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APPLICATION OF REMOTE SENSING AND GEOGRAPHIC
INFORMATION SYSTEMS TO LAND USE
PLANNING IN SOUTHERN GHANA

by

PETER A. KWAKU KYEM, B.A (Hons.)

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of

Master of Arts

Department of Geography

Carleton University

Ottawa, Ontario

Canada

September 1991

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Application of Remote Sensing and Geographic
Information Systems to Land Use
Planning in Southern Ghana

submitted by
Peter Amos Kwaku Kyem, B.A. (Hons.)
in partial fulfilment of the requirements for
the degree of Master of Arts

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September, 1991

ABSTRACT

The natural resources of the forest lands of Southern Ghana play a central role in generating income for the development of the country. Past misuse and exploitation have caused considerable land degradation and land use problems. To establish long term viability of the agricultural resource base in the region, a flow of reliable data is required to plan for the efficient use of the land. The study investigates the viability of adopting remote sensing and GIS technologies to provide a database of land information to facilitate land use planning in the region. The two systems are employed in a case study to examine their potentials. The study concludes that both technologies have the capability to improve the collection, processing, storage and presentation of data on resources of the region. However, before the technologies could be effectively adopted, several economic, technical and social problems need to be addressed.

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**Application of Remote Sensing and Geographic
Information Systems to Land Use
Planning in Southern Ghana.**

CHAPTER 1

INTRODUCTION

1.1 Preamble.

This thesis investigates the feasibility of employing remote sensing and geographic information processing systems in the establishment of a database of land information for agricultural land use planning in the tropical rain forest region of southern Ghana. A case study approach is adopted to provide an interpretation of soil survey data from a test area in the region.

1.1.1 Background.

The development of sustainable agricultural development policies requires regular collection and analysis of data on resources. In Ghana, as in many developing countries, there is very little timely and reliable information about resources. The initial mapping capacity established by the Colonial Administration has deteriorated due to limited funding and lack of expertise. As a result, maps of some of the natural resources are outdated and new mapping is limited.

An example of the consequences is that planning officials are unable to determine reliably the actual area of arable land that is available for agricultural production in any planting season. It is difficult, without adequate data on the natural resources, to identify the processes of land use change and assess land capability upon which relevant agricultural development models and plans for improvement in agriculture can be based.

Land resources have been the primary base of the country's development since colonial times (World Bank 1988:8). Ghana has traditionally exported cocoa, timber and such minerals as gold, bauxite, manganese and diamonds to generate income for the country's development. The exploitation of the country's land resources intensified after the adoption in 1983 of an International Monetary Fund/World Bank structural adjustment programme for economic development. The programme seeks to rehabilitate the economy mainly through the raising of output of export commodities to earn foreign exchange (World Bank 1981). Consequently, since the adoption of the programme, the government has promoted exports through price incentives offered only to tradeable commodities (West Africa 1989a:345). The export of cocoa, timber and minerals has therefore risen in recent years but local food production has shown little increase.

The various economic activities currently taking place in the forest region have led to the independent pursuit of

production goals without regard for the potentials of the land to support such production ventures. This has created land use conflicts and has caused widespread land degradation in the forest region. At the beginning of this century, the country possessed about 9.8 million hectares of forest estate (Twum-Barimah 1981). By 1950, a little more than half of the estate remained and thirty years later, the forest had been reduced to only 1.7 million hectares (Gorintz 1987:55). In spite of the rapid deforestation, land use planning and management in the country has been characterized by short-term responses to particular crises. The land use conflicts and the impact of the resource exploitation on food production have been noticed by several prominent Ghanaians including traditional leaders and members of government. Nana Adu Bonsra, chief of a village in the Eastern province of Ghana, is reported to have called on the government to review some of the concession agreements made with timber companies to save the country's forests and soils (West Africa 1987:1940). Similarly, Ghana's minister in charge of agriculture, Commodore Steve Obimpeh, observed in an address at a workshop in Accra that the carrying capacity of land in the country has been unduly stretched by poor methods of farming. He warned that if the drive to increase timber exports does not slacken, the country's base for food production would be destroyed (West Africa 1987:1940).

1.1.2 Development Challenges.

These observations give an indication of the agricultural land use problems encountered in the forest region and provide clues to the concern for long-term gains expected from the agricultural uses of the country's land. The observations also raise questions which require immediate attention. Do the current uses of land in the forest region offer possibilities for sustained agricultural production? If the exploitation of the mineral and timber resources cannot be stopped or severely limited, then what improvements can be made within the current land use practices to increase local food production? How can policies concerning agricultural land use planning in the country be made when information on the resources is very limited in its availability and reliability?

In view of the great need for economic development and the heavy debt owed to foreign financial lenders and organizations, it would not be practical, at least in the near future, to stop the exploitation of the land resources in the country. But the great demand for the land resources also makes it imperative to search for ways to manage the resources based on timely and relevant data.

1.1.3 Need for Land Information.

In Ghana and other developing tropical countries, land use conflicts are going to be continuing elements of the

resource management problem. The conflicts will continue because economic growth will require expansion and intensification in the productive use of the land resources. It may, however, be noted that the low agricultural production and environmental degradation encountered in the forest region are often related to land use which is inappropriate to land conditions in a particular area. For example, farmers in the region tend to identify soils by their colour and often use indicator plants to help them locate suitable soils for particular crops. They may not be always right in their predictions. Under such situations the experience to identify fertile soils is gained over a period of time and as such may not be available to new farmers who migrate into the region. Thus insufficient prior knowledge of land capability is a contributing factor to the lowering of agricultural production in the region.

There is therefore a need for a basis for guiding investment into arable farming and for selecting the appropriate land that can sustain agricultural production. In the United States of America, Canada and other countries, the provision of land information systems offers potential solutions to key economic questions related to the allocation of land between sectors of the economy.

Such schemes are based on techniques which assess the actual and potential uses of land in terms of land characteristics and grade the land into capability classes according to the

degree of limitations found within each capability class (Davidson 1982:17). Even though the need to adopt similar methods to solve land use problems in Ghana has been expressed by the country's leaders (University of Ghana 1989), it is not known whether the land information system could be successfully established. Meanwhile the unavailability of data on resources and the socio-economic conditions in the country continue to inhibit effective planning. The situation creates an urgent need for efficient data gathering and processing systems, an issue which this study addresses.

1.2 Objectives of the study.

This study aims at investigating the prospects of adopting remote sensing and GIS technologies to provide a database of land information to facilitate land use planning in the tropical rainforest region of Ghana. A case study approach is adopted to examine the potentials for adopting the two technologies in the country.

It should be noted that the development of a database for agricultural land use planning forms only a part of the overall efforts needed to increase agricultural production in the region. It would require among other things decisions regarding the setting of priorities with respect to producing commodities for home consumption and for export, the provision of irrigation facilities and the provision of appropriate incentives to farmers. However, research into the application

of remote sensing and GIS for the development of a database of land information is important because the two systems can be used to provide baseline data for agricultural land use planning in the region. The development of a land information system could, through facilitating the agricultural land use planning process, help local farmers locate areas of potential agricultural land in the region. The database would input information into the planning strategy to aid in the allocation and use of agricultural land in the region. The study could, in addition to making a contribution to academic discussions on land use, facilitate the search for strategies for land resource management in Ghana.

1.3 Methodology

For illustrative purposes, a case study approach is adopted to interpret the soil survey data of a test area in the Pra-Offin basin (see figure 2.1). The data are analyzed and used to set up a database of land information to produce a land productivity potential map. Data for the case study are derived from Landsat Thematic Mapper 5 (TM5) imagery of December 1986 secured from the Canada Centre for Remote Sensing (CCRS), Ottawa, soil survey data and a topographic map of the area.

Basically, the method involves digitizing topographic, land use, soils, and land cover maps into the GIS. Interpretations and classification of the remote sensing data

on the basis of land cover are made on an EASI PACE image analysis system at CCRS and imported into an Integrated Land and Water Information (ILWIS) GIS software system at the Earth Science Department of Carleton University. In the second phase of the approach, the maps are processed in the ILWIS GIS system to create a new database. The final product can be visualized as several layers of information each representing one data source, all referenced to real world co-ordinates. In this data set, information can be integrated, queried and analyzed to generate a final soil productivity potential map. The productivity classes portray areas of land which possess high potentials for agricultural production.

1.4 Organization of the study.

The study is divided into six main sections. Immediately following this introductory chapter is chapter two in which the background issues to the problems of land use and land degradation in the forest region are discussed. This is followed by an examination of previous attempts at managing the land resources of the area. The chapter concludes with a review of literature on remote sensing and geographic information processing systems applications in Ghana.

Chapter three is devoted to a discussion of the roles that land information systems play in facilitating decision-making about land use problems. Chapter four focuses on the practical application of these technologies in data capture,

processing and the development of a database for a test area. The discussion of findings of the study appears in chapter five. It includes an evaluation of the prospects for integrating remote sensing and GIS technologies in developing a database of information to facilitate land use planning in Ghana. In chapter six, a summary of conclusions reached in the research and recommendations for further study are presented.

CHAPTER 2

BACKGROUND ISSUES IN LAND USE CONFLICTS AND LOW AGRICULTURAL PRODUCTION IN THE FOREST ZONE OF SOUTHERN GHANA

2.1 Introduction

Agriculture and forestry make the largest contribution to Ghana's gross domestic product (World Bank 1988:1). The wildlife resources of the forest provide 75% of animal protein intake of Ghanaians (Asibey 1985). In addition to these resources, the forest lands contain all the minerals produced in the country. Throughout history, the land resources of the forest region have attracted speculators. The exploitation of the resources for export has caused land degradation and many land use conflicts that currently threaten agricultural production in the forest zone.

This chapter focuses on the historical developments of problems of land use and land degradation encountered in the tropical rain forest region of Ghana. It is hoped this background information will provide an insight into the origin, nature and extent of land use problems in the region. Such information could also provide the knowledge that would be needed to interpret data on land resources of the region, particularly land use and land cover types derived from remote sensing images. A brief description of the study area is followed by an examination of the background issues in land resource exploitation in the area under study. Toward the end

of the chapter, the literature about the application of remote sensing and geographic information systems in Ghana is reviewed.

2.2 The study area.

The total forest area of Ghana is about 82,576 sq. kilometres which represents about one-third of the total land area of the country (Brookman-Amissah 1983:2). About 16,790 square kilometres of the total forest is in protected reserves distributed throughout the country. The remaining forest comprises land undergoing natural regeneration following a period of farming.

