LAND USE/ LAND COVER DYNAMICS DUE TO POPULATION GROWTH AND CONSEQUENT EXPANSION OF AGRICULTURAL LAND IN MINDIF REGION OF NORTHERN CAMEROUN

BY

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CERTIFICATION

This dissertation entitled **'Land Use/Land Cover Dynamics due to Population Growth and Consequent Expansion of Agricultural Land in Mindif Region of Northern Cameroun'** meets the regulations governing the Award of Master of Technology in the Department of Geography, Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to My Mother, for being the best mother I could think of and to my Uncle, Dr Mouhaman Arabi, for helping so much in completing this work.

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First all, I would like to say how fortunate I fell to have the opportunity to complete this work and for this I must thank the Almighty ALLAH (SWA). I am particularly indebted to my Supervisor, Dr. H. Saba who never lost faith in me and suggested correction that enable me complete this work.

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ABSTRACT

The study was carried out in the Mindif region of the extreme northern province of Cameroun. The aim was to analyze temporal dynamics and identify driving forces for land use and land cover changes between 1975 and 2002. A combination of field work, interview schedule, and GIS/Remote Sensing Techniques were used. Information collected from the interviews was used to explain and understand the digital results. It was found that the study area witnessed an important conversion of woodland to cropland, and that the more population grows, the more land is reclaimed for agriculture. The increase of cropland land between 1990 and 2002 was more than 80% of what was observed between 1975 and 1990. Scrubland slightly increased as woodland decreases. A correlation coefficient of the order r = 0.96 was found between cropland and population, meaning that population strongly determines increase in cropland and that 92% of the variation in the cropland is determined by population increase. Besides, a perfect linear relationship with a correlation coefficient r of 0.952 and a coefficient of determination R of 0.907 was observed between woodland and cropland, meaning that increase in cropland causes the decrease of woodland at about 90%. Despite the observed degradation of woodland in the study area, the people in the study area seem not to care about it as no action is been taken. In view of this, the study recommends a strict monitoring of farming and fuel wood collection in the study area.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Human history reveals an escalating trajectory of alterations and transformations of the earth that sustains life (Annenkov and Jelecek, 1985 reported by Turner II *et al*. 1990). This trajectory has not been uniform, however, but has been punctuated by periods of rapid increase in the scales and rates of change, usually concentrated within specific regions of the world. The issue of land use and land cover is of paramount importance to environmental issues on all spatial and temporal scales (Watson, 1996 in Fresco *et al*, 1996).

In recent years, there has been a virtual explosion of concern about environmental deterioration in the world. These environmental problems include deforestation, soil erosion, desertification, loss of soil fertility and bio-diversity, urban air and water pollution among others. The productive potential of many natural ecosystems and agricultural lands have been declining due to land use change.

In Africa, the most vulnerable and most affected part of the continent lies within the Sudan-Sahelian zone (Agyepong, 1996). The Sahel is susceptible to land degradation as a result of natural and human induced processes. The seasonal and annual variability of rainfall and the corresponding mobility of the animal and human population produce substantial spatial and temporal variability of degradation affecting the environment.

In the Extreme-northern Province of Cameroun, which is in the Sudan-sahelian part of the country, population increase creates a continually need for fuel wood and arable land for agriculture. The woodlands witness therefore an intensive exploitation with an estimated population of 2,900,000 inhabitants in 2002 (MINEPAT, 2002), 80% of the population relies on agriculture for their subsistence and on fuel wood for domestic energy use. The survival of the woodlands is also threatened by natural conditions such as prolonged dry seasons, erratic rainfall, drought and desertification typical of the Sahel regions. These have led to a shortage of wood resources and space for grazing.

The Mindif region is witnessing changes in land use and the natural vegetation cover. However, despite the seeming degradation of natural vegetation, there is a scarcity of reliable data on the problem. Very often general hypotheses are presented (Mvondo, 2000). The monitoring of this situation necessitates reliable information about the exploitation of both the temporal and spatial changes. There is therefore a need to understand the nature of changes affecting the land use and land cover.

1.2 Aim and objectives

The aim of the study is to identify and analyze temporal dynamics and the driving forces of land use and land cover changes in the study area. In so doing, the study intends to achieve the following objectives. They are:

1. To produce map of the land use and land cover dynamics between 1975 and 2002,
2. Examine these changes with regards to possible linkages with the farming and fuel wood collection,
3. Examine people's response to the observed changes.

1.3 Justification of the study

The contribution of this work will be at three levels. The study intends to draw the attention of both the government and the people of Mindif on the degradation of natural vegetation cover dynamics to appreciate the rate of change in the study area and be able to make comparison with other case studies. The study will also create awareness about people's perception of environment changes in Mindif subdivision.

1.4 Statement of research problem

Rapid human population growth in the Sudan-sahel in general and in the Extreme-northern province of Cameroon in particular has created an increasing need for fuel wood and arable land for agriculture. In the Mindif subdivision when the population density was low, land was abundant and met the needs of the population. Problems of land degradation, management and exploitation were not observed. Presently cultivated fields have increased at the detriment of grazing areas and woodlands; such that some indigenous pasture areas have almost disappeared (Mvondo, 2000).

In order to ensure a sustainable land use, it is essential to understand the processes leading to the creation of new farms. There is however a dearth of reliable information about the dynamics of land use and land cover in the Mindif region.

Very few studies such as Seiny (1990), Ntoupka (1994), Donfack (1993) and fotsing (1997) were carried out in areas not very far from the Mindif subdivision. None has really addressed the dynamic of land use and land cover time and space. Seing (1990) for example studied the hydraulic regime of soil in Muda region relating agricultural practices to soil erosion. Ntoupka (1994) studied the dynamics of woody savannah in laf Region, relating the available vegetal species to human activities such as grazing, bush fire and fuel wood collection. Donfack (1993) studied a fallow land investigating the semi-natural ecosystems in relation to the type of soil and human interference. It is therefore essential to examine the spatial and temporal dynamics of land use and land cover in Mindif in order to understand the driving forces leading to the changes.

1.5 Scope and limitations of the study

The study will be carried out in the Mindif subdivision, in the extreme-northern province of Cameroun. The spatial evolution of cultivated areas and natural vegetation cover will be assessed for a period of 27 years between 1975 and 2002. This will be done through the analysis of the relationship between population growth and the evolution of cultivated areas on one hand, and the relationship between cultivated areas and the natural vegetation on the other hand.

The main limitation of the study is the fact that all images available were taken during the dry season. It would have been interesting to distinguish between wet and dry features but the shortage of materials and time could not allow such investigation althrough the field investigation reflect part of the rainy season features since it was done in the early part of that season . It was only possible to undertake a general assessment of the various land uses and land cover types.

1.6 Description of the Study Area

This study was carried out in the subdivision of Mindif in the extreme-northern province of Cameroun. The area is precisely located between Latitudes 10° 10' and 10 ° 40' north and longitudes 14° 10'and 14 ° 50' east (Figures 1 and 2). This area is characterised by a vast plain with a mean altitude of about 425m above mean sea level. Very few mountains are found, the highest peak is 769m. The rivers drain or flow from west to east, and are characterized by seasonal rivers and streams locally known as Mayo.

The climate of this region is that of the Sudan Sahel type, with a long dry season and a short rainy season. The dry season lasts from October to May, while the rainy season starts from June and ends in September with a mean annual rainfall of 800mm. The temperature is generally high most of the year with a mean of 28 ° C (MINREST, 2000).

The vegetation comprises two distinct strata: a woody stratum made up of a variety of trees and shrubs such as *Acacia seyal, Tamarindus indica (Tamarind tree)* and *Balanites aegyptiaca*, and an irregular herbaceous stratum with some bare spaces locally called "*harde* " made up of species such as *Andropogon, Loudetia togoensi*s, and *Aristida.*

The population was estimated at 61, 000 people in 2002. About 75% of the population engages in agriculture and cattle rearing. Agriculture plays a very important role in the subsistence and exchange economy of the population as a source of food and revenue. Guinea corn, millet, maize, beans and cotton are the main crops cultivated.

Slash and burn is the major method of cultivation. Animal traction and manual labor are used in the farming. Mindif is also an excellent zone for cattle rearing because of its important herbaceous stratum. Animals such as cattle, sheep and goats graze on natural pastures during the rainy season and on the remains of farms after harvest during the dry season.

