural Land Shortfall (Negative values) LLA - Low Land Availability (0-24%)
MLA - Medium Land Availability (25-50%) HLA - High Land Availability (50% and above)

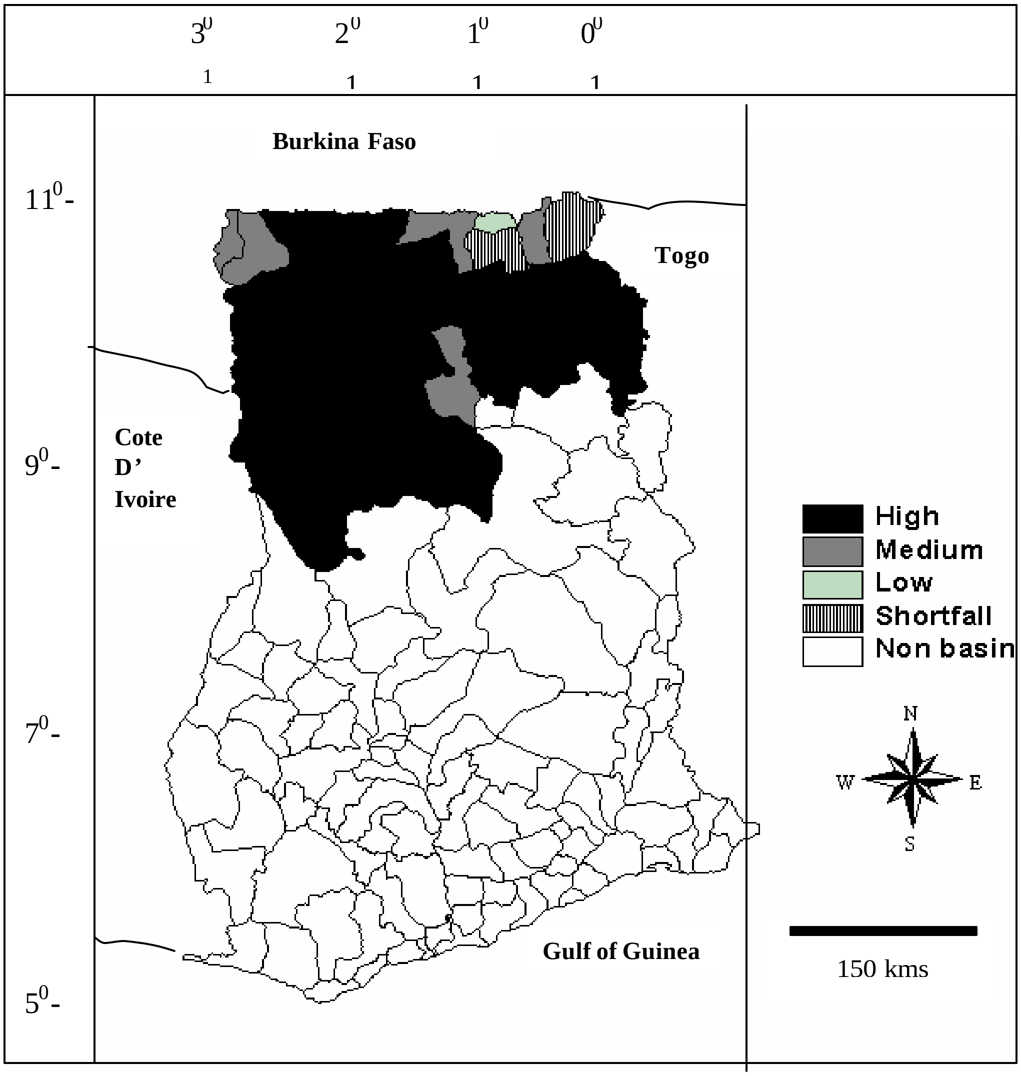

Figure 5.8: Agricultural land availability status, White Volta, 2010

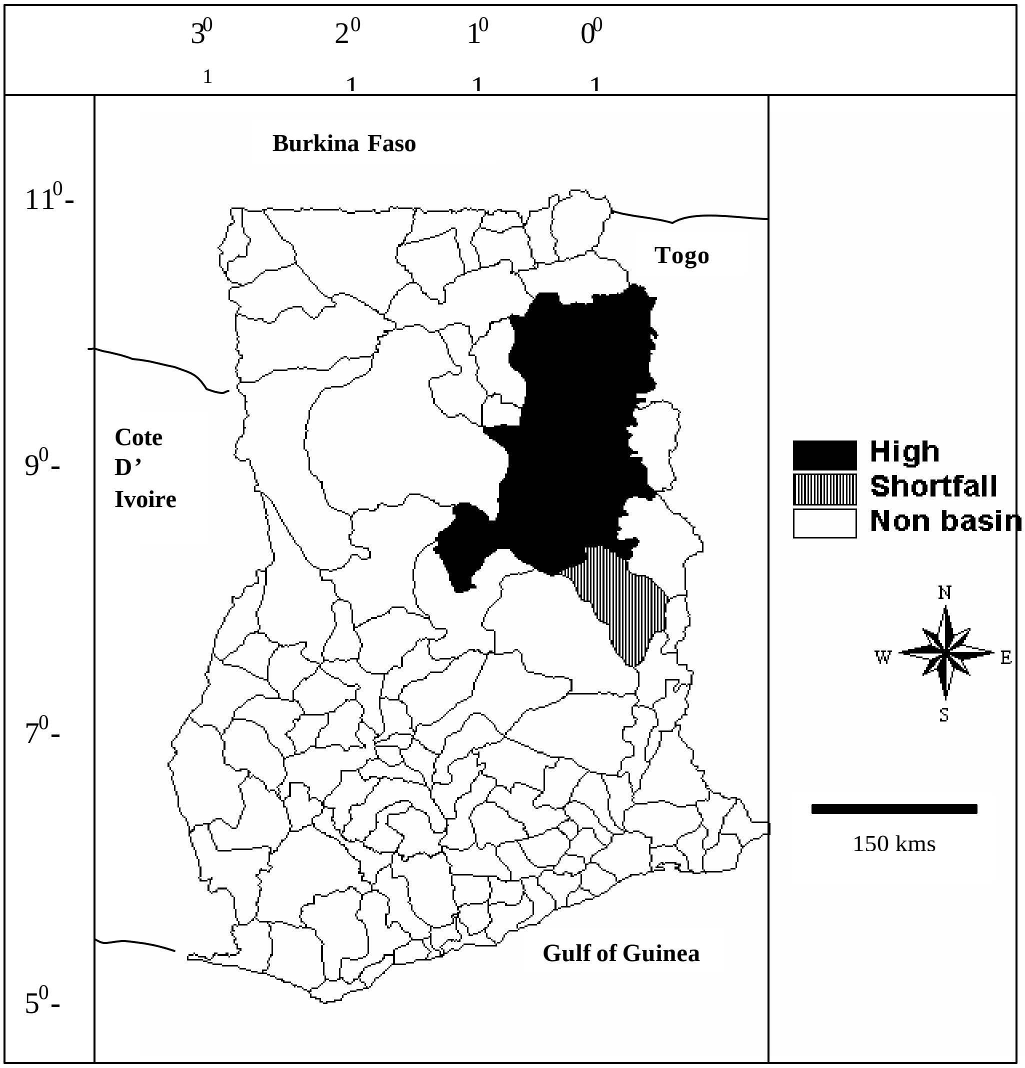

Figure 5.9: Agricultural land availability status, Daka, 2010

5.8 Population and agricultural land use in the study districts

The preceding sections have looked at the relationship between three demographic variables and agricultural land use at the basin level to give a general view of the situation in the Volta basin as far as population and agricultural land use relationships are concerned. The following sections will zoom in on the two selected study districts, namely the Kassena-Nankana District in the White Volta sub-basin, and the Ejura-Sekyedumase District in the Main Volta basin, to have a closer look at the population-agricultural land use relationship.

The general analysis at the basin level considered an 8 year period, i.e., 1992-2000, due to lack of reliable data. However, this analysis will consider a 16 year period, i.e., 1984-2000. The information on population is derived from the 1984 and 2000 population censuses of Ghana, and that of agricultural land use was collected during the field survey.

It can be observed from Table 5.7 that, apart from Atibaabisi, population declined in all the other localities in the Kassena-Nankana District within the period 1984-2000. However, agricultural land use increased in most of the localities with the exceptions being Nabango and Mirigu.

Table 5.7: Population and agricultural land use in the Kassena-Nankana District, 1984 & 2000

Locality	**Population**		**Agricultural land use (acres)**	
	1984	**2000**	**1984**	**2000**
Telania	1146	1139	174	234
Navrongo	19690	15983	101	166
Bonia	1839	1371	61	92
Kanania	1499	1421	182	198
Atibaabisi	1942	3325	49	93
Yua Afarigabisi	716	711	68	71
Nabango	1237	1229	86	74
Paga	7958	7819	96	118
Mirigu	676	672	88	86
Badania	1311	1303	58	80
Manyoro	981	975	55	59
Janania	1040	1033	57	67

Source: 1984 Population Census of Ghana, Special Report on Localities by Local Authority, 2000 Population and Housing Census, Special Report on 20 Largest Localities (GSS 2002a) and Field Survey, 2001 & 2002

In the Ejura-Sekyedumase District, Table 5.8 shows that only two of the localities, namely Hiawoanwu and Bonyon, experienced population declines, and agricultural land use increased in all localities between 1984 and 2000.

Table 5.8: Population and agricultural land use in the Ejura-Sekyedumase District, 1984 & 2000

Locality	**Population**		**Agricultural land use (acres)**	
	1984	**2000**	**1984**	**2000**
Hiawoanwu	2268	1823	216	339
Kasei	942	1836	180	330
Dromankuma	2145	2291	250	396
Bonyon	894	803	234	410
Aframso	1100	1336	133	324
Afrante	1825	2043	126	306
Anyinaso	3536	4707	182	288
Sekyedumase	6903	10085	308	551
Ejura	18775	29478	363	800

Source: 1984 Population Census of Ghana, Special Report on Localities by Local Authority, 2000 Population and Housing Census, Special Report on 20 Largest Localities (GSS 2002a) and Field Survey, 2001 & 2002

The results of a correlation coefficient of determination (R^2) analysis give contrasting pictures of the two districts in both years as far as the population and agricultural land use relationship is concerned. For example, while there is a very weak correlation in the Kassena-Nankana District for both years (0.01 in 1984 and 0.09 in 2000), there is a moderate positive correlation of 0.64 in 1984 and a strong positive correlation of 0.88 in 2000 in the Ejura-Sekyedumase District. This gives an indication that growth in agricultural land use in the Ejura-Sekyedumase District has kept pace with population growth.

6 EFFECTS OF DIRECT AND INDIRECT DEMOGRAPHIC FACTORS ON AGRICULTURAL LAND USE

The previous chapter looked at the relationship between population size, population density as well as annual population growth rate and agricultural land use in the five sub-basins of the Volta River in Ghana for 1992 and 2000, and in the two selected study districts for the years 1984 and 2000. As mentioned in the introduction to this study, apart from the demographic factor, there are other factors influencing agricultural land use. For purposes of this study, those factors have all been considered under one umbrella and termed the indirect demographic factors.

This section of the study therefore considers the indirect demographic factors in the two study districts between 1984 and 2000, and ascertains whether there have been any significant differences both spatially and temporally. The next part of the chapter presents a bivariate analysis of the indirect demographic as well as the direct demographic factors and agricultural land use. The aim is to establish associations between the independent variables and the dependent variable (agricultural land use).

The third part of the chapter employs a multivariate analysis to look at the relationships between the above-mentioned factors, and to identify statistically significant predictors of agricultural land use. This stage of the analysis moves from the level of establishing mere associations between the independent and dependent variables to the aspect of predictions. The ultimate goal is to identify the most important predictor variables of agricultural land use change within the period and areas of study. Agricultural land use in this instance refers to the total cropped area (in acres) of the household; the information was gathered during the field survey.

The indirect demographic factors considered in this study include the educational level of households, proportion of major farmers in household, presence or otherwise of electricity as a source of energy, household income from off- and on-farm activities, average household expenditure on food, and household affluence (measured in two forms, firstly by ownership of car, motorcycle, bicycle, television and radio, and secondly, by ownership of livestock, namely, cattle, sheep and goats). The rest are the farming systems, practices, implements and tools used (tractor, inorganic fertilizer and improved seed variety), type of land tenure arrangement, the availability of extra land to practice agricultural extensification, land fallow, and average distance travelled to farthest farm.

Finally, another demographic variable, namely household size, was included in the model to augment the other demographic variable, which is population of the locality. As mentioned earlier, other physical/natural/environmental factors namely climate (sunshine, precipitation, and temperature), geomorphology (altitude, and slope), soil (fertility, drainage, permeability, texture), and geology can influence agricultural land use. However, these variables are excluded from this study, because they form the central variables in other sub-projects of GLOWA.

6.1 Land use/cover in the study districts

Figure 6.1 is presented to give a historical view of the different land use/cover in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively. Wide open savannah woodland with crop cover was very dominant in the two districts. This reveals that the two study areas are savannah areas. While the Kassena-Nankana District can be described as a dry savannah, the Ejura-Sekyedumase District can be described as a derived savannah area. The Kassena-Nankana District also has a sizeable area of grassland, a phenomenon that does not prevail in the Ejura-Sekyedumase District, buttressing the fact that the former is a dry savannah region.

Figure 6.2 also gives an idea of the agricultural and non-agricultural areas in the two districts in 1990. A visual inspection of the two maps shows that, while about 50% of the Kassena-Nankana District was utilised for agriculture, close to 90% of the land in the Ejura-Sekyedumase was utilised for agriculture. The possible reason that could be attributed to the situation in the Ejura-Sekyedumase District is population pressure.

Finally, Figure 6.3 is presented to show the forest cover situation in the two districts in 1990, since this is related to agricultural land use. It can be seen clearly from the two maps that both areas have very low forest cover. In the Kassena-Nankana District, a small patch is found at the southern tip of the district, while a few were found scattered around the Ejura-Sekyedumase District. These areas are forest reserves.

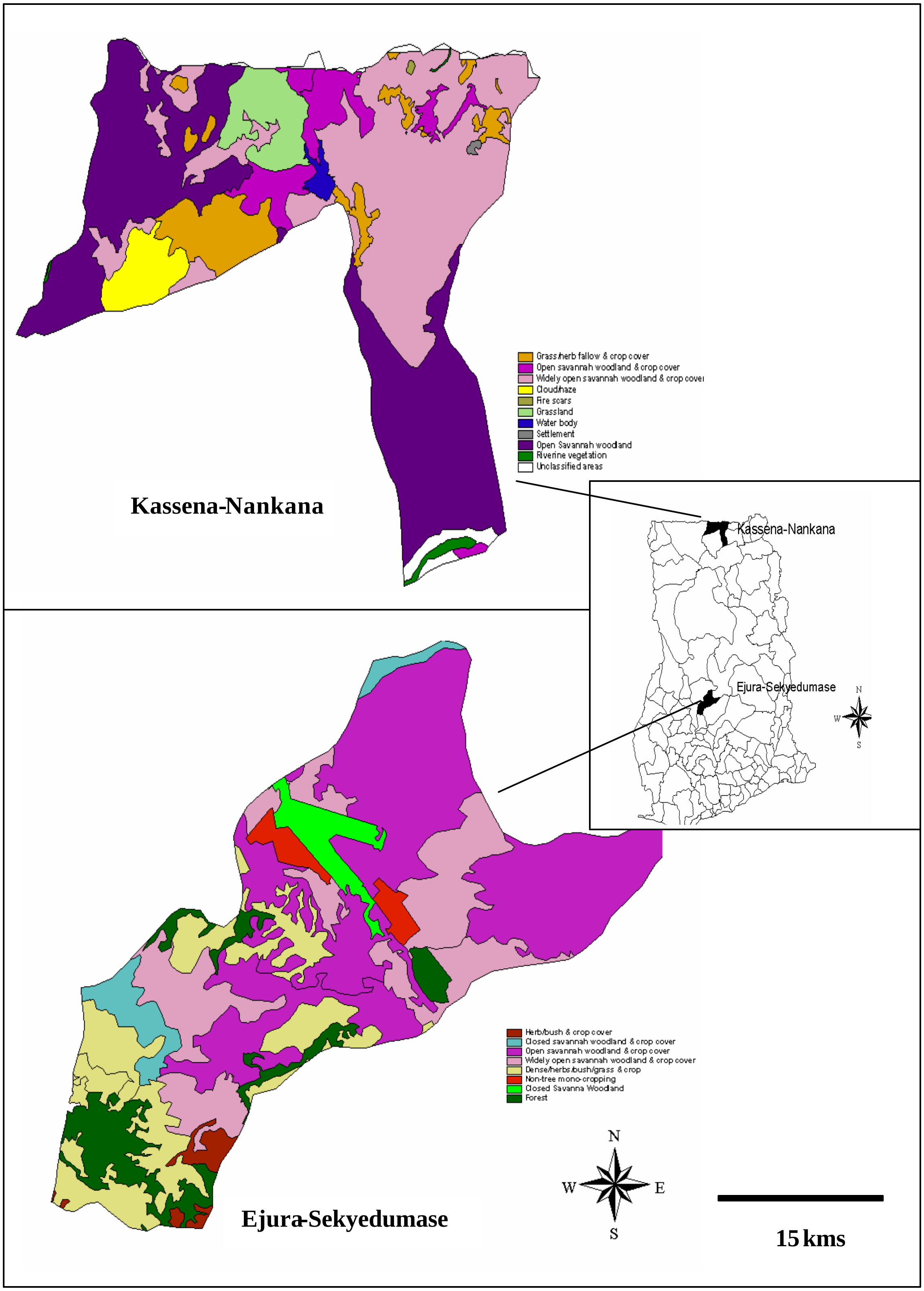

Figure 6.1: Land use/cover in the two study districts, 1990

Source: Developed from Agyepong et al., 1999

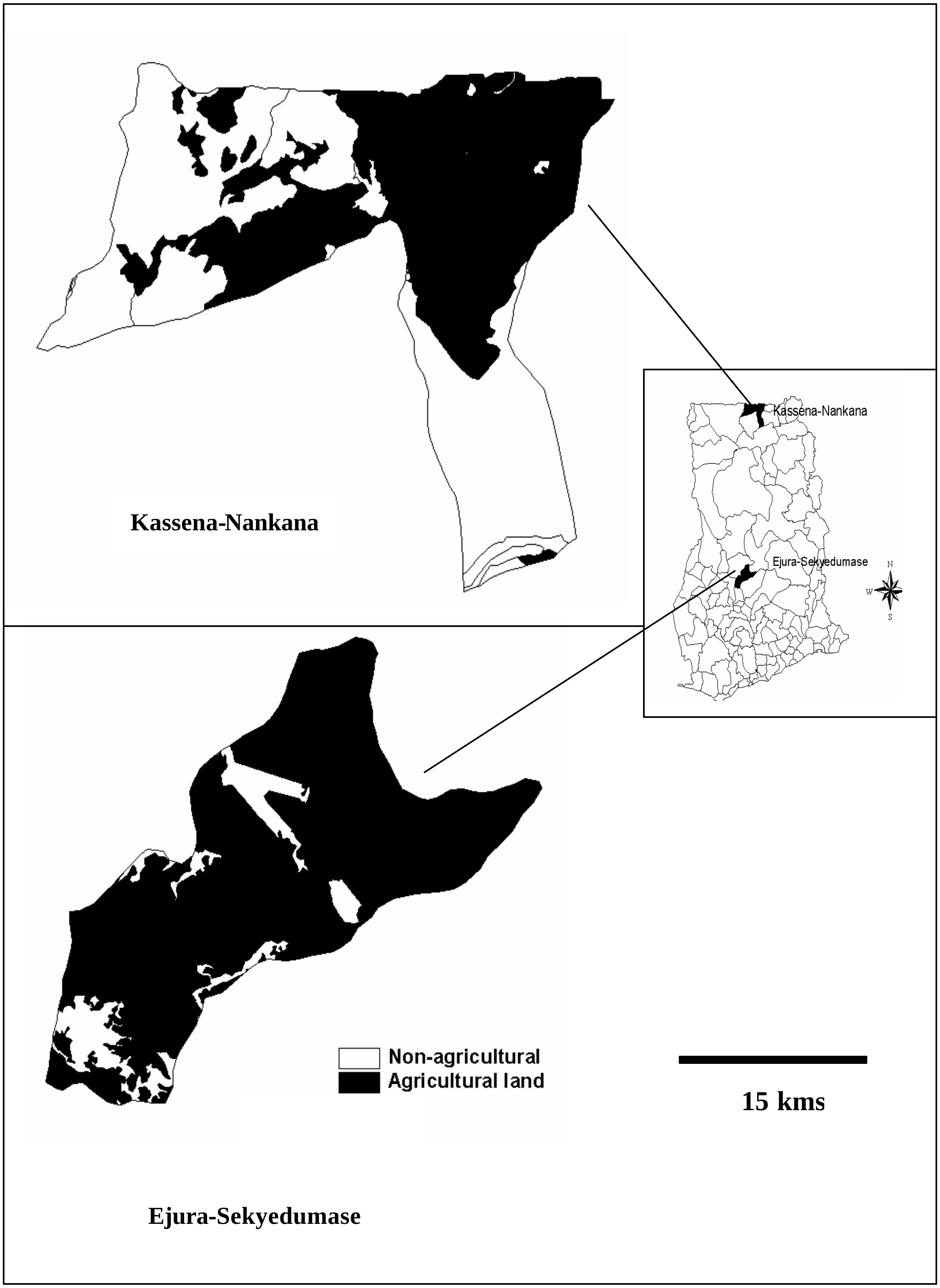

Figure 6.2: Agricultural and non-agricultural land use in the two study districts, 1990

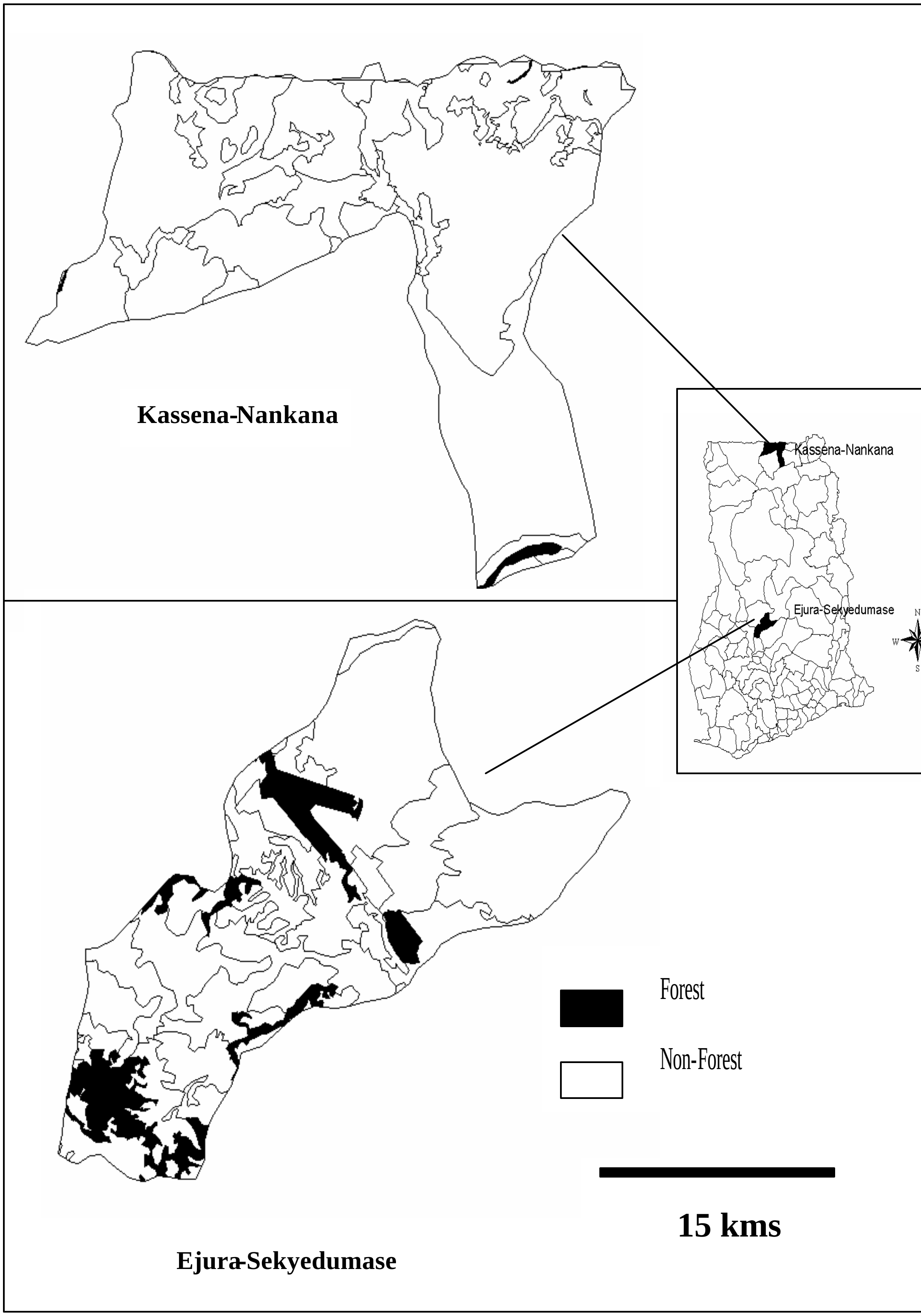

Figure 6.3: Forest and non-forest areas in the two study districts, 1990

6.1.1 Size of farm holdings

Table 6.1 presents the percentage distribution of households and the total cropped area in both study areas and for both years. Most of the households in the Kassena-Nankana District have farm holdings of 10 acres or less. Secondly, the total cropped area in the Kassena-Nankana District has not changed so much between 1984 and 2000. The only notable exception is that more households have farm holdings ranging between 1-5 acres in 2000 than in 1984, suggesting that the size of farm holdings may be decreasing in the district. This could be attributed to increase in population as more farmers are sharing same farm holdings a system referred to as the "huza". In the Ejura-Sekyedumase District, quite a substantial number of households, about 7%, have farm holdings of 30 acres and above. The Ejura-Sekyedumase District has a lot of migrant farmers who tend to have larger farm holdings compared to indigenous people.