A section of the Pra-Offin basin lying within the semi-deciduous forest region of southern Ghana has been selected for the case study (see figure 2.1). The area embodies both primary and secondary forests and it is a region where gold miners, loggers, cocoa and food farmers constantly vie for land. It thus epitomizes the characteristics of the forest vegetation and the land use problems currently being experienced in the region. It is also the area where some data were found for the study.

The area incorporates sections of the Central and Ashanti regions. The climate, vegetation and soils are typical of the tropical semideciduous forest zone.

Figure 2.1 Map of Ghana showing study area

Mean annual rainfall is about 1,600 millimetres and is distributed in two seasons (Dickson and Benneh 1974:34). The first rainy season occurs between May and July while the second lasts from September to October. Relative humidity averages 65%-75% during the dry season (November to March) and increases to about 85%-95% during the rainy season (May to October). Mean monthly temperature is about 27° Celsius and is relatively constant throughout the year. Dunkwa, a typical meteorological station in the area, receives a mean annual rainfall of 1,610 millimetres and an average monthly temperature of about 27° Celsius.

2.2.2 Geology and soils.

The study area, like other parts of the forest, is underlain by Precambrian rocks belonging to the Birrimian and Tarkwaian formations (Kesseh 1988). The Birrimian formation is divided into lower and upper series with the lower Birrimian represented by a great thickness of isoclinally folded and steeply dipping bands of phyllite, greywacke, tuff and lava. The Upper Birrimian series lie unconformably over the lower Birrimian and consists of metamorphosed basaltic and andesitic lava and some rocks of the lower Birrimian system (Bates, 1962:53). These rocks contain all the minerals mined and exported from the country and account for gold and diamonds which occur in the study area. The Tarkwaian formation consists principally of materials eroded from the

Birrimian and deposited in elongated rift basins bordered by granitic-greenstone beds of the Birrimian system (Kesseh, 1988).

The study area forms part of a relief generally termed the forest dissected plateau (Dickson and Benneh 1974:114). Intensive weathering and erosion have reduced the ancient rocks to a uniformly low height of about 100 to 600 metres above sea level. Tributaries of the Pra, Offin and Ankobra rivers drain the area. Soils under the forest have been classified as Oxisols and Ochrosols (Brammer 1962:92), which correspond with Oxysols and Ultisols of the United States classification system. They are distinguishable from other soils in the country by their greater accumulation of organic matter in their surface horizons. The Ochrosols occur in the study area and are less leached and hence less acidic than the oxysols of the wet evergreen forest found along the southwest coast. The soils in the region are generally deep, well drained and loamy and vary in colour from reddish brown on summits to grey in the valley bottoms. They support cocoa, coffee and other cultivated tree crops. On the other hand, the soils suffer from heavy leaching which sometimes robs them of major nutrients required for plant growth.

2.2.3 Economic Development.

The Pra-Offin basin generally lacks basic infrastructure. Dickson and Benneh (1974) described the region as consisting of a broad belt of land sparsely populated and generally lacking economic development. However, the region is rich in natural resources and offers opportunities for people with pioneering spirit. Population densities for the area range between ten and fifty persons per square kilometre. Higher densities are recorded around mining and lumbering centres. The few roads in the area connect mining and logging centres like Dunkwa and Obuasi to regional capitals and ports along the coast.

The inhabitants are Akan speaking people who live in small rural settlements. Major economic activities of the people include cocoa cultivation, logging and mining. The system of farming is shifting cultivation. Rights to land are communally shared by extended families or clan members. Peasant farming is devoted to producing plantain, yam, cocoyam, maize and other crops for local consumption while cocoa, coffee and oilpalm are cultivated for export.

2.3. Pre-Colonial development.

Prior to European colonization, the people of the forest region had developed a subsistence economy dominated by the cultivation of food crops. Farming was based on shifting cultivation which involves the clearance and cultivation of

a plot of land after burning. As yields tail off in the second or third year, the field is abandoned for a new one. In the fallow period which may last from five to ten years, trees spring up, grow and add litter to the soil to replenish its organic matter and nitrogen content. The development of this system of farming might have been facilitated by physical and social factors of the region. First, the deeply weathered soils of the tropical rainforest tend to be low in nutrients. Clearance of the vegetation deprives the soil of its nutrient supply from leaf fall and causes an intensification of the processes of leaching and erosion which further depletes nutrients of the soil. Consequently, crop yields fall drastically after the first year thereby necessitating movement on to a new plot of land. Second, population was sparse and so land was in abundant supply (Osei 1984:103). The shifting cultivation system thus appears to have resulted from a rational appraisal of social and ecological conditions and has been found to be ecologically useful in tropical environments where no great population pressure is experienced (Richards 1983:25).

2.3.1 Land tenure.

The agricultural system and other land use practices of the inhabitants were sustained by a land tenure system which was linked to religious elements of worship of the people. Land was perceived as a spiritual "female force" representing

fertility (Pogucki 1968:4). Every river and hill as well as exceptionally big trees within many parts of the forest region including the study area had their own guardian spirits which were accessible to the people. The spirits could go to the aid of the people in times of danger but would bring misfortune if they were abused (Pogucki 1968:5).

The spiritual sanctity attached to land and other resources meant that before a hill was mined or a piece of land was tilled it became necessary to seek the consent of the spirit concerned and to keep it placated annually. The Odwira festival celebrated annually among the Akuapems and the Eluo festival of the Nzimas are examples of rituals undertaken to appease spirits prior to the use of the land.

Ownership of land was principally by allodial rights acquired through a peaceful occupation of unoccupied forest land, a ritual transfer of land from one group of people to another, or by conquest and forcible ejection of the rightful owners (Pogucki 1968:40). Once acquired, the land, including those in the study area, came to belong to a kinship group the membership of which traced their inheritance from a common female ancestor (Rattray 1923:231, Pogucki 1968:37). Rattray has observed that "there is in Ashanti no such a thing as individual ownership of land" (Rattray 1923:231). Land is not a property that could ever belong to one person within the extended family (Howard 1978:37). Rights in such property as timber, minerals and other items considered to be of high

economic value were, as they are today, separated from the rights to the land and invested in the head of the clan. The clan head managed all such resources on behalf of the group and used income generated from the resources to fulfil ceremonial and spiritual needs of the clan (Benneh 1970:45). The inhabitants of the forest region thus had a secured land tenure system which also promoted a sustained use of land resources.

2.3.2 Trade.

In addition to hunting and farming, people in the forest region engaged in a long-distance trans-Saharan trade which took gold, ivory and later slaves from West Africa to the Mahgreb and beyond (Kay 1972:4; Acharga 1978:2). As early as 1400, traditional gold mining was a widespread activity in the forest. Kitson and Felton, former officers of the Ghana geological survey department, reported widespread ancient native gold mining in the study area and in the forests of Ashanti, Sehwi, Fanti and Wassaw (Kiston and Felton 1936). A great number of people appeared to be involved in gold prospecting, mining and trade. Skertchey, writing in 1878, indicated that there were about six thousand men, women and children engaged in gold mining in the Tarkwa district alone (Skertchey, quoted in Junner 1937).

Prior to the arrival of Europeans in Ghana, the forest dwellers were engaged in subsistence farming which was making

an impact on the country's forest. Speculative activities like the trans-Saharan trade had provided an impetus for gold mining. The question of whether the current land use problems and the large scale destruction of the forest would not have occurred without European colonization is difficult to answer. It could, however, be argued that growth in population and increases in the degree of commercialization of the Ghanaian economy would have had devastating effects on the country's land resources and land use practices. But as Boserup argues, population pressure provides a useful economic stimulus to technological innovation and systems of land tenure correlate with stages in the development of agricultural technology (Boserup 1965). The assumption therefore is that the value systems and techniques of production of the inhabitants would have evolved in common with the overall development of the society. Thus, if local value systems had not been suddenly supplanted by western values at the time, mechanisms could have developed within the local culture to control the use of resources. Rather, what happened at the time and which has unfortunately continued till now, was the abandonment of the virtues embodied in the religious control of resource utilization. In their place was substituted a utilitarian approach to resource use. But this approach was adopted without the necessary accompanying conventions and the technology to repair the environment after use. In the present state where people adopt an utilitarian approach to

resource use but do not have the technology and the tenet to rehabilitate the environment, resource and environmental destruction are bound to occur. A typical example is the destruction of food farms by local gold prospectors.

2.4 Economic development under colonial governments.

The people of the forest region had their first contact with Europeans in 1471 when a Portuguese expedition landed on the Ghanaian coast (Howard 1978:21). Soon the overland trans-Saharan trade came to be supplanted gradually by a maritime trade which linked the region's subsistence economy with developed and highly monetized economies in Europe. Successive European powers fought for the control over the country's land resources until 1874 when the British established themselves in the southern portion of the country (Kay 1972:4).

2.4.1 Agriculture.

With growing industrialization in Britain, the Colony, as the southern forest region was called, was assigned the role of supplying raw materials to feed factories in metropolitan Britain (Konings 1986:12, Beckman 1981:1, Kay 1972:19). The people were encouraged through the offer of incentives to produce palm oil, rubber and later cocoa for export (see table 2.1 for production figures).

Cocoa cultivation began in the Eastern province where the crop was successfully introduced in 1879 by a Ghanaian emigrant returning from the island of Marcias Nguema (previously Ferando Po). This was after several attempts by the Basel Missionaries to introduce the crop into the country had failed (Dickson and Benneh 1974:96).

Table 2.1.

Ghana: Volume of Major Exports: 1900-1959.
5-Year Averages, in 000's.

Year	Gold	Diamonds	Manga- nese	Cocoa	Rubber	Palm* products	Timber**
	<u>ozs</u>	<u>carats</u>	<u>tons</u>	<u>tons</u>	<u>tons</u>	<u>tons</u>	<u>cu.feet</u>
1900-04	41.4	--	--	2.3	1.2	26.6	1000
1905-09	242.0	--	--	11.4	1.4	18.1	1600
1910-14	343.0	--	--	41.3	0.9	17.5	2900
1915-19	388.0	--	19.4	96.6	0.7	8.8	1400
1920-24	227.2	0.1	96.0	168.2	0.1	5.8	2500
1925-29	206.2	0.4	359.2	224.4	0.4	7.8	2100
1930-34	295.2	1.2	264.0	227.0	0.5	5.0	500
1935-39	566.6	1.3	399.4	272.0	0.5	7.6	1100
1940-44	724.4	1.0	463.2	153.9	1.7	7.1	2140
1945-49	603.2	0.9	685.4	225.3	0.7	5.7	6100
1950-54	724.6	1.9	700.8	232.0	0.3	6.0	10003
1955-59	772.6	2.8	496.5	229.6	0.3	7.7	23207

Source: Compiled from Kay (1972:336-337)

* Palm products consists of palm kernels and palm oil.