1.7 Structure of the work

This work is subdivided into five chapters. Chapter one introduces the work where the statement of research problem, the aim and objectives, and the research questions are explained, it also indicates the scope and significance of the study. Chapter two explains the conceptual framework and reviews the literature of past work. Chapter three presents the methodology. In chapter four, data are analysed; the results are presented and discussed. Chapter five summarizes the work, and concludes with some recommendations.

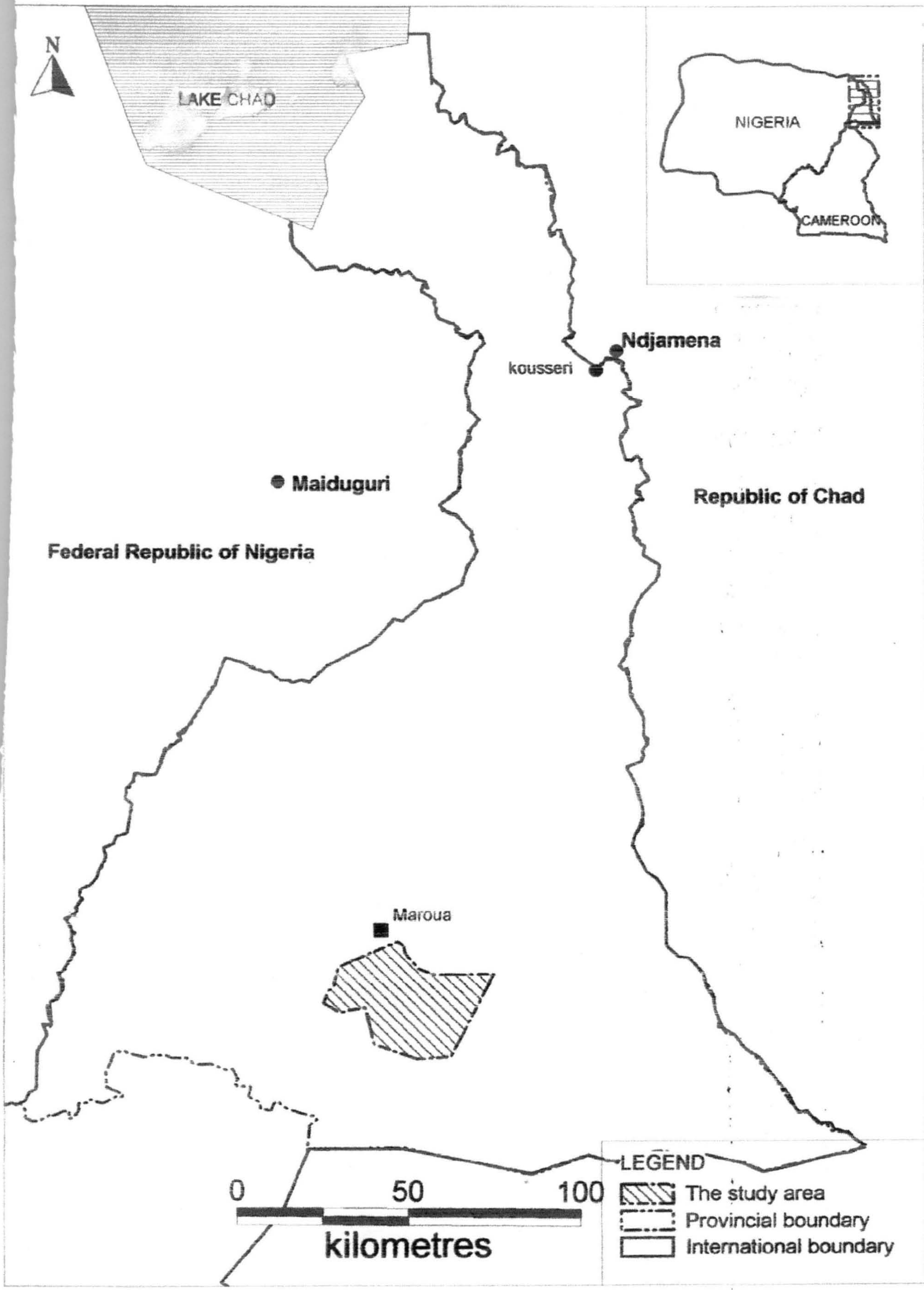


Figure 1: The location of the study area

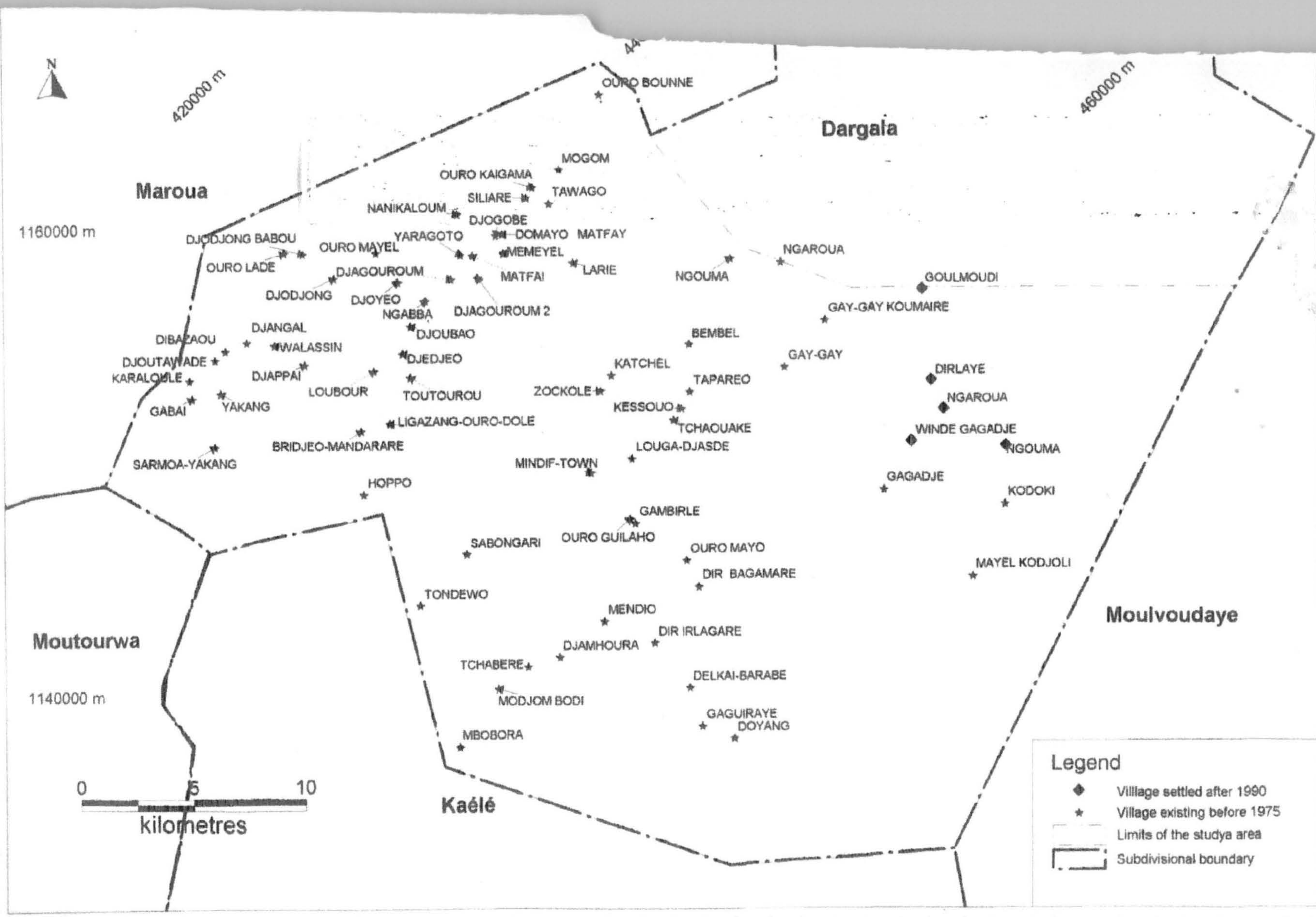


Figure 2: The location of the villages in the study area

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual framework

One of the earliest conceptualization of the effects of population growth on agriculture and economic development is that of Thomas Malthus. He stated that population tends to grow geometrically and food production arithmetically, so the former tends to outrun the later over time. Malthus thus viewed agriculture as continuously expanding into increasingly inferior lands over time, tending to result in a decline in average land productivity (Bilsborrow and Ogendo, 1992). Malthus considered an increase in the land under cultivation, as a response to an increase in population pressure. This is achieved by either clearing more of one's own lands or migrating to other areas to develop new lands for agriculture. Boseerup (1965) reported by Bilsborrow and Ogendo (1992) postulated that as population grows land becomes scarce, relative to the population and is therefore used more intensively.