Table 6.1: Percentage distribution of households by total cropped area and study area, 1984 & 2000

Size (acres)	Kassena-Nankana				Ejura-Sekyedumase			
	1984		2000		1984		2000	
	N	%	N	%	N	%	N	%
1-5	125	67.2	182	72.1	79	43.4	52	20.6
6-10	38	20.4	47	18.7	53	29.1	87	34.5
11-15	13	7.0	14	5.6	15	8.2	52	20.6
16-20	7	3.8	7	2.8	15	8.2	18	7.2
21-25	-	-	1	0.4	5	2.8	22	8.7
26-30	2	1.1	1	0.4	2	1.1	3	1.2
30 & above	1	0.5	-	-	13	7.2	18	7.2
Total	**186**	**100**	**252**	**100**	**182**	**100**	**252**	**100**

Source: Field Survey, 2001 & 2002

6.1.2 Crops grown

A variety of crops are grown in the two study districts. As shown in Table 6.2, maize *(Zea mays)* is the most important crop grown in the Ejura-Sekyedumase District, while groundnut *(Arachis hypogaea)* is grown by the majority of the farmers in the Kassena-Nankana District. A few of the farmers grow fruits, and tree crops such as cotton *(Gossypium herbaceum)*, cocoa *(Theobroma cacao)*, oil palm *(Elaeis guineensis)*, cashew *(Anacardium occidentale)*, shea nut *(Butyrospermum parkii)*, etc., in both areas. Furthermore, while cassava *(Manihot esculenta)* and yam *(Dioscorea divaricata)*, which are root crops, are widespread in the Ejura-Sekyedumase District, they are not grown at all in the Kassena-Nankana District. Also, while sorghum *(Sorghum bicolar)* and millet *(Panicum colonum)* (savannah crops) are widely grown in the Kassena-Nankana District, they are scarcely grown in Ejura-Sekyedumase. Due to the fact that the Ejura-Sekyedumase District has two rainfall regimes, maize, yam and cassava are planted during the major rainy season, and cowpea *(Vigna unguiculata)* and the vegetables are planted during the minor rainy season.

Table 6.2: Percentage distribution of crops grown by study area - 2000

Crops grown	**Kassena-Nankana**	**Ejura-Sekyedumase**
Maize *(Zea mays)*	14	90
Cowpea *(Vigna unguiculata)*	61	46
Groundnut *(Arachis hypogaea)*	94	43
Sorghum *(Sorghum bicolar)*/ Millet *(Panicum colonum)*	80	1
Tree crop (cotton *(Gossypium herbaceum)*, cocoa *(Theobroma cacao)*, oil palm *(Elaeis guineensis)* etc.	1	9
Sweet potatoes *(Ipomoca batata)*	7	0.3
Rice *(Oryza sativa)*	54	8
Vegetables (tomato *(Lycopersicon esculentum)*, pepper *(Capsicum baccatum)*, onion *(Allium spp.)*, egg plant *(Limnanthes douglasii)*	29	52
Fruits	0.6	0.3
Cassava *(Manihot esculenta)*	-	53
Yam *(Dioscorea divaricata)*	-	59

Source: Field Survey, 2001 & 2002

6.2 Indirect demographic factors

6.2.1 Educational level of household members

The quality of a population, with regard to its educational attainment is very important and can influence agricultural land use in any community. This is borne out of the fact that, in communities with low educational attainment, there is the tendency for its members not to be able to find employment in the highly skilled labor sectors and therefore engaging in unskilled labor especially subsistence farming. This scenario has implications for land use as more people may seek farmland to utilize.

In Table 6.3, the educational level of the households for 2000 is presented. In the Kassena-Nankana District, 44.2% of the respondents have never had any formal education, while in the Ejura-Sekyedumase District, 34.6% of the respondents have no formal education. This situation buttresses the well-known notion that educational levels among the populations in the Northern Regions of Ghana are lower than that of their counterparts in the South. Worth noting here, however, is the fact that more (1.8%) people in the Kassena-Nankana District have tertiary education when compared to their counterparts in the Ejura-Sekyedumase District, which has only 0.8% of its population with a tertiary level of education.

Table 6.3: Percentage distribution of respondents by educational level and study area, 2000

Educational Level	**Kassena-Nankana**		**Ejura-Sekyedumase**	
	N	**%**	**N**	**%**
No schooling	624	44.2	554	34.6
Primary/Elementary	131	9.3	307	19.2
Secondary/JSS	171	12.1	360	22.4
Vocational/Technical	27	1.9	9	0.6
Tertiary	26	1.8	12	0.8
Still in school	433	30.6	327	20.3
Other	1	0.1	34	2.1
Total	**1413**	**100**	**1603**	**100**

Source: Field Survey, 2001 & 2002

There is twice the number of people (41.6%) in the elementary and secondary levels of education in the Ejura-Sekyedumase District than in their counterparts in the Kassena-Nankana District (21.4%). However, this situation reverses when one considers the highest levels of education, i.e., the vocational and tertiary levels. At these levels, the Kassena-Nankana District has 3.7% of its population, while the Ejura-Sekyedumase District has only 1.4% of its population at the two levels. Furthermore, a look at the proportions still in school shows a greater percentage (30.6%) in the Kassena-Nankana District than in the Ejura-Sekyedumase District (20.3%).

The analysis suggests that more people in the Ejura-Sekyedumase District are found at the point of entry into the educational system, i.e., at the lowest levels, compared to their counterparts in the Kassena-Nankana District. However, as students move up the educational ladder to the highest levels of education, the situation reverses and the opposite is the case. This may be indicative of a high school drop-out rate for the students in the Ejura-Sekyedumase District, probably to take up farming, which, as will be portrayed later on in this chapter, is very lucrative.

A ranking system for the various levels of education was adopted to ascertain the educational level of the households. Household members with no schooling were ranked one, those who attained elementary level were ranked two, and secondary education was ranked three. The vocational education was given rank four, and any tertiary form of educational level rank five. However, members of households who were still in school were excluded from the ranking.

The total score of household members was divided by the number of household members who are still in school, to obtain the average educational level of the household; this value was used in the regression model described later in this chapter. It was only possible to gather information on the educational level and the four other variables (i.e., income from on and off-farm activities, expenditure on food, and availability of land for extensification) at the time of the interviews and thus not for 1984. Therefore, those variables are considered only in the spatial and not in the spatio-temporal model.

6.2.2 Occupation of household members

As envisaged, the majority of the population (71.9% and 69.9% in the Kassena-Nankana District, and 69.9% and 72.1% in the Ejura-Sekyedumase District for 1984 and 2000, respectively) in both districts have farming as their major occupation both in 1984 and 2000, and this certainly affects agricultural land use and underscores the point already mentioned that the two districts are farming ones. According to Table 6.4, the next popular occupation in the districts is trading, which employs 9.6% and 11.3% of the population in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively, in 2000. Both districts have important market towns, i.e., Navrongo in the Kassena-Nankana District, and Ejura in the Ejura-Sekyedumase District. This explains why trading is the next major occupation after farming. Due to the fact that the two districts are made up of predominantly farming communities, only few people are engaged in other forms of occupation. For instance, only 0.8% and 0.4% of the population in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively, were engaged in the construction industry in 2000.

Table 6.4: Percentage distribution of respondents by major occupation, study area and year

Major occupation	**1984**		**2000**	
	KN N=657	**ES** N=751	**KN** N=854	**ES** N=970
Farming	71.9	72.7	69.9	72.1
Trading or sales	9.0	11.2	9.6	11.3
Clerical and related	0.2	-	0.1	0.3
Construction	0.6	0.3	0.8	0.4
Professional/managerial	4.6	2.9	4.8	3.0
Industrial	0.6	0.4	0.7	0.4
Handicraft	2.1	4.0	2.5	3.5
Other labourers	4.3	4.0	5.3	4.2
Unemployed	6.7	4.5	6.3	4.8

Source: Field Survey, 2001 & 2002

Furthermore, substantial proportions of the population in the two districts are engaged in professional or managerial occupations. In Kassena-Nankana, this is 4.8% of the population, while in the Ejura-Sekyedumase District it is 3%. There are more professional workers in the Kassena-Nankana district probably because of the Tono irrigation project. Located in Navrongo, the project attracts professional workers from all over Ghana. There were few people (6.3% in the Kassena-Nankana and 4.8% in the Ejura-Sekyedumase District) in both districts who were unemployed in 2000. Unemployment figures were very low in both districts because most people engage in farming. Those who stated they were unemployed might be people who are not interested in farming due to higher educational levels attained. There were no significant shifts in the occupational trends between 1984 and 2000. The proportion of major farmers in the household has also been included in the regression model.

6.2.3 Electricity as a source of energy

The availability of electricity in a community can be mentioned as one of the factors that engineers technologies, which can be used to transform land cover. The study therefore made enquiries into households with electricity in the two study areas (Table 6.5), and the time electricity was installed in the houses in the two study areas (Table 6.6), to ascertain whether electricity was introduced into the communities early enough to make a marked contribution to agricultural land use.

Table 6.5: Percentage distribution of houses by electricity usage, study area and years, 2000

Electricity	**Kassena-Nankana**		**Ejura-Sekyedumase**	
	1984	**2000**	**1984**	**2000**
Yes	3.0	9.9	1.0	60.3
No	97.0	90.1	99.0	39.7
Total	**100**	**100**	**100**	**100**

Source: Field Survey, 2001 & 2002

In Table 6.5, only one out of ten houses in the Kassena-Nankana District had electricity in 2000, a marked difference from what pertains in the Ejura-Sekyedumase District, where six out of ten houses had electricity installed. About three-quarters of Ghana lacks access to power and Northern Ghana is one of the deprived areas. This explains why there is more access to electricity in the Ejura-Sekyedumase District compared to Kassena-Nankana. Most of the electricity in Ghana is generated through hydroelectric power plants at Akosombo with a capacity of 912 MV and Kpong (160 MV). There are plans to build a third at Bui on the Black Volta with a capacity of 400 MV. When the Bui projected is completed, most of Northern Ghana may have access to electricity.

Table 6.6: Percentage distribution of years in which electricity was installed in the houses by study area

Year	**Kassena-Nankana**		**Ejura-Sekyedumase**	
	N	**%**	**N**	**%**
Before 1960s	1	4	5	3.3
1960s	-	-	1	0.7
1970s	7	28	-	-
1980s	-	-	-	-
1990s	6	24	53	34.7
2000s	11	44	93	61.3
Total	**25**	**100**	**152**	**100**

Source: Field Survey, 2001 & 2002

In both study areas electricity was installed in most of the houses after 1990. Availability of electricity has been considered as a dichotomous variable in the regression model, and the presence of electricity in the household is given a rank of one and the absence of electricity a rank of zero.

6.2.4 Household off-farm income

Monthly household off-farm income, defined as income from non-farm activities earned by households as well as income from sale of farm produce, were analyzed to give an idea of the income levels of the two districts. This is very significant, because households that earn additional money from non-farm activities may be in a position to invest more in their farms and may increase their farm holdings as opposed to households with little or no income from non-farming activities. The same is true for income from sale of farm produce. However, households may tend to produce only for their consumption, since other financial obligations may be met by the additional income accruing from off-farm activities. Details of the monthly household off-farm income are shown in Table 6.7 and that of the farm income is shown in Table 6.8.

Table 6.7: Percentage distribution of off-farm income by household and study area, 2000

Off-farm income (thousands of Cedis)	Kassena-Nankana		Ejura-Sekyedumase	
	N	%	N	%
None	85	44.0	125	49.8
1-50	25	13.0	28	11.2
51-99	10	5.2	16	6.4
100-199	22	11.4	22	8.8
200 - 299	12	6.2	16	6.3
300 -599	17	8.8	24	9.6
600 -999	11	5.7	11	4.3
1,000 -1,999	11	5.7	8	3.2
2,000 and above	-	-	1	0.4
Total	**193**	**100**	**251**	**100**

Source: Field Survey, 2001 & 2002

Note: €1 = 5,500 Cedis at time of interview

It can be observed from Table 6.7 that little disparity exists between monthly off-farm incomes in the two districts. The analysis shows that 44% and 49.8% of the households in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively, have members who engage only in farming and thus, have no income from non-farm activities. Secondly, 13% and 11.2% of the households in the Kassena-Nankana and Ejura-Sekyedumase Districts earn between ¢1,000 and ¢50,000, respectively. The highest monthly income earned by any household in the Kassena-Nankana District is less than ¢2 million, while 0.4% of the households in the Ejura-Sekyedumase District earn a monthly income of more than ¢2 million from non-farming occupations.

6.2.5 Household farm income

Income from sale of harvested farm produce for the year 2001 was also analyzed to give an indication of the disparities in income between the two districts. In Table 6.8, the majority (51.2%) of the households in the Kassena-Nankana District stated that the food they grow on their farms goes to feed the household. Thus, they seldom have food in excess for marketing to earn an income. This situation is exactly the opposite in the Ejura-Sekyedumase District, where only 2.4% of the households do not earn an income from the sale of farm products.

Table 6.8: Percentage distribution of households by annual farm income and study area, 2000

Annual farm income (millions of Cedis)	**Kassena-Nankana N**	**Kassena-Nankana %**	**Ejura-Sekyedumase N**	**Ejura-Sekyedumase %**
None	106	51.2	6	2.4
Less than 1	89	43.0	32	12.9
1- 4.9	11	5.3	134	53.8
5 – 9.9	1	0.5	55	22.1
10 – 14.9	-	-	12	4.8
15 – 19.9	-	-	3	1.2
20 – 29.9	-	-	4	1.6
30 and above	-	-	3	1.2
Total	**207**	**100**	**249**	**100**

Source: Field Survey, 2001 & 2002

Furthermore, while 43% of the households in the Kassena-Nankana District earn less than ¢1 million from the sale of farm products annually, this only applies to 12.9% of the households in the Ejura-Sekyedumase District. Also, while only 5.3% of the households in the Kassena-Nankana District earn between ¢1 million and ¢4.9 million, 53.8% of the households in the Ejura-Sekyedumase District earn within this range. Whereas none of the households in the Kassena-Nankana District earn more than ¢10 million from the sale of farm products, 8.8% of their counterparts in the Ejura-Sekyedumase District earn more than ¢10 million, and in fact, 1.2% of the households in the Ejura-Sekyedumase District earn as much as ¢30 million or more.

The analysis above has revealed the contrasting nature of the two districts with respect to their income levels. Firstly, it clearly shows that farming is very lucrative in the Ejura-Sekyedumase District, and the district is economically better endowed than the Kassena-Nankana District. Secondly, the Kassena-Nankana District is dominated by subsistence farmers, who spend some of their income on the purchase of food, and do not have enough to market. It is, therefore, assumed that the disparity between the two districts in terms of income from sale of farm products will have an effect on agricultural land use; this scenario has therefore been considered in the model.

6.2.6 Household expenditure on food

In typical agrarian systems like the ones being considered by this study, households might want to minimise their expenditures on food by putting more land under cultivation to feed the household. The ideal situation would therefore be to have no costs for food. The amount of money a household spends on food can thus influence the total land area cropped by this household. It is assumed that households with high expenditures on food will have smaller areas of cropped land. Information was gathered on the households' expenditures on food items, namely, grains, beans, roots and tubers, fruits, vegetables, meat and diary products (Table 6.9).

Table 6.9: Percentage distribution of monthly household expenditure on food by study districts, 2000

Monthly expenditure (thousand Cedis)	**Kassena-Nankana (%)**	**Ejura-Sekyedumase (%)**
None	4.0	2.8
1 - 49.9	45.5	5.2
50 - 99.9	23.4	14.7
100 – 149.9	13.1	17.9
150 – 199.9	2.8	15.5
200 – 249.9	4.0	17.5
250 – 299.9	3.2	8.2
300 – 499.9	3.2	13.1
500 – 999.9	0.4	3.2
1,000 +	0.4	1.9

Source: Field Survey, 2001 & 2002

Only few households in both districts did not spend any money on food. However, while almost 46% of the households in the Kassena-Nankana District spent less than ¢50,000 on food, in the Ejura-Sekyedumase District, it is only 5.2%. Despite the fact that the previous analysis showed that a great deal of income is accrued from the sale of farm products, indicating a high food production in the Ejura-Sekyedumase District, about 6% of the households in that district spent more than ¢500,000 on food as compared to about 1% in the Kassena-Nankana District. Average household expenditures on food have been inputted as one of the independent variables in the model.

6.2.7 Household affluence

To determine the wealth of household members, enquiries were made into ownership of the household items shown in Table 6.10, and the ownership of livestock, specifically cattle, sheep and goats. This determination was made against the background that some of these items are sold out by household members to help resolve economic problems.

Table 6.10: Percentage distribution of ownership of selected household items by study area, 1984 & 2000

Item	Kassena-Nankana		Ejura-Sekyedumase	
	1984	**2000**	**1984**	**2000**
Bicycle	30.7	32.5	17.9	19.0
Car	0.6	0.5	0.7	1.1
Motorcycle	2.8	2.9	0.5	0.4
Radio	26.0	27.3	26.8	27.7
Television	2.4	3.2	8.7	9.1

Source: Field Survey, 2001 & 2002

There are differences in the two study areas as far as ownership of these items is concerned. In 2000, television ownership in the Ejura-Sekyedumase District is almost thrice that of the Kassena-Nankana District. Also, more people owned radios and cars in the Ejura-Sekyedumase District compared to the Kassena-Nankana District. This gives an indication that the Ejura-Sekyedumase District is more affluent and modern than the Kassena-Nankana District.

Due to the fact that the use of bicycles and motor-cycles is the major mode of transportation, it is widespread in the Northern Regions of Ghana as compared to the south; this assertion is confirmed by the fact that in 2000, more people (32.5%) in the Kassena-Nankana District owned a bicycle than their counterparts in the Ejura-Sekyedumase District (19.0%). Ownership of a motorcycle is no exception to the above assertion, as 2.9% of the respondents in the Kassena-Nankana District owned a motorcycle as compared to 0.4% in the Ejura-Sekyedumase District. There have not been many changes in the ownership of these items between 1984 and 2000.

The periods in which the selected household items listed in Table 6.11 and 6.12 were purchased in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively, were used as a proxy to determine the evolution of wealth in the households. Most of the household items in both districts were purchased after 1980.

Table 6.11: Percentage distribution of selected household items by period they were purchased for the Kassena -Nankana District

Item	**Period purchased**					
	1960s	**1970s**	**1980s**	**1990s**	**2000s**	**Total (N)**
Bicycle	1.0	1.6	10.9	72.8	13.7	313
Motorcycle	-	3.6	3.6	67.8	25.0	28
Car	-	-	16.7	50	33.3	6
Radio	0.8	3.5	8.6	69.1	8.0	256
Television	-	3.5	0.4	2.0	4.1	29

Source: Field Survey, 2001 & 2002

Table 6.12: Percentage distribution of selected household items by period they were purchased for the Ejura-Sekyedumase District

Item	**Period purchased**					
	1960s	**1970s**	**1980s**	**1990s**	**2000s**	**Total (N)**
Bicycle	0.5	4.1	11.4	67.0	17.0	194
Motorcycle	-	-	25.0	50.0	25.0	4
Car	-	-	-	80.0	20.0	10
Radio	0.7	1.4	8.9	53.8	35.2	290
Television	-	1.1	3.2	53.8	41.9	93

Source: Field Survey, 2001 & 2002

As far as livestock ownership is concerned, a contrasting picture emerged. While ownership of cattle, sheep and goats was very high in the Kassena-Nankana District, the situation was different in the Ejura-Sekyedumase District (Figure 6.4). The following reasons can be attributed to this situation. Firstly, the savannah landscape found in the Kassena-Nankana District makes the movement of livestock easier than in the forest landscapes of the south. Secondly, grasses are widespread in the Kassena-District and thus grazing of livestock becomes easier. This is different from what pertains in the Ejura-Sekydumase District where livestock are mainly kept in pens. Thirdly, livestock especially cattle, feature prominently in the cultural practices of the people of the Kassena-Nankana District compared to Ejura-Sekyedumase. For instance, cows are used to pay bridal prices during marriage ceremonies. The analysis further shows that while ownership of cattle and sheep decreased between 1984 and 2000 in the Kassena-Nankana District, ownership of goats increased. However, in the Ejura-Sekyedumase District, there were increases in ownership of all categories of livestock during the period.