** Timber exports consist of logs from 1900-1959 plus the exports of sawn timber and logs from 1950-1959.

Farmers in the province were attracted to the production of cocoa, and in 1885, Ghana made its first shipment of 112 pounds of dry cocoa beans abroad. With the assistance of the government, the cultivation of the crop spread rapidly

throughout the forest region, from the Eastern province into Ashanti and later into the Brong-Ahafo and Western provinces where new forest lands were still available. In 1920, about 125,000 tons of cocoa, representing 83% of the country's total exports were shipped out of the country (Kay 1972:15, also see table 2.1). By 1960, cocoa exports had reached 303,000 tons with the industry employing about 552,350 people (Dickson and Benneh 1974:95). The output of cocoa increased to 397,300 tons in 1975 but by 1984, production had fallen to 166,700 tons (Ghana 1983:4). The drastic fall in production was partly due to the neglect of the industry by successive governments following reductions in the world market price for the crop (Ghana 1983:4-6). Between 1987 and 1990 cocoa production averaged about 230,000 tons (Ghana 1989:5).

The introduction of cocoa into the country had significant impact on the organization of production and the system of land tenure in the forest. First, an export product was for the first time based on planned cultivation which involved the clearance of vast portions of the forest. Gradually, more and more lands came to be occupied by cocoa plantations. The cultivation of cocoa caused a shift in the use of the land from the cultivation of annual crops to perennials.

Second, cultivated cocoa trees came to be privately owned even though, under Akan customary law, the land on which cocoa farms were established ought not be owned privately (Rattray

1923:216). It therefore became crucial to redefine usufruct rights to land ownership and to initiate privatization and sale of land in the region (Pogucki 1968:38). Thus, in addition to breaking the old belief in land tenure, cocoa cultivation marked the beginnings of competition for land in the region.

Third, the attractive income and prestige that was reaped from cocoa cultivation attracted people and caused a shift in the distribution of population from several parts of Ghana and beyond the country's borders into the forest region (Hill 1963, Ewusi 1983:19). The stage was thus set for the alteration of the people-land distribution in the forest. Frankel estimates that in 1938 about one million acres of land in the country were under cocoa (Frankel S.H. quoted in Howard 1972:75). A sample survey of agricultural activities in Ghana also revealed in 1972 that cocoa was cultivated on 3.6 million acres of land which represented about seventy percent of all forest lands and fifty six percent of all cultivated land in the country (Ghana 1972:2). With cocoa taking up such a great proportion, very little of the forest lands was left to be distributed among mining, logging, food farming and other land uses in the region.

2.4.2 Mining.

In addition to agricultural products, the country was noted for the export of several minerals. It was gold that

gave the country its pre-independence name (the Gold Coast) and attracted the Portuguese to the Ghanaian coast in 1471 (Howard 1972:60). Relying on existing local knowledge and expertise, European traders moved into gold prospecting and mining after initially engaging in gold trade with the forest settlers through intermediaries. Howard reports that by 1890 the local inhabitants had been driven out of the gold mining business in the country and in 1901, as many as 400 foreign companies were registered to mine gold in the region (Howard 1972:64). According to Ilegbume (1976), if all the concessions granted to foreign gold prospectors by local chiefs had been used during the gold boom of 1900, very little land would have been left for cultivation in the forest region.

The increased need for mineral supplies during the First World War boosted mineral exploration and led to the discovery of manganese at Nsuta in 1916 and bauxite at Awaso around the same time. Diamonds were also discovered in the forest at Akim Abuakwa district in 1919 and later in the valley of river Bonsa near Dunkwa. It was estimated in 1917 that about 1,070 acres of forest land were being consumed annually by mining (Gold Coast Conservator of forest's report quoted in Howard 1978:45).

The logging of the forest was delayed by poor transportation until developments in gold mining stimulated the construction of railways and roads to link the forest

region to the coast (Dickson and Benneh 1974:112-115). The roads and railways opened up the forest and facilitated not only European-controlled mining and logging, but also commercial agriculture by the inhabitants (Acharga 1978:5).

Thus, independent Ghana inherited an economy geared towards the production of raw materials (cocoa, timber and minerals) for export. In the process of development, food production received little attention thus necessitating the importation of food and other products used locally. The pre-colonial subsistence economy had been integrated into the global economy. However, the manufacturing sector of the local economy was poorly developed. The contribution of this sector to gross national product was estimated to be only 0.4% in 1954 (Acharga 1978:7). The infrastructure of roads and railways in the country connected the mining and logging centres in the forest region to the ports along the coast and so opened up the forest to further exploration and exploitation.

2.4 Post-independence Development.

After independence in 1957, the government of the first Republic made attempts to diversify the economy and to break the links of dependency on the export sector (Marshall 1976:52). Import substitution industries were set up but fluctuations in the price of Ghanaian exports, especially

cocoa, rendered all such efforts futile. After this period, political instability and economic mismanagement among leaders of the country further thwarted economic development efforts and thus created conditions which necessitated major changes in the economy (Marshall 1976 59-62, World Bank 1989:2-3). The pattern of production has hardly changed since independence and the country continues to depend upon the export of agricultural goods and minerals to generate income for development.

In 1983, Ghana adopted a World Bank/International Monetary Fund sponsored structural adjustment programme to salvage the economy. The programme, like all other major development projects executed in the country, depends heavily upon income generated from exports. The Ghanaian government has, since the adoption of the programme, adopted several measures including price incentives, subsidies and tax holidays to promote the production and export of commodities (West Africa 1989a:345). The drive to increase exports has therefore been very great but local food production has received very little attention in policies adopted under the economic development programme.

2.5 Land resource management attempts in Ghana.

The cocoa farms, mining and logging concerns which came to be established in the forest required separate plots of land for their successful operation. The rush to acquire land in the forest created conflicts in the early days of forest

exploitation and hence necessitated intervention and control from the Colonial government.

The first attempt to manage the forest resources was made with the passing of the Public Lands Ordinance of 1876 (Brookman-Amissah 1983:7). The Ordinance sought to regulate the administration of public lands. It also empowered the Colonial government to take over land for public use without the payment of compensation. In 1894, and again in 1897, similar Land Bills were promulgated. The objectives this time were to invest all "waste lands in the crown" in order to protect native interests against foreign prospectors and to regulate the use of land by both natives and foreigners (Kimble 1963:341). Ghanaians saw the bills as attempts to take away their inalienable rights to land while the foreign prospectors complained of interference from the government (Howard 1978:41). Growing opposition from both sides caused the annulment of these laws in 1878.

Efforts at land management at this time was not so much an attempt to conserve the resources but rather an undertaking by the Government to gain control over the resources so as to restore order in the acquisition of land to facilitate the exploitation of the resources (Howard 1978:41-43). Native opposition to such attempts was also aimed at protecting their inalienable rights to land rather than protesting against the use of the land (Howard 1978:42).

An important step at conserving the country's land resources was taken in 1900 when the Government enacted the Concessions Ordinance Bill to check the reckless and dubious ways by which concession rights to timber and minerals were being negotiated (Owusu 1978, Howard 1978 :41-43). The government followed this up with a Timber Protection Ordinance in 1907 and a Forest Bill in 1911. The bill laid the foundation for forest management in Ghana (Brookman-Amissah 1978:8). It authorized the Government to create forest reserves in suitable areas and to declare compulsorily reserves on any land found suitable for that purpose (Brookman-Amissah 1978:8). In addition, the Bill made provisions for the introduction in 1928 of what came to be known as the 'Taungya system of farming'. It was a plan which allowed food farmers to cultivate portions of the reserved forest while the Forestry Department planted timber seedlings on those farms. The farmers were obliged to tend the trees until the farms were abandoned. The forest reserves remain protected and currently represent the true forest vegetation in the country. They are distinguished from other forests by their straight boundaries.

The Forest Bill was replaced in 1927 by a Forest Ordinance which was later extended to cover Ashanti and the Northern Territories. Several other Ordinances and amendments to existing ones were made in 1935, 1949 and 1959. The Administrative of Lands Act of 1962 granted the country's

president the exclusive right to hold all land in trust for the people and to manage it for public good (Pugocki 1968:27, Brookman-Amissah 1983:14). Today, the Lands Commission performs these duties on behalf of the Head of State. In March 1980, the Ghana Forestry Commission was established to regulate the exploitation of the forest resources and to manage forest and wildlife resources in the country. A similar organization, the Minerals Commission, was set up in 1984 to organize the production and sale of the country's minerals. There is also a ministry of Natural Resources which is charged with the responsibility of managing all natural resources in the country

Thus, Ghana continues to produce cocoa, timber and minerals for export. Cocoa cultivation in particular, has taken up a very large portion of the forest. The country depends on income from the sale of export commodities produced from the forest region to finance development projects. The mining and logging activities coupled with the shifting cultivation system of farming practised by farmers of the area have caused extensive deforestation. With the country's population growing at a rate of 2.6% annually, serious land use problems are likely to occur if current land management methods are not improved.

2.6 Remote sensing and geographic information system applications in Ghana.

The use of such data collection and analysis techniques as remote sensing and geographic information system (GIS) has proven to be important in Africa and elsewhere in the developing world where natural resource exploitation is constantly causing environmental degradation (Falloux 1989:1). However, despite the diverse and growing applications of these technologies in developed countries, their adoption in the tropics has been slow. The reasons for this vary from one country to another and may reflect both technical and cultural conditions in individual countries. In the field of remote sensing and GIS significant advances have been achieved in India and Brazil (Eden 1986:7). Extensive applications of both technologies are found in parts of Latin America, Saudi Arabia, Thailand and in East Africa where the Global Environmental Programme of the UNDP have been established (Clarke 1986).

In Africa, concern for the adoption of remote sensing technology was formally expressed in 1975 at Nairobi when representatives of member states of the Organization of African Unity (OAU) unanimously adopted a resolution endorsing the establishment of regional centres for receiving and processing data transmitted by remote sensing satellites. An African Remote Sensing Council came to be formed in 1977 and regional training centres were established in Burkina Faso,

Zaire, Egypt, Kenya and Nigeria.

Remote sensing technology is not new in Ghana. Aerial photo interpretation has for a long time formed part of the cartography courses in the Universities of Ghana, Cape Coast and the geodetic section of the engineering department of the University of Science and Technology at Kumasi. The Soil Research Institute at Kumasi also uses aerial photographs for soil mapping. These studies have, however, remained theoretical and have not been applied to support policy-making on resources of the country (Dodoo 1975:1-2).