In a study of land use and land cover change in the Great Plains of the United States of America, Riebsame *et al.* (1994) conceptualized land use change as:

$$I = PAT,$$

where Impact (I) or change is the function of Population (P), Affluence (A), and Technology (T).

This formula embodies the conventional emphasis on economic factors such as production and consumption. Other researchers like Meyer and Turner (1992) have recognized the need to expand the notion of driving forces to encompass all realms of social life, especially people's aspiration, perception, and attitudes and features of social and political institution, such as how land is divided within families or how the government taxes inheritance. Malthus' theory and Meyer and Turner (1992) recognitions will be considered as basis for the present study.

As soon as humans use land, the question arises as to what extent human extractions and disturbances interrupt the ecosystem's capacity to evolve (Fresco and Kronenberg, 1992). Humans have expanded their activities into all corners of the biosphere, and today land use and land cover changes are major significant driving agents of global environmental change (Skole, 1996 reported in Fresco *et al.*, 1996). Land use and land cover changes have been addressed by the scientific community in different parts of the world. Various researchers have worked at global, regional and local scales in different ways and have come out with valuable findings.

2.2 Definition of land use and land cover

Trebuil (1994) defined land use as human activity associated with a specific piece of land. He also defined land cover as the type of feature present on the surface of the earth. Ludeke and Plohl (1996) defined land cover changes as the conversion of natural vegetation to agriculture and the anthropogenic degradation of the natural vegetation.

Helmut and Lambin (2001) defined land cover as the biophysical attributes of the earth's surface and land use as the purpose or intent applied to human activities that directly alter the physical environment. Sanderson (1996) reported by Fresco *et al.* (1996) stated that land cover change is the result of driving forces expressed at multiple scales. Proximate determinants include changes in population size and choice of land uses.

2.3 Population growth and land use change

According to Bilsborrow and Ogendo (1992), there are four phases involved in the response of land use practices to population growth, each involving several adjustments, many of which are consecutive and others concurrent, and some even cumulative. The four phases may be classified as: tenurial, land appropriation, technology, and demographic.

The statement that population pressure on land use is likely to be felt first through changes in tenure arrangement is based on the fact that:

(1) pressure exerted on land by a growing population of necessity generate questions about individual and group entitlement to growing scarcity of land, and

(2) out migration is not a desirable option. Being at the centre of economic and social security in predominantly agrarian systems, the right of access to, and control of land i.e., tenure is the key to decision-making about its use. Ogendo (1990) reported in Bilborrow and Ogendo (1992) stated that the analysis of agrarian systems characterized by rapid population growth, high density per unit of land, and low net out-migration rates, suggest that the tenurial phase of population/and use may involve any or all of the following adjustment: the first is toward retention of substantive equity in terms of space and distribution. In the face of external and internal stimuli, tenurial regimes will initially respond by trying to accommodate present and future claimants, and use pattern of the resources of the community in question. Ideal lands may be distributed for agricultural use for example. The second involves a general reduction in the operational space to which different claimants are entitled. The quality of access in terms of the use function, to which the land rights of all inhabitants correspond, remains the same. This involves a general reduction of a new category of access rights of the reclassification of old ones. In this stage the tenure regime will thus try to restore equilibrium in man-land ratios by making more resources available to permanent or traditional members of the community at the expense of other members (Mackenzie, 1989) reported in Bilsborrow and Ogendo (1992).

The second major phase of adjustment is termed land extensification, the appropriation of land rights, usually in frontiers not controlled by, or perceived as available to a given community. This occurs as soon as communities no longer have a sufficient stock of land in its immediate area for future claimants. Thus, in areas where there remains land that is both arable and physical accessible, extensification of agriculture may occur involving out migration (rural-rural) of families to unoccupied lands and often land conflicts with existing, indigenous population groups may result.

The third phase, which involves the adoption of new technologies of land use, is often a measure of social and cultural flexibility in society. It is not therefore always a response to external stimuli. For this reason agrarian communities in Africa and Latin America for example have been known to accept the introduction of cash crops in place of subsistence crops without fundamental changes in tenurial regime. Boserup (1965), reported in Bilsborrow and Ogendo (1992) suggested that the distinctive feature of technological changes associated with population growth is that it is accompanied by intensification, which is an increase in land productivity. Technology represents, therefore a more advanced phase in land use management.

The demographic phase is usually, in the absence of outside intervention, the last response in the population land use continuum. Davis (1963) reported in Bilsborrow and Ogendo (1992) observed that this involves fertility reduction through either postponement of marriage or reduction in marital fertility, or both. The extent to which this phase occurs is interrelation to land intensification and to the adoption of new technologies. This is in the sense that (a) out migration is an alternative to fertility reduction and (b) intensification makes possible the survival of a larger family unit.

Bilsborrow and Ogendo (1992) added that the context directly influence what types of response occurs. That is major determinants of the extent to which land tenure changes, extensification or intensification of agriculture takes place. The forms in which they occur, and whether demographic factors play a significant role or not include land quality and quantity, topography, climate, institutional and attitudinal factors deriving ultimately from the country's history. These include the prevailing land size, the existing tenure arrangements and community control, and government policies including how they mediate the effects of international factors. Bilsborrow and Ogendo (1992) concluded that the greater the land resources available and potentially arable, the more likely are extensification instead of intensification.

2.4 Importance of vegetation cover

Vegetation is, in terms of penology the composition of communities and fractional cover, a sensitive and early indicator of climate variability. Changes in the composition of vegetation communities are probably the most sensitive indicator of environmental variability. Vegetation cover provides means of subsistence to a considerable number of people in the world (FAO, 1994 reported in Mbairamadji 2000). It contributes to the maintenance of the hydrologic cycle, to the conservation of biodiversity, to ecological equilibrium, and to cultural values and natural patrimonies (Mbairamadji, 2000). Vegetation also provides considerable quantities for forage for animal feeding and medical use. The international Union for Nature Conservation (IUCN *et al,* 1991 reported in Mbairamadji 2000) stated that the quantity and the values of goods and services provided by the vegetation cover are difficult to estimate; it offers important revenue and lays a determinant economic role in many households.

2.5 Causes of land changes

Natural forces have always influenced the earth's surface. However, man made changes of land cover are currently the most important and most rapid of all changes (Fischer, 1996 reported by Fresco *et al*, 1996). The development of knowledge and technology level of human beings has increased their ability to transform the surface of the earth.

Helmut and Lambin (2001) classified causes of deforestation in three categories. These are proximate causes, underlying driving forces and other causes. Turner *et al* (1990) reported by Helmut and Lambin (2001) argued that proximate causes are human activities that directly affect the environment and constitute the proximate source of change in land cover and land use. Helmut and Lambin (2001) observed that the underlying driving forces are social processes that are seen as a complex of social, political, economic, technological, and cultural variables that constitute initial conditions in human-environment relations that are structural in nature. The group of other factors is composed of predisposing environmental factors such as land characteristics, features of the biophysical environment, and sudden shifts in human-environment condition. These could be of social nature like wars, abrupt economic changes, or biophysical drivers like drought or forest fires.

Miklewski and Miklewska (1996) argued that land cover change is driven by a multitude of processes. Vegetation growth or clearing for example results in the alteration of its cover due to natural changes in climate and soil. In the past, major land conversions have occurred as a consequence of deforestation resulting from land clearing to convert land for crop and livestock production, conversion of land for habitation, infrastructure and industry, and the exploitation of land for minerals. More subtle processes, termed land cover modification affect the characteristics of land cover without changing its overall classification. There can be for example the invasion of new species in a given area, or a decrease of the density of the vegetation cover as a result of change in climate conditions or due to natural selection.

Walker (1996) observed that environmental changes arise from a variety of reasons, but the human demand for land is a key factor. Wood (1998) suggested that the relationships between population and deforestation are medicated by the types of economic activities that people perform, and a host of additional factors such as tenure security, the availability of investment capital and access to markets.

Davis (1963) reported by Bilsborrow and Ogendo (1992) developed "the theory of multi-phase response" to explain the inter-relations between population and environmental changes by explaining how people in Japan and Western Europe responded to threats to their living standards in the 19^{th} and 20^{th} centuries. He postulated that they would change their demographic behavior by postponing marriage, reducing fertility or out-migrating. Davis thus concluded that several responses could occur simultaneously. Boseerup (1965) reported by Bilsborrow and Ogendo (1992) on the other hand postulated that as population grows, land becomes scarce, relative to population and is therefore used more intensively.