Household affluence was measured, by two variables, namely, ownership of household items and livestock The animals were ranked according to their value on the market. Ownership of a cow in a household was given a rank of 3, ownership of sheep a rank of 2, while ownership of a goat got a rank of 1. The ranks 3 and 1 does not necessarily denote that the item ranked 3 is three times higher than the one ranked 1.

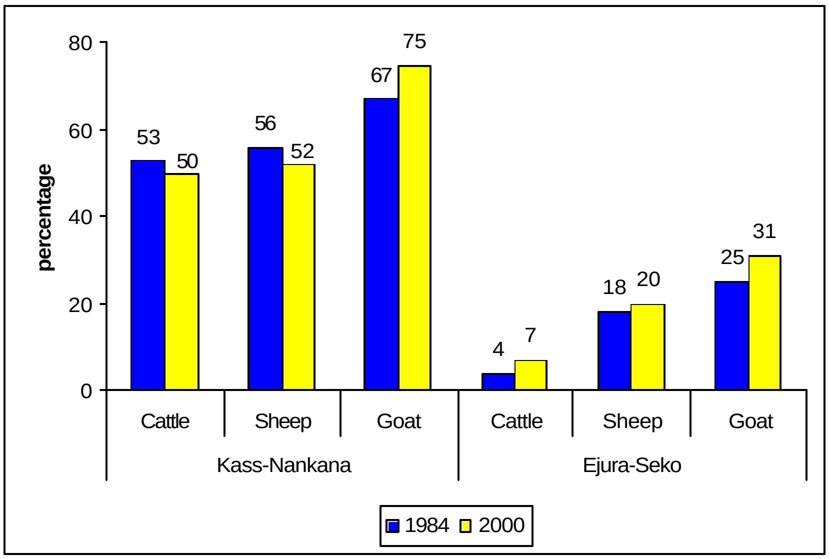

Figure 6.4: Percentage distribution of farmers by livestock ownership and study area, 1984 & 2000

Source: Field Survey, 2001 & 2002

6.2.8 Farming systems, practices and inputs

The type of farming system used, be it slash-and-burn, crop rotation, land fallow etc; the inputs, whether they are tractors, improved seed varieties, inorganic fertilizers, the type of land tenure, be it customary/communal, tenancy, family or individual ownership, may all play a role in affecting agricultural land use in any community. The following sections discuss these factors, which are later in the chapter included as independent variables together with the other factors already discussed to ascertain their effect on agricultural land use.

6.2.8.1 Land tenure systems

The type of land tenure predominant in any community plays a significant role in the agricultural system, and can greatly influence the total agricultural land cropped. This assertion is being made as a result of the fact that in communities where there are flexible land tenure systems, members may put more land under cultivation. However, members may be frustrated and land accessibility may be difficult in areas with very stringent land tenure systems or in situations where land may be hired. The study considered four kinds of land tenure systems, namely, tenancy, customary or communal, family and individual ownership.

As shown in Figure 6.5, 11% of the farmers in the Kassena-Nankana District are tenant farmers whereas twice that number (22%) are tenants in the Ejura-Sekyedumase District. The Ejura-Sekyedumase District has more tenant farmers because of its status as a migrant area. As far as customary or communal ownership of land is concerned, there is not much difference between the two districts, since 17% and 14% of the farmers in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively, have customary or communal land ownership.

However, there is a big difference between the districts as far as family ownership of land is concerned. In the Kassena-Nankana District, 70% of the lands are family owned as against 41% in the Ejura-Sekyedumase District. Most of the ethnic groups in Northern Ghana inherit patrilineally and therefore have strong family ties; this is reflected in the results. Finally, there are more farmers with individual land ownership in the Ejura-Sekyedumase District (23%) than in the Kassena-Nankana District (2%) due to the status of the Ejura-Sekyedumase District as a migrant area. The amount of money paid per acre of land varied considerably in the Ejura-Sekyedumase District ranging from ¢10,000 to ¢80,000 per acre and payments could be made by cash or harvested product. Land tenure arrangements did not change between 1984 and 2000.

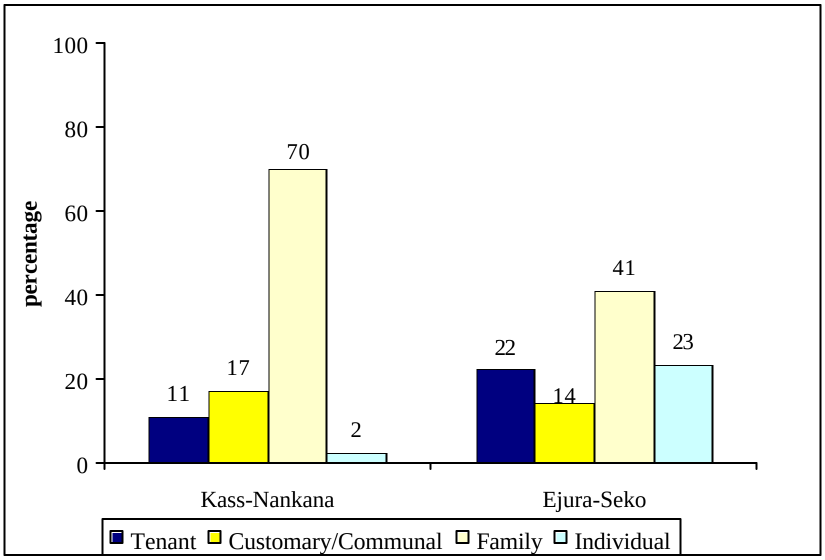

Figure 6.5: Percentage distribution of farmers by type of land ownership and study area, 2000

Source: Field Survey, 2001 & 2002

In the model, the land tenure variable was treated as a dichotomous one, with tenancy arrangements having a rank of 1 as against all other forms of land ownership, be they individual, family or customary, which is given a rank of 2. In other words, land tenure is perceived as either owned by the farmer in the various forms mentioned as against not-owned, which is then considered as tenancy.

6.2.8.2 Tractor, inorganic fertilizer and improved seed variety use

The types of agricultural input available to any community and at any point in time greatly influence the agricultural system, and may affect the total cropped area and the agricultural output in general. The study considered three agricultural inputs, namely, tractor, inorganic fertilizer and improved seed variety, and envisaged that in communities and periods where their utilization is widespread, a resultant increase in cropped area would occur and vice versa. Each household member, who is either a major or minor farmer, was asked whether he/she used any of the three inputs mentioned and, if yes, whether he/she used the inputs in 1984 and 2000. The results are presented in Figure 6.6.

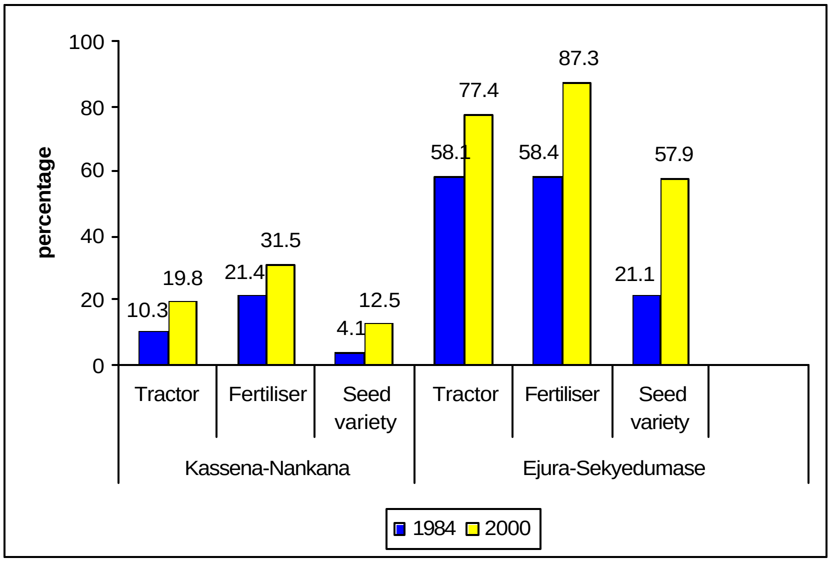

Figure 6.6: Percentage distribution of farmers who use tractor, inorganic fertilizer, improved seed variety on their farm by study area, 1984 & 2000

Source: Field Survey, 2001 & 2002

In Figure 6.6, the use of all the three inputs was much higher for both 1984 and 2000 for the Ejura-Sekyedumase District than that of the Kassena-Nankana District. The reason behind this is explained below. The Ejura-Sekyedumase District, is located in the transitional ecological zone of Ghana, and therefore between the resource endowed south and the impoverished north. It has attracted a lot of seasonal and permanent farm migrants, mainly from Northern Ghana. Migrant farmers tend to have bigger farm holdings, and use more mechanized farming inputs compared to indigenous farmers, because, unlike indigenous farmers they are mostly driven by economic reasons since they eventually have to make the return journey home. In each district, the use of the three inputs was higher in 2000 than in 1984. The amount of fertilizer used per acre of land depends on the crop. However, on the whole, about 100 kg of fertilizer is used per acre of land. Tractor services attract a fee of ¢70,000 per acre in both districts. Moreover, about four small bowls of maize seeds are grown on an acre of land. The proportion of major and minor farmers who used any of the three inputs in 1984 and 2000 was entered into the model for each household.

6.2.8.3 Land fallow practice

The practice of leaving land to fallow in an agricultural system can be said to be interrelated to the availability of land in the system. This is due to the fact that in systems and periods where land is available, there is a tendency for land to be left to fallow. However, the opposite is the case in areas and during periods where there is pressure on the land. The study investigated whether land fallow was being practiced in any of the study areas and, if so, to what extent did it play a role in the total cropped area in the two study areas for 1984 and 2000.

Figure 6.7 gives an indication of the proportion of farmers who practiced land fallow in the two study areas in 1984 and 2000. In both study areas, the percentage of farmers who practiced land fallow decreased slightly, i.e., from 25.5% to 23% in the Kassena-Nankana District and from 43.2% to 41.3% in the Ejura-Sekyedumase District. Secondly, land fallow practice was more predominant in the Ejura-Sekyedumase District than in the Kassena-Nankana District for both 1984 and 2000.

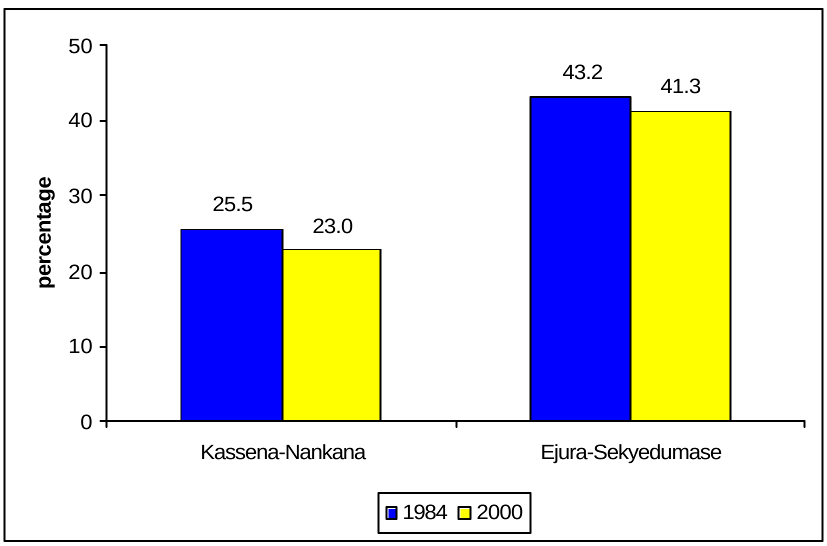

Figure 6.7: Percentage distribution of farmers who practice land fallow by study area, 1984 & 2000

Source: Field Survey, 2001 & 2002

The study further investigated the number of years allowed for land to fallow for both 1984 and 2000. The results are shown in Table 6.13. Average fallow years allowed in both districts decreased between 1984 and 2000. In the Kassena-Nankana

District, average fallow years decreased from 2.5 to 2.3, and in the Ejura-Sekyedumase District, from 3.4 to 2.7 years. In both years, average fallow periods are longer in the Ejura-Sekyedumase than in the Kassena-Nankana District. The average number of years allowed for land fallow in every household in the two districts in 1984 and 2000 was computed and included as an independent variable to assess the role it plays as far as the utilization of agricultural land is concerned.

Table 6.13: Percentage distribution of farmers by land fallow years allowed and study area, 1984 & 2000

Fallow year(s)	**Kassena-Nankana**				**Ejura-Sekyedumase**			
	1984		**2000**		**1984**		**2000**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
1	11	22.0	15	26.3	9	10.8	22	21.2
2	12	24.0	21	36.8	23	27.7	31	29.8
3	20	40.0	14	24.6	18	21.7	25	24.0
4	3	6.0	4	7.0	15	18.1	15	14.4
5	4	8.0	2	3.5	10	12.1	8	7.6
6	-	-	1	1.8	4	4.8	1	1.0
7	-	-	-	-	1	1.2	1	1.0
8	-	-	-	-	-	-	1	1.0
9	-	-	-	-	-	-	-	-
10	-	-	-	-	3	3.6	-	-
Total	**50**	**100**	**57**	**100**	**83**	**100**	**104**	**100**
Mean fallow years	**2.5**		**2.3**		**3.4**		**2.7**	

Source: Field Survey, 2001 & 2002

6.2.8.4 Distance traveled to farm

The distance traveled to a farm is related to land accessibility and availability. In agricultural systems where there is less pressure on land, farmers may travel shorter distances to their farms. However, as land availability decreases as a result of pressure on land, people may travel longer distances to their farms. An investigation was carried out in this study to determine the average distance traveled by the household members to their farthest farms in the two districts. The result is shown in the Figure 6.8. The average distance traveled by the household members to their farthest farms was included in the multiple regression model to ascertain the role it plays in total agricultural cropped area. That is to say, to find out whether households that travel longer distances to their farms have, on the whole, smaller cropped agricultural land areas than their counterparts who travel shorter distances to their farms.

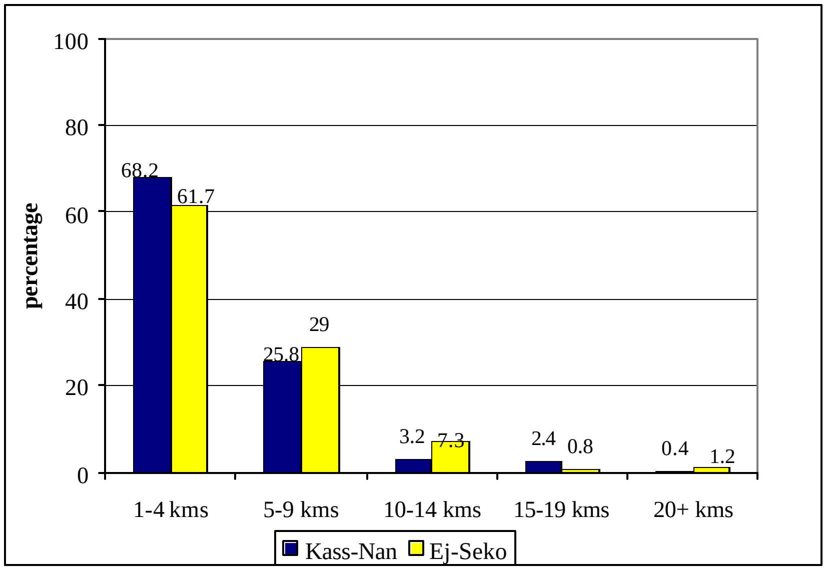

Figure 6.8: Percentage distribution of households by distance traveled to farthest farm and study area, 2000

Source: Field Survey, 2001 & 2002

6.2.8.5 Extensification

The availability of additional arable land for the households can encourage agricultural extensification, since households would turn to those lands to increase productivity during times of soil fertility decline in cultivated areas. This scenario can play a role in the total agricultural land cultivated. The household heads were asked whether they had farmed new lands within the preceding five years and, if yes, how large (in acres) the area was. The responses are shown in Figure 6.9.

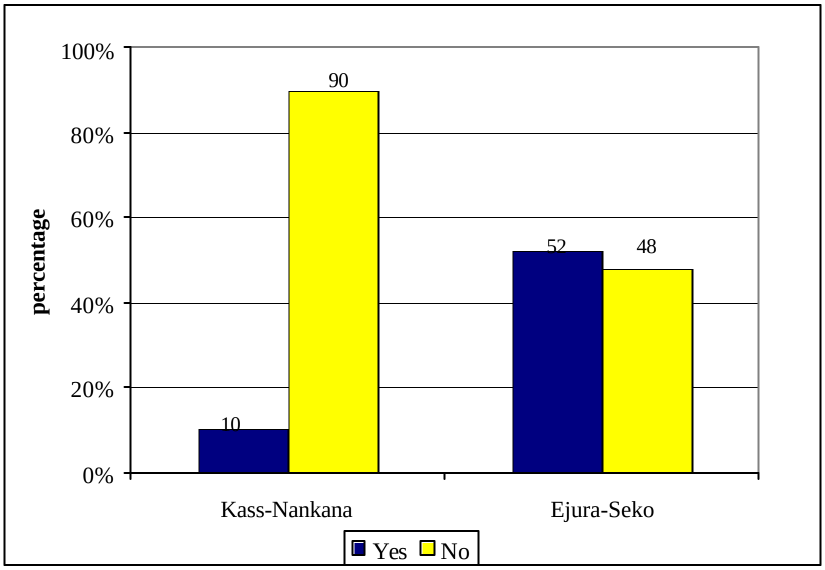

Figure 6.9: Percentage distribution of farmers who have cultivated new lands within the last five years by study area

Source: Field Survey, 2001 & 2002

While 52% of the farmers in the Ejura-Sekyedumase District had cultivated new lands within the preceding five years, this applied to only 10% of the farmers in the Kassena-Nankana District. This further underscores the fact that land was more available in the Ejura-Sekyedumase District. The size of the new areas cultivated by each household was included in the model.

6.3 The demographic factor

The demographic information used for the regression model in the later sections of this chapter comprises the population for the various localities used in the study and household size. However, the three components of the population, namely fertility, mortality and migration (in and out migration) are discussed and growth rates for the year 2001 assessed to give an idea of the population dynamics in the study areas. The data for this analysis were gathered during the field survey.

6.3.1 Fertility, mortality and migration

The births and deaths in the households between 1996 and 2001 were recorded in the two study areas to determine the trends over the previous five years. The results are presented in Appendix 6. The highest number of births of 58 and 90 were recorded in 1999 for the Kassena-Nankana District and 2000 for the Ejura-Sekyedumase Districts, respectively. As far as the lowest number of births are concerned, 41 and 66 were recorded in 2001 for the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively. The birth rate, also called the crude birth rate (CBR), which indicates the number of live births per 1,000 population in a given year, was calculated to be 24 for the Kassena-Nankana District and 32 for the Ejura-Sekyedumase District. The national CBR for mid 2001 was 32 (Population Reference Bureau (PRB) 2001), which implies that the birth rates in the Kassena-Nankana District were below the national average. The formula and procedure used is shown in Appendix 7.

As far as mortality is concerned, Appendix 6 presents the deaths in the two districts from 1996 to 2001. The highest number of deaths recorded were 21 in 1997 in the Kassena-Nankana District and 13 in 1997 and 2001 in the Ejura-Sekyedumase District. The lowest number of deaths were recorded in 1999 for both districts. The Crude Death Rate (CDR) for 2001 was also calculated for the two districts and was 8 for the Kassena-Nankana District and 6 for the Ejura-Sekyedumase District. According to the PRB (2001), the national CDR for mid 2001 was 10. This means that crude death rates for the study areas do not deviate significantly from what pertained nationally.

The number of out migrants in the two study areas from 1996 to 2001 is also presented in Appendix 6. The year of highest out-migration from the Kassena-Nankana and Ejura-Sekyedumase Districts was in 2000 and 2001, respectively, and the year of lowest out-migration was 2001 for the Kassena-Nankana District and 1998 for the Ejura-Sekyedumase District. The out-migration rates (OMR) were calculated to be 14 for the Kassena-Nankana District and 23 for the Ejura-Sekyedumase District (see Appendix 7). The analysis in Table 6.14 shows that the destination of the majority (34.4%) of migrants from the Kassena-Nankana District was the Ashanti Region. This is followed by other parts of the Upper East Region, which received 22.1% of the migrants, the Brong-Ahafo Region (15.3%), Greater Accra Region (12.7%), and the Northern Region (3.8%). A few migrants went to the neighboring countries such as

Burkina Faso and Togo, while others emigrated to Europe and North America (Canada and USA).

Table 6.14: Percentage distribution of out-migrants by destination and study area

Destination	**Kassena-Nankana**		**Ejura-Sekyedumase**	
	N	**%**	**N**	**%**
Upper West	3	1.2	2	1.3
Upper East	54	22.1	3	1.8
Northern	9	3.8	17	10.5
B. Ahafo	37	15.3	14	8.7
Ashanti	84	34.4	92	57.5
Western	13	5.3	2	1.3
Central	2	0.8	-	-
Eastern	4	1.6	3	1.9
Greater Accra	31	12.7	18	11.3
Burkina Faso	2	0.8	-	-
Togo	1	0.4	-	-
Nigeria	-	-	1	0.6
Europe	2	0.8	4	2.5
USA	1	0.4	2	1.3
Canada	1	0.4	2	1.3
Total	**244**	**100**	**160**	**100**

Source: Field Survey, 2001 & 2002

In the Ejura-Sekyedumase District, the majority (57.5%) of the migrants went to other areas in the Ashanti Region. The next major destination for migrants from this district was the Greater Accra Region (11.3%), and then Northern Region (10.5%). Other destinations include the regions Brong-Ahafo (8.7%), Upper East (1.8%), Eastern (1.9%), and Upper West (1.3%). More than thrice the number of migrants from the Ejura-Sekyedumase District (5.1%) migrate to Europe and North America than from the Kassena-Nankana District (1.6%).

The reasons for migration were analyzed; the results are presented in Table 6.15. In the Kassena-Nankana District, the majority (46.7%) of the migrants go to look for work, while about 15% each go for schooling and marital reasons. A significant proportion (4.1%) of the migrants from the Kassena-Nankana District temporary migrate mainly to Southern Ghana to farm during the lean farming season in the north, and a few go to work as household helps.