Aerial photo survey of parts of the country has been undertaken by several multinational flying firms. In 1946, a South African firm (ADC) acquired aerial photographs of parts of southwestern Ghana for use in oil exploration by the Anglo-Saxon Petroleum Company. A similar aerial photo survey was conducted by Hunting Surveys Limited of England in 1960. The British Department of Overseas Surveys began aerial photo mapping for use in settlement planning and land use mapping of Northern Ghana around 1961. In 1962, a private Canadian Company (Terra Surveys) undertook an aerial photo survey of parts of southern Ghana for oil explorations along the coast. A common feature of all these aerial surveys has been that they are planned and executed by foreign firms and as such the acquisition and use of the photos have been controlled by the firms.

Satellite imagery has also found applications in the

country. Northern Ghana was included in a study undertaken between 1975-76 to provide a resource database for settlement planning in areas of the Volta basin where river-blindness disease had been controlled (Derigan 1980). The project which utilized Landsat imagery resulted in the generation of extensive data on resources of the region.

Amamoo-Otchere also used Landsat images of the White Volta basin in Northern Ghana to demonstrate how effectively Landsat-derived data and manual cartographic data could be integrated to facilitate interpretation (Amamoo-Otchere 1980). In another project, Osae used Landsat images to map the surface water resources of the Upper region of Ghana (Osae 1981).

It appears little consideration has been given to the development of a technique which combines the use of GIS and satellite images to provide data for land resource management in the country. A land use map of the whole country was prepared from aerial photographs by the Soil and Land use Survey Department of the Ministry of Agriculture in 1961, but since then, no significant land use survey has been undertaken. The Soil Research Institute at Kumasi prepares land use maps from aerial photographs as part of surveys for soil mapping, but such maps are never published.

Titriku and Anku (1989) combined aerial photographs and Landsat images to update small scale soil and vegetation maps of the Volta region of Ghana. The study revealed a drastic

reduction in the size of the region's forest reserves, but unlike the present study, the authors were more interested in soil studies than in mapping land resources for planning purposes.

Gyamfi-Aidoo also considered the prospects of utilizing remote sensing and GIS technologies for environmental management in Africa and made special reference to Ghana (Gyamfi-Aidoo 1988). He concluded that the two technologies could provide a cost-effective means of addressing the environmental problems currently facing African countries.

In a study covering Eastern Ghana and parts of Togo and Benin, Adjei (1989) reported that the Landsat image used in the study revealed shear zones marking sites of economic mineral occurrences hitherto unknown or unrecognized. He urged that since all the minerals currently being mined in the country were discovered through traditional methods over half a century ago, efforts should be made to use remote sensing and other modern technologies in prospecting for minerals in the country. The study thus draws attention to the need to adopt these technologies in Ghana.

Remote sensing technology has also been used to collect and study data on the country's water resources and to provide data for the formulation of an overall water policy in the country (Amuzu 1989). An exploratory investigation into the use of Landsat images in forest inventory work in the country

has also proved successful (Abugro 1989). Asiamah and Senyah (1989) also used remote sensing methods to produce a land capability map which has since been used to encourage settlement in areas of the Volta basin where river blindness disease had been controlled.

The above studies reveal some applications of the remote sensing and GIS technologies in the country but the resource information they provided remain scattered in the various departments and institutions and may not be available to land use planners in the country. To engage in an integrated land use planning, it would be necessary to engage in regular collection and updating of data on the country's land resources. Once collected, the data will have to be stored, processed and presented in a way that would facilitate decision making on land use. This implies that further processing of data resulting from remote sensing applications in the country are necessary to transform them into a database of information to facilitate land use planning.

CHAPTER 3

LAND INFORMATION SYSTEMS AND LAND USE PLANNING.

3.1 Introduction.

The diversified resources of the forest lands in southern Ghana make up a great proportion of the potential income needed for the country's present and future development. The main concern, as was noted in the previous chapter, focuses on policies and strategies that need to be adopted to ensure the development of the forest resources in a way that both the societal interests and the environmental resource base would be sustained and protected.

The landscape of the region reflects mainly the decisions made by individuals or groups with regard to the use of the land resources in the past. In the Ghanaian situation, decisions to allocate land to various uses are very important because they have long-term implications for the sector of the economy which occupies the land later, and for other sectors precluded from the use of such resources. For instance, a plot of land allocated to cocoa cultivation for export is likely to remain in that capacity for several years. Most of the forest soils and the underlying rocks are known to possess a capability for a wide range of uses. Decisions on land use are therefore very important in the development of the region's agriculture.

Resources have been perceived as raw materials of nature which assume important roles only when they are discovered and used by people (Zimmerman 1951:7). The emphasis placed on the economic function of resources appears to have influenced exploitation of the forest resources in Ghana. The utilitarian approach to resource exploitation has also formed the basis of many economic development models adopted in the country. But then it is necessary to ask:

1) To what extent can commodity exporting countries such as Ghana continue to ignore the attributes of the land which sustain agricultural production?

2) How can the increasing internal demand for food and the persistent demand for foreign exchange be jointly satisfied?

3) What areas of the forest lands have the potential to support food production?

In examining these issues, this chapter will review some of the roles that land information systems can play in facilitating land use planning in Ghana.

3.2 Land use Planning.

In many developing countries (including Ghana), the extraction of resources generates conflict among local, national and external interests (Redclift 1984:102) and problems of environmental degradation are becoming a major concern. Meeting the demands of a rapidly growing population

against the background of diminishing land resources in these countries requires effective land use planning which will match the potentials of the land with the needs of the people. Policy makers in these countries need to make choices among alternate uses of the land resources to support development and to minimize food imports which are increasingly becoming a big drain on scarce foreign exchange. It is also necessary to ask where to locate new developments, settlements and farms as the countries embark on development. There is, therefore, the need for proper assessment of land to provide qualitative classification of its capabilities for major kinds of land use in such primary commodity exporting countries as Ghana.

3.2.1 Land as a resource.

Land is seen differently by many people. To some, land is the surface of the earth on which people live. Others see it as an immovable property in the form of a capital or a consumer good. The Food and Agricultural Organization (F.A.O.) defines land as:

"an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man". (F.A.O. 1976:67).

Land can thus be considered to include surface and near surface features of the Earth. The actual value of any

portion of land depends partly upon the potential uses it offers and on how well those potentials are identified and utilized in the fulfilment of individual and societal interests. Since the land has capability for several uses, an assessment of the land potentials would help to determine the rational allocation of the limited land resources among competing interests.

Soil is an attribute of land which is used as a medium for plant growth. People depend on soil resources for food, fibre, some minerals and for other raw materials. The soil therefore has several uses all of which are influenced by different conditions and limitations. Different cultivated crops, for instance, take different proportions of nutrients from the soil. The evaluation and presentation of favourable and adverse effects of possible uses of the soil would thus facilitate the adoption of strategies that could lead to improved agricultural production.

Land use planning is a major component of rural development which aims at guiding decisions on land use in such a way that the land resources would not only be preserved but would be put to the most beneficial use for the society (C.R.D. 1979). The process entails the compilation and analysis of data on land characteristics and soil properties to facilitate the allocation of land to particular uses. Land use planning may thus be defined to include three distinct processes referred to as land allocation strategies, capability and land suitability analyses.

3.2.2 Land allocation methods.

Many of the existing land allocation methods fail to match land use requirements with the potentials of the land. A soil survey, for instance, provides a classification of land with regards to its inherent soil properties without making any reference to the many intended uses to which the soil may be put. The information about soil and land characteristics contained in such soil maps is concealed in technical terms. The technical nature of the soil survey map therefore limits its practical uses for planners and policy makers.

Economic evaluation of land by cost-benefit analysis is based on the assumption that a desired objective can be achieved by choosing the lowest-cost alternative which maximizes desired objectives (O'Riordan 1972:31). While in theory the technique justifies the economic rationality of projects by ensuring that total benefits exceed total cost, it would fail to resolve problems of land allocation in the forest region of southern Ghana. This is because the technique is based on quantifiable benefits but it would be difficult, if not impossible, to assess much of the subsistence production (especially food farming) undertaken by peasant farmers in Ghana in terms of such criteria.

3.2.3 Land capability and land suitability analyses.

A soil survey produces a great volume of data on the distribution of soil properties in an area. The data are

often used to assess the potentials of the land to support land use practices. This interpretation of soil data, which often takes the form of evaluating soil potentials, is frequently referred to as land evaluation (Davidson 1982:15). Land suitability and land capability analyses have been used with regard to the evaluation of land in several different ways for different purposes (FAO 1976; Dent and Young 1981; Davidson 1982:16).

The land capability assessment relates to analyses in which areas of land are assessed for major kinds of uses and classified into capability categories from the best to the worst (Young 1976:128). The land capability map thus describes the potentials of the land to support different kinds of land use such as arable farming, permanent grazing and forestry. In the land suitability analysis on the other hand, the land is assessed in terms of its suitability for specified kinds of use (Dent and Young 1981:140). In the process, the suitability of the land is assessed, classified and presented separately for each kind of use.

Land evaluation is thus based on a wider range of data on land resources than what is obtained from soil survey alone. It is based on the physical and chemical properties of soils and land characteristics. Smit and others (1979:7) have noted that by considering both what is known about the capability of the land and the stated societal needs the land is called upon to fulfil, the evaluation process gives a good

indication of how important an area is for the attainment of some known objective. Thus, by facilitating effective decision-making with regards to land use planning, the technique has the potential of improving land resource management.

3.3. Land Information system.

Land evaluation provides analytical results which are used as an input in planning (Putte 1989:139). This implies that land evaluation results should be made available in such a format that alternate farming systems and crop combinations can be easily analyzed during the planning process. Thus, a major source of improvement in land use planning is efficient organization and storage of all available data on land resources and the provision of rapid information retrieval system.

A land information system according to Hamilton and Williamson (1985) is a tool for legal, administrative and economic decision-making and an aid for planning and development, which consists, on one hand, of a database containing spatially referenced land-related data for a defined area, and on the other hand, of procedures and techniques for the systematic collection, updating, processing and distribution of the data. The development of a land information system for a region could thus serve three important functions in improving data availability. First,

the process of constructing the database encourages planners to make an inventory of all existing relevant data. Second, the data once collected are stored and made available through a simple retrieval system in the GIS. Third, the data could be easily updated to reflect current conditions. Remote sensing and GIS have supported the setting up of land information systems by providing data about land resources, processing the data and presenting them in easily discernible formats like maps and tables.