Leonard (1987) reported by Bilsborrow and Ogendo (1992) provides evidence from Central America, attributing the loss of forest cover broadly to a combination of population growth, economic expansion, and government policies. The high human concentration in these highlands regions resulting from both population growth and extreme landholdings is associated with the deforestation of all trees on small mini fundia farms. Mendez (1987) reported by Bilsborrow and Ogendo (1992) found out that a correlation between population density and the extent of deforestation significant in a study carried out in Guatemala.

The decline of population density in a given area favors the regeneration of the natural vegetation. This position was held by Duguy (1998) when studying the patterns and driving forces of land use change in Eastern Spain between 1956 and 1994. He found that an important decrease of crop's areas (-45.5%) led to the increase of low and medium cover shrub land's (+55%) and made easier the afforestation with pines. This change occurred as a result of rural exodus, which affected most of the rural areas in Spain during the sixties and caused extended crops abandon.

In the case of Brazil, the influx of migrants into the Amazon has resulted in clearing of vast stretches of tropical forest. However, the association between demographic increase and land cover change is neither linear nor straightforward. The relationships between population and deforestation are mediated by the types of economic activities that people perform, and host of additional factors such as tenure security, the availability of investment capital and access to markets (Wood, 1996). In Africa, the most vulnerable and most affected part of the continent lies within the Sudano-sahelian zone. The Sudano-sahelian zone is susceptible to land degradation as a result of natural and human induced processes. The seasonal and annual variability of rainfall and the corresponding mobility of animal and human population produce substantial spatial and temporal variability of degradation affecting the environment like deforestation and soil erosion.

In sub-Saharan Africa, complex interactions have been observed in several parts of the continent. The case of Kenya for example supports several propositions: population growth and higher density or population pressure contributing to, but are not always the agents of catastrophes such as flooding. The effects are always mediated by land tenure arrangements, natural resource availability, and technology (Bilsborrow *et al*, 1992).

Arid and semi-arid savannahs in sub-Saharan Africa are recognized as being particularly dynamic ecosystems. These range land ecosystems undergo rapid and extensive shifts between multiple alternative vegetation stages as a result of highly variable and unpredictable rainfall, herbivore populations, bush fire and other influences. In many of these areas there has been a major land use conflict between conservation and development (Homewood and Brockington 1996).

Agyepong, (1996) said that the extensive conversion of the vegetal cover in Ghana is the result of the inability of the traditional system of land use, the bush-fallow system, to adapt to the forces of increasing population, urbanization and the monetization of the economy. As a result of this cropping system, the entire closed forest outside the 16,788 km^2 hectares of protected forests has been converted. The effect is generally indicated in the deterioration of soil quality, productivity per unit effort and the degradation of the environment.

2.6 Consequences of land use and cover change

Land use changes such as the expansion or intensification of agriculture have caused and continue to cause severe effects in most of the human and natural sectors of global system (Ladeke and Plochl, 1996). Direct effects in different natural sectors are for example the erosion of soils, the population or groundwater, the enhancement of atmospheric carbon dioxide concentration and loss of bio-diversity (Ladeke and Plochl, 1996). In many cases, these degradation processes yield responses in the human sphere such as migration, urbanization and economic marginalization, which may again induce new land, use changes (Ladeke and Plochl 1996).

While investigating these problematic man-environment interactions in the Sahel, Ladeke and Plochl (1996) found that the situation is characterized by the vicious circle of soil degradation leading to economical marginalization of subsistence farmer who have no alternative except to intensify and expand the agricultural use of marginal land, again leading to further soil degradation.

Land cover change from natural vegetative cover to human use, affects the availability of natural inputs in ecosystems, facilitation of exotic species invasions, and accelerates natural processes of ecosystem change (Walker, 1996). Urban expansion into natural areas alters flows of water, energy, and materials, and consequently leads to numerous impacts beyond the urban boundary.

Walker (1996) added that agricultural and urban encroachments of natural areas whether leading to outright conversion of modifications of land cover, radically alter nearby ecosystems and cause regional transformations in environmental quality. According to him, land cover change and associated environmental impacts are especially pronounced where rapid urban growth occurs in close proximity to land with extensive ecological resources.

General concern exists over the negative ecological effects of land use that require drastic conversions of vegetation cover. Changes in vegetation cover in turn leads to problems of soil productivity and pests at the agricultural plot level. At the regional level the changes cause losses of flora and fauna, soil erosion and changes in the hydrology. Losses in bio-diversity and carbon dioxide emission are noticed at the global level. Changes in land use and land cover can affect bio-diversity at all three levels: genetic, species and ecosystem.

In a study carried out in Mexico, Ochoa-Gaona *et al,* (1996), documented the trend or replacement of humid old-growth, oak dominated by dry pine-dominated stands. They found that the total species richness is slightly higher in old growth than in higher perturbed pine-dominated stands located in similar climate and edaphic conditions.

Seiny (1990) in a study of the hydrologic regime of soils in the area of Muda in Extreme-North Cameroun, found that the agricultural practices of people in that area cause the physical degradation of the upper layer of the soil. Therefore the erosion that follows causes the loss of fertility of soils.

Ntoupka (1994) in a study of the dynamics of a woody savanna in the area of Laf in the Extreme-North Province of Cameroun, stated that the vegetal species of the area are a product of the selective processes of human activities such as man made bush fire, fuel wood collection and animal grazing.

Conversion of less-used landscapes to those dominated by crops and livestock appear initially to increase species and landscape diversity however, at high levels this conversion decreases diversity (Reid, 1996). Species are both lost and gained during this conversion, with large-bodied species most affected. According to Reid (1996), during this conversion, farming systems that are the most structurally complex maintain species diversity at higher levels than more simple systems.

A study carried out by Donfack (1993) in a fallow land of the Extreme-North of Cameroon revealed that the semi-natural ecosystems can reconstitute themselves after a period of 12 years. However, this is dependant on the type of soil and human interference through bush fire, fuel wood collection and animal grazing.

Boren *et al* (1995) found in a hardwood forest tall-grass prairie acetone in northern Oklahoma that both native grasslands and forests were fragmented in the low density population landscape whereas forests were increasingly fragmented in the high density population landscape between 1966 and 1990. The explanation was that the cover types in most of the high density population areas required more intensive inputs and management, which resulted in a landscape with lower diversity, higher homogeneity, and greater patch fragmentation compared to the low density areas.

A work carried out by Kosmas and Cerontidis (1998) in the island of Lesvos in Greece revealed that olives trees extended over areas occupying land, which was previously devoted to pasture and annual crops, and that between 1986 and 1996 the area cultivated with olives increased by about 15%. Also, deciduous oak forests were extended during this century as chemicals produced from acorns were used in a thriving leather industry. The total area of pine forests did not change, however their geographical distribution has slightly changed.

Patterson and Liverman (1998), while studying land cover change in Mexico between 1970 and 1990, noted a dramatic loss of forest cover in many regions, an increase in natural and cultivated pasture, and expansion and intensification of crop production. For them land use practiced in the area was the principal cause of forest lost.

Villagers in northern Cameroun admitted that there is a selective diminution of woody species (Fotsing, 1997). This occurs through the creation of farms, fuel wood collection and natural degradation. When creating new farms, villagers do not cut all the trees. Some species like *Faidherbia Albida* are left on the farm because of their fertilizing capacity. The collection of fuel wood is also selective in the sense that some species of the acacia family are preferred because people think that they produce more heat.

A change in land cover from grass land to irrigation agriculture, exotic forests or squatter camps can affects various hydrological responses, which may result in changes in water yield and water quality of catchments areas as observed by Shulz, 1996 reported by Fresco *et al* (1996).

In most of the savannah of West Africa, conflicts over the use of crop residues, fallow land, access to dry season forages, and water are growing (Japtap *et al*, 1998). A study of feed sufficiency for livestock carried out in Nigeria by Japtap *et al*, showed that as a result of land use change in 1990, feed deficit was experienced over 15% of the area. Using projected livestock increases in 2005 and 2020, the areas of deficit are likely to increase exponentially to 33%, respectively.

All of these studies recognized that land use and land cover changes are strongly interrelated. However, people's knowledge to these changes has almost not been fully addressed in the study area. The present work intends therefore to fill in this gap in knowledge.