Table 6.15: Percentage distribution of out-migrants by reasons for migration and study area, 2000

Reasons	Kassena-Nankana		Ejura-Sekyedumase	
	N	%	N	%
Schooling	37	15.2	48	30.0
Marriage	39	15.9	28	17.5
Look for work	114	46.7	30	18.8
Start new job	20	8.2	29	18.1
Farm	10	4.1	6	3.8
Household helps	6	2.5	4	2.5
Other	18	7.4	15	9.4
Total	**244**	**100**	**160**	**100**

Source: Field Survey, 2001 & 2002

In the Ejura-Sekyedumase District, the majority (30%) of the people migrate for schooling purposes. However, marriage (17.5%), search for employment (18.8%), and start a new employment (18.1%) are also reasons given for migrating. Other reasons are farming, which constitutes 3.8% of the population, and household helps, which accounts for 2.5% of the migrants from the Ejura-Sekyedumase District.

The study also made enquiries into remittances received by households from members who live away from home; the results of the analysis are presented in Table 6.16. This was done against the background that there is increasing evidence that remittance from household members living away from their homes forms a significant proportion of household incomes in Ghana.

Table 6.16: Percentage distribution of out-migrants who remit by study area, 2000

Remit	Kassena-Nankana		Ejura-Sekyedumase	
	N	%	N	%
Yes	91	37.6	30	19.9
No	151	62.4	121	80.1
Total	**242**	**100**	**151**	**100**

Source: Field Survey, 2001 & 2002

In the Kassena-Nankana District about 37.6% of the households receive remittance from household members living away from home. This number is obviously greater than that for the Ejura-Sekyedumase District, where this value is only 19.9%.

To get an idea of the volume of migration to the study areas, the study also asked questions on the number of people who had moved into the study areas and stayed for more than six months for the period 1997-2001. This was done against the background that capturing the in-migration situation at the national level is a very difficult task. However, the in-migration data for the Kassena-Nankana District was gathered amongst the household head and the spouse only, whereas in the Ejura-Sekyedumase District it was collected amongst all household members. The total sample size was therefore 273 for the Kassena-Nankana District, while in the Ejura-Sekyedumase District, sample size remained the same. The number of in-migrants in the two study areas from 1997-2001 is presented in Appendix 6.

In the Kassena-Nankana District, 2000 was the year a large number of migrants entered the region, whereas in the case of the Ejura-Sekyedumase District this was 1999. The lowest years of in-migration were 1997 and 2000 for the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively. The in-migration rate (IMR) is calculated to be 18 and 7 for the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively.

Comparing the demographic indicators in the two study districts, it could be seen that average annual per cent growth rate in births was higher in the Ejura-Sekyedumase District than in the Kassena-Nankana District. However, there were more deaths in the Kassena-Nankana District compared to the Ejura-Sekyedumase District. Furthermore, there was more out-migration from the Kassena-Nankana District than from the Ejura-Sekyedumase District and, probably as a result of this, there was more in-migration to the Ejura-Sekyedumase District than to the Kassena-Nankana District within the period 1997-2001.

Table 6.17: Average annual per cent growth rate of selected demographic indicators in households by study area, 1997-2001

Indicator	**Kassena-Nankana**	**Ejura-Sekyedumase**
Births	4.0	6.2
Deaths	1.2	0.8
Out-migration	3.0	2.4
In-migration	0.8	1.2

Source: Field Survey, 2001 & 2002

Finally, the population growth rates for the two districts in 2001 were estimated from natural increase and net migration rates; the values are 0.5% for the Kassena-Nankana District and 1.0% for the Ejura-Sekyedumase District.

6.3.2 Household size

Household size is the other demographic variable used in this study. In Table 6.18 household size varies greatly in the two study areas. While the Kassena-Nankana District had about 4.2% single households in 1984, only 0.5% of the households in the Ejura-Sekyedumase District were single member households. The situation however, changed considerably for both districts in 2000, with no single member households. This could be attributed to population increase between 1984 and 2000.

Table 6.18: Percentage distribution of household size by study area, 1984 & 2000

Household size	Kassena-Nankana		Ejura-Sekyedumase	
	1984	2000	1984	2000
1	4.2	-	0.5	-
2	12.6	4.8	20.6	2.4
3	28.9	5.6	18.4	2.8
4	13.2	15.5	12.6	6.7
5-9	37.9	58.2	42.1	63.9
10-14	3.2	11.9	4.2	17.8
15-19	-	4.0	0.5	3.6
20 & above	-	-	1.1	2.8

Source: Field Survey, 2001 & 2002

On the whole the Ejura-Sekyedumase District has bigger household sizes compared to the Kassena-Nankana District. For example in 1984, about 1.6% of the households in the Ejura-Sekyedumase District had households with at least 15 members, a situation which did not exist in the Kassena-Nankana District. Similarly, in 2000, while 6.4% of the households had 15 and more members in the Ejura-Sekyedumase District, only 4% of the households had this number in the Kassena-Nankana District. The largest household recorded in the Ejura-Sekyedumase District in 2000 comprised 49 members, while that of the Kassena-Nankana District was 19.

6.4 Bivariate analysis

A logical first step in the analysis of agricultural land use change would be to look out for high, or marked, correlations between the dependent and the independent variables. This analysis would give an indication of which variables in the model are likely to have a common cause and which ones not. To identify such possible associations, a bivariate analysis was carried out for each of the independent predictors in the model and for each study district and study year, using the Pearson's correlation coefficient, to ascertain the level of associations. The rationale for the bivariate analysis for the aggregate study was to help identify the relevant factors for the multivariate analysis. The results of the bivariate analysis are presented in Tables 6.19 and 6.20.

Table 6.19: Bivariate relationships between total cropped area (acres) and independent variables for all study districts by study years

Variable	**Strength of the relationship**	
	1984	**2000**
Educational level	-	0.31
Major farmers	-0.08	-0.23
Electricity	-	0.65**
Off-farm income	-	0.23
On-farm income	-	0.69**
Food expenditure	-	0.73**
Affluence (items)	0.08	-0.09
Affluence (livestock)	0.06	-0.24
Land tenure	-0.32	-0.37
Tractor use	0.30	0.55*
Inorganic fertilizer use	0.24	0.59**
Improved seed variety use	0.10	0.81**
Land fallow	0.81**	-0.20
Distance to farthest farm	-	0.66**
Extensification	-	0.71**
Household size	0.75**	0.72**
Population	0.47*	0.65**

** Correlation is significant at the 0.05 level (2-tailed)*
*** Correlation is significant at the 0.01 level (2-tailed)*

Table 6.19 shows that many of the bivariate correlations conform to the theoretical expectations of this study. This is due to the fact that almost all the variables, with the exception of educational level of household members, proportion of major farmers in the household, off-farm income, household affluence (measured by ownership of livestock and other household items), land tenure arrangements and land fallow do not have statistically significant relationships with total cropped area of the household in 2000.

Secondly, a variety of factors are associated with total cropped area of a household, though these factors vary among area of study and period. Such differences observed in the explanatory variables could be attributed to the homogeneity that exists in the study areas, and the lack of significant differences between the variables used for the study and the dependent variable, which is total cropped area of the household.

Table 6.20: Bivariate relationships between total cropped area (acres) and independent variables by study districts and study years

Variable	**1984**		**2000**	
	KN	**ES**	**KN**	**ES**
Educational level	-	-	0.33	-0.18
Major farmers	0.12	-0.82**	-0.26	-0.80*
Electricity	-	-	0.11	0.44
Off-farm income	-	-	0.14	0.84**
On-farm income	-	-	0.32	0.08
Food expenditure	-	-	0.33	0.63
Affluence (items)	0.39	0.30	0.26	0.78*
Affluence (livestock)	0.54	0.73*	0.61*	0.28
Land tenure	0.18	-0.79*	0.13	-0.87**
Tractor use	-0.22	0.31	0.05	0.27
Inorganic fertilizer use	0.07	0.10	0.29	0.10
Improved seed variety use	-0.02	-0.29	0.66*	0.48
Land fallow	0.87**	0.65	-0.25	0.62
Distance to farthest farm	-	-	0.61*	0.75*
Extensification	-	-	0.51	0.06
Household size	0.53	0.86*	0.32	0.83**
Population	0.09	0.89**	0.16	0.93**

* *Correlation is significant at the 0.05 level (2-tailed)*
** *Correlation is significant at the 0.01 level (2-tailed)*

An issue worth mentioning is the statistically significant relationship between the use of improved seed variety and total cropped area for the Kassena-Nankana District in 2000. However, improved seed variety use does not explain any variation in total cropped area among the households in this district in 1984. This observation could therefore be attributed to the fact that the use of technologically improved agricultural inputs increased quite substantially between 1984 and 2000 in the Kassena-Nankana District.

Another variable that affected total cropped area as far as the temporal aspect is concerned, is household affluence as measured by ownership of certain household items. This is due to the fact that it had a statistically significant relationship with total cropped area in 2000 in the Ejura-Sekyedumase District, but not in 1984 for both study districts, indicating that household affluence has improved considerably in the Ejura-Sekyedumase District between 1984 and 2000 and that has led to increases in cropped area.

Furthermore, variables such as household affluence in terms of ownership of items, land tenure arrangements, inorganic fertilizer use, household size, the population of the locality and major farmers in the Kassena-Nankana District and tractor and inorganic fertilizer use, household size and population of the locality in the Ejura-Sekyedumase District have basically maintained similar relationships with total cropped area between the period 1984 and 2000.

Also, land fallow years allowed had a statistically significant relationship with total cropped area in the Kassena-Nankana District in 1984 but not in 2000. The fact that land fallow is positively correlated with agricultural land use in the Kassena-Nankana District in 1984 could be interpreted to mean that there was abundance of land and land fallow did not really affect the total land area cropped by the household. However, the scenario changes in 2000, in the same district, with a negative correlation, connoting an inverse relationship. This may give an indication that land fallow practice dwindled in the Kassena-Nankana District during the study period and the more land people leave to fallow, the less land area they are able to crop.

It is also important even at this bivariate stage of the analysis to consider the spatial dimension of the relationships. That is to say, to look at variations in the variables at the same point in time but for the different study areas, since the homogeneity found in the variables of these areas could affect the total area cropped by the household.

In 1984 some of the variables portrayed the same relationships in terms of significance, when correlated with total cropped area. However, the notable exceptions were: proportion of major farmers in the household, affluence (livestock), land tenure arrangements, household size and population of the locality, which had statistically significant relationships with total cropped area in the Ejura-Sekyedumase District but not in the Kassena-Nankana District, and land fallow which had a statistically significant relationship with total cropped area in the Kassena-Nankana District but not in the Ejura-Sekyedumase District.

The conclusion that can be drawn from such results is that, as far back as 1984, population growth increased agricultural land use in the Ejura-Sekyedumase District, but not in the Kassena-Nankana District. This is due to the fact that the two demographic variables, namely, household size and population of the locality, had statistically significant positive relationships with total cropped area. Also, the fact that affluence (livestock) had a statistically significant relationship with cropped area in the Ejura-Sekyedumase District indicates that this is a more prosperous district.

It was expected that the more "major farmers" found in a household, the more land area would be cropped and vice versa. However, the opposite was the case in the Ejura-Sekyedumase District in 1984, where the fewer "major farmers", the more land area cropped. This can be interpreted to mean that even though many of the farmers in the Ejura-Sekyedumase District in 1984 were minor farmers and therefore had other occupations, they were still very effective farmers, a situation which might not have existed in the Kassena-Nankana District. Finally, land fallow is the only variable that had a statistically significant relationship with cropped area in the Kassena-Nankana District but not in the Ejura-Sekyedumase District in 1984, which goes to suggest that more farmers left land to fallow in this district than in the Ejura-Sekyedumase District.

The situation in 2000 is, however, different and the results of the bivariate analysis further underscore the fact that the Ejura-Sekyedumase District is more economically endowed than the Kassena-Nankana District. The economic variables such as income from off-farm activities and ownership of items (affluence) have statistically significant relationships with total cropped area in the Ejura-Sekyedumase District but not in the Kassena-Nankana District. An exception is ownership of livestock (affluence), which is a statistically significant variable in the Kassena-Nankana District in 2000 but not in the Ejura-Sekyedumase District. Apparently, the influence of livestock ownership has changed and this has now become more important in the Kassena-Nankana District but might have outlived its usefulness in the Ejura-Sekyedumase District. Finally, improved seed variety use, a technological variable, is statistically significant in the Kassena-Nankana District, but not in the Ejura-Sekyedumase District.

6.5 Multivariate analysis and cropped area patterns

The bivariate relationships give only a limited description of cropped area differences. A multiple regression analysis was thus performed to isolate the net effect of each of the interconnected variables upon cropped area. The multivariate analysis is presented under three themes: (1) spatial determinants of agricultural land use (2) spatio-temporal determinants of agricultural land use, and (3) determinants of agricultural land use in the Volta River basin of Ghana.

6.5.1 Spatial determinants of agricultural land use

A number of interesting findings emerge from the results of the first stage of the multivariate analysis, which are presented in Tables 6.21 to 6.24. Of great interest is the spatial difference with reference to the relationship between the independent variables and the dependent variable.

Table 6.21: Results of stepwise multiple regression showing statistically significant predictors of cropped area – Kassena-Nankana District, 1984

Variable	**Unstandardised coefficients**		
	Beta (ß)	**Standard error**	***t***
Constant	-4.12	2.79	-1.48
Fallow	6.29	0.89	7.11
Major Farmers	0.08	0.04	2.35
R = 0.92	R^2 = 0.85	Adjusted R^2 = 0.82	

Table 6.22: Results of stepwise multiple regression showing statistically significant predictors of cropped area - Ejura-Sekyedumase District, 1984

Variable	**Unstandardised coefficients**		
	Beta (ß)	**Standard error**	***t***
Constant	7.29	1.12	6.52
Population	0.01	0.01	5.04
R = 0.89	R^2 = 0.78	Adjusted R^2 = 0.75	

Table 6.23: Results of stepwise multiple regression showing statistically significant predictors of cropped area – Kassena-Nankana District, 2000

Variable	Unstandardised coefficients		
	Beta (ß)	**Standard error**	***t***
Constant	-3.19	1.27	-2.51
Farthest Farm	2.19	0.33	6.57
Off-farm income	-0.01	0.01	-5.12
Extensification	29.61	8.80	3.37
R = 0.95	R^2 = 0.90	Adjusted R^2 = 0.85	

Table 6.24: Results of stepwise multiple regression showing statistically significant predictors of cropped area - Ejura-Sekyedumase District, 2000

Variable	Unstandardised coefficients		
	Beta (ß)	**Standard error**	***t***
Constant	11.18	0.98	11.46
Population	0.01	0.01	6.66
R = 0.93	R^2 = 0.86	Adjusted R^2 = 0.84	

In Table 6.21, years allowed for land to fallow and proportion of major farmers were statistically significant predictors of cropped area in the Kassena-Nankana District in 1984. Land fallow is positively correlated with cropped area in the model, which implies that the more land people left to fallow, the more land area they had cropped. Farmers who allowed an additional year of fallow in 1984 had 6 more acres of farmland than their counterparts. As mentioned earlier on, the situation could be that land was more accessible and available with a concomitant low pressure on land in 1984, and thus, irrespective of the area of land left to fallow, there was still enough land to bring about substantial cropped areas.

However, the situation changed in 2000, since land fallow not only ceased to be a statistically significant predictor of cropped area in the Kassena-Nankana District, but also had a negative relationship (see Appendix 8). Since there is evidence of a population increase between 1984 and 2000 in the Kassena-Nankana District, this scenario can be said to conform to the Malthusian theory, as modified by Mortimore (1993), which stated among other things that an increase in population density brings about the shortening of the fallow period that is needed to rejuvenate soil fertility. Also, each additional major farmer in the Kassena-Nankana District in 1984 increased total cropped area by 0.1 acre.

In the Ejura-Sekyedumase District, a demographic indicator, i.e., population of the locality, was a statistically significant predictor of cropped area in 1984. Each additional person added to the locality resulted in an increase of almost an acre farmland. This could imply that, as far back as 1984, population pressure was being felt on agricultural land in the Ejura-Sekyedumase District, but not in the Kassena-Nankana District.

Finally, none of the agricultural technological indicators (use of tractor, fertilizer and improved seed variety for farming) were predictors of agricultural land use in both areas in 1984 as was envisaged. This gives a strong indication that innovations in mechanized forms of farming had not spread to any part of the study area in 1984, and simple subsistence forms of farming were still being practiced.

In 2000, distance to farthest farm, off-farm income, and extensification, were predictors of cropped area in the Kassena-Nankana District, while the population of the locality again predicted cropped area in the Ejura-Sekyedumase District. Distance to farthest farm in the Kassena-Nankana District has a positive correlation with agricultural land use. This means that the farther the people traveled to their farms, the more land they cropped. In fact, every extra kilometer a farmer travels to the farm resulted in 2 acres of additional farmland cultivated. This result may, therefore, indicate that longer distances traveled to farms in the Kassena-Nankana District do not necessarily result in smaller cropped areas.

It is surprising to note, that income from on-farm activities, does not play any statistically significant role in agricultural land use in any of the districts. This is due to the fact that enormous disparities existed between the income patterns from this source between the two districts. It was expected that at least income gained from the sale of farm produce would be channeled into farming in the Ejura-Sekyedumase District, but that is not the case. With reference to income from off-farm activities, the analysis shows that extra income earned off-farm is not necessarily invested into farming activities, since the variable has an inverse relationship with farmland. Finally, expenditure on food also did not play any significant role in the utilization of agricultural land. It was anticipated that the more expenditure households incur on food, the more land would be put under cultivation, but this does not seem to be the case in either districts.

Finally, the agricultural extensification variable included in the model only affected agricultural land use in the Kassena-Nankana District. It was presumed that there would be extra land available to households to turn to in times of scarcity. However, this does not seem to play any role at all in total acreages cropped by households in the Ejura-Sekyedumase District. The irony of the situation is the fact that agricultural extensification plays a greater role in the Kassena-Nankana District. Farmers there have, on average, 30 more acres of land to extend to than their counterparts in the Ejura-Sekyedumase District. It was observed during the field study that a lot of households over-cultivate the same piece of land around their compounds, which is a form of agricultural intensification. Thus, if so much land is available in the district, the question then remains, why is compound farming so widespread there? One possible answer to this question may be that households simply do not have the capacity both technologically and financially to practice extensification, even though arable lands may be available.

6.5.2 Spatio-temporal determinants of agricultural land use

The second stage of the multivariate analysis considered the spatio-temporal differences between the dependent and the independent variables. Some interesting observations emerged. Firstly, the analysis shows that land tenure arrangement (whether ownership or rental), the presence or otherwise of electricity as a source of household energy, affluence (items and livestock ownership), the use of tractor, inorganic fertilizer, and improved seed variety for farming as well as household size did not influence agricultural land use in both districts and in both years. The non-significance of electricity as a predictor of agricultural land use was buttressed by the analysis in the opening sections of this chapter, which show that electricity was not widely utilized in both areas and years.

Secondly, another significant outcome from the multivariate analysis is the fact that technologically improved techniques of farming such as the use of tractors, inorganic fertilizers and improved seed varieties have not made much headway in these areas.

The results do not fully complement the view of Boserup (1965) in her neoclassical model of land use. Among other things she states that in highly populated areas, there would be the need to sustain a large growing population and that this will culminate in the adoption of more intensive farming methods, which would require additional labor inputs per unit area. The Ejura-Sekyedumase District might not have experienced the sort of population density Boserup describes in her model to warrant the use of more intensive farming techniques. The study shows that increase in population has resulted in an increase in agricultural land use since 1984.

Furthermore, the amount of land left to fallow and the proportion of major farmers in the households were statistically significant predictors of agricultural land use in the Kassena-Nankana District in 1984. In 2000, these predictors were distance traveled to farthest farm, off-farm income and extensification.

Finally, both in 1984 and 2000, the demographic indicator, i.e., population of the locality, was a statistically significant predictor of agricultural land use in Ejura-Sekyedumase. The analysis confirms the status of the Ejura-Sekyedumase District as a migrant-receiving area as already mentioned in this chapter. Added pressure is brought to bear on agricultural land due to migrant farmers.

6.5.3 Determinants of agricultural land use in the Volta River basin of Ghana

At the third stage of the multivariate analysis, all relevant factors were introduced by combining the two study areas and years. The results are shown in Tables 6.25 and 6.26.

Table 6.25: Results of stepwise multiple regression showing statistically significant predictors of cropped area - All districts, 1984

Variable	Unstandardised coefficients		
	Beta (ß)	Standard error	*t*
Constant	-3.88	1.99	-1.95
Fallow	3.86	0.83	4.66
Household size	1.72	0.48	3.61

R = 0.89 $R^2 = 0.80$ Adjusted $R^2 = 0.78$

Table 6.26: Results of stepwise multiple regression showing statistically significant predictors of cropped area - All districts, 2000

Variable	Unstandardised coefficients		
	Beta (ß)	Standard error	*t*
Constant	-9.64	4.14	-2.33
Improved Seed Variety	0.18	0.04	4.30
Household size	1.87	0.60	3.14

R = 0.87 $R^2 = 0.76$ Adjusted $R^2 = 0.73$

Unlike the individual years in the respective study areas, some new variables emerge as statistically significant predictors of household total cropped area. These include improved seed variety and household size. The importance of household size in the overall model emphasizes the importance of the demographic factor for agricultural land use. Any additional member added to the household in 1984 and 2000 resulted in an increase of almost 2 acres of farmland. Also, as far as the overall model is concerned, between 1984 and 2000 the use of improved seed variety, an agricultural technological variable, became statistically significant and any farmer who used this increased his/her farmland by almost 0.2 acres. Thus, the use of technologically advanced forms of farming is gradually becoming prominent in the study areas even though it is not on a massive scale. Thus, the hypothesis that the use of technologically advanced forms of farm inputs is increasing the amount of cropped area in the two study districts is rejected.

The analysis described in this chapter have revealed that several variables operate at the household level to influence agricultural land use, and that the variables used in the regression models to describe the relationship were very good, illustrated by the fact that coefficient of determination values for all models ranged from 0.76 to 0.90. Secondly, these variables do not have the same characteristics for every locality and year. It clearly emerges that time and space differentials account for whether a variable turns out to be a statistically significant predictor of agricultural land use or not.

Furthermore, as the level of analysis changed from the aggregate level to the specific study areas and years, some of the variables that were seen to be statistically significant predictors at the aggregate level lost their significance. Finally, part of the unexplained variance in the utilization of agricultural land observed among the study areas and years can be attributed to other factors, such as physical, natural or environmental, which form the central thesis of another study in the GLOWA Project.

7 POPULATION AND FOREST COVER IN THE VOLTA RIVER BASIN

According to the Food and Agriculture Organization, the annual rate of deforestation in Ghana was 1.72% per annum or 120,000 hectares each year during the period 1990-2000 (FAO, 2000). The impact of deforestation is widespread, affecting the livelihoods of the local people, disrupting important environmental functions and severely disturbing the biological integrity of the original forest ecosystem.