3.3.1 Geographic information system.

A Geographic Information System (GIS), according to Marble (1987:3), is a computer-based data processing system with the following components:

- (a) a data input subsystem which collects and/or processes spatial data derived from existing maps, remote sensors and other sources,

- (b) a data storage and retrieval subsystem which organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis as well as permitting rapid and accurate updates and corrections to be made to the spatial database,

- (c) a data manipulation and analysis subsystem which performs a variety of tasks such as user-defined aggregation rules or producing estimates of parameters or constraints for various space-time optimization or simulation models and;

(d) a data reporting system which is capable of displaying all or part of the original database as well as manipulated data and the output from spatial models in either tabular or map form. The GIS can therefore be used to process, display and store not only spatial data but also attributes that are geographically linked to the spatial data.

The software component of a GIS consists of five basic modules (figure 3.1). These include a data input and verification unit, a storage and database unit, an output and presentation unit, a data transformation unit and a query input which provides the link with the user.

Figure 3.1

Software components of a GIS.

Source : After Burrough (1986:8)

The effectiveness of the use of GIS to provide decision-makers with appropriate information depends in part upon the quality and applicability of the data and on how the data are organized in a database (Chambers 1989:2). A database has been defined as an organized collection of related sets of data structured and managed in such a way that application programs and users view the whole set of data or a subset of the collection as a single unit (Burrough 1986:13). It consists of several files of data which could be retrieved, manipulated and extracted selectively to produce an output which may facilitate an application (Aronoff 1989:151).

The database is made up of two basic parts: a graphics database which contains all the locational information relating to mapped features and an attributes database which holds all of the descriptive information relating to the mapped features. It is thus a computer filing system in which graphics and attributes data are stored in a special way to make them readily available for processing, retrieval and output.

Aronoff (1989:154-5) and Burrough (1986:13-35) found database development to be vital for the computer processing of all spatial data including land-related information. The data are not only collected but are processed, organized and stored in an orderly manner to provide readily available information to planners, government officials, private investors and community groups who may require such

investors and community groups who may require such information for decision making. Aronoff (1989:154) has noted that aside from providing speed and ease of access to the data, the database system facilitates reduction in redundancy, enhances data sharing among several users and facilitates the enforcement of accepted standards on the centralized data. In addition, it permits data to be updated, retrieved and modified to suit different users at different times. The accuracy, correctness, validity, consistency and completeness of data can also be more easily achieved in the well structured and organized database than can be done with unstructured data (Aronoff 1989:154).

Prior to the introduction of computers into map-making, paper and film served as the database for spatial phenomena. In Ghana, paper is still the principal means of data storage. The use of paper as a medium of data storage and retrieval has serious limitations on the collection, coding and use of information (Burrough 1986). The original data has to be reduced in volume after which many details are lost. Data retrieval is made difficult and expensive, always involving the retrieval of a combination of other spatial data. Paper is static and subject to tear and crumbling and thus serve as a poor medium of storage for data. This is irrespective of the fact that paper is still the most widely used medium for displaying data. The advent of GIS created a means to make existing maps more cheaply and perhaps more efficiently from

a central database. Computer publication of maps allow different graphical experimentation with the same data and facilitates map-making and updating when data are already in a digital form.

According to Estes (1985), the database of a land information system facilitates the creation, updating and editing of maps and provides a tool for enhancing decision-making. A schematic representation of the decision-making process and its interface with the database system is provided in fig 3.2.

Figure 3.2.

Interface between a decision-making process
and a database system.

Source: after Brooks et al., (1986:477)

It is clear from figure 3.2 that the database can provide baseline information about an area that can be used to identify alternate solutions to problems, forecast the outcomes of options and monitor the impact of decisions. Within the land information system, a well organized database system could thus offer opportunities to model important land use problems to ease the search for solutions.

3.3.2 Remote Sensing technology.

Remote sensing has been defined as "the art and science of obtaining information about an object, an area or phenomena through the analysis of data acquired by a device that is not in direct contact with the target under investigation" (Lillesand and Kiefer 1979:1). It consists of the measurement and recording of electromagnetic energy reflected from or emitted by Earth's surface materials (Mather 1987:1). Thus, the nature of the earth's surface materials (land cover types) are not detected directly from photographs or remotely sensed images but deduced from the radiance measurements through either computer processing of digital images or visual interpretation of hard copies of such images or photographs.

Photographic systems which generally produce instantaneous and fixed records of a target are limited to the visible range (0.3 to 0.9 microns) of the electromagnetic spectrum and provide a view of the reflectance properties of materials but contain little of their emitted properties

(Mather 1987:1). Remote sensing from space, on the other hand, involves multispectral sensing whereby images are acquired simultaneously in several bands in a series of scan lines representing digital or numerical record of radiance measurements made at regular intervals along a scan line.

Landsat was the first unmanned imaging system designed and launched into space from about 1972 specifically, to collect data on terrestrial resources. Landsat 1 was launched into a circular, sun-synchronous orbit of about 900 kilometres in altitude. It crossed the equator at 9.42 a.m. local time at each pass to take advantage of clear early morning skies. The orbital pattern produced a repetitive coverage of an area on the Earth's surface in 18 days. Subsequent Landsat programmes 2 and 3 retained most of these features and, like Landsat 1, carried two imaging systems. These were a three channel Return Beam Vidicon system and a four channel Spectral scanner.

Landsats 4 and 5 launched in July 1982 and March 1984 respectively differed from previous Landsats. Both were launched into a sun-synchronous orbit of about 705 kilometres from the Earth's surface and carried two scanning systems. The first is a multispectral scanner similar to those carried on previous Landsats; the other is a seven-channel scanner generally called "Thematic Mapper" (TM). It collects data from spectral bands ranging between 0.45 and 12.5 microns and has a spatial resolution of 30 metres (120 metres for the

thermal band 6). The system characteristics of Landsat 4 and 5 are specified in table 3.1.

Table 3.1.

System and sensor characteristics of Landsat 4 and 5.

System Characteristics

ORBIT: - - - - - Near Polar, Sun-synchronous
 ALTITUDE: - - - - - 705 Kilometres.
 INCLINATION:- - - 98.2°
 EQUATORIAL CROSSING TIME:- - 0945 Hours Local time.
 REPEAT CYCLE: - - 16 days.

Sensor Characteristics.

<u>SENSOR</u>	<u>BAND</u>	<u>SPECTRAL RANGE (micrometres)</u>	<u>RADIOMETRIC RESOLUTION</u>	<u>SPATIAL RESOLUTION. (metres)</u>
MSS	1 or 4	0.5-0.6	64	79
MSS	2 or 5	0.6-0.7	64	79
MSS	3 or 6	0.7-0.8	64	79
MSS	4 or 7	0.8-1.1	64	79
TM	1	0.45-0.52	256	30
TM	2	0.52-0.60	256	30
TM	3	0.63-0.69	256	30
TM	4	0.76-0.90	256	30
TM	5	1.55-1.75	256	30
TM	6	10.40-12.50	256	120
TM	7	2.08-2.35	256	30

 Source: Lillesand and Kiefer 1979 pp. 443-454.

One great advantage which satellite remote sensing offers in the collecting of data is the overview and the revisit capabilities it provides for monitoring the use of resources in an area. The digital nature of such data makes it easy to integrate with other data into a GIS.

3.4 Development of Land information systems.

Land information systems (LIS) have been in use in the developed world for some time now. In the United States of America, the development of LIS to facilitate land evaluation first occurred within the Soil Conservation Service of the United States Department of Agriculture (USDA). This was in response to soil erosion problems in the Mid-West region during the 1930s (Klingebiel and Montgomery 1961). The system, which is still in use, assesses limitations to the actual and potential land uses imposed by land characteristics and grades the land into capability classes according to the degree of limitations found within a given land area (Davidson 1980:17).

In Canada, a system for land inventory was established in 1963. The project involved a comprehensive survey of land resources in all the settled parts of the country to provide a basis for resource management and land use planning (Canada Land Inventory 1965). The Canadian system maintains a capability assessment plan for forestry, recreation and wildlife and employs seven main classes as against the eight classes of the USDA system.

The earliest assessment of land for different uses in Great Britain resulted from land utilization surveys undertaken throughout the country in the 1940s (Stamp 1962). The objective of the survey was to assess potential land uses in terms of land characteristics. The country's current land

information system for land evaluation is modelled on the USDA method but maintains significant differences of its own (Davidson 1982:24).

Land information systems have been developed in several other parts of the world. In New Zealand, one of such systems offers land suitability classifications for pastoral and cropping purposes. This LIS has also formed the basis for extensive soil studies in the Netherlands (Beek 1974, Vink and van Zuilen 1974).

The need to adopt these technologies in Ghana's developmental process was restated when, in an address at a seminar on remote sensing and GIS applications, the Minister in charge of lands and mineral resources observed that;

"the National Economic Recovery Programme is largely environmental resource based, mainly export production from the soils and forests. It is true that the formal inventory status of these resources has increased during the present century,... the most part of the surveys and assessments of the natural resources have been done through conventional ground methods and limiting application of aerial photography. The present accelerated rate of development requires much increased and diversified resource information and timeliness of delivery. It is no longer efficient to rely entirely on the slow ground method of acquiring the vital data necessary for sound developmental decisions to be made" (University of Ghana 1989:2).

It could be inferred from the Minister's assertion that the role remote sensing and GIS technologies could play in the processing of data on the country's resources has been partly recognized. What is not known is whether the technologies can be efficiently adopted in the country. To explore this issue

further, we shall, in the next chapter, use the GIS and remote sensing technologies to interpret a soil survey data and a TM 5 image for use in database development for a test area in southern Ghana.

CHAPTER FOUR

CASE STUDY

4.1 Introduction

This chapter focuses on the application of remote sensing and GIS technologies in developing a database of information from soil survey data for a test area in the Pra-Ofin basin of southern Ghana. The first part of the chapter is devoted to a description of the sources of data. This is followed by the development of a database of information for evaluating soil potentials in the test area.

Land use management practices which emphasize soil productivity are site specific and are influenced by several factors (Boul and Cuoto 1981:244). These factors include soil type, ambient weather, site characteristics and soil management practices. In the evaluation of land or soil for purposes of land use, various combinations of these parameters are used to group soil mapping units into discretely ranked categories. Some classification systems, such as the soil capability classification of the United States Department of Agriculture, assess the land in terms of a soil potential index which takes into account such variables as the site characteristics and conditions which adversely affect land use, effective yield of a crop, the potential cost of developing the land and costs due to limitations imposed by

land conditions (USDA 1978).

Other land evaluation systems do not include data on yields but combine various land qualities that are believed to influence crop yields. These include methods which provide a soil productivity index or rating by means of parametric techniques. In such methods, the effects of land and soil properties that affect crop yield are assessed individually and then combined arithmetically. Examples are the Storie index developed by Edwards (1970) and Soil Productivity rating proposed by Riquier and others of the Food and Agricultural Organization (FAO) (Riquier et al. 1970). The indices used by Riquier and others for the soil potential productivity rating include soil moisture, drainage conditions, soil effective depth, texture, organic matter content, cation exchange capacity, base saturation of soils, nature of clay and mineral reserves in the soil.