2.7 Application of Remote Sensing to Land Use Land Cover Change, Population Growth and Sustainability Trajectories

Among the earliest social applications of remote sensing were those addressing land-use and land-cover data derived from remotely sensed imagery that are used in conjunction with socio-economic data to identify relationships between socio-economic "drivers" (e.g. policies, demographic trends, economic factor) and changes in landscape.

The focus of this section is more narrowly on the remote sensing applications utilized by scientists in this area. Here we focus primarily on land conversion from natural (largely forested) states to other land uses, and on use of remote sensing in conjunction with other data to identify sustainability trajectories

2.7.1 Land use and land Cover (LULC) change

The greatest amount of research attention is the land-use and land-cover change arena has been dedicated to deforestation. Time series remote sensing imagery has been particularly valuable for this kind of research because conversion of forested land to other uses is in comparison to other conversions (e.g. residential to commercial uses or cropland to pasture land), or cropland to pasture land), fairly easy to detect. The most widespread application is simply to monitor the amount and rates of forest cover change between two time periods (e.g. the Forest Resources Assessment of the FAO).

To qualify as a social science application, there need to be some attention paid to the social determinants of deforestation, and not simply the rates of deforestation. This generally entails the combined analysis of remote sensing and socio-economic data. One approach has been to combine census data collected by administrative units with data from remote sensing satellites. For example, Wood and Skole (1998) used census data based on administrative units (municipals) in the Brazilian Amazon, together with forest cover change terms aggregated to those units, to identify and rank in importance the socio-economic and demographic variables associated with forest clearing. They found little correlation between population density and deforestation, but when they add a new variable (the number of migrants in rural areas), the coefficient of determination, R2 increased significantly. Their model also include a proxy variable for conflicts between small land holders and ranchers, which was statistically, suggesting that such conflicts might increase the likelihood of land clearing to establish de facto ownership of land.

Pfaff (1999) combined aggregated forest change terms from remote sensing data and included both population and economic variables in his analysis of deforestation in the Amazon. The major empirical finding was the importance of land characteristic (soil quality and vegetation density) and factors affecting transportation costs. Government development projects also appear to have an effect on deforestation rates.

One problem with utilizing available data sets from census and other sources is that researches might miss important casual variables that are not included in public data sources. Wood and Skole (1998) explore this issue, and suggest that one approach is to use models based on agricultural and population census data, and then to visits administrative units that are outliers in the model (those with large error terms) to identify what explanatory variables might be missing from their models. In this way the predictive model can be made more robust.

Another problem with using public source data is that, for confidentiality reasons, such data are usually aggregated to standard administrative units (such as country census tract). In order for the social science and remote sensing data to correspond to one another, the remote sensing data need to be aggregated and analyzed at the same level (e.g. countries in the Amazon basin, Rindfuss *et al.* 2001). This means that researches lose the ability to pinpoint causal variables at a finer scale, such as decisions made by individual land holders or communities, to that particular pixel or group of pixels. In an ideal world, one would ask a much closer spatial congruence between the independent variable (e.g. the socio- economic determinants) and the cover change occurring at the smallest unit available (e.g. the 30m resolution of a landsat TM pixel).

To address these problems, several research teams have invested significant resources in farm property and household level surveys, which then are linked to remote sensing imagery at either the same or higher levels. If the locations of household plot are spatially registered using a Global Positioning Satellite (GPS) unit, then linking this to the survey data and to spatial coordinates in the remote sensing image is relatively straight forward. This general approach has been used by Moran and Brondizio (1998) and McCracken *et al* (1999) in the Brazilian Amazon; by Walsh *et al* (2000) in the Ecuadorian Amazon; by Southworth and Tucker (2001) in Honduras; by Entwistle *et al* (1998) and Rindfuss *et al* (2002) in Thailand. Each of these studies is briefly examined below.

In Moran and Brondizio's research, the remote sensing imagery itself is used to identify the potentially fruitful areas for field research. They chose Landsat scenes in which there was an identifiable soil and vegetation gradient, and with representative patterns of land use and population distribution. They then sampled within those scenes, choosing locations then household characteristics. They discovered a high correspondence between soil fertility and rates of secondary succession; they were also able to identify economically important land uses that would have been invisible to a pure remote sensing image interpretation.

A team of researcher sat the Anthropological Centre for Training and Research on Global Environmental Change (ACT) overlaid a grid of property boundaries onto Land sat scenes for 1985 and 1991 in a GIS format (McCracken *et al.* 1999). Analysis at the property level found patterns of land-cover classes that reflect differences in live hood strategies of households. The overlay itself represented an integration of social data (property lines) with biophysical parameters (forest cover). This was supplemented with surveys of plots where unusual pattern were found. Through this work they were able to identify differences in land use patterns based on the life cycle of the household (from young, nuclear families to older, intergenerational families). Younger families tend to clear land at higher rates initially, and to maintain more in annual crops, moving eventually into combinations of cropping and animal husbandry (grazing), whereas older, more established families have a more diversified portfolio of land uses. Furthermore, there is an important interaction between the cycle and the initial conditions of soil fertility's with the families on richer soils having a more diversified portfolio than those on very poor soils. Thus, it is the interaction of demographic and biophysical variables that plays a significant role in the level of diversification of portfolios.

Walsh *et al.* utilize longitudinal survey data (1990 and 1999) coupled with remote sensing imagery (Landsat, SAR, and IKONOS), GIS techniques and layers of biophysical factors and transportation infrastructure to identify the determinants of agriculture intensification into the Ecuadorian Amazon, and to model future land-cover change. The strength of their research rests upon the longitudinal approach. The 1990 sample included 419 settler plots. These plots were revisited in 109 peri-urban parcels). Unlike McCracken et al. the data on land cover characteristics for the parcels were not derived from remote sensing imagery, but from the farm-level surveys. The remote sensing data were used primarily to measure landscape-level changes in land cover, and to generate pattern metrics using Fragstats. As an indication of the rate of deforestation, in 1996 one-half of the landscape was still under high density forest cover, by 1996 the proportion was only one third. Based on the survey data, they found that plots more distant from roads and in hillier terrain generally have proportion forested. Household labor and presence of hired labor both had a negative effect on forest cover, while off-farm employment had a positive effect on forest cover. This rich data set also provides windows into livelihood strategies and a myriad of other research questions.