This chapter relates the trends and patterns of population, population density and annual population growth in the various sub-basins (Chapter 5) to forest cover. It begins by assessing the amount of forest available in 1990 and 2000 in the respective local/urban councils, and concludes with an assessment of the relationship between population and forest cover in 1990 and 2000, to ascertain whether any of the above demographic variables play a statistically significant role in forest cover.

Predictions regarding forest cover that might be lost as a result of changes in any of the demographic variables having a strong relationship with forest cover in the studied sub-basins in 2000 was computed for the year 2010 based on a simple regression model and demographic projections. The forest cover predicted for 2010 was matched with actual forest cover in 2000, determined from remote sensing analysis of satellite images. A forest availability status table was generated to give an indication of the amount of forest cover that would be available for the local/urban councils in the sub-basins in the year 2010.

7.1 Forest resources of Ghana

The Republic of Ghana can be said to be well forested, with around 39% forest cover, and a further 37% woodland. Ghana can be divided into two broad ecological zones, namely the tropical high forest, which covers much of the southern third of the country, with areas of scrub and grassland near the coast and around the Volta River, and mangrove vegetation around lagoons, and a savannah zone, which blankets the inland two-thirds of the country.

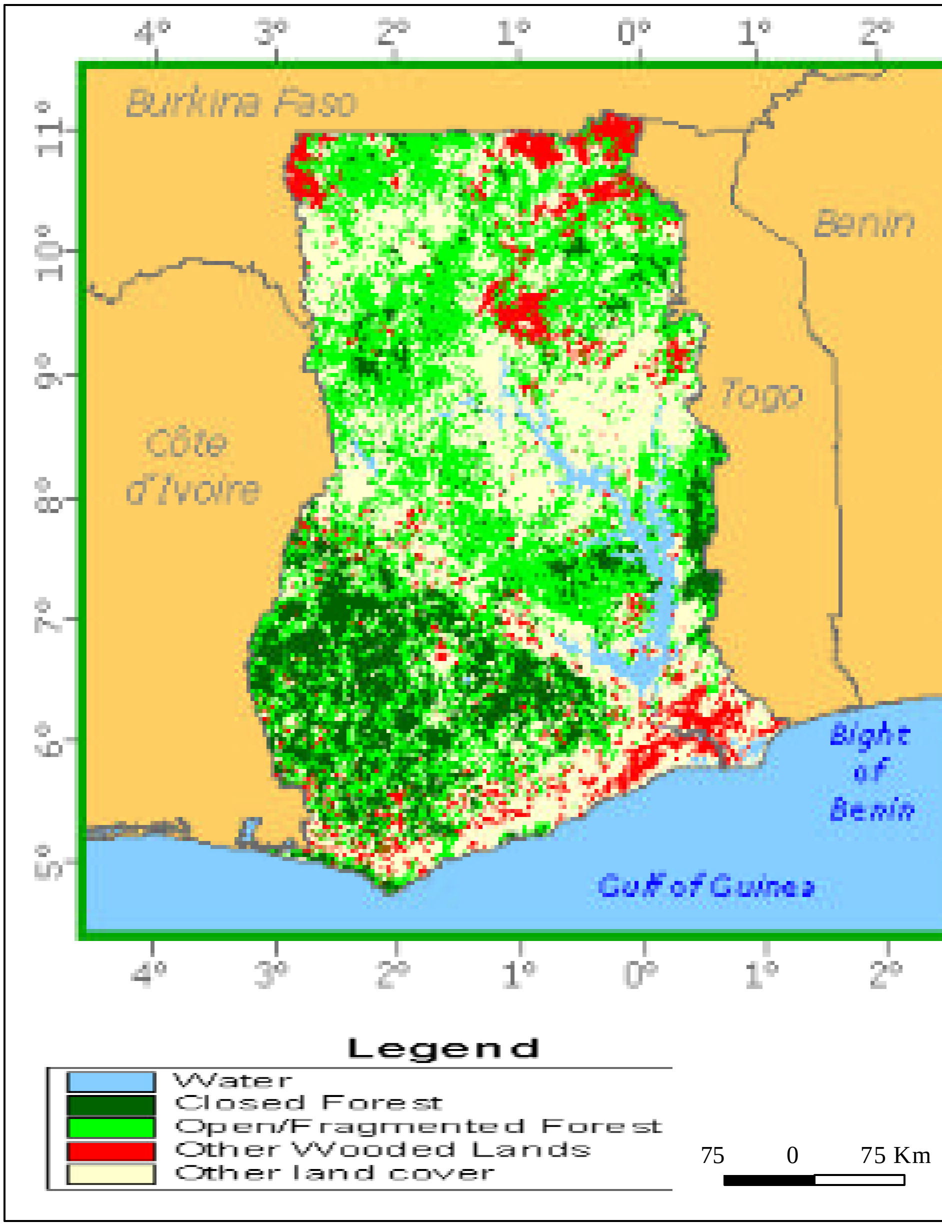

Figure 7.1: Forest map of Ghana, 2000

Source: Extract from Global Forest Cover Map, Forest Resource Assessment (FAO, 2000)

The high forest can be separated into rainforest in the most south-western part of the country, characterised by a *Cynometra-Lophira-Tarretia spp*. association; and moist semi-deciduous forests containing *Triplochiton scleroxylon* and *Celtis spp*. Ghana has a modest area of teak (*Tectona grandis*) plantations. Ghana's network of protected areas encompass around 2% of the forest area; the premier forest reserve is Kakum National

Park, a 360 km^2 rainforest park. Only the government is responsible for the management of forests. Landowners, farmers and communities etc., mainly derive benefits from these forests and are not responsible for their management (International Tropical Timber Organization (ITTO) 1999).

The forestry sector plays an important role in the economy. Since 1970, it has accounted for 5-6% of the country's Gross Domestic Product (GDP) and provides employment to about 70 000 people. Despite their importance, forest resources declined considerably from the middle of the 1970s until the early 1980s (FAO, 1995a). Ghana produces moderate quantities of tropical hardwood (sawn timber and wood-based panels) for the domestic market and for export. Exports of logs have been banned since 1995. Wood is an important source of fuel in Ghana, fuelwood and charcoal meeting 86% of the country's fuel needs (GSS, 2000). Important non-wood forest products in Ghana include bush meat, building materials, wild fruits, nuts, and medicinal plants (especially chew sticks).

Finally, forest plantations have been developed to counter the high rate of deforestation. An exotic species, *Tectona grandis,* makes up more than half the plantations area and it has shown remarkable performance since it was introduced in the national plantation project in 1970. A fourth of the total plantation area is rubber, while the rest is planted with other species, both indigenous and exotic (FAO 1995b and 1998).

However, reforestation in the past has not been sufficient to match the rate of deforestation, due to the fact that plantation development has not been sustained for the past several decades. A decade of economic decline in which there was little activity in the forestry sector followed the launch of the national plantation project. Another plantation programme was launched in the Northern and Upper Regions in 1976. This also slowed down due to lack of funds in the early 1980s. After a drought in 1983, the government mounted another national-level campaign for plantations (FAO, 1995a). Currently, the Government of Ghana is implementing a forest resources management project; the objective is to strengthen the capacity of Ghana's forestry sector to manage forests under a sustainable management policy (ITTO, 1999).

7.2 Forest cover in the Volta River sub-basins

Forest cover in all the sub-basins in 1990 and 2000 can be said to have been generally very low as shown in Table 7.1 and Figure 7. 2; this reflects the current status of forest cover in Ghana. The highest forest cover of about 14.2% was found in the Black Volta sub-basin, and the lowest of 2.2% in the Daka sub-basin in 1990. In 2000, the Main Volta sub-basin had the highest forest cover (5.2%), and the Black Volta the lowest (2.1%). When the situation is considered in absolute terms, all sub-basins had a forest cover of less than 5000 km^2 in 1990 and 2000 km^2 in 2000.

As far as the annual rate of change in forest cover is concerned, all sub-basins experienced declines in forest cover. The highest deforestation rate of 348 km^2 per annum in this 10-year period was recorded in the White Volta sub-basin, with the lowest rate of 0.3 km^2 in the Daka sub-basin. The analysis further shows that an annual deforestation rate of 6.9% was experienced in the entire Volta basin during the period 1990-2000, a figure which is higher than the national deforestation rate of 1.7% in the same period.

Table 7.1: Forest cover (in km^2) by sub-basins, 1990 & 2000

Sub-basin	Land area (km^2)	1990 Forest cover (km^2)	1990 % land area	2000 Forest cover (km^2)	2000 % land area	Annual change (1990-2000) km^2	Annual change (1990-2000) %
White Volta	39948	4891	12.2	1408	3.5	-348	-7.1
Black Volta	27580	3911	14.2	575	2.1	-334	-8.5
Main Volta	36424	4259	11.7	1897	5.2	-236	-5.6
Daka basin	6656	146	2.2	143	2.2	-0.3	-0.2
Total	**110608**	**13207**	**11.9**	**4023**	**3.6**	**-918**	**-6.9**

Source: Computed from Satellite image,1990/91 & 2000

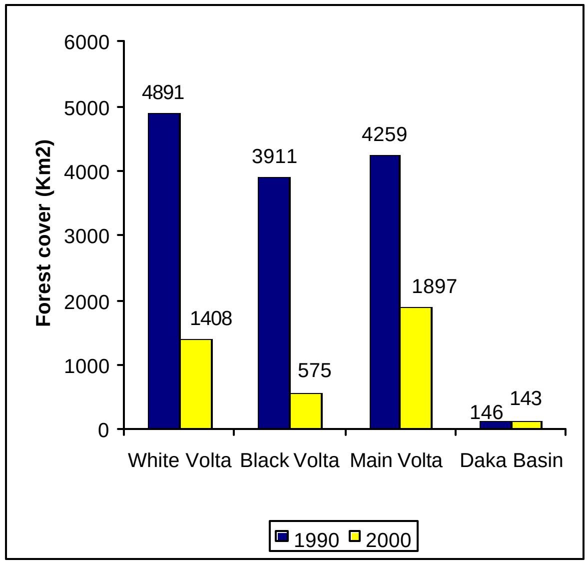

Figure 7.2: Forest cover by sub-basins, 1990 & 2000

Source: Computed from Satellite images, 1990/91 & 2000

As far as the specific local/urban councils within the various sub-basins are concerned, the Lawra-Jirapa, Sandema and Tolon in the White Volta, Jaman and Berekum in the Black Volta, Tamale and Savelugu in the Main Volta, and Kete-Krachi in the Daka sub-basin can be described as the "hot-spots". Those are areas that have lost almost all of their forest cover (Appendix 9). However, Kusanaba-Zebilla and Damango in the White Volta, Bole in the Black Volta, as well as Salaga, Kwame Danso and Atebubu in the Main Volta are areas where substantial amounts of forest cover still remain.

Finally, all local/urban councils in the White Volta sub-basin experienced deforestation between 1990 and 2000. The only exception was Kusanaba-Zebilla, which maintained the same forest cover during the period, perhaps as a result of reserved forests. In the Black Volta sub-basin, the situation was similar, since all the local/urban councils experienced deforestation, with the Atebubu district experiencing an annual increase of 0.2 km^2. In the Main Volta sub-basin, about 65% of the local/urban councils experienced forest decline, while the rest experienced minor annual increase rates and the Daka sub-basin had a mixture of very minor increases and decreases in forest cover. Figure 7.3 shows the forested areas in Ghana in 1990.

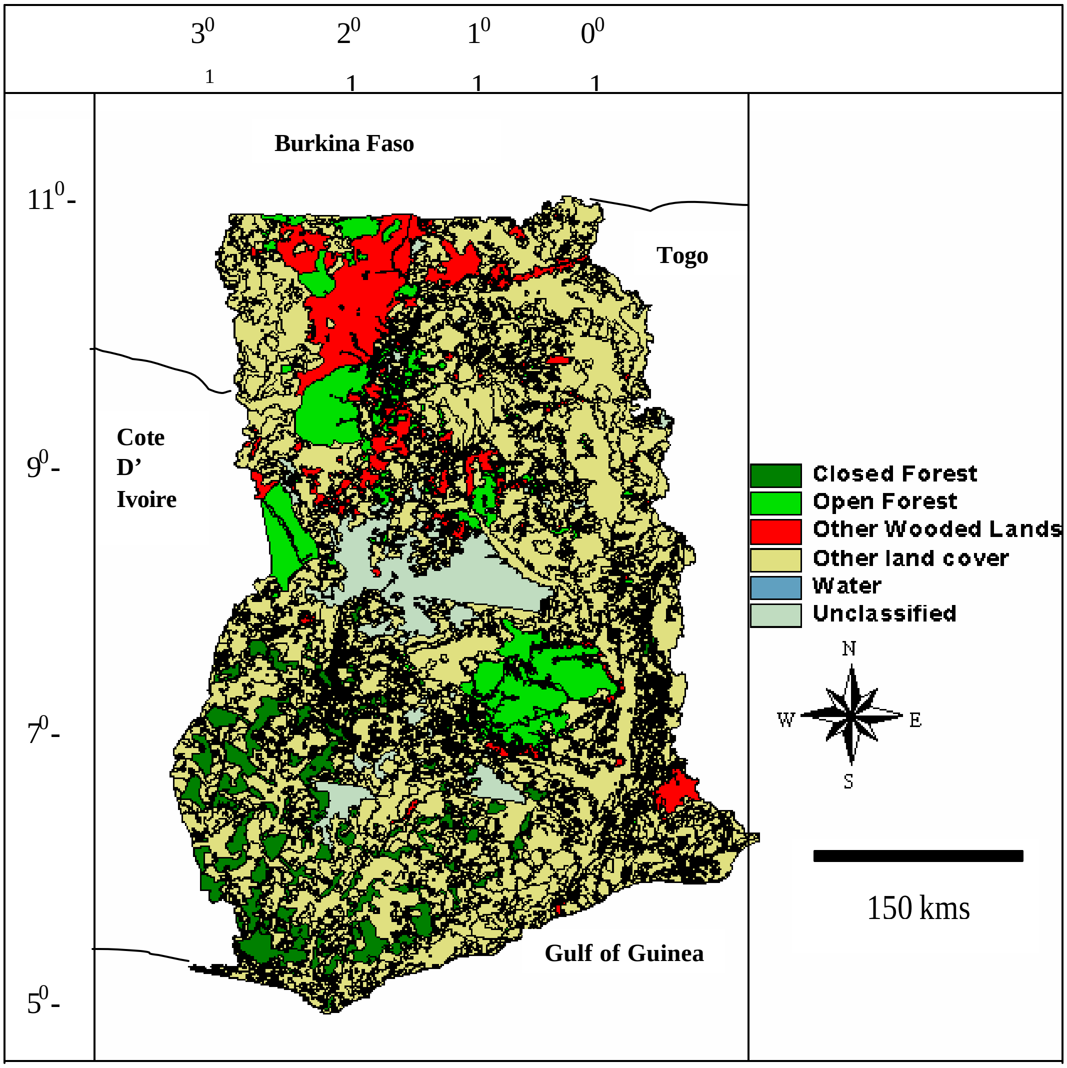

Figure 7.3: Forest map of Ghana, 1990

Source: Developed from Agyepong et al., 1999

7.3 Relationship between population size, population density, population growth rate and forest cover

The results of the correlation coefficient analysis reveal very low correlations, ranging from 0.05 to 0.34 between population size and forest cover in 1990 and 2000, respectively, in all sub-basins. No clear pattern can be seen in both years for annual population growth rates. However, correlations between population density and forest cover in all sub-basins showed a negative correlation in 1990 and 2000, i.e., an inverse relationship to forest cover, indicating that the increase in population density is causing deforestation (Table 7.2).

Table 7.2: Correlation coefficients (r) of forested area (km^2) on the one hand and population size, population density and population growth rate on the other in the sub-basins of the Volta River, 1990 and 2000

	Population		**Population density**		**Annual growth rate (%)**	
Sub-basin	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**
White Volta	0.12	0.23	-0.31	-0.13	0.29	0.29
Black Volta	0.30	0.05	-0.18	-0.50	0.18	0.25
Main Volta	0.11	0.13	-0.20	-0.29	-0.09	-0.13
Daka	0.31	0.34	-0.64	-0.59	-0.11	-0.10

It becomes clear from the analysis that population density is the only variable from the three analysed in this chapter, which best explains forest cover variations in the various sub-basins of the Volta River in Ghana. It was, therefore, used as the demographic variable for predicting the effect of population growth on forest cover in the sub-basins in 2010.

Figures 7.4 and 7.5 show the relationship between population density and forest cover in 2000 for the two sub-basins that had the strongest relationships, namely the Black Volta (-0.50) and Daka (-0.59) sub-basins, and have therefore been used for the prediction. Also, the coefficient of determination values and the simple regression models used for the prediction have been indicated.

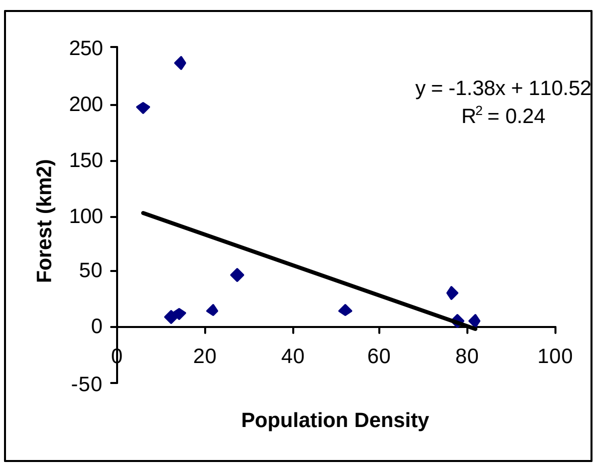

Figure 7.4: Relationship between population density and forest cover, 2000 - Black Volta sub-basin

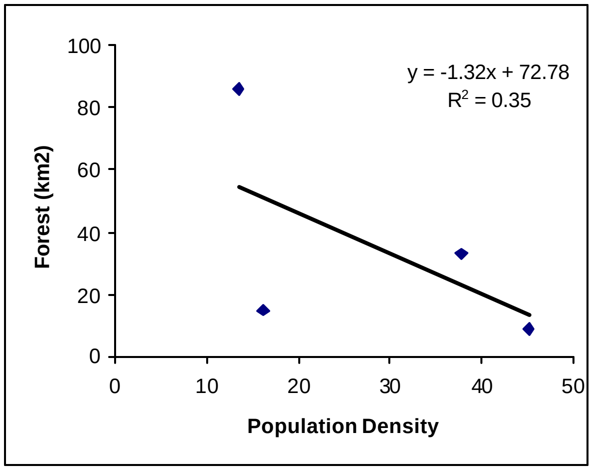

Figure 7.5: Relationship between population density and forest cover, 2000 - Daka sub-basin

It can be seen from the two figures that a unit increase in population density has a corresponding decrease of 1 km^2 in forest cover in both sub-basins, implying that population increase definitely affects forest cover in both sub-basins. The effect of population increase on forest cover is slightly more pronounced in the Black Volta than in the Daka sub-basin. This scenario, therefore, confirms the hypothesis that population is inversely related to forest cover in these sub-basins.

7.4 Population density and forest cover availability - 2010

According to the classification used, the results of the forest cover availability status shown in Table 7.3 show that only the Jaman and Berekum Local/urban Council areas that fall within the Black Volta sub-basin will have depleted forest cover as a result of changes in population density. All the other areas within the sub-basin will have some amount of forest cover in 2010, irrespective of changes in population density that might occur.

On the other hand, the Kete-Krachi Local Council in the Daka sub-basin will experience depleted forest cover in 2010 as a result of increase in population density, while the Gushiegu-Chereponi, Bimbilla and Salaga Local Councils will have some forest cover in 2010 despite increases in population density.

Table 7.3: Forest cover status for the Black Volta and Daka, 2010

Black Volta	Projected population density 2010	Forest cover (km^2) 2000	Predicted forest cover 2010	Difference	Status
Tumu	15.5	8	-4	4	FA
Lawra-Jirapa	55.3	16	-4	12	FA
Nadawli-Funsi	14.4	12	-0.1	12	FA
Wa	88.7	31	-17	14	FA
Bole	18.8	237	-6	231	FA
Damango	7.6	197	-2	195	FA
Wenchi	22.9	15	-1	14	FA
Atebubu	36.8	48	-13	35	FA
Berekum	112.4	6	-43	-37	FD
Jaman	108.5	5	-42	-37	FD
Daka					
Gushiegu-Chereponi	20.7	15	-6	9	FA
Salaga	13.8	86	-0.4	86	FA
Bimbila	45.9	33	-11	22	FA
Kete-Krachi	70.2	9	-33	-24	FD

FD Forest Depletion (Negative values)
FA Forest Availability (Positive values)

7.5 Indirect demographic causes of deforestation

Apart from the demographic factors analyzed, other factors such as farming systems, practices and inputs used, specific crops grown, household consumption patterns and source of fuelwood as energy for cooking, extensification of agricultural lands, and general living conditions are perceived in this study as indirect demographic factors causing deforestation.

7.5.1 Fuelwood as major source of energy for cooking in households

The study reveals that fuelwood, either burnt and transformed into charcoal, or dried, is the major source of energy for cooking in households in the two districts. Apart from 1% and 3.2% of the households that solely used liquefied petroleum gas (LPG) and millet stalks, respectively, for cooking in the Kassena-Nankana District, the remaining households depend on fuelwood. The scenario is similar in the Ejura-Sekyedumase District, with only 1% of all households using LPG for cooking. A household in the Kassena-Nankana and Ejura-Sekyedumase Districts, on average uses 6.4 and 9.3

kilograms of fuelwood, respectively, for cooking per day to feed the growing number of household members. It is also shown that 79% and 81% of the households in the two districts directly cut the fuelwood from the bushes.

Furthermore, the study also shows that the households are poor. Households in the Kassena-Nankana District earn an average of the equivalent of €78 per month and their counterparts in the Ejura-Sekyedumase District €879 from the two major sources of household income, namely, from on- and off-farm activities. The combined activities of households cutting fuelwood to burn and charcoal contractors can be argued to be one of the prominent causes of deforestation in the two districts.

7.5.2 Agricultural activities

Agricultural activities can be seen as another cause of deforestation. The study shows that 70% and 72% of the population in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively, are major farmers. Also, cropped areas of the two districts increased by 31% and 3% per annum between 1992 and 2000 in the Kassena-Nankana and Ejura-Sekyedumase Districts respectively, to basically provide food for an increased number of household members in the Kassena-Nankana District, and to serve the former purpose as well as for sale, to supplement household income in the Ejura-Sekyedumase District.

These increases have mainly been facilitated by the use of improved agricultural tools and inputs. For example 77%, 87% and 60% of the farmers in the Ejura-Sekyedumase District use tractors, inorganic fertilizer and improved seed varieties, respectively, on their farms. These implements and inputs have been used to transform the land cover and hitherto forest areas have been converted to agricultural lands.