Mansfield (1979) also used four soil characteristics namely, soil depth, drainage conditions, texture and the presence of coarse material to assess land capability for annual rainfed arable cropping in Northern Nigeria. Muchena (1979), working with the Kenyan Soil Survey, developed a system of land evaluation based on three criteria. These were soil moisture and storage capacity, the possibilities for the use of local agricultural implements and the soil's resistance to erosion. Boul and Cuoto (1981) designed a soil fertility capability system for use in the humid tropics. The method

focuses on soil properties that are directly related to the management of crops in the field. Parameters used for the fertility capability evaluation include soil texture, aluminium toxicity, organic matter content, soil reaction, soil salinity, clay content, moisture holding capacity and the cation exchange capacity of soils.

It becomes clear from the above discussion that most land evaluation strategies have a local rather than universal application. The strategies vary in terms of the procedure used for the assessment and the number and nature of soil and land conditions used as criteria. Sometimes changes in environmental conditions and the availability of data could cause variations in the methodology. For example, the USDA method uses the frequency of flooding as a criteria for assessment but not all areas of a country may be subjected to flooding.

4.2 Data sources for the case study.

Ensuing from the above discussion on land evaluation strategies, we might find it ideal, in evaluating land for the rainfed arable farming in the forest region of Southern Ghana, to include data on soil characteristics, land conditions, effective yield of crops, proximity to markets, potential cost of developing a parcel of land, land ownership and land cover. These data, and those that may be defined in the course of time, could be used to set up a database of land

information for the region. Unfortunately, most of these data are not currently available. It was also not possible within the time this thesis was written to take a trip to the area to collect data. Data for the case study have therefore been extracted from soil survey data of the test area which were procured from the Soil Research Institute at Kumasi, Ghana, and from Landsat TM 5 image obtained from the CCRS. Other data include soil and topographic maps of the area.

4.2.1 Landsat TM 5 data.

A full scene display of the Landsat TM 5 image taken on December 19, 1986 was made and the study area selected.

A preliminary enhancement of the data involving the calculation of image statistics revealed that only the images contained in TM 5 bands 4,5,6,and 7 were clear and contained no clouds. Bands 1, 2 and 3 on the tape contained low-grade data. The cause of the blurring of data in the lower bands may partly be due to the absorption and scattering of radiation by dust particles carried over the Sahara desert by the strong harmattan winds which dominate the West African subregion from November to March. Data contained in bands 4, 5 and 7 were therefore selected for the study.

A geometric correction package (GCP) in the EASI/PACE image processor used for processing the image allowed for an interactive selection of nineteen pairs of ground control points from the topographic map of the area and an image

database display on the monitor. The programme used the selected points to correct the image geometrically.

The raw image lacked contrast and as such enhancement methods had to be employed to stretch the range of grey levels in the image to fit the full length of the grey values (0-255). Enhancement techniques adopted include the linear, histogram equalization and piece-wise stretches.

The linear contrast stretch involved the mapping of the pixel values (PV's) from the observed range (PVmin) to the full range of the display device (PVmax). The PVmin was the smallest pixel value in the image and the PVmax the highest grey value corresponding to the 0-255 grey levels of the 8-bit radiometric resolution of the TM 5 image. The range of pixel values in the image were thus stretched uniformly to fill the total range of the output device. Even though the output image was better than the raw data display, the technique assigned equal grey values to both the well reflected roads, settlements and bare soil and the poorly reflected rivers. The displayed tones showed little radiometric detail; consequently most of the natural and human features in the image were found to be indistinguishable.

A histogram equalization stretch was performed to facilitate interpretation of the image. Using the histogram equalization programme in the PACE image analysis system, the three bands 4, 5 and 7 were loaded on to the monitor and auxiliary segments representing look up tables (LUT's) were

created. The LUT segments and the original image channels were then used to create a new image. The programme then assigned a greater range of grey levels (hence more radiometric detail) to the frequently occurring section of the image histogram to stretch it over a larger portion of the display level while the infrequently occurring image values were assigned a small range of image values. The contrast in the image improved tremendously, but the predominantly green cover of the forest vegetation obscured the various levels and classes of the vegetation. Linear features such as roads, railways and rivers were also not easily recognisable. It was therefore necessary to selectively exaggerate the output levels of these features with a piece-wise or customized stretch programme to facilitate interpretation.

The piece-wise stretch technique gives the user full control of the contrast stretch function so that the input and output stretch ranges of both the pixel values and grey levels are user determined. The resulting image displayed a great contrast between certain forms of the forest vegetation, settlements and roads within the area.

Both the supervised and unsupervised classifications were performed to group features in the image into categories. A computer-aided classification programme was applied to the pixel values of the image to create a histogram of the data. The histogram data were then clustered into eight unsupervised

classes. The output of the unsupervised classification was used as a guide for the selection of training areas for the supervised classification.

The supervised classification began with the selection of training sites which are representative examples of different information categories. Based partly on the knowledge of the area and the results of the previous classification, six land cover types were defined and used for the selection of training sites. A sample signature segment for each class was created. A maximum likelihood classifier programme using the minimum and maximum pixel values (Gaussian threshold) stored in each class signature was applied to the three bands (4, 5 and 7) to determine the classes of given pixels. The resulting classified image (figure 4.1) displayed the following land cover types:

- 1) Closed forest zone: This consists of land covered by trees with a canopy closure greater than 70%. It is made up of reserved forests which were created under the Forest Bill of 1911. Under the bill, sections of the forest were thoroughly surveyed, mapped and preserved for future use. Selective logging is the only economic activity permitted in the forest. The reserved forest thus maintains straight

UNCLASSIFIED
CLOSED FOREST ZONE
REGROWTH
SHIFTING CULTIVATION
BARE SURFACES
SHADOWS
WATER BODIES

CLASSIFIED IMAGE OF PRA-OFFIN BASIN

(Figure 4.1) LANDSAT TMS BANDS 4,5 AND 7

1:500000

boundaries and retains most of its species and floristic composition which is in sharp contrast to the adjoining vegetation which is continuously disturbed by shifting cultivation system of farming.

2) Regrowth: This category is made up of land left to fallow long enough after shifting cultivation for vegetation to regenerate into a secondary forest. Canopy closure is less than 40%. It includes all cocoa, coffee and oilpalm plantation farms.

3) Shifting cultivation: areas of land under active cultivation, freshly burned or abandoned; regrowth is of a scrub type of vegetation. This category occurs frequently among settlements in the region and comprises all areas of current arable farming in the region.

4) Bare surfaces: land surfaces devoid of vegetation cover and including all settlements in the area.

5) Water bodies: rivers, streams and other water bodies found in the region. Mechanical dredging for gold in the bed of the Offin river (which runs across the study area) disrupts its natural flow and makes its colour brown. In the image therefore, the river displays reflectance levels similar to some land cover in the area.

6) Shadows: reflectance differences caused by shadows cast by the high forest vegetation or rugged topography. The major land cover categories derived from the classified image reflect levels of deforestation under the shifting

cultivation system practised by farmers in the region. This is recognized from variations in the intensity of reflected energy displayed by the land cover of the area (Figure 4.1).

4.2.2 Soil survey data.

Soils of the study area consist of the following types: (see figure 4.2)

1. Soils developed over granite:

A1 Nyanao-Tinkong association.

2. Soils developed over Birrimian rocks (Phyllite)

B1 Bekwai-Oda association

B2 Atukrom-Asikuma association

3. Soils developed over Tarkwain rocks (Quartzite, phyllite and schists)

C1 Juaso-Mawso association

C2 Pamasua-Debia association

4. Soils developed over Alluvium:

D1 Awaham-Kakum-Chichiwere association.

Figure 4.2
Distribution of Soils
(Pra-Offin Basin)

- A1
- B1
- B2
- C1
- C2
- D1

▲

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The soil and site parameters used in the case study include soil pH, cation exchange capacity, surface texture, organic matter content, moisture holding capacity and the nitrogen, phosphorus and potash contents of the soils see table 4.1.

Table 4.1

Soil parameters used for the study.
(for surface 10 inches or 25 cms.).

Soil type	Soil texture	pH	N %	K %	P ppm.	MO %	OM %	CEC
A1	sandy loam	6.8	0.78	0.20	106.2	0.9	1.1	5.1
B1	loam	5.6	0.20	0.09	387.5	3.1	2.2	8.3
B2	clay loam	6.4	0.40	0.25	126.1	5.0	6.9	6.5
C1	clay loam	6.1	0.37	0.43	143.8	2.3	2.7	7.7
C2	silty loam	5.2	0.14	0.15	136.9	1.1	1.1	4.1
D1	sandy loam	5.0	0.07	0.19	68.9	0.8	2.7	4.2

Source: Soil research Institute, Kumasi, Ghana.

N=nitrogen, K=potassium, P=phosphorus, MO=moisture holding capacity, OM= organic matter content, CEC= cation exchange capacity (meq per 100 grams).

Two criteria were used in the selection of the soil parameters. First, the soil parameters had to be important in influencing crop production and second, the parameters had to vary sufficiently within the test area to be good indicators of pattern differences. Attribute data on the different soil groups were based on the plough layer (top 0-10 inches or 25 centimetres). This is the layer much used and hence disturbed by crop cultivation. It is also the zone most closely related to soil and crop management.

4.3 Database development.

The soil map was digitized into the ILWIS GIS system and the attribute data of the various soil types were then entered into a table attached to the soil polygons in the GIS. Other data included in the database design (see fig 4.3) include roads and rivers of the area digitized from the topographical map.

Figure 4.3

Database design.

Non-spatial files	Spatial files
<div> Soil attributes 1. soil pH. 2. phosphorus 3. nitrogen 4. potash 5. water holding capacity 6. cation exchange capacity 7. organic matter content 8. surface texture </div>	<div> 1. soil attributes maps 2. soil polygon map 3. land cover map 4. roads map 5. drainage map </div>

4.3.1 Data Integration and mapping.

The integration of data to derive the soil potential ratings map was carried out with the help of a Map calculation function in the raster module of the ILWIS GIS. The soil polygon map was rasterized and classified according to the attribute values of the various soils contained in the attribute table linked to the polygons. This initial

classification resulted in the creation of attribute maps whose pixel values reflected those of the corresponding polygons.