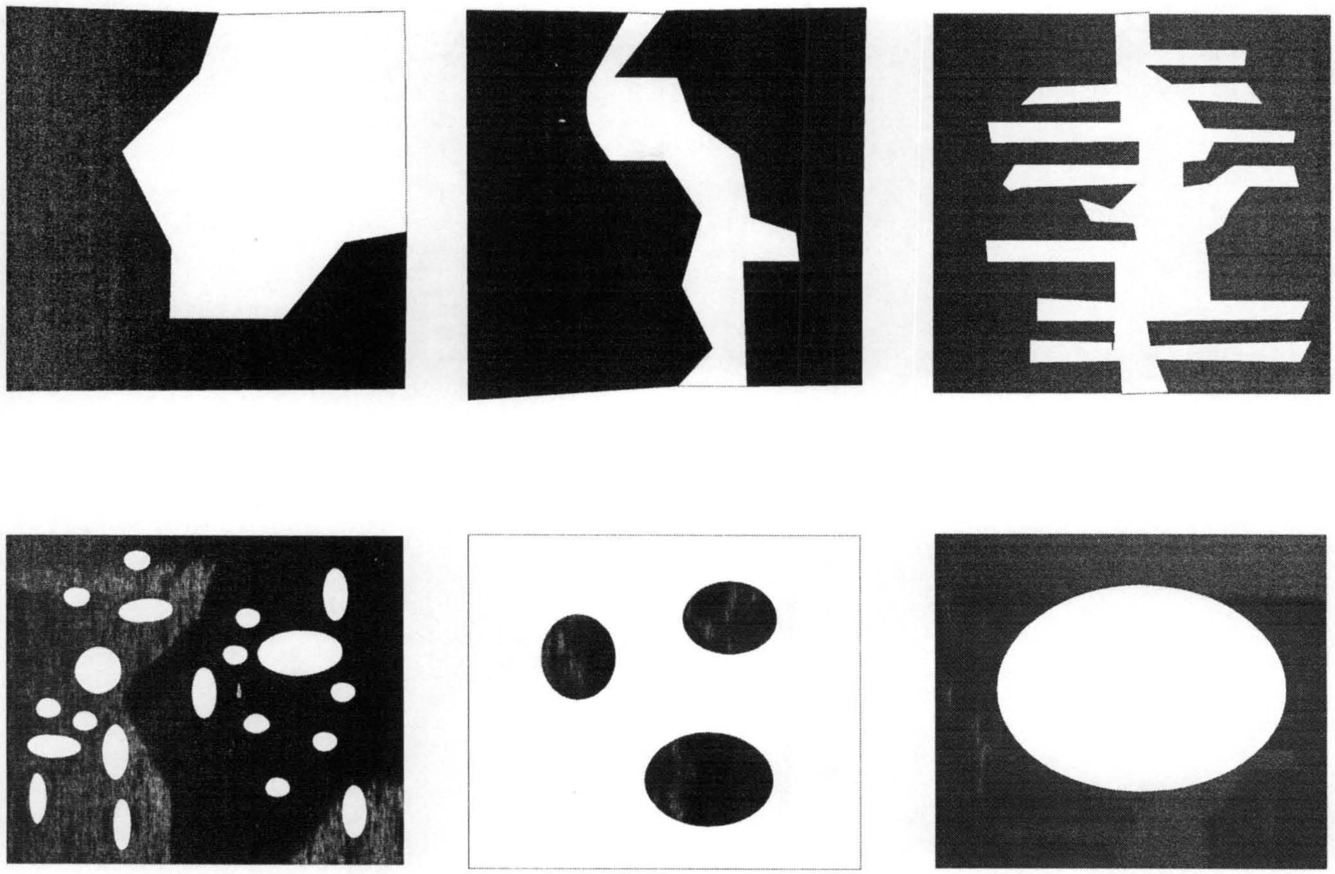
Sourthworth and Tucker's analysis in the country of La Campa in western Honduras combined 113 household surveys, 79 forest plot inventories, remote sensing for two dates (1987 and 1996) and 131 training samples (observation of land cover selected on the basis of image analysis). The remote sensing analysis revealed a net trend of reforestation. This was due in part to a country-wide ban logging, conversion of communal lands to private holdings, and intensification of agriculture with simultaneous abandonment of less productive subsistence plots. Spatial factors such as topography and accessibility to road networks played a significant role in determining forest cover change. Although the remote sensing data were linked to individual plots in this analysis, the household survey provided important contextual information that assisted significant in the analysis of the land cover change data. The authors suggested that the reforestation trend in La Campa may in fact be transitional privatization of land by a wealthier minority combined with population growth and trends towards market oriented agricultural production (especially coffee) may increase pressures on remaining communal forest resources in the future.

Entwisle *et al.* linked household survey data for communities to remote sensing imagery for the area surrounding Nan Rong, a community in Thailand. At a first stage in their research, this community-rather household based approach was necessary because, unlike the Amazon, farmers tend to reside in clustered villages to work to fields, which are dispersed in a patch work around the villages. At a later stage, they invested considerable effort at one of their study sites in linking households to specific, geo-referenced plots of land through utilization of maps based on remote sensing imagery and household community interviews (Rindfuss *et al,* 2002). The pattern is complex because there are one-to-one, one-to many and many -to-one relationship between households and plots of land. The research, which is still under way, will provide powerful insights into households decisions regarding land use, land renting, migration, and labor supply, as well as information on social networks and the diffusion of innovations.

There have been fewer attempts to link remote sensing and socioeconomic data for the study of other land-cover conversion e.g. from productive subsistence agricultural land to 'degraded' land or from natural vegetation and agriculture to urban land uses. Xu *et al* (2000) studied the impact of urbanization on arable lands in Fujian province using a combination of remote sensing, census and economic data. They concluded that the region's rapidly growing economy, with a Gross provincial product of 2.0 billion Yuan in 1990 that increased to 12.5 billion Yuan in 1996, was primarily responsible for the growth in urban extent from 4,495 to 7,864 km2 during the same time period.

Millington *et al* (1999) utilised Landsat TM and MSS imagery from 1972 through 1992 to analyse land use in an arid to semi-arid region in northern Jordan. Their time series data showed a distinct increase in the amount of rained and irrigated cultivation over the time period, which in turn was linked to population increase and government polices. They noted that identification of rained fields was made more difficult by the spectral similarity between theses, stone – strewn lava-flow surface and rangelands.

Finally, there has been some attention to the link between the social processes of deforestation and the spatial patterns of deforestation that appear on the ground. Geist and Lambin (2001) summarised the research in this area based on a statistical analysis of deforestation case studies. The results of their analysis are shown in a schematic form in Figure 3. Moving clockwise from upper left, the geometric pattern of deforestation is commonly associated with large-scale clearing for commercial agriculture, large scale pasture, or industrial forestry plantation settlements. The corridor pattern of deforestation occurs in areas of roadside colonization by spontaneous migrants, and is commonly driven by road extension. The fishbone pattern is only found in the Brazilian Amazon, and is associated with planned resettlement, colonisation and transmigration. It represents a process of roadside frontier colonisation. The island pattern is associated with peri-urban areas, and is related to semi- urban settlement in forested areas. The patchy pattern is commonly related to high population density areas with residual forest patches, and is associated with permanent cultivation of food and to a lesser degree cash-crop production. The diffuse pattern is associated with traditional small-holder subsistence agriculture and in particular shifting cultivation permanent cultivation by small holders.



2.7.2 Sustainability Trajectories

Sustainability was defined by the world commission on Environment and Development (Bruntland commission 1987) as "the ability to meet today's global economic, environmental and social needs without compromising the opportunity for future generations to meet their". In the context of land-cover change, there is interest in understanding transitions in land use from sustainable practices to more sustainable practices. Remote sensing can provide a valuable tool by enabling researchers to examine large areas for "signatures of sustainability" or signs that the landscape may be entering a phase of "criticality".

Millette *et al* (1995) examined three villages in the Kathmandu valley of Nepal for pathways to criticality, which they defined as a regional situation in which the rate or extent of environmental degradation precludes the continuation of current human use systems or levels of human well-being, given feasible adaptations and societal capabilities to respond. They included that despite the difficulties of analyzing remote sensing imagery in a mountainous area where high slope angles and shadows complicate image analysis, remote sensing imagery in combination with ground-based data can "provide information highly germane to the analysis of changing nature society relations, including trajectories toward endangerment and criticality". However, they suggestd that such studies still require detailed ground-based case studies; the imagery can then be used to further inform the case study and to extend the analysis to wider areas, taking care that similar socio-economic and environmental contexts prevail.

Although not explicitly developed as a "sustainability" study, Tappan *et al* (2000) utilized time series to declassified intelligence satellite data from the 1960's (Argon and Corona) in conjunction with LandSat imagery for the 1990's to analyse trends in land cover and soil fertility in the peanut basin of West-Central Senegal. The study covered 30 years, from 1963 to 1992, a period that saw significant demographic, economic, technological and culture changes. The most striking land-cover change is the wholesale expansion of agriculture at the expense of the bush lands that made up the "commons" for grazing and firewood collection. Savannah woodlands and mangroves declined in aerial extent during this period, and soil conditions appeared to have deteriorated. They concluded that as the expansion of few cultivated areas is no longer possible, and the commons are no longer available for the production of needed goods and services, farmers would need to adopt new strategies of soil, water and vegetations conservation.

Based on a high correction between night-time lights emitted and GDP, Sutton and Costanza (2002) developed a novel application of the defense metrological satellite program's Operation line-scan system (DMSP OLS) data, which measures luminosity as a proxy for economic activity, they mapped the location of major economic activities for each country and overlaid that map with another data set that measures the location of ecosystems services product (ESP). They found that among industrialised countries, smaller ones such as Belgium, Luxembourg and the Netherlands had very small proportion (under 3%) of economic product derived from ecosystem services whereas larger ones could attribute substantially more of their GDPs to ecosystem services (e.g. Australia at 67%, and U.S. at 49%).For non-industrialized tropical countries, in excess of 90% of their total product could be directly or indirectly attributable to ESP. the authors compared these new measures with two existing measures of environmental sustainability, the environmental sustainability Index and the ecological Footprint Eco-Deficit, and suggest that the spatially explicit nature of their data sets (developed on a 1 square Km grid can permit modeling to characterise changes over time in the value of ecosystem services.

Turner (2001) described advances in what he termed 'integrated land science', in which the environmental, human and remote sensing/GIS sciences unite to solve various questions about land-use and land-cover changes and the impacts of these changes on humankind and the environment. The focus is on new and improved methods of detection and on predictive models, which falls in the categories of econometric, explanatory, agent-base or scenario-driven. The modeling efforts are bringing together researchers from disparate communities in the social and remote sensing sciences. He saw advances in integrated land science as being critical to the transition towards sustainability.