The increases in cropped areas have also resulted in the shortening of fallow periods. The study shows that fallow periods have reduced from 2.5 to 2.3 and 3.4 to 2.7 years between 1984 and 2000 in the Kassena-Nankana and Ejura-Sekyedumase Districts, respectively. The shortening of the fallow period prevents the regeneration of secondary into primary forests and farmed lands into secondary forest.

Furthermore, some of the agricultural practices employed in these areas have also contributed to deforestation. The slash and burn technique is widespread in these areas and have contributed to the loss of forest cover. The type of crop grown is a further factor. For example, yam, a root crop widely grown in the Ejura-Sekyedumase District by about 59% of the farmers, is a climbing plant and requires erected poles to grow on. The farmers therefore use the stumps of trees cleared from forests to support the yam plant. Every new yam-growing season therefore requires the clearing of forest areas; this has been practiced over the years, gradually causing deforestation.

7.5.3 Livestock production

Finally, livestock production, a very important component of the economy of the two districts has also caused deforestation. Cattle, sheep and goats are not only kept for prestige, but also used for security in times of economic crisis. In the Kassena-Nankana District, a household on average owns 43 cattle, 49 sheep and 54 goats, while in the Ejura-Sekyedumase District, a household owns 30 cattle, 24 sheep and 35 goats. Free-range grazing, where the livestock is mainly allowed to graze in open fields, is widely practiced. Vegetative areas are cut down to allow the growth of fresh pasture for livestock.

8 CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

The Volta River basin is one of the most economically deprived areas in Africa. Rain-fed and some irrigated agriculture is the main economic activity of the majority of the population living in this region. High population growth rates have brought in their wake increasing pressure on land and water resources. Precipitation in the region is characterized by large variability as expressed in periodic droughts. Due to large variability in precipitation patterns, the development and optimum use of (near) surface water resources are the key to improved agricultural production in the West African savannah, some of which lies in the Volta River Basin. As a result of the interplay between land/atmosphere, energy, water (vapor) and land use, significant shifts in land use patterns will bring about spatio-temporal changes in weather patterns and rainfall characteristics.

Due to the issues mentioned, there is the need for a sustainable management of the water resources of the Volta River Basin. The project Global Change in the Hydrologic Cycle (GLOWA) therefore seeks to analyze the physical and socio-economic determinants of hydrological cycles, which will eventually lead to the development of a scientifically sound decision support system for the assessment, sustainable use and development of water resources in the Volta Basin of West Africa.

However, it is a well-perceived notion that man and his activities are the major drivers behind land use change, and these factors therefore become very central in any analysis that considers changes in land use patterns. This study was therefore carried out as a sub-project of the GLOWA Volta Project, and it specifically looked at the relationship between population and other socio-economic dynamics, on the one hand, and agricultural and forest land use on the other, and predicted the effect of changes in population on the two land uses in 2010 in the Volta Basin of Ghana. The study is connected with other sub-projects to not only attain the broad objectives of the GLOWA Volta Project, but also to add to the knowledge of the driving forces behind land use changes at a regional scale, which will ultimately assist in the understanding of global environmental change.

At the basin level, population data were derived from Population Census Reports of Ghana for 1960, 1970, 1984 and 2000, while forest cover information was derived from land cover and land use maps of 1990/91 and 2000, which were developed using Landsat Thematic Mapper (TM) satellite images. Agricultural land use data were obtained from the Ghana Ministry of Food and Agricultural Censuses of 1992 and 2000. Furthermore, a soil suitability map for 90-day maize *(Zea mays)* was remapped into a binary layer of '*suitable'* and *'not suitable'* for agriculture, and used to predict the effect of population change on agricultural land use.

At the district level, the main source of data was primary. A structured and open-ended questionnaire was administered between November 2001 and March 2002 amongst 252 households in 12 localities in the Kassena-Nankana District, and 252 households in 9 localities in the Ejura-Sekyedumase District.

In assessing the effect of population growth on agricultural land use, the analysis shows that there is a weak relationship between population density and annual population growth rate on the one hand and cropped area on the other in all sub-basins for the years 1992 and 2000. However, with population size a moderate to strong correlation between population growth and agricultural land use was found in all sub-basins for both study years, with the Daka sub-basin having an almost perfect correlation. This suggests that growth in population caused a corresponding increase in agricultural land use.

Slight changes in the correlation coefficients for both 1992 and 2000 were seen for the White, Main Volta, Oti, and Daka sub-basins, suggesting that temporally, relationship between population growth and agricultural land use has basically remained the same. The Black Volta sub-basin had a strong positive correlation in 1992 which reduced to a weak one in 2000.

The coefficient of determination (r^2) between population size and agricultural land use for the year 2000 showed a moderate positive relationship for the White Volta sub-basin and a strong relationship for the Daka sub-basin. The rest of the sub-basins, however, had weak relationships. As a result, predictions of change in cropped area that would occur as a result of population growth were computed for the year 2010 based on simple regression models and the projected populations of the two sub-basins only. The results were used to construct a land availability status map for 2010. The results show that the Bawku and Bolgatanga-Tongo Urban Councils in the White Volta, and the Kete-Krachi Local Council in the Daka will experience agricultural land shortfalls in the year 2010 as a result of changes in size of population.

At the district level, a contrasting picture between the two districts in both years was revealed, due to the fact that a very weak correlation was found in the Kassena-Nankana District compared to a rather strong positive correlation in the Ejura-Sekyedumase District. The results imply that growth in agricultural land use has kept pace with population growth in the Ejura-Sekyedumase District.

The study also assessed the role that other socio-economic factors as well as the demographic factors collectively play in influencing agricultural land use in the two study districts. The results show that years allowed for land to fallow and the proportion of major farmers were statistically significant predictors of cropped area in the Kassena-Nankana District in 1984. However, the situation changed in 2000, since land fallow not only ceased to be a statistically significant predictor of cropped area in the Kassena-Nankana District, but also had a negative relationship with cropped area.

In the Ejura-Sekyedumase District, a demographic indicator, i.e., population of the locality, was a statistically significant predictor of cropped area in 1984. However, all agricultural technological indicators, namely the use of tractor, fertilizer and improved seed variety for farming were not predictors of agricultural land use in both areas in 1984. This is an indication that innovations in mechanized forms of farming had not significantly spread to any part of the study area in 1984.

In 2000, distance to farthest farm, off-farm income, and practice of agricultural extensification were predictors of cropped area in the Kassena-Nankana District. The population of the locality again predicted cropped area in the Ejura-Sekyedumase District. With reference to income from off-farm activities, the analysis shows that extra income earned off-farm is not necessarily invested into farming activities. The variable had an inverse relationship with farmland. Expenditure on food also played no role in the utilization of agricultural land contrary to expectation, and agricultural extensification was mainly practiced in the Kassena-Nankana District.

A spatio-temporal analysis of the relationship shows that land tenure arrangement (whether ownership or rented), presence of electricity as a source of household energy, affluence (items and livestock ownership), use of tractor, inorganic fertilizer and improved seed variety for farming as well as household size did not influence agricultural land use in both districts and years. Actually, technologically improved farming techniques such as the use of tractors, inorganic fertilizers and improved seed varieties have not made much headway in these areas.

Finally, population of the locality was a statistically significant predictor of agricultural land use in the Ejura-Sekyedumase District in both years. When the two study districts were collectively analyzed, new variables, namely improved seed variety and household size, emerged as statistically significant predictors of household total cropped area.

The effect of population change on forest cover between 1990 and 2000 was another objective of the study. Very weak relationships existed between population size as well as annual growth rate on the one hand and forest cover on the other, in all sub-basins for both years. However, correlations between population density and forest cover in the White, Black, Main and Daka sub-basins were negative in 1990 and 2000, indicating that increase in population density was causing deforestation. When annual growth rates of the population were correlated with forest cover, no clear pattern was discovered in the results for both 1990 and 2000.

Predictions show that only the Jaman and Berekum Local/urban Council areas that fall within the Black Volta sub-basin will have depleted forest cover as a result of changes in population density. All the other areas within the sub-basin will have some amount of forest cover in 2010, irrespective of changes in population density that might occur. On the other hand, the Kete-Krachi Local Council in the Daka sub-basin will experience depleted forest cover in 2010 as a result of population density change, while the Gushiegu-Chereponi, Bimbilla and Salaga Local Councils will have some forest cover in 2010 despite changes in population density. Finally, other indirect demographic factors, namely, the farming systems, practices and inputs used, type of crops grown, household consumption patterns, source of fuelwood as energy for cooking, extensification of agricultural lands, and general living conditions were all shown as indirect demographic reasons for deforestation.

The study shows that both direct and indirect population factors affect agricultural land use either by bringing about intensification or extensification. Both agricultural practices have an impact on the environment. As this study shows, extensification leads to deforestation. It was also observed during the field study, that in areas where intensification was being practiced, loss of soil fertility and degradation occurred. On the other hand, degradation in agricultural and forest land resources have also had an effect on population, with the most favored option being migration to other resource- endowed areas. Whatever side of the population-environment nexus one looks at, these two phenomena affect each other in one way or another.

8.2 Recommendations

The issue of sustainable development can be described as a concept that the Ghanaian psyche is familiar with. This is due to the fact that long before the famous definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" by the Gro Harlem Bruntland's Commission, which was set up by the World Commission on Environment and Development (WCED) in 1987, Sir Nana Ofori Atta II, an illustrious son of Ghana and a traditional ruler made the following assertion in 1929:

> *"The land belongs to the dead, the living*
> *and the countless generations yet unborn".*

This perception of development has been embedded in the very traditional practices of the people of Ghana and it is no wonder that in most of the rural communities of the country, there are days set aside in every week when farmers, fishermen and hunters are forbidden to go to their farms, to sea and even to enter the forest for a prey. It is also a taboo to enter sacred traditional groves, which are demarcated forest areas where rituals are performed for the community. These taboos are observed with all seriousness, and penalties ranging from heavy fines to even complete banishment from the community are meted out to offenders. Furthermore, in most cultures in Ghana, the land is believed to be the residing place of the earth goddess, hence the name "*Asaase Yaa*", and it is perceived that any harm caused to the land is tantamount to causing harm to the earth goddess, who is believed to be the wife of "*Otwerediampong Kwame*", the omnipotent God above, who is the custodian of the land.

Thus, Ghana is a society with noble tenets and its people recognize that the resources placed at their disposal was handed over to them by an ancestral generation, and they in turn are to look after it very well and subsequently hand it over to posterity. They even have demarcated forest areas for rituals. Why is there such wanton destruction of forest resources and massive conversion to agricultural land over a relatively short period of time to the extent that even sacred traditional groves have been encroached upon? The simple answer to this question is survival.

Society and its people must not demise but must be perpetuated. As a result, society does everything within its means in order to survive, and when its existence is threatened and there are no alternatives for its survival, it will go against its own beliefs, values and ideals. Under such circumstances, issues like sustainable development do not really have any meaning. In the face of immense and abject poverty experienced by most of these communities, it sometimes looks as if they have reached their Malthusian limits due to the ecological constraints imposed by natural resources, and have no alternatives to circumvent these constraints. This study recommends two broad prone attacks to solving the problem of degradation in forests and agricultural resources. These are ecological and demographic and are discussed below.

The first is how to tackle the ecological problem. This study reveals that almost all the districts in the Daka sub-basin, and quite a substantial number of districts in the White Volta sub-basin, will have high agricultural land availability to support any rate of population growth in the future. It would be very tempting, therefore, to recommend to the government of Ghana to encourage seasonal as well as permanent agricultural migrants to settle in these areas. However, if one should pause for a moment, one would reconsider such a recommendation. This is because the question that would need to be answered is what will be the fate of these areas with high agricultural land potential in the near future when migrants flock there? The fear is that very soon these areas will be rendered bare and we would enter a vicious circle.

Boserup's idea comes to mind in such a scenario. In her view, so long as an area has low population density there will be room for long fallow periods, and required outputs for agriculture can be obtained without the investment of additional capital. However, in highly populated areas there will be the need to sustain a large and growing population, and this will culminate in the adoption of more intensive farming methods, which will require additional labor inputs per unit area. It is recommended that one of the ways out of this ecological dilemma is the practice of agricultural intensification.

This study reveals that very few farmers in the White Volta basin have access to the improved agricultural equipment and inputs that are necessary for the practice of agricultural intensification, and efforts should be made by the government to make these available to farmers. Ironically though, in the Main Volta basin the opposite is the case. Although the majority of farmers, especially in the Ejura-Sekyedumse District, have access to tractors which can be hired, improved seed varieties and inorganic fertilizer, the practice of agricultural extensification is the norm. To address this category of farmers, it is recommended that the government should embark on a campaign to educate these farmers about the benefits of intensification.

The mediating perspective considered in this study identified certain socio-economic as well as political issues that play a role in the population-environment relationship. In light of this, it is recommended that the quality of the population in terms of raising the level of educational attainment should be of prior concern to the government. When the population is well educated and has opportunities to work in more skilled occupations, they may not rely so heavily on the environment for their sustenance, since there would be diversification into other occupations. This situation could arise even in the face of increased population growth.

It is recommended that industrialisation, which would bring a complete turn around in the country's over-reliance on its limited agricultural and forestry resources, should be the ultimate goal of the government. It is, therefore, a step in the right direction that the government of Ghana has outlined in its "Vision 2020" programme of development to make Ghana attain middle-income status. This entails industrialisation by the year 2020, since ultimately it is the only way out of this ecological problem.

With respect to deforestation, the study revealed that the Jaman and Berekum Local Councils in the Black Volta sub-basin, and Kete-Krachi in the Daka sub-basin will have depleted forest in 2010, as a result of increases in population density. This shows that deforestation is very much a feature of these sub-basins, and the government should intensify the campaign to curb it. Deliberate bush-burning by hunters and herdsmen, and the slash and burn practice by farmers should be discouraged.

It is recommended that the government should take a closer look at the People Land Management and Ecosystem Conservation (PLEC) project, a United Nations University (UNU) initiative. It involves a collaborative effort between scientists and small farmers from across the developing world to develop sustainable and participatory approaches to conservation, especially of biodiversity based on farmers' technologies and knowledge within small farmers' agricultural systems. Since selected communities in Ghana are being used as case studies, the results could be replicated in other areas.

The Government is also urged to do its utmost to bring to fruition the West African Gas Pipeline (WAGP) project, which will make liquefied petroleum gas from neighboring Nigeria available at affordable prices for a majority of the rural communities. This will prevent the over reliance on fuelwood for household activities in these communities and thus spare the forest. Finally, effective ways of growing certain crops such as yam should be found to prevent the destruction of forests.

The second recommendation is the tackling of the population problem. There used to be a period in Ghana where size of population itself was not an issue of concern but the rate at which the population was growing. This sentiment was emphatically stated in the 1969 population policy document of Ghana. This thinking was the result of the fact that the country had vast agricultural and forest resources and in fact most of the country, especially the northern area, was sparsely populated. It is not that most of the country is populated in contemporary times. Infact extensive areas of Ghana are still sparsely populated. However, most of the vast areas have no potential for agricultural expansion due to poor soil quality, and the few potential areas have already been settled over the years.

The major population challenges in the country are therefore the rapid growth rate of the population mainly as a result of high fertility and the youthful nature of the population. Numerous factors account for the rapid population growth rate, but generally these comprise easy access to marriage, a permissive attitude towards multiple partners, a supportive kinship and household patterns which make children little burden to parents, as well as a nearly pathological fear of childlessness.

Ghana's population is estimated to double in 26 years and, according to the 2000 population and housing census, the proportion of the population under 15 years is 41.3%. This has resulted in a high dependency burden, with almost the same amount of adults looking after the same number of children. Currently, the dependency population is 46.6%. This also includes elderly people aged 64 years and above, who constitutes 5.3% of the population. In most developed societies, the elderly are not much of a problem since most of them rely on business investment, social security or pensions in their old age. However, this is not the case in Ghana due to inefficient or even absence of reliable pension schemes. The elderly therefore become a burden on the adult working population in the country.

Furthermore, according to the 1998 Demographic and Health Survey (DHS) in Ghana, about 94% of all women know of a family planning method and about 74% know where they can purchase contraceptives or obtain family planning services. However, it is when it comes to using these that the problem arises. It is a situation that has been described as the “unmet need”. According to the same survey, only 13% of all women used any modern method of contraception in 1998. This number should certainly rise if the country were to make any inroads in its efforts to curb the high population growth rate. Efforts should also be made to erode the use of traditional and outmoded contraceptives such as the use of charms, amulets and concoctions, since about 9% of all women claimed in the 1998 DHS that they use these. These methods have no scientific basis and have failed to prevent pregnancies.

As part of the fertility analysis of households in this study, information on determinants of fertility was gathered on women belonging to two age cohorts, namely women aged between 20-29 and 40-49 years. The results show that 57% of all women married before the age of 20. Not only was early age at marriage a problem, but also marriage itself was found to be cherished to the extent that about 96% of the women even in the 20-29 cohort stated that they have ever been married. Furthermore, preference of large family sizes is still predominant, about 21% of the women claim they prefer a family size of seven or more. To some women, the wish for a large family has religious reasons, which can be traced to the command in Genesis 1:28 of the Holy Bible which states among other things *“…Be fruitful, and multiply, and replenish the earth, and subdue it”*.

Illiteracy was also identified as a debilitating factor in curbing high fertility due to the fact that 61% of the women had never had any formal education. Infant and child mortality rates were also high in these areas, with about 11% of all the women stating that they have experienced the loss of a child. When this happens, couples tend to replace the child. Finally, due to the fact that there are no reliable schemes to cater for the women during their old age, 95% of them stated that they look up to their children for support in their old age, and therefore tend to give birth to more children.

All the issues raised are not favorable for a transition to lower fertility, which would eventually curtail the high population growth rate being experienced in the country. The government is therefore urged to raise the age of marriage, do more regarding education particularly of the girl-child in the rural communities, intensify programs to lower infant and child mortality rates, educate people on the need for smaller family sizes and expedite action on the proposed national health insurance and other social insurance schemes. For the first time in the history of Ghana, there is a Ministry for Women Affairs, and one responsible for Girl-child education. It is recommended that these ministries be given the needed support to carry out their mandates, which are to enhance girl-child education and to improve the living conditions of women.

Another issue is breaking the vicious cycle of rapid population growth. The cycle starts with a high dependency burden which leads to low savings and investments which in turn culminate in low economic growth, then poverty or low standards of living leading to high fertility. This leads to a high population growth rate and then back to a high dependency burden to complete the cycle. Two suggestions have been offered to break this cycle. The first one is economical. It suggests that when massive economic transformation takes place in the country, it will lead to a high standard of living, which will lead to a low population growth rate and subsequently a low dependency burden.

The second alternative is attacking the population problem with good and sound population programs and policies, which will result in a low population growth rate that will again lead to a low dependency burden, high savings and investments, high economic growth and finally a high standard of living. The former could be argued to be somehow exogenous, since economic emancipation of the country to some extent has to do with the outside world and with forces that could be beyond the reach of the players in the country. However, the latter is something which is certainly achievable, if there are effective population programs and support for its implementation.

Finally, it must be mentioned that environmental sustainability is everybody's challenge. While in the rich countries, the by-products of industrial and agribusiness production poison soils and waterways, in the developing countries, massive deforestation, harmful farming practices and uncontrolled urbanization are major causes of environmental degradation. As Mr. Kofi Atta Annan, the 7th Secretary-General of the United Nations puts it in his speech to the Millennium Summit of 2000: the founders of the United Nations in 1945 set out to provide freedom from want and freedom from fear to the peoples of the world. However, they did not anticipate that the world would be faced with a third freedom, which is the freedom of future generations to sustain their lives on this planet. In his view, members of the world's community have been plundering our children's future heritage to pay for environmentally unsustainable practices in the present and this could be disastrous for posterity.

Another recommendation goes to the GLOWA project. The overall objective of the project is to analyze the physical and socio-economic determinants of hydrological cycles, with the aim to develop a scientifically sound decision support system for the assessment, sustainable use and development of water resources in the Volta Basin of West Africa. However, it is a well-perceived notion that man and his activities are the major drivers behind land use change, which ultimately have ramifications for hydrological cycles. It is therefore recommended that the social processes taking place at the community level should be given more prominence in the project.

Furthermore, this study mainly concentrated on demographic and socio-economic and institutional factors affecting agricultural and forest land uses. However, as mentioned in the study, other physical/natural/environmental factors, namely, climate (sunshine, precipitation, and temperature), geomorphology (altitude, and slope), soil (fertility, drainage, permeability, texture), and geology are also factors that come to play in the population and environment nexus. It is recommended that a study that incorporates these factors, together with the socio-economic factors should be carried out within the context of the GLOWA project. This will provide a holistic understanding of the relationship between population and environment in the Volta River basin, thus providing a better understanding of environmental change first from a local and eventually to a global perspective. It will also strengthen the co-operation between the various researchers and the inter-disciplinary approach, which is the trump-card of the project, would be brought out the more.

Finally, on the general field of population-environment research, it is important to note that the majority of population and environment relationships are played out as local dramas and should be first fully understood in this context. Even global environmental impacts (e.g., loss of biodiversity or global warming) have their roots in processes played out within regions, communities, and households. With other processes (e.g., soil degradation and deforestation, urban environmental deterioration), their localized character is more intuitively apparent. Due to this, the world would benefit greatly by an emphasis on research that attempts to explain as well as possible a limited phenomena in a specific context.

In the past, much of the resources and attention which have been put into the study of population and environment relationships have gone to large-scale multidisciplinary studies or sophisticated macro-level modelling and simulation exercises. In the future, equal attention should also be given to micro-level studies. A greater knowledge of population-environment relationships in the immediate future resides in the accumulation of these more localized studies. Ultimately, a more generalized vision of these relationships, including the understanding of global relationships, may emerge from the accumulation of micro-level studies. It is recommended that for the near future, the 'bottom-up' approach of micro-level study rather than the 'trickle-down' approach of macro-level study should be the driving force in social science research on population and environment relationships.