With the creation of the attribute maps, it became possible to derive maps showing the distribution of varying levels of the selected parameters. All the soil and site parameters were first grouped into four classes and indices assigned to them as: 1 = high, 2 = moderately high, 3 = low, and 4 = very low. A classification table based on the indices was then generated for each set of attribute data to classify the pixel values of the attribute maps. This resulted in the creation of classified attribute maps whose pixel values reflected the indices allocated to the various parameters. See figures 4.4 and 4.5 for samples of the classified maps.

The derivation of the soil potential ratings map was based on the aggregate values of the indices created for the classified attribute maps. A table resulting from the aggregation process is shown in Table 4.2

Table 4.2

Parametric indices for soil potential ratings.

Soil group	pH	MO	N	P	K	ST	CEC	OM	Total
A1	2	4	1	4	2	4	3	3	24
B1	4	1	3	1	4	1	1	3	18
B2	1	1	2	3	2	4	2	1	16
C1	1	2	2	2	1	3	2	2	15
C2	3	3	4	2	3	2	4	4	25
D1	3	3	4	4	3	4	4	2	27

Source: Derived from Table 4.1

Figure 4.4

Surface Texture

- Loam
- Silty Loam
- Clay Loam
- Sandy Loam

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Figure 4.5

Soil PH

- Neutral
- Moderately Acid
- Acidic
- Very Acidic

A

1:500000

The final soil potential ratings map (figure 4.6) indicates that soil groups C2 and B2 have high productivity potentials, B1 has a moderately high productivity potential, A1 and C2 have low productivity potentials and D1 has a very low potential to support agriculture in the region.

4.4 Relationships between soil productivity groups and Land cover.

One lesson that may be learned from the historical development of commercial agriculture in the forest region is the fact that a great number of soils identified as fertile are currently under cocoa farms or reserved forests. Consequently, these fertile soils of the area are not available for arable farming and it is soils outside these zones that are intensively used by food farmers. Under the shifting cultivation practices adopted by farmers in the region, most of the soils become impoverished after brief periods of continuous use. It is therefore possible for land cover categories mapped from the Landsat image to reveal information about soil fertility and its availability for arable farming in the region.

The major land cover categories derived from Landsat TM 5 image with an overlay of soils of the area are shown in figure 4.7.

Figure 4.8

Soil Potential Rating

- High
- Moderately High
- ▨ Low
- Very Low

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Figure 4.7

Major land cover types
with soil boundaries

- Settlements
- ▨ Shifting cultivation
- Regrowth
- Reserved forest

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As can be seen from figure 4.7, the reserved forest occupies much of the area of soils with the greatest productivity potential in the region. The remaining of the productive soils have also been intensively cultivated. The soils have thus been disturbed by several years of burning and cultivation. The intensity of cultivation and hence disturbance can be determined from the number of settlements located within the boundaries of soil groups C2 and B2. The soil with the lowest productivity potential (D1) occurs on the active flood plains of the Offin. The low productive potential of soils in the active flood plain is likely due to poor drainage and low organic matter content.

CHAPTER FIVE

DISCUSSION

5.1 Introduction.

The practical application of remote sensing and GIS in providing a database of land information for soil productivity evaluation in a section of the Pra-Offin basin in Ghana was presented in chapter 4. In this chapter we will review the remote sensing and GIS systems used for the study and evaluate the prospects for adopting the remote sensing and GIS technologies for land use planning in Ghana.

5.2 Review of the Land evaluation strategy.

The soil productivity evaluation considered in chapter four, like other land evaluation methods, is a classification system which groups soils into ranked categories according to selected soil and land conditions. Lack of data limited the number of parameters that could have been combined with the soil survey data to set up the database. The database is thus far from being complete. Additional data on slopes, erosion, agricultural production figures, soil management practices and other factors which affect the growth and development of crops in the locality need to be integrated into the system. With this additional data, more comprehensive models can be developed from the database to evaluate soils in the region effectively.

However, the database of land information provides baseline data to assist farmers locate potentially productive soils for arable farming in the forest region. The soil productivity classification map is easier to interpret than the soil survey data. The resulting database could thus be useful for decision-making in land use planning within the locality.

Within the GIS environment, the database could be queried to derive maps and other information on the nutritional status of mapped soils in the study area which could be used by local and regional agricultural development officers to make recommendations for fertilizer applications. It would be easy to update the information contained in the database to reflect changing conditions. Additional information could also be added to the database at any time.

The effective utilization of the database would depend upon the education of farmers and on the validity of recommendations contained in the maps. The soil productivity potential map would require field trials and the results will have to be validated with production responses of local crops before it could be safely recommended with confidence for use by farmers.

5.3 The ILWIS GIS used for the case study.

The ILWIS GIS (version 2.1) used for the case study has been designed to operate in both raster and vector modules

but the vector module is essentially limited to the transfer of analogue data into a vector format (Gorte 1991:217). The use of raster data structures to store spatial data introduces errors in the transformation of the original analogue map (Valenzuela 1991:219). The system, like most others in the market, has no in built prompts to warn users of inappropriate use of important functions. It produces only segment files for output in postscript laser printers. This means that all colour and other attributes of polygons are lost when postscript printers are used.

The learning curve for the system is quite long. Like in many geographic information systems, the modelling options available are many and varied. This requires that users acquire a knowledge of both the applications field and the functions of the system if the system is to be used effectively. Unfortunately, the ILWIS GIS is poorly documented. There are many undocumented functions present in the system which leads to a trial and error approach when using the software.

One fact that became clear in the course of the study is that even though several remote sensing and GIS application software systems are being developed, data sharing can be hindered by incompatibilities imposed by systems currently in use. For example, it was very difficult to import the classified TM 5 image from the PACE image processing system into the ILWIS GIS. A hard copy of the image had to be

printed and interpreted before the resulting land cover categories were digitized into the GIS. Each remote sensing or GIS system is designed to process and store data in a special format. Most developers design their systems as the final destination of spatial data (Piwowar et al 1990:1498) even though each system has its own limitations. The incompatibilities existing among the various systems and the fact that some software packages are poorly documented suggest that initially, the adoption of remote sensing and GIS systems in developing countries like Ghana should proceed with caution.

5.4 Prospects for the development of Land information systems in Ghana.

The idea of adopting technologies developed in industrialized countries to solve problems in developing countries is hotly debated. Writers like Sagasti (1973) and Malingreau (1981) argue that lack of right attitudes, underdeveloped economies, poorly developed infrastructure and institutional obstacles limit successful applications of modern technology in developing countries. However cogent this assertion may be, it is also necessary to consider the fact that it would be difficult for the developing countries of today to follow the evolutionary path that industrialized countries sought to development in the past. The computer technology from which GIS and remote sensing systems are

derived has affected several organizations and institutions in developing countries. Ghana's strong external links with Western industrialized countries means that it is affected by the computer revolution currently being experienced in those countries. The promotional activities of vendors and the demonstrational effect of the use of the remote sensing and GIS by foreign experts working on international donor sponsored projects in the country have already aroused a general awareness on the part of many people in the country (University of Ghana 1989). It would therefore benefit the country to import the technologies, absorb them and either modify some aspects to suit local conditions or use them to solve local problems. How successfully this can be done depends upon how well the problems arising out of the adoption of both technologies in the country would be addressed.

5.4.1 Potentials of GIS and Remote sensing in the region.

The lack of information about the country's natural resources and the nature and amount of data required for land use planning make it imperative to adopt remote sensing and geographic information processing systems. Both systems were used together in the case study to collect, process and display information about land resources of the region. The two systems are complementary and can be effectively linked to improve the quality and potential use of information on the country's land resources.

The Landsat TM 5 image provides information on land use, soils and geology in situations where systematic and processed data are lacking (Dangermond et al. 1987:10). The image has several advantages over other methods of collecting data on natural resources and human features of the forest region. It required fewer people and hours to extract the information from the Landsat TM 5 image than it would have taken to employ, train and equip several people to produce comparable results manually. Asiamah and Senyah (1989:85) after using remote sensing methods in a study covering parts of the Upper East and Northern regions of Ghana reported that the system facilitated a timely completion of the project in four months instead of the estimated two years which manual methods would have taken to do the same work. The acquisition and use of the data would be cheaper than doing the same thing through field surveys. With regard to the soil productivity evaluation process, the Landsat image facilitated the compilation of a land cover map of the area and provided new evidence that can be used to update roads of the study area. The classified image also revealed the extent of deforestation in the region (see figure 4.1).

Small classes of information similar in tone to the predominantly forested zone appeared in several areas of the classified image. This shows that the regrowth and shifting cultivation categories in the image are derivatives of the forest vegetation. Several years of shifting cultivation

practices have degraded the original forest vegetation currently preserved in the reserved forest. This evidence is supported by the widespread occurrence of small settlements set up by farming communities within the non-forested portions of the image.

The classification process revealed that further classification of the non-forested portions of the image into land use categories was not possible. The forest is selectively logged and the small and scattered nature of farms make it difficult to detect the land use.

One other advantage of using the Landsat TM 5 image is the overview it provided of the land resources and human features of the area. This made it possible to study the resources within naturally defined regions such as the drainage basin chosen for the case study. In addition, the combination of the two systems in the collection and analysis of data on the soil conditions meant that the database would be available for verification, updating and improvement at subsequent times.

The prospects for the adoption of these technologies have been increased by a continuous fall in the price of computer hardware and accessories and the increasing availability of powerful microcomputers. Currently, most of the GIS and remote sensing software programmes run on microcomputers. The micro-computers are easy to use and maintain and are far cheaper than main frame computers.

5.4.2 Remote sensing and GIS facilities available in Ghana.

There is a National Remote Sensing Committee which coordinates the activities of all bodies and personnel engaged in the application of both technologies. Some Ghanaians benefit from the training facilities offered by remote sensing centres at Oagadougou in neighbouring Burkina Faso and Ile Ife in Nigeria. A few Ghanaians also benefit annually from scholarships offered by the Dutch government for studies at the International Institute for Aerospace Survey and Earth Sciences, Enschede, the Netherlands.

A workshop organized in Accra in 1989 to find out the status of GIS and remote sensing applications in the country was attended by over one hundred persons who had received various levels of training in remote sensing and GIS. Papers presented at the seminar covered a wide spectrum of applications in both fields. It was revealed at the workshop that varying GIS and remote sensing application facilities exist in research institutions, universities, ministries and other organizations in the country (University of Ghana 1989:2). Plans are also under way to set up a centre for remote sensing at the Department of Geography and Resource development of the University of Ghana. However, in spite of the available facilities and the potentials which the remote sensing and GIS technologies have for the acquisition and processing of data on land resources of the country, several technical, social and economic problems will have to be

addressed before both technologies could be effectively employed to facilitate land use planning in the country.