Although not yet operational, scientists at the Potsdam institute for Climate Impact Research are promoting the concept of a 'sustainability Geo-scope'. According to its proponents (Lotze-Campen *et al*, 2002), the Geo-scope would provide a framework for an observation and monitoring system on a global scale, comprising economic, social, environmental and institutional issues. Data sources would include a combination of satellite remote sensing, socio-economic data and on-the-ground observations. The concept ties in with earlier proposals for a 'syndromes approach' to global change research, in which a sample of areas is intensively monitored around the world for the identification of syndromes of un-sustainability that can be addressed through concerted policy action (WBGU 1996). Syndromes are functional patterns of people-environment relations, characteristic of negative constellations of nature and androgenic trends of global change and their respective interactions. Examples of syndromes identified include the "Sahel syndrome", Rural Exodus syndrome and waste Dumping syndromes".

CHAPTER THREE

METHODOLOGY

3.1 Definition of Technical Terms Used

Contrast Enhancement: Highlighting the

False Color Composition: Adding more colours to an imagery

IDRISI: G.I.S Software

Landsat: Satellite

Multi-Spectral Scanner: A scanner of multiple spectrums

MapInfo: G.I.S Software

Thematic Mapper: Satellite

Saturation: Filling in colors into an imagery to its maximum

3.2 Materials Used

The study used both primary and secondary data. Primary data were obtained from direct field observations, GPS points and information interviews. Secondary data were obtained from the available satellite images of 1975, 1990 and 2002, the topographical map at the scale of 1/2000 000. Available reports from the local offices for agriculture and forestry and 1987 census records.

3.2.1 Direct Observation and GPS Point Recording

A general landscape observation was first carried out with existing imagery and map in hand to confirm the information displayed with direct visual observation. Main units of natural vegetation cover and land use types were identified and described in order to look at their diversity (Appendix 2).

Simultaneously, geographical coordinates were recorded with the GPS at approximately the centre of any meaningful units in order to get the units' coordinates right. A description of each homogeneous zone was done. This step lead to the elaboration of a list of questions asked during the interview.

3.2.2 Image Processing and Analysis

The available images are from the landsat Multi-spectral Scanner (MSS) of 1975, Landsat Thematic Mapper (TM) of 1990 and 2002 (Appendixes 3, 4 & 5). These images were processed and analyzed with the IDRISI and Mapinfo GIS softwares. The following table shows the characteristics of the images used.

Table 1: Spatial, Temporal and Spectral Characteristics of the Satellite Images

N"	Source	Acquisition Date	Spatial Resolution	Spectral resolution
1	Landsat MSS	December 1975	57m	4 Bands
2	Landsat TM	November 1990	28.5m	7 Bands
3	Landsat TM	February 2002	30m	7 Bands

For the purpose of this work, three bands were used for 1975 and 1990 images. These were the red, green and blue bands. Only one composite image is available for the 2002 image, and that one was in the tiff format that could be displayed and interpreted in any vector GIS Programme as a raster layer.

3.3 Issues Discussed

An interview was carried out after landscape observation. It focused on the identification of the date, nature, origin, cause, extent and consequences of the changes observed. This was conducted in villages located in areas where changes have been noticed on the classified images. A total 155 persons were selected based on the snow ball theory among people of 45 years and above because of their supposed knowledge of the history of the area for the interview (Appendix 1). General issues were introduced first in the conversation to give the informant the opportunity to guide the discussion towards what, according to him were determining factors explaining the observed changes. Cross checking of the important information between informants was done.

3.4 Data Presentation

Various techniques were used to produce the land use and land cover maps of the area for 1975, 1990 and 2002. These include, contrast enhancement, false colour composition, and classification.

3.4.1. Image Colour Composition

In order to increase the amount of information that can be displayed on the images, each of the three bands will be enhanced using the linear with saturation method at 2.5% from which a standard color composite image was be produced for each of the three images. The resulting images were such that land use and land cover types could be easily distinguished based on their colors and their digital values. A preliminary unsupervised classification of the area will be performed on the image to generate preliminary thematic maps for use in the field surveys.

3.4.2 Classification

During the field investigations, a ground truth survey of various land cover type was carried out based on the color composite and the preliminary classification images. Geographical positions were taken at approximately the middle of each meaningful cover type to confirm its position on the map (Appendix 2).

Two supervised classification methods were applied. These were the digital and the visual method. The digital classification was done in IDRISI, through the creation of training sites on the color composite images and the creation of spectral signatures files according to the ground truth information. The software then classified the images using the information provided. The visual classification was also performed in IDRISSI software. The limits of the various classes observed were then manually traced on the computer screen after visual identification based on the knowledge of the area and the field investigation.

Finally the combination of the two methods was retained because it proved to be more reliable. Six major classes were obtained and three maps were produced. The classification was designed to make them comparable for the assessment of the changes. The first map was produced from the Landsat TM of 2002. This is because it was the most recent and therefore easier to identify and classify features from this image than from the other images. The second map was that of 1990, and the last one was that of 1975. The changes have occurred since 1975 and the features of that time were then identified through a backward interpretation.

3.4.3 Mapping and choice of classes

All the satellite images were taken during the dry season and the field investigation was carried out in the early part of the rainy season. Although this did not allow the full observation of all the land cover and land use types of the study area in the middle of the rainy season, we have at least been able to distinguish some spectral signatures of rainy season crops such as the rainy season sorghum for example, grown from June to November. This was the same for cotton and the dry season sorghum, though it was difficult to distinguish these crops by their signature. However, the cultivated areas for all these crops were seen on the image. Cultivated areas were therefore considered as a single class. Some grassland displayed the same signature as bare ground. At many locations bare ground and grassland were mapped in the same class. The number of land cover classes was therefore decided according to the interest of the study and the information obtained in the field observation.

Table 2: Classification System Used

S/N	Land use and land cover type	Description
1	Cropland	Land cultivated for row crop and cereal grains
2	Woodland	Land with trees and shrubs
3	Scrubland	Land with grass and shrubs
4	Bare Ground	Sand, bare Land and with very little

		grass
5	Rock	Bare rock and mountains
6	Settlement	Settled area, especially Mindif town

3.4.4 Change Assessment

A projection formula will be applied to the population data available from the 1987 census report and administrative estimate, in order to obtain the estimated data for 1975, 1990, and 2002 (Moreaux *et al,* 2001)

$$\mathbf{Pop\ (n) = Pop\ (1987) \times (1 + GR/100)^{(n - 1987)}}$$

Where:

Pop (n) represents the population of the target year,

Pop (1987) represents the population in the 1987 from the census record,

N represents the target year,

GR represents the Growth Rate (2.8)

1 is a constant

100 is the total percentage of annual growth.

The administrative map of the study area, the villages, the rivers and streams, and road maps was digitized from the topographical map. The land use and land cover maps were combined with various data layers, especially villages, rivers and stream. The croplands were isolated from the other classes to make a separate map. Using the overlay techniques, a combination of different layers were made to help obtained maps.

The surface area of Mindif subdivision and that of the various classes were calculated using GIS techniques for the three maps separately. The results were used for simple statistical analysis. Simple correlation analysis was carried out between population and cropland (Appendix 3) on one hand and between cropland and woodland (Appendix 4) on the other hand. We obtained the coefficient of correlation and a coefficient of determination using a computer program called Statistical Package for Social Sciences (SPSS).

Land use and land cover maps were later on used for GIS spatial analysis. These GIS analysis will involve overlaying various data layers obtained from the topographical map to the land use and land cover maps, and the maps of crop land at the three different dates. These maps were overlaid to display the spatial relationship between the location of various land use and land cover types and the villages on one hand, and the stream and rivers on the other. Overlaying the maps of crop land displayed the evolution of cultivated areas from 1975 to 2002 (Figures 7, 8, 9).

Factors that could explain the changes in the characteristics of the agrarian system and the way people respond to the changes were identified from the interviews. Possible casual relationship between the factors and the changes established.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Results

The present study was carried out in an area of approximately 97,500 hectares large. After the interpretation of the Landsat data, six land uses and land cover types were retained in the study area. This aggregation gives the following classes: cropland, woodland, scrubland, bare ground, rocks and settled area.