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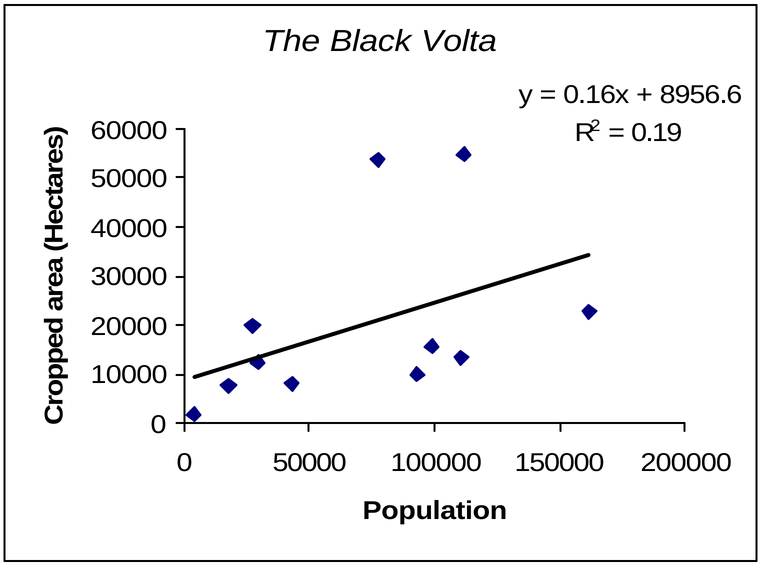
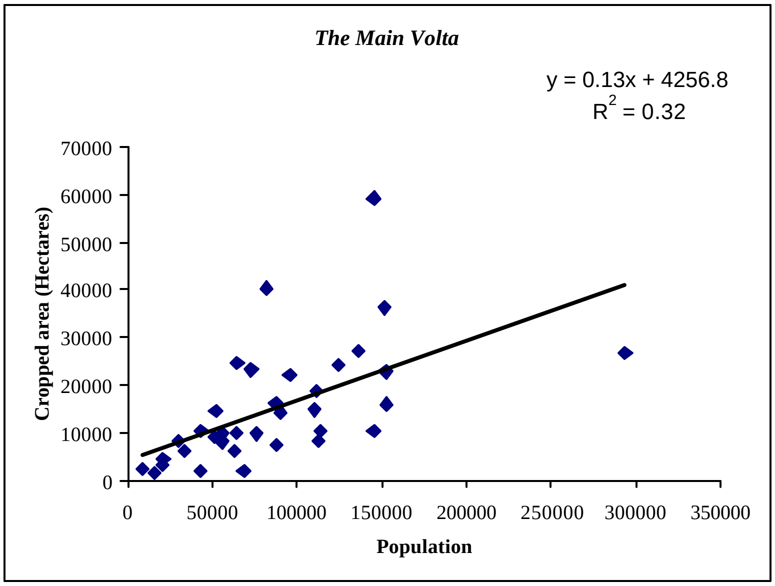
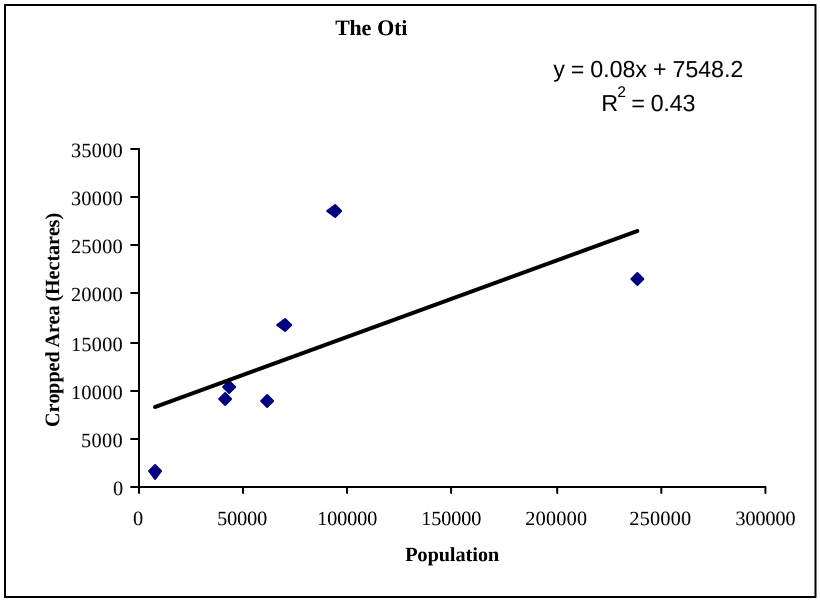
10 APPENDICES

Appendix 1. Scatterplot showing relationship between population and land use (cropped area) in the sub-basins, 2000






The Oti
y = 0.08x + 7548.2
R2 = 0.43
Cropped Area (Hectares)
35000
30000
25000
20000
15000
10000
5000
0
0
50000
100000
150000
200000
250000
300000
Population

Appendix 2. Population of the Sub-Basins, 1960-2010

The White Volta

Local/Urban Council	***Population***					
	1960	**1970**	**1984**	**1992***	**2000**	**2010***
Sandema	20402	51782	66357	70741	75375	81650
Navrongo	28823	48086	63391	63350	63309	63258
Chiana -Paga	32285	50920	86289	86236	86182	86115
Bolgatanga-Tongo	34275	95010	146658	183761	228815	303332
Bongo-Nabdam	19095	77192	95263	86191	77885	68727
Kusanaba -Zebilla	25839	44714	63565	71634	80585	93569
Tempane-Garu	41001	61716	87492	96928	107244	121892
Bawku	34807	74851	110797	122747	135809	154359
Pusiga-Pulikam	23351	38587	52932	58643	64885	73751
95% Tumu	37488	40320	56061	67603	81170	102571
20% Lawra-Jirapa	10869	15041	17691	17598	17505	17390
50% Wa	15143	23651	34483	52665	78711	133639
66.7% Nadawli-Funsi	35002	42595	54509	54840	55172	55590
12.5% Bole	3245	6168	10667	13053	15893	20455
62.5% Damango (incl. Damango)	23363	33250	51879	51845	51947	51905
75% Tolon	38273	39053	66130	81383	99625	129132
66.7% Savelugu (excl. Savelugu)	16149	24658	38341	36675	35072	33177
33.3% Gushiegu-Chereponi	11916	18387	33980	37698	41768	47557
60% Nalerigu	31594	51442	85045	94526	104918	119736
Walewale	35649	39614	59130	83052	115025	175882
Total	**518569**	**877037**	**1280660**	**1440219**	**1616895**	**1933687**

Source: 1984 Population Census of Ghana, Special Report on Localities by Local Authority and 2000 Population and Housing Census, Special Report on 20 Largest Localities.

*Projected Figures

The Black Volta

Local/urban Council	***Population***					
	1960	**1970**	**1984**	**1992***	**2000**	**2010***
5% Tumu	1973	2122	2951	3558	4272	5398
80% Lawra-Jirapa	43476	60164	70762	74048	77467	81989
33.3% Nadawli-Funsi	17475	21266	27241	27392	27544	27735
50% Wa (incld. Wa)	29486	45025	88583	99707	112033	129887
87.5% Bole	22715	43176	74668	91372	111254	143191
31.25% Damango (exl. Damango)	8394	12745	19678	23987	29098	37269
66.7% Jaman	31145	40624	58640	76497	98934	137931
46.2% Berekum (excl. Berekum)	18493	25893	26003	10038	43075	59348
97.1% Wenchi (incld. Wenchi)	68843	95246	151935	156804	161808	168315
50% Nkoranza (incl. Kintampo)	31122	35278	75340	83652	92756	105721
11.1% Atebubu	3889	6560	11372	14408	18130	24370
Total	**277011**	**388099**	**607372**	**669319**	**736722**	**921154**

The Main Volta

Local/urban Council	*Population*					
	1960	**1970**	**1984**	**1992***	**2000**	**2010***
16.7% Gushiegu-Chereponi	5976	9221	17024	18897	20947	23866
33.3% Savelugu (incl. Savelugu)	11032	17251	27612	28765	29959	31530
25% Tolon	9053	13018	22043	27127	33208	43044
Tamale	48345	98560	167778	223157	293881	419774
33.3% Yendi (excl. Yendi)	11446	18899	28163	35088	43458	57204
6.25% Damango (excl. Damango)	1679	2549	3936	5913	8708	14484
71.4% Salaga (incl. Salaga)	30557	52143	90203	106187	124593	152776
Kwame Danso	12500	31122	61858	71383	82166	98274
50% Nkoranza (incl. Nkoranza)	31122	35278	75901	69987	64480	58262
88.9% Atebubu	31148	52541	92580	116313	145200	193133
50% Techiman (excl. Techiman)	12352	26564	45091	63176	87300	133075
16.7% Bechem/D. Nkwanta	3420	12797	15456	17871	20609	24710
40% Offinso	21045	37589	53578	54517	55470	56688
90% Ejura-Sekyedumasi	20569	33179	54897	63387	73003	87378
66.7% Mampong (incl. Mampong)	23981	37301	50840	70126	95518	142784
96.7% Nsuta-Kwamang-Beposo	24342	31694	50805	89644	152202	309521
93.3% Sekyere	45677	59108	79131	93983	111114	137768
50% Ashanti Akim/K.Odumase	15638	35583	49294	55887	63239	73983
66.7% Abetifi	24539	40293	50096	86801	145063	288375
75% Begoro (incl. Begoro)	23192	39784	56201	60280	64616	70531
57.1% Manya Krobo	42128	64564	76817	82292	88106	96025
60% Yilo Krobo (incl. Somanya)	29344	37414	52024	51825	51626	51379
Afram	10660	31486	82725	106454	135928	186302
Akwamu-Anum-Boso	23797	43024	55827	65200	75920	92174
50% Koforidua (excl. Koforidua)	26398	34888	46241	56369	68384	87593
85.7% Akropong	36510	58488	72957	80984	89773	102285
31.4% Kete-Krachi	12387	33768	56912	81183	114044	177786
66.7% Tongu	47431	65767	77217	58077	43229	30279
Dutasor	25809	35433	47152	51524	56246	62839
Dayi/Gbi	81015	120249	156915	154758	152627	150009
Kpando	16548	27345	35605	64786	112961	238723
Buem	28162	40718	43983	83590	151276	337564
Akan Bonwire/Wawa	47532	86874	94075	70323	52001	36145
Biakoye	33424	43284	49682	74833	110452	184306
16.7% Ada	7388	8656	11949	13646	15550	18358
Total	**876146**	**1416432**	**2052555**	**2501014**	**3032857**	**4268927**

The Oti

Local/urban Council	***Population***					
	1960	**1970**	**1984**	**1992***	**2000**	**2010***
40% Nalerigu	21063	34294	56697	63017	69945	79824
33.3% Gushiegu-Chereponi	11916	18387	33980	37698	41768	47557
33.3% Yendi (excluding Yendi)	11446	18899	17646	28053	43458	77577
42.9% Bimbila (incl. Bimbila)	14522	32165	45341	53056	61895	75329
Saboba-Zabzugu	19504	49728	72261	82439	93847	110650
4.8% Salaga (excl. Salaga)	2054	3505	5475	5593	8376	8602
65.7% Kete-Krachi	25918	70654	119080	111884	238621	371994
Total	**106423**	**227632**	**350480**	**385877**	**557910**	**771533**

The Daka

Local/urban Council	***Population***					
	1960	**1970**	**1984**	**1992***	**2000**	**2010***
16.7% Gushiegu-Chereponi	5976	9221	17041	18906	20947	23850
33.3% Yendi	11446	18899	17646	28053	43458	77577
23.8% Salaga (excl. Salaga)	10184	17379	27147	33673	41531	42652
57.1% Bimbila (excld. Bimbila)	19329	42812	60349	70618	82382	100263
2.9% Kete-Krachi	1144	3119	5256	7498	10533	16420
Total	**48079**	**91429**	**127439**	**159688**	**198851**	**260761**

Appendix 3. Population density of the sub-basins, 1960-2010

The White Volta

Local/urban Council	*Area (Km2)*	*1960*	*1970*	*1984*	*1992**	*2000*	*2010**
Sandema	2220	9.2	23.3	29.9	31.9	34.0	36.8
Navrongo	886	32.5	54.3	71.5	71.5	71.5	71.4
Chiana -Paga	756	42.7	67.4	114.1	114.1	114	113.9
Bolgatanga-Tongo	1313	26.1	72.4	111.7	140	174.3	231
Bongo-Nabdam	591	32.3	130.6	161.2	145.8	131.8	116.3
Kusanaba -Zebilla	979	26.4	45.7	64.9	73.2	82.3	95.6
Tempane-Garu	1072	38.2	57.6	81.6	90.4	100	113.7
Bawku	717	48.5	104.4	154.5	171.2	189.4	215.3
Pusiga-Pulikam	308	75.8	125.3	171.9	190.4	210.7	239.5
95% Tumu	6611	5.7	6.1	8.5	10.2	12.3	15.5
20% Lawra-Jirapa	371	29.3	40.5	47.7	47.4	47.2	46.9
50% Wa	1464	20.1	30.8	35.9	36	53.8	91.3
66.7% Nadawli-Funsi	3852	9.1	11.1	14.1	14.2	14.3	14.4
12.5% Bole	1090	3.0	5.7	9.8	12	14.6	18.8
62.5% Damango (incl. Damango)	9829	1.7	2.6	4.5	5.3	5.3	5.3
75% Tolon	1097	34.9	35.6	60.3	74.2	90.8	117.7
66.7% Savelugu (excl. Savelugu)	2479	13.7	13.9	17.7	14.8	14.2	13.4
33.3% Gushiegu-Chereponi	2308	5.2	8	14.7	16.3	18.1	20.6
60% Nalerigu	2810	11.2	18.3	30.3	33.6	37.3	42.6
Walewale	3077	11.6	12.9	19.2	27	37.3	57.2
Total	**43830**	**12.4**	**20.6**	**29.6**	**32.9**	**36.9**	**44.1**

The Black Volta

Local/urban Council	*Area (Km2)*	*1960*	*1970*	*1984*	*1992*	*2000*	*2010**
5% Tumu	348	5.7	6.1	8.5	10.2	12.3	15.5
80% Lawra-Jirapa	1484	29.3	40.5	47.7	49.9	52.2	55.3
33.3% Nadawli-Funsi	1926	9.1	11	14.1	14.2	14.3	14.4
50% Wa (incld. Wa)	1465	20.1	30.7	60.5	68.1	76.5	88.7
87.5% Bole	7631	3.0	5.7	9.8	12	14.6	18.8
31.25% Damango (exl. Damango)	4915	1.7	2.6	4.0	4.9	5.9	7.6
66.7% Jaman	1271	24.5	32	46.1	60.2	77.8	108.5
46.2% Berekum (excl. Berekum)	528	35	49	49.2	19	81.6	112.4
97.1% Wenchi (incld. Wenc hi)	7350	9.4	13	20.7	21.3	22	22.9
50% Nkoranza (incl. Kintampo)	3002	10.4	11.8	25.1	27.9	30.9	35.2
11.1% Atebubu	662	5.9	9.9	17.2	21.8	27.4	36.8
Total	**30582**	**9.1**	**12.7**	**20.0**	**21.9**	**24.1**	**30.1**

The Main Volta

Local/urban Council	***Area (Km²)***	***1960***	***1970***	***1984***	***1992****	***2000***	***2010****
16.7% Gushiegu-Chereponi	1154	5.2	8	14.8	16.4	18.2	20.7
33.3% Savelugu (incl. Savelugu)	1240	8.9	13.9	22.3	23.2	24.2	25.4
25% Tolon	366	24.7	35.6	60.2	74.1	90.7	117.6
Tamale	241	200.6	409	696.2	926	1219.4	1741.8
33.3% Yendi (excl. Yendi)	1468	7.8	12.9	19.2	23.9	29.6	39
6.25% Damango (excl. Damango)	983	1.7	2.6	3.2	6	8.9	14.7
71.4% Salaga (incl. Salaga)	9254	3.3	5.6	10.1	11.5	13.5	16.5
Kwame Danso	7438	1.7	4.2	8.3	9.6	11.1	13.2
50% Nkoranza (incl. Nkoranza)	3002	10.4	11.8	25.5	23.3	21.5	19.4
88.9% Atebubu	5300	5.9	9.9	17.5	22	27.4	36.4
50% Techiman (excl. Techiman)	579	21.3	45.9	56.1	109	150.8	229.8
16.7% Bechem/D. Nkwanta	74	46.2	172.9	208.9	242	278.5	339.9
40% Offinso	672	31.3	55.9	79.7	81.1	82.6	84.4
90% Ejura-Sekyedumasi	1112	18.5	29.8	34.2	57	65.7	78.6
66.7% Mampong (incl. Mampong)	469	51.1	79.5	122.7	149.5	203.7	304.4
96.7% Nsuta-Kwamang-Beposo	1953	12.5	16.2	26	45.9	77.9	158.5
93.3% Sekyere	3938	11.6	15	20.1	23.9	28.2	35
50% Ashanti Akim/K.Odumase	584	26.8	60.9	71.9	95.7	108.3	126.7
66.7% Abetifi	1110	22.1	36.3	45.1	78.2	130.7	259.8
75% Begoro (incl. Begoro)	853	27.2	46.6	65.9	70.7	75.8	82.7
57.1% Manya Krobo	731	57.6	88.3	105.2	112.6	120.5	131.4
60% Yilo Krobo (incl. Somanya)	500	58.7	74.8	104.1	103.7	103.3	102.8
Afram	5040	2.1	6.3	16.4	21.1	27	37
Akwamu-Anum-Boso	769	31	56	72.6	84.8	98.7	119.9
50% Koforidua (excl. Koforidua)	49	538.7	712	943.7	1150.4	1395.5	1787.6
85.7% Akropong	526	69.4	111.2	138.7	154	170.7	194.5
31.4% Kete-Krachi	2576	4.8	13.1	22.1	31.5	44.3	69
66.7% Tongu	1627	29.2	40.4	47.4	35.7	26.6	18.6
Dutasor	756	34.1	46.9	62.4	68.2	74.4	83.1
Dayi/Gbi	1655	49	72.7	94.8	93.5	92.2	90.6
Kpando	378	43.8	72.3	94.2	171.4	298.8	631.5
Buem	435	64.7	93.6	101.1	192.2	347.8	776
Akan Bonwire/Wawa	1828	26	47.5	51.5	38.5	28.5	19.8
Biakoye	717	46.6	60.4	69.3	104.4	154.1	257.1
16.7% Ada	109	67.8	79.4	109.6	125.2	142.7	168.4
Total	**59486**	**14.7**	**23.8**	**34.5**	**42.0**	**51.0**	**71.8**

TheOti

Local/urban Council	***Area (Km^2)***	***1960***	***1970***	***1984***	***1992****	***2000***	***2010****
40% Nalerigu	1873	11.3	18.3	30.3	33.7	37.3	42.6
33.3% Gushiegu-Chereponi	2308	5.2	8	14.7	16.3	18.1	20.6
33.3% Yendi (excluding Yendi)	1468	7.8	12.9	12	19.1	29.6	52.9
42.9% Bimbila (incl. Bimbila)	1637	8.9	19.7	27.7	32.4	37.8	46
Saboba-Zabzugu	4652	4.2	10.7	15.5	17.7	20.2	23.8
4.8% Salaga (excl. Salaga)	617	3.3	5.7	8.9	9.1	13.6	13.9
65.7% Kete-Krachi	5387	4.8	13.1	22.1	20.8	44.3	69.1
Total	**17942**	**5.9**	**12.7**	**19.5**	**21.5**	**31.1**	**43.0**

The Daka

Local/urban Council	***Area (Km^2)***	***1960***	***1970***	***1984***	***1992****	***2000***	***2010****
16.7% Gushiegu-Chereponi	1154	5.2	8	14.8	16.3	16.2	20.7
33.3% Yendi	1468	7.8	12.9	12	19.1	29.6	52.9
23.8% Salaga (excl. Salaga)	3085	3.3	5.6	8.8	10.9	13.5	13.8
57.1% Bimbila (excld. Bimbila)	2183	8.9	19.6	27.7	32.4	37.7	45.9
2.9% Kete-Krachi	234	4.9	13.3	22.5	32	45	70.2
Total	**8124**	**5.9**	**11.3**	**15.7**	**19.7**	**24.5**	**32.1**

Appendix 4. Annual population growth rates of the sub-basins

The White Volta

Local/urban Council	***Annual population growth rate***		
	1960-1970	**1970-1984**	**1984-2000**
Sandema	9.8	1.8	0.8
Navrongo	5.3	2.0	-0.01
Chiana-Paga	4.7	3.8	-0.01
Bolgatanga-Tongo	10.7	3.2	2.8
Bongo-Nabdam	15.0	1.5	-1.3
Kusanaba-Zebilla	5.6	2.6	1.5
Tempane-Garu	4.2	2.5	1.3
Bawku	8.0	2.8	1.3
Pusiga-Pulikam	5.2	2.3	1.3
95% Tumu	0.7	2.4	2.3
20% Lawra-Jirapa	3.3	1.2	-0.1
50% Wa	4.6	2.7	5.3
66.7% Nadawli-Funsi	2.0	1.8	0.1
12.5% Bole	6.6	4.0	2.5
62.5% Damango (incl. Damango)	3.6	3.2	-0.01
75% Tolon	0.2	3.8	2.6
66.7% Savelugu (excl. Savelugu)	4.3	3.2	-0.6
33.3% Gushiegu-Chereponi	4.4	4.5	1.3
60% Nalerigu	5.0	3.7	1.3
Walewale	1.1	2.9	4.3
Total	**5.4**	**2.7**	**1.5**

The Black Volta

Local/urban Council	***Annual population growth rate***		
	1960-1970	**1970-1984**	**1984-2000**
5% Tumu	0.7	2.4	2.3
80% Lawra-Jirapa	3.3	1.2	0.6
33.3% Nadawli-Funsi	2.0	1.8	0.1
50% Wa (incld. Wa)	4.3	5.0	1.5
87.5% Bole	6.6	4.0	2.5
31.25% Damango (exl. Damango)	4.3	3.2	2.5
66.7% Jaman	2.7	2.7	3.3
46.2% Berekum (excl. Berekum)	3.4	0.1	3.2
97.1% Wenchi (incld. Wenchi)	3.3	3.4	0.4
50% Nkoranza (incl. Kintampo)	1.3	5.6	1.3
11.1% Atebubu	5.4	4.0	3.0
Total	**3.4**	**3.3**	**1.2**

The Main Volta

Local/urban Council	*Annual population growth rate*		
	1960-1970	**1970-1984**	**1984-2000**
16.7% Gushiegu-Chereponi	4.4	4.5	1.3
33.3% Savelugu (incl. Savelugu)	4.6	3.4	0.5
25% Tolon	3.7	3.8	2.6
Tamale	7.4	3.9	3.6
33.3% Yendi (excl. Yendi)	5.1	2.9	2.8
6.25% Damango (excl. Damango)	4.3	3.2	5.1
71.4% Salaga (incl. Salaga)	5.5	4.0	2.0
Kwame Danso	9.6	5.0	1.8
50% Nkoranza (incl. Nkoranza)	1.3	5.6	-1.0
88.9% Atebubu	5.4	4.1	2.9
50% Techiman (excl. Techiman)	8.0	3.9	4.2
16.7% Bechem/D. Nkwanta	14.1	1.4	1.8
40% Offinso	6.0	2.6	0.2
90% Ejura-Sekye dumasi	4.9	3.7	1.8
66.7% Mampong (incl. Mampong)	4.5	2.2	4.0
96.7% Nsuta-Kwamang-Beposo	2.7	3.4	7.1
93.3% Sekyere	2.6	2.1	2.2
50% Ashanti Akim/K.Odumase	8.6	2.4	1.6
66.7% Abetifi	5.1	1.6	6.9
75% Begoro (incl. Begoro)	5.6	2.5	0.9
57.1% Manya Krobo	4.4	1.2	0.9
60% Yilo Krobo (incl. Somanya)	2.5	2.4	-0.1
Afram	11.4	7.1	3.2
Akwamu-Anum-Boso	6.1	1.9	1.9
50% Koforidua (excl. Koforidua)	2.8	2.0	2.5
85.7% Akropong	4.8	1.6	1.3
31.4% Kete-Krachi	10.6	3.8	4.4
66.7% Tongu	3.3	1.2	-3.6
Dutasor	3.2	2.1	1.1
Dayi/Gbi	4.0	1.9	-0.2
Kpando	5.2	1.9	7.5
Buem	3.8	0.6	8.0
Akan Bonwire/Wawa	6.2	0.6	-3.6
Biakoye	2.6	1.0	5.1
16.7% Ada	1.6	2.3	1.7
Total	**4.9**	**2.7**	**2.5**