5.4.3. Technical problems.

From preliminary studies in the selection of TM 5 image for the case study reported in this thesis, it was realized that in the tropical zones of the world where Ghana is found, satellite remote sensing data are usually not available during the growing season which coincides with the rainy season. Several days of cloud cover make it impossible to collect information on land cover. The dry season might also not be suitable as dust particles and other particulate matter blown from the Sahara desert by harmattan winds intercept radiation. In the dry season some plants shed their leaves and bushes wither and exhibit different reflectance values which make it difficult to interpret the data.

The landsat TM has an equatorial crossing time of approximately 9.30 a.m. and a spatial resolution of 30 metres. The system parameters therefore appear to suit land use studies in the mid-latitude zones of the world. In these regions, long periods of clear weather, a homogeneous agricultural system characterized by large areas of single crops and pure stands of forests make satellite remote sensing more suitable for mapping resources in countries of the temperate regions.

In Ghana and other tropical countries, potential remote sensing applications in land use studies are limited by the small and irregular size of farms, non-uniform planting dates and the practice of mixed cropping. It was revealed in the study that it is only possible to classify the TM 5 image into forested and non-forested segments. Further classification of the non-forested land cover into land use categories was not possible. It also became evident that similarities of spectral reflectance between cultivated permanent crops such as cocoa and some tree species in the forest make it difficult to interpret the image on the basis of land cover. Moreover, most of the algorithms developed for the computer processing of landsat images have been designed for use with spectral data alone. Using other data such as soil types and slopes in the classification process may improve the accuracy of classifying non-forested vegetation in the tropical areas (Hoffer et al 1980:421), but it would require different algorithms such as the layered classifier in which spectral data are used as one phase of the classification process.

There is the other problem of data availability in the country. GIS requires data to function. In some ways the establishment of a GIS may induce the search for data but at least some data are needed to start a GIS project. Socio-economic data which are required to supplement data on the physical environment to undertake integrated land use analyses

are limited to very old census reports. Topographic maps available in the country are old. The map procured for the case study was printed in 1976. All measurements on the map were calibrated in the imperial system and this caused much complication in the integration of data from the TM 5 image and the locally produced maps. It was also difficult to correct the TM 5 image geometrically with information from the local maps. Most roads which appeared as paths or tracks on the topographic map had been reconstructed by the time the satellite data was taken in 1986. Consequently, the positions of the roads changed in the TM 5 image. It was thus realized that the satellite data can be used to update the existing topographic maps of the region.

5.4.4 Social implications.

Mckenzie and others (1982) have explained that micro-computers can assist rural dwellers establish control over the development process in their locality by helping them gain control of the information needed to plan and manage resources. However, the extent to which rural dwellers in Ghana could gain control over decision making processes with the adoption of remote sensing and GIS technologies is debatable. It would be difficult for the farmers to control the decision making process in their localities because the funds to acquire the land information system would come from the government. It is the government that controls

development planning in the country and therefore decisions about projects and the data to be collected for planning remain with it. Thus Fox (1991:69), quoting Danziger, rightly stated that computers tend to reinforce not only the structure of control but also the prevailing political and organizational biases of existing governments.

The application of GIS and remote sensing technologies is not independent of social, economic and political structures which influence their use (Davey 1991:387). The structures influence the directions which technological research and development would go in the country. For instance, the adoption of remote sensing and GIS systems to process data would affect the way decisions are made and passed on to the public. The adoption could also open up the activities of some government departments and organizations to public scrutiny and may lead to the demand for more accountability. For example, the forest monitoring capabilities offered by remote sensing and GIS technologies could reveal the impact of farming, logging and mining activities on the forest. Such revelations could cause a public outcry for a change in the method of allocating forest to the various export-oriented activities in the region. This might prompt the government to restrict the dissemination of such information. Thus while the technologies could be used to process and display information which could facilitate decision making, they could also offer information which make

other decision making processes difficult.

A successful implementation of remote sensing and GIS in the country would necessitate a change in the current structure and function of administration in the country and in the manner data on land resources are compiled and stored. Akom (1982) reported in a study on information systems for planning in the country that the various Departments of administration in Ghana carry out independent plans for development projects. Data collection on such vital areas as rural development and land use is not coordinated. For instance, Akom (1982) stated in his study that the Department of Agriculture and the Central Bureau of Statistics collect data on the prices of similar agricultural products produced and sold in the country. The fragmentation of data and the duplication of data collection among various Departments of Government would make it difficult to adopt GIS and remote sensing technologies for regional or national level planning in the country.

There are also fears from potential users that once both technologies become widely applied in the country, the traditional knowledge in survey and cartographic methods which has been acquired over years of practice would be substituted for operations performed by remote sensing and GIS systems. People's anxiety are increased by possible job losses and the loss of knowledge and experience gained through surveying and mapping.

5.4.5 Economic problems.

The prospects for the application of remote sensing and GIS technologies in the country are limited due to the lack of appropriate data on resources. Remote sensing applications in the country have mainly involved aerial photography and very few of the satellite remote sensing applications have been without a considerable assistance from donor agencies and governments. The funding needed to set up GIS and remote sensing projects in Ghana may come from international agencies as it has been with the provision of satellite data in the past. Whether or not remote sensing and GIS technologies could be successfully implemented would thus depend on the choice to be made between spending grants or borrowed money on more demanding social development programmes or on the establishment of remote sensing and GIS centres.

The absence of satellite data receiving stations in sub-Saharan Africa means that the images are obtained either through a third party or received too late to be of much benefit to users in the country. There is also the problem of lack of roads and other basic infrastructure in the country. This is particularly so in the forest region where resource exploitation has created several land use problems. The supply of electricity is very intermittent especially during periods of drought. These shortcomings would tend to limit the chances of successfully adopting the remote sensing and GIS technologies in the country. They also raise

questions with regards to how the processed information on resources, environmental and economic conditions of the country could be effectively utilized to enhance land use planning in the rural areas of the country.

Another area of concern for the adoption of the remote sensing and GIS technologies in the country is the manpower and training requirements of the scheme. In the developed countries, the development of these technologies is carried out in local Universities and Research Institutes where applications are supported by continuous research and the training of personnel. This ensures easy adoption and continuous development in the methods of application. In Ghana, it is the government departments and agencies which have begun to install these systems with the help of international agencies. For instance the first GIS unit in the country has been established at the Environmental Protection Agency with financial assistance from the United Nations Development Programme (UNDP) (University of Ghana 1989:3). The training of personnel is therefore carried out outside the Universities by International software companies who have little or no knowledge about conditions in the country. But for the remote sensing and GIS technologies to be effectively utilized in planning in the country, training programmes on the limitations and functions of the systems would also be needed for policy makers, planners, programmers and technicians.

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CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS.

6.1 Summary.

This study sought to examine the opportunities and constraints to the adoption of remote sensing and GIS technologies in facilitating land use planning in the forest region of southern Ghana. It has been established that the weak Ghanaian economy, which necessitates the exploitation of the forest resources for development, emphasizes the needs for timely and accurate data on the environment and resources to facilitate effective land use planning. The information needed to carry out integrated land use planning is generally lacking. The study revealed that remote sensing and GIS systems can be effectively employed to collect, process and present data to support decisions on land use in the forest region. It, however, became apparent in the course of the study that several problems will have to be addressed before both technologies could be efficiently and effectively utilized in land use planning in the country. The problems include lack of financial resources to undertake such projects, unavailability of skilled personnel to use and maintain the hard and software systems, lack of basic data on the socio-economic conditions and the land resources of the forest region and administrative bottlenecks that may restrict the adoption of the systems in the country.

6.2 Recommendations.

The study recommends the following measures for the adoption of the remote sensing and GIS technologies in the country.

1. To overcome the perennial problem of inadequate financial resources to establish such projects, it would be necessary for Ghana and other countries in the West African subregion to enter into or strengthen existing bilateral and regional cooperative arrangements in remote sensing and GIS applications. Ghana and her neighbours could pool resources to improve facilities at remote sensing training centres at Oagadougou in Burkina Faso and Ille Ife in Nigeria. Within the regional cooperation arrangement, it should be possible to undertake the training of personnel, set up data processing centres within member countries and undertake common research projects to enhance development within the subregion.

2. Remote sensing, GIS and related studies in computer technology should be introduced at all levels of education in the country. Such studies should form an integral part of university education and should include the development of hard and software systems, application methods, maintenance of hardware systems and data modelling. Remote sensing and GIS training facilities should be provided in the universities and research institutions in the country so that it would be possible with the training, to develop appropriate models to facilitate land use planning in the country.

3. Efforts should be made to collect and store data on the country's resources to facilitate remote sensing and GIS applications in the country. Perhaps initially, the remote sensing technology could be used to take an inventory of the country's natural resources. To avoid the duplication of efforts at data collection within government establishments, the Central Bureau of Statistics department should be strengthened and empowered to set up a national data bank. Uniform standards and criteria for collecting, monitoring and storing data should be established for all departments. The coordination of efforts at data collection should involve all district, regional and national planning units.

4. In view of the financial and human resource situation of the country, it would be better to adopt an incremental approach to the adoption of the remote sensing and GIS technologies in land use planning in the country. The systems could first be installed at a geography department in a university or in a government department where the people are already familiar with maps. Once installed, the project could serve as a demonstration for other departments and users. The small unit could later evolve into an integrated land information system.

5. In spite of the fact that remote sensing and GIS appear to provide a more rapid means of response to the data needs of the country, the conventional cadastral methods and traditional surveys should not be abandoned. The adoption of

the new technologies should be seen as supplementing the existing conventional methods.

6.3 Conclusion.

The forest region of southern Ghana is an area of rapid change, particularly with respect to its land resources and land use. Rapid population growth, poor methods of farming, mining and logging have caused several land use problems and widespread deforestation. Addressing these problems would require efficient land use planning based on accurate and reliable data. Remote sensing and GIS technologies could be employed to provide a cost-effective and efficient means of addressing the data needs for land use planning in the region. Certainly, there are many problems to be addressed if the two technologies are to be effectively adopted to provide a database of land information to facilitate land use planning. The greatest need, however is for the country to be receptive and adaptive yet cautious in its approach to the adoption of both technologies.

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APPENDIX A
SOURCES OF DATA FOR THE CASE STUDY.

The dataset that was used for the Case study consisted of:

1. Landsat Thematic Mapper 5 scene taken on December 19, 1986 obtained from the Technology transfer and International Development Section of the Canadian Centre for Remote Sensing, Ottawa.
2. Soil map at 1:125000 and Soil Survey Data from the Soil Research Institute at Kwadaso, Kumasi, Ghana.
3. Topographic maps at 1:50000 and 1:625000 dated 1976 obtained from the Survey Department, Ghana.

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