The Oti

Local/urban Council	***Annual population growth rate***		
	1960-1970	**1970-1984**	**1984-2000**
40% Nalerigu	5.0	3.7	1.3
33.3% Gushiegu-Chereponi	4.4	4.5	1.3
33.3% Yendi (excluding Yendi)	5.1	-0.5	5.8
42.9% Bimbila (incl. Bimbila)	8.3	2.5	2.0
Saboba-Zabzugu	9.8	2.7	1.7
4.8% Salaga (excl. Salaga)	5.5	3.2	0.3
65.7% Kete-Krachi	10.6	3.8	4.4
Total	**7.9**	**3.1**	**3.0**

The Daka

Local/urban Council	***Annual population growth rate***		
	1960-1970	**1970-1984**	**1984-2000**
16.7% Gushiegu-Chereponi	4.4	4.5	1.3
33.3% Yendi	5.1	-0.5	5.8
23.8% Salaga (excl. Salaga)	5.5	3.2	2.7
57.1% Bimbila (excld. Bimbila)	8.3	2.5	2.0
2.9% Kete-Krachi	10.6	3.8	4.4
Total	**6.6**	**2.4**	**2.8**

Appendix 5. Cropped area (in hectares) of the major crops in the sub-basins, 1992 & 2000

The White Volta

Local/urban Council	***1992***	***2000***	***% Annual growth rate 1992 and 2000***
Sandema	93270	42250	-6.8
Navrongo	8602	29970	31.0
Chiana -Paga	7328	25530	31.0
Bolgatanga-Tongo	61480	79400	3.6
Bongo-Nabdam	NA	15420	NA
Kusanaba-Zebilla	17780	39815	15.5
Tempane-Garu	54826	45001	-2.3
Bawku	36671	30099	-2.3
Pusiga-Pulikam	15753	12930	-2.3
95% Tumu	27663	36958	4.3
20% Lawra-Jirapa	1637	13400	89.9
50% Wa (excluding Wa town)	27273	54640	12.5
66.7% Nadawli-Funsi	29219	40045	4.6
12.5% Bole	4188	1889	-6.9
62.5% Damango (incl. Damango)	16063	4344	6.5
75% Tolon	8325	18300	15.0
66.7% Savelugu (excl. Savelugu)	10339	16742	7.8
33.3% Gushiegu-Chereponi	9424	9078	-0.5
60% Nalerigu	25800	5110	-0.4
Walewale	33300	34050	0.3

Source: Ministry of Food and Agriculture, Ghana, 20001
NA – Data not available

The Black Volta

Local/urban Council	***1992***	***2000***	***% Annual growth rate 1992 and 2000***
5% Tumu	1456	1945	4.3
80% Lawra-Jirapa	6548	53600	89.9
33.3% Nadawli-Funsi	14588	19993	4.6
50% Wa (incld. Wa)	27273	54640	12.5
87.5% Bole	29316	13223	-6.9
31.25% Damango (exl. Damango)	8032	12172	6.5
66.7% Jaman	8985	15848	9.5
46.2% Berekum (excl. Berekum)	10490	7982	-3.0
97.1% Wenchi (incld. Wenchi)	29681	22789	-2.9
50% Nkoranza (incl. Kintampo)	14268	9842	-3.9
11.1% Atebubu	5166	7385	5.4

The Main Volta

Local/urban Council	***1992***	***2000***	***% Annual growth rate 1992 and 2000***
16.7% Gushiegu-Chereponi	4726	4553	-0.5
33.3% Savelugu (incl. Savelugu)	5162	8358	7.8
25% Tolon	2775	6100	15.0
Tamale	38200	26600	-3.8
33.3% Yendi (excl. Yendi)	10090	10423	0.4
6.25% Damango (excl. Damango)	1606	2434	6.5
71.4% Salaga (incl. Salaga)	27995	24061	-1.8
Kwame Danso	29155	40312	4.8
50% Nkoranza (incl. Nkoranza)	14268	9842	-3.9
88.9% Atebubu	41374	59147	5.4
50% Techiman (excl. Techiman)	19885	16038	-2.4
16.7% Bechem/D. Nkwanta	4797	3310	-3.9
40% Offinso	5329	8069	6.4
90% Ejura-Sekye dumasi	18549	23145	3.1
66.7% Mampong (incl. Mampong)	13295	22042	8.3
96.7% Nsuta-Kwamang-Beposo	12323	22704	10.5
93.3% Sekyere	16901	18682	1.4
50% Ashanti Akim/K.Odumase	9807	6213	-4.6
66.7% Abetifi	11873	10223	-1.6
75% Begoro (incl. Begoro)	29700	24514	-2.1
57.1% Manya Krobo	10906	7458	-4.0
60% Yilo Krobo (incl. Somanya)	12030	8986	-3.1
Afram	40400	27287	-4.0
Akwamu-Anum-Boso	10000	9786	-0.3
50% Koforidua (excl. Koforidua)	1225	1891	6.8
85.7% Akropong	20482	14280	-3.8
31.4% Kete-Krachi	7913	10284	3.8
66.7% Tongu	1932	1961	0.3
Dutasor	7800	9770	3.1
Dayi/Gbi	8100	16000	12.3
Kpando	6600	8350	3.4
Buem	24400	36200	6.0
Akan Bonwire/Wawa	10200	14620	5.4
Biakoye	12500	14800	2.3
16.7% Ada	6780	1469	-9.8

The Oti

Local/urban Council	***1992***	***2000***	***% Annual growth rate 1992 and 2000***
40% of Nalerigu	17200	16740	-0.4
33.3% of Gushiegu-Chereponi	9424	9078	-0.5
33.3% of Yendi (excluding Yendi)	10090	10423	0.4
42.9% of Bimbila (incl. Bimbila)	19005	8958	-6.5
Saboba-Zabzugu	28100	28590	0.3
4.8% of Salaga (excl. Salaga)	1882	1618	-1.8
65.7% of Kete-Krachi	16556	21518	3.8

The Daka

Local/urban Council	***1992***	***2000***	***% Annual growth rate 1992 and 2000***
16.7% of Gushiegu-Chereponi	4726	4553	-0.5
33.3% of Yendi	10090	10423	0.4
23.8% of Salaga (excl. Salaga)	9332	8023	-1.8
57.1% of Bimbila (excld. Bimbila)	25296	11923	-6.6
2.9% of Kete-Krachi	731	950	3.8

Appendix 6. Demographic indicators by locality and district, 1997-2001

Births

	Kassena-Nankana						*Ejura-Sekyedumase*				
Locality	**1997**	**1998**	**1999**	**2000**	**2001**	**Locality**	**1997**	**1998**	**1999**	**2000**	**2001**
Telania	4	6	1	9	3	Hiawoanwu	12	9	13	15	11
Navrongo	2	3	1	8	3	Kasei	9	14	4	4	5
Bonia	4	0	6	2	3	Dromankuma	5	2	7	8	8
Kanania	10	5	14	8	7	Bonyon	8	7	10	10	4
Atibaabisi	5	6	4	3	0	Aframso	6	9	6	6	8
Yuwa	5	4	5	4	0	Afrante	7	2	10	7	9
Nabango	5	5	3	2	6	Anyinasu	6	6	13	10	6
Paga	2	5	3	4	9	Sekyedumase	11	8	11	8	6
Mirigu	5	5	6	3	4	Ejura	14	14	7	22	9
Badania	6	1	2	3	2						
Manyoro	5	2	8	1	2						
Janania	2	3	5	4	2						
Total	**55**	**45**	**58**	**51**	**41**	**Total**	**78**	**71**	**81**	**90**	**66**

Source: Field Survey, 2001, 2002

Deaths

	Kassena-Nanakana						*Ejura-Sekyedumase*				
Locality	**1997**	**1998**	**1999**	**2000**	**2001**	**Locality**	**1997**	**1998**	**1999**	**2000**	**2001**
Telania	2	2	0	6	1	Hiawoanwu	2	0	2	1	1
Navrongo	2	2	4	1	0	Kasei	0	0	0	4	0
Bonia	0	0	0	1	1	Dromankuma	0	3	1	1	1
Kanania	8	5	0	1	3	Bonyon	1	1	1	2	3
Atibaabisi	2	0	1	1	0	Aframso	2	0	0	0	0
Yuwa	0	3	1	1	0	Afrante	3	0	0	1	0
Nabango	0	3	0	1	3	Anyinasu	2	1	0	0	0
Paga	3	0	2	1	4	Sekyedumase	3	0	0	0	2
Mirigu	4	0	0	2	0	Ejura	0	3	1	2	6
Badania	0	0	0	1	0						
Manyoro	0	1	1	0	0						
Janania	0	1	0	0	1						
Total	**21**	**17**	**9**	**16**	**13**	**Total**	**13**	**8**	**5**	**11**	**13**

Out-Migration

	Kassena-Nankana						*Ejura-Sekyedumase*				
Locality	**1997**	**1998**	**1999**	**2000**	**2001**	**Locality**	**1997**	**1998**	**1999**	**2000**	**2001**
Telania	4	2	6	2	2	Hiawoanwu	5	2	3	7	5
Navrongo	3	3	3	5	2	Kasei	0	2	1	2	3
Bonia	2	1	1	3	2	Dromankuma	2	2	2	0	4
Kanania	6	1	8	8	4	Bonyon	2	0	2	0	8
Atibaabisi	3	5	5	2	0	Aframso	3	5	5	8	4
Yuwa	2	5	10	8	1	Afrante	4	3	7	5	7
Nabango	7	10	2	10	3	Anyinasu	2	1	2	2	1
Paga	3	1	1	3	1	Sekyedumase	5	4	3	6	14
Mirigu	4	1	2	2	0	Ejura	1	0	3	3	1
Badania	2	1	0	1	4						
Manyoro	3	2	5	2	5						
Janania	2	1	1	3	0						
Total	**41**	**33**	**44**	**49**	**24**	**Total**	**24**	**19**	**28**	**33**	**47**

In-Migration

	Kassena-Nankana						*Ejura-Sekyedumase*				
Locality	**1997**	**1998**	**1999**	**2000**	**2001**	**Locality**	**1997**	**1998**	**1999**	**2000**	**2001**
Telania	0	0	1	3	1	Hiawoanwu	1	1	0	3	5
Navrongo	0	5	0	2	0	Kasei	2	1	2	2	2
Bonia	0	1	0	2	1	Dromankuma	2	2	3	2	1
Kanania	0	1	4	0	2	Bonyon	1	1	3	0	1
Atibaabisi	0	0	2	0	1	Aframso	3	0	0	1	1
Yuwa	0	0	0	0	0	Afrante	1	3	3	0	0
Nabango	0	1	0	0	0	Anyinasu	5	3	3	1	0
Paga	1	2	5	4	0	Sekyedumase	2	2	7	1	0
Mirigu	0	0	1	2	0	Ejura	2	1	1	0	4
Badania	1	0	0	0	0						
Manyoro	1	2	0	2	0						
Janania	1	1	0	2	0						
Total	**4**	**13**	**13**	**17**	**5**	**Total**	**19**	**14**	**22**	**10**	**14**

Appendix 7. Calculating the demographic rates

$$CBR = \frac{\text{Number of births}}{\text{Total Population}} \times K$$

where K a constant is 1000.

Due to the fact that the total number of household members could be determined for the year 2001, when the data was gathered, the CBR for 2001 has been calculated for the two districts. The total number of household members in the sampled areas is 1710 and 2034 for the Kassena-Nankana and Ejura-Sekyedumase Districts respectively. The calculated CBR is therefore 24 for the Kassena-Nankana District and 32 for the Ejura-Sekyedumase District.

The Crude Death Rate (CDR) for 2001 has also been calculated for the two districts using the formula below.

$$CDR = \frac{\text{Number of deaths}}{\text{Total Population}} \times K$$

The CDR for Kassena Nankana is 8 and for Ejura-Sekyedumase, 6. According to the Population Reference Bureau (2001) the national CDR for mid 2001 is 10.

The out-migration rates are calculated below for the two districts.

$$OMR = \frac{\text{Number of out-migrants}}{\text{Total Population at origin}} \times K$$

OMR is calculated to be 14 for the Kassena-Nankana District and 23 for the Ejura-Sekyedumase District.

The in-migration rate for 2001 for the two districts is calculated below.

$$IMR = \frac{\text{Number of in-migrants}}{\text{Total Population at destination}} \times K$$

The IMR is calculated to be 18 and 7 for the Kassena-Nankana and Ejura-Sekyedumase District respectively.

Growth rate:

The population growth rates for the two districts in 2001 has been calculated from natural increase and net migration rates.

$$\text{Rate of Natural increase} = \frac{\text{Births in 2001} - \text{Deaths in 2001}}{\text{Total population in 2001}} \times 100$$

$$RNI = \frac{41-13}{1710} \times 100$$

$= 1.6$

for Kassena-Nankana District

$$RNI = \frac{66-13}{2034} \times 100$$

$= 2.6$

$$\text{Net Migration Rate} = \frac{\text{No. of immigrants} - \text{No. of emigrants in 2001}}{\text{Total population in 2001}} \times 100$$

$$NMR = \frac{5-24}{1710} \times 100$$

$= -1.1$

GR = Rate of Natural increase + Net migration Rate

$GR = 1.6 + (-1.1) = 0.5\%$

For Ejura-Sekyedumase District

$$NMR = \frac{14-47}{2034} \times 100$$

$= -1.6$

$GR = 2.6 + (-1.6) = 1\%$

Appendix 8. Excluded variables in multiple regression model

Kassena-Nankana District - 1984

Variable	*Unstandardised coefficients* Beta (ß)	Significance	*t*
Tractor use	-0.025	0.873	-0.165
Inorganic fertilizer use	-0.001	0.996	-0.005
Improved seed variety	0.005	0.977	0.030
Affluence (Livestock)	0.094	0.562	0.605
Population	0.228	0.244	1.257
Land tenure	0.021	0.884	0.151
Affluence (Items)	-0.127	0.482	-0.737
Household size	-0.204	0.282	-1.152

Ejura-Sekyedumase District - 1984

Variable	*Unstandardised coefficients* Beta (ß)	Significance	*t*
Land Fallow	0.138	0.591	0.567
Tractor use	0.139	0.479	0.755
Inorganic fertilizer use	0.107	0.583	0.580
Improved seed variety	-0.018	0.929	-0.092
Affluence (Livestock)	0.227	0.383	0.942
Major farmers	-0.202	0.622	-0.520
Land tenure	0.423	0.476	0.760
Affluence (Items)	0.022	0.915	0.111
Household size	0.427	0.167	1.574

All districts - 1984

Variable	*Unstandardised coefficients* Beta (ß)	Significance	*t*
Tractor use	0.078	0.492	0.703
Inorganic fertilizer use	0.092	0.408	0.849
Improved seed variety	-0.061	0.585	-0.557
Affluence (Livestock)	0.078	0.492	0.702
Major farmers	0.020	0.866	0.172
Population	0.039	0.763	0.307
Land tenure	-0.098	0.393	-0.876
Affluence (Items)	-0.111	0.361	-0.939

Kassena-Nankana District - 2000

Variable	Unstandardised coefficients Beta (ß)	Significance	*t*
Household size	0.167	0.232	1.360
Education	-0.013	0.961	-0.051
Land Fallow	-0.300	0.136	-1.775
Tractor use	0.073	0.641	0.496
Inorganic fertilizer use	0.089	0.558	0.627
Improved seed variety	0.217	0.286	1.194
Affluence (Livestock)	0.132	0.461	0.798
On-farm income	0.118	0.656	0.472
Major farmers	-0.289	0.157	-1.663
Population	0.043	0.917	0.110
Electricity	0.279	0.352	1.026
Land tenure	-0.019	0.905	-0.125
Affluence (Items)	0.216	0.400	0.920
Food Expenditure	0.062	0.857	0.190

Ejura-Sekyedumae District - 2000

Variable	Unstandardised coefficients Beta (ß)	Significance	*t*
Household size	0.149	0.608	0.542
Education	-0.014	0.932	-0.089
Land Fallow	-0.123	0.585	-0.577
Tractor use	0.143	0.346	1.022
Inorganic fertilizer use	0.062	0.691	0.417
Improved seed variety	-0.050	0.790	-0.278
Distance to farthest farm	0.300	0.081	2.095
Affluence (Livestock)	-0.098	0.562	-0.614
Off-farm income	0.256	0.319	1.087
On-farm income	0.107	0.488	0.738
Major farmers	-0.155	0.545	-0.642
Electricity	0.128	0.431	0.845
Land tenure	0.164	0.747	0.337
Extensification	0.019	0.902	0.129
Affluence (Items)	0.288	0.127	1.769
Food Expenditure	-0.244	0.345	-1.024

All districts - 2000

Variable	***Unstandardised coefficients*** **Beta (ß)**	**Significance**	***t***
Education	0.070	0.701	0.391
Land Fallow	0.037	0.787	0.275
Tractor use	0.088	0.565	0.589
Inorganic fertilizer use	0.106	0.516	0.666
Distance to farthest farm	0.249	0.099	1.761
Affluence (Livestock)	-0.096	0.510	-0.675
Off-farm income	-0.013	0.923	-0.098
On-farm income	0.279	0.159	1.482
Major farmers	0.026	0.852	0.189
Population	0.207	0.202	1.334
Electricity	0.088	0.611	0.519
Land tenure	-0.181	0.199	-1.345
Extensification	0.261	0.346	0.973
Affluence (Items)	-0.063	0.633	-0.487
Food Expenditure	0.173	0.410	0.848

Appendix 9. Forest cover by sub-basins, 1990 & 2000

White Volta

Local/urban Council	*Land area (Km^2)*	*1990*		*2000*		*Annual change (1990-2000)*	
		Forest cover (Km^2)	**% land area**	**Forest cover (Km^2)**	**% land area**	**Km^2**	**%**
Sandema	2220	77	3.5	9	0.4	-7	-8.8
Navrongo	886	159	18.0	82	9.3	-8	-4.8
Chiana-Paga	756	135	17.9	70	9.3	-7	-4.8
Bolgatanga-Tongo	1313	688	52.4	181	13.8	-51	-7.4
Bongo-Nabdam	591	32	5.4	30	5.1	-0.2	-0.6
Kusanaba-Zebilla	979	204	20.8	204	20.8	0	0
Bawku	717	54	7.5	39	5.4	-2	-2.8
Pusiga-Pulikam	308	23	7.5	17	5.5	-1	-2.6
Tumu	6611	856	13.0	152	2.3	-70	-8.2
Lawra-Jirapa	371	21	5.7	4	1.1	-2	-8.1
Wa	1464	730	49.8	31	2.1	-70	-9.6
Nadawli-Funsi	3852	100	2.6	23	0.6	-8	-7.7
Bole	1090	252	23.1	34	3.1	-22	-8.7
Damango	9829	1309	13.3	393	4.0	-92	-7.0
Tolon	1097	18	1.6	4	0.4	-1	-7.8
Savelugu	2479	22	0.9	10	0.4	-1	-5.5
Gushiegu-Chereponi	2308	26	1.1	30	1.3	-0.4	1.5
Walewale	3077	185	6.0	95	3.1	-9	-4.9
Total	**39948**	**4891**	**12.2**	**1408**	**3.5**	**-348**	**-7.1**

Source: Computed from Satellite image, 1990/91 & 2000

Black Volta

Local/urban Council	*Land area (Km^2)*	*1990*		*2000*		*Annual change (1990-2000)*	
		Forest cover (Km^2)	**% land area**	**Forest cover (Km^2)**	**% land area**	**Km^2**	**%**
Tumu	348	45	12.9	8	2.3	-4	-8.2
Lawra-Jirapa	1484	83	5.6	16	1.1	-7	-8.1
Nadawli-Funsi	1926	50	2.6	12	0.6	-4	-7.6
Wa	1465	730	49.8	31	2.1	-70	-9.6
Bole	7631	1767	23.2	237	3.1	-153	-8.7
Damango	4915	654	13.3	197	4	-46	-7
Jaman	1271	257	20.2	5	0.4	-25	-9.8
Berekum	528	87	16.5	6	1.1	-8	-9.3
Wenchi	7350	192	2.6	15	0.2	-18	-9.2
Atebubu	662	46	7.0	48	7.3	0.2	0.4
Total	**27580**	**3911**	**14.2**	**575**	**2.1**	**-334**	**-8.5**

Main Volta

Local/urban Council	*Land area (Km²)*	*1990* Forest cover (Km²)	*1990* % land area	*2000* Forest cover (Km²)	*2000* % land area	*Annual change (1990-2000)* Km²	*Annual change (1990-2000)* %
Gushiegu-Chereponi	1154	14	1.2	15	1.3	0.1	0.7
Savelugu	1240	11	0.9	5	0.4	-1	-5.5
Tolon	366	6	1.6	2	0.6	-0.4	-6.7
Tamale	241	16	6.6	1	0.4	-2	-9.4
Damango	983	131	13	39	4.0	-9	-7.0
Salaga	9254	299	3.2	259	2.8	-4	-1.3
Kwame Danso	7438	2003	26.9	602	8.1	-140	-7.0
Atebubu	5300	366	6.9	387	7.3	2	0.6
Techiman	579	8	1.4	74	12.8	7	82.5
Offinso	672	78	11.6	68	10.1	-1	-1.3
Ejura-Sekyedumase	1112	51	4.6	132	11.9	8	15.9
Mampong	469	264	56.2	31	6.6	-23	-8.8
Afram	5040	978	19.4	187	3.7	-79	-8.1
Kete-Krachi	2576	34	1.3	95	3.7	6	17.9
Total	**36424**	**4259**	**11.7**	**1897**	**5.2**	**-236**	**-5.6**

Daka

Local/urban Council	*Land area (Km²)*	*1990* Forest cover (Km²)	*1990* % land area	*2000* Forest cover (Km²)	*2000* % land area	*Annual change (1990-2000)* Km²	*Annual change (1990-2000)* %
Gushiegu-Chereponi	1154	13	1.1	15	1.3	0.2	1.5
Salaga	3085	100	3.2	86	2.8	-1	-1.4
Bimbila	2183	30	1.4	33	1.5	0.3	1.0
Kete-Krachi	234	3	1.3	9	3.9	1	20.0
Total	**6656**	**146**	**2.2**	**143**	**2.2**	**-0.3**	**-0.2**

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