Cropland includes cultivated area for rainy and dry season sorghum, groundnut, maize, cotton, beans onion, and orchards. Woodland includes land with woody species (trees and shrubs). Scrubland includes areas with grass and scrubs and other herbaceous species. Bare grounds include sands, completely bare soil, and areas with almost no vegetation cover. Rock includes bare rock and mountains. Settled area includes land identified as human settlements, especially the town of Mindif, the biggest human settlement in the study area. The result reveals that a large portion of the northern part of the study area is abandoned to dry season agriculture while woodland is dominant in the south east (Figures 4, 5, 6).

The statistical analysis shows that the settled area increased from 214 hectares in 1975 to 602 hectares in 2002, cropland increased from 7,291 hectares in 1975 to 20,232 hectares in 2002, woodland decreased from 41,804 to 32,571 hectares. The interpretation and analysis of the land use and land cover pattern in 1975 (Table 3) therefore shows that the extent of settled area was about 0.2% of the study area, cropland was about 7.5%, woodland over 52.2% of the area, and meanwhile scrubland occupied 34.6% and bare ground 5.4% of the study area.

Table 3: Area of land use and land cover types in 1975

LULC Type	Area in Hectares	% Area
Settled Area	214	0.2
Cropland	7291	7.5
Woodland	50872	51.2
Rock	105	0.1
Scrubland	33728	34.6
Bare Ground	5249	5.4
Total	**97459**	**100**

Table 4 reveals that in 1990 settled area occupied 0.3% of the area, cropland covered 10.3%, woodland covered 43.0% and scrubland covered 36.9%. Bare ground accounted for 9.2% of the study area.

Table 4: Area of LULC types in 1990

LULC Type	Area in Hectares	% Area
Settled Area	337	0.3
Cropland	10056	10.3
Woodland	41859	43.0
Rock	105	0.1
Scrubland	35980	36.9
Bare ground	9118	9.4
Total	97455	100

In the year 2002 (Table 5), settled area occupied 0.6% of the study area, cropland occupied 20.8%, while woodland occupied 33.4%. Scrubland occupied 37.9m% and bare ground occupied on 7.2%.

Table 5: Area of LULC in 2002

LULC Type	**Area in Hectares**	**% Area**
Settled Area	602	0.6
Cropland	20232	20.8
Woodland	32580	33.4
Rock	109	0.1
Scrubland	36904	37.9
Bare ground	7032	7.2
Total	97459	100

Table 6: Temporal evolution of LULC types

	1975 (hectares)	% 1975	1990 (hectares)	%1990	2002 (hectares)	% 2002
Settled Area	214	0.2	337	0.3	602	0.6
Cropland	7291	7.5	10058	10.3	20232	20.8
Woodland	50872	51.2	41859	43.0	32580	33.4
Rock	105	0.1	105	0.1	109	0.1
Scrubland	33728	34.6	35980	36.9	36904	37.9
Bare ground	5249	5.4	9118	9.4	7032	7.2
Total	97459	100	97455	100	97458	100

Table 7: Percentage growth of LULC from 1975 to 1990

LULC TYPE	1975 (hectares)	1975 (%)	1990 (hectares)	1990 (%)	Evolution (btw 75-90,hectare)	Growth (%)
Settled Area	214	0.2	337	0.3	123	57.4
Cropland	7291	7.5	10056	10.3	2765	37.9
Woodland	50872	51.2	41859	43	-9013	-17.7
Rock	105	0.1	105	0.1	0	0
Scrubland	33728	34.6	35980	36.9	2252	6.7
Bare ground	5249	5.4	9118	9.4	3869	73.7
Total	97459	100	97455	100	-	26.3

Table 8 Percentage growth of LULC from 1990 to 2002

LULC Types	1990 (hectare)	1990 (%)	2002 (hectare)	2002 (%)	Evolution (btw90-02,hectare)	Growth (%)
Settled Area	337	0.3	602	0.6	265	78.6
Cropland	10056	10.3	20232	20.8	10176	101.2
Woodland	41859	43	32580	33.4	-9279	-22.2
Rock	105	0.1	109	0.1	0	0
Scrubland	35980	36.9	36904	37.9	924	2.5
Bare ground	9115	9.4	7032	7.2	-2083	-22.9
Total	97455	100	97459	100	-	22.9

Table 9 Temporal percentage of growth between1975-2002

LULC Types	1975 – 1990 (%)	1990-2002 (%)	1975-2002 (5)
Settled Area	57.5	78.6	68.1
Crop	37.9	101.2	69.6
Woodland	-17.7	-22.2	-19.9
Rock	0	0	0
Scrub	6.7	2.5	4.6
Bare Ground	73.7	-22.9	25.4
Total	26.3	22.9	24.6

Table 10 Temporal evolution of land use and land cover types

Year	Population (in habitants)	Cropland (hectares)	Woodland (hectares)
1975	28950	7858	50937
1990	44365	10056	41904
2002	61800	20232	32571

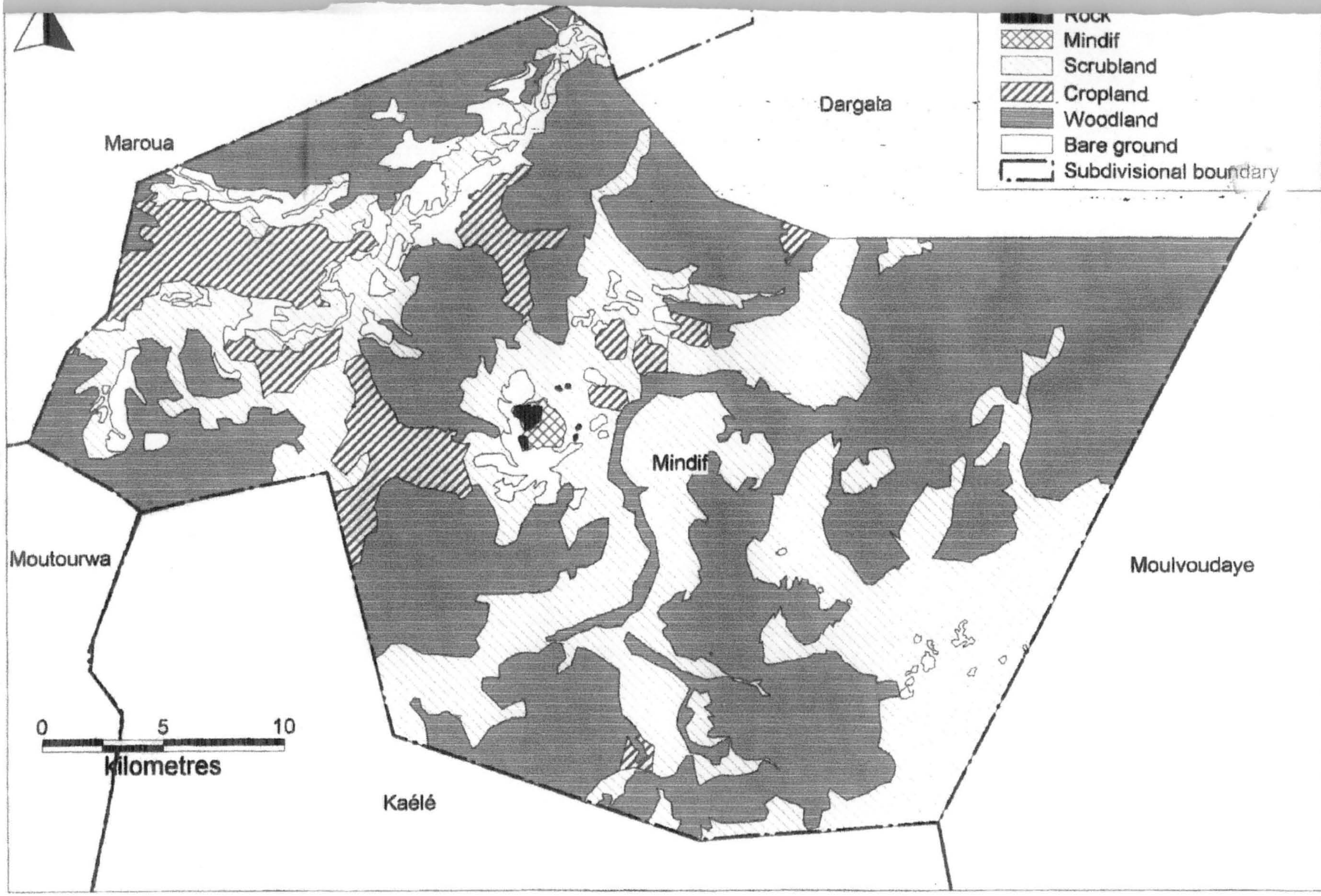


Figure 4: The pattern of landuse and land cover in 1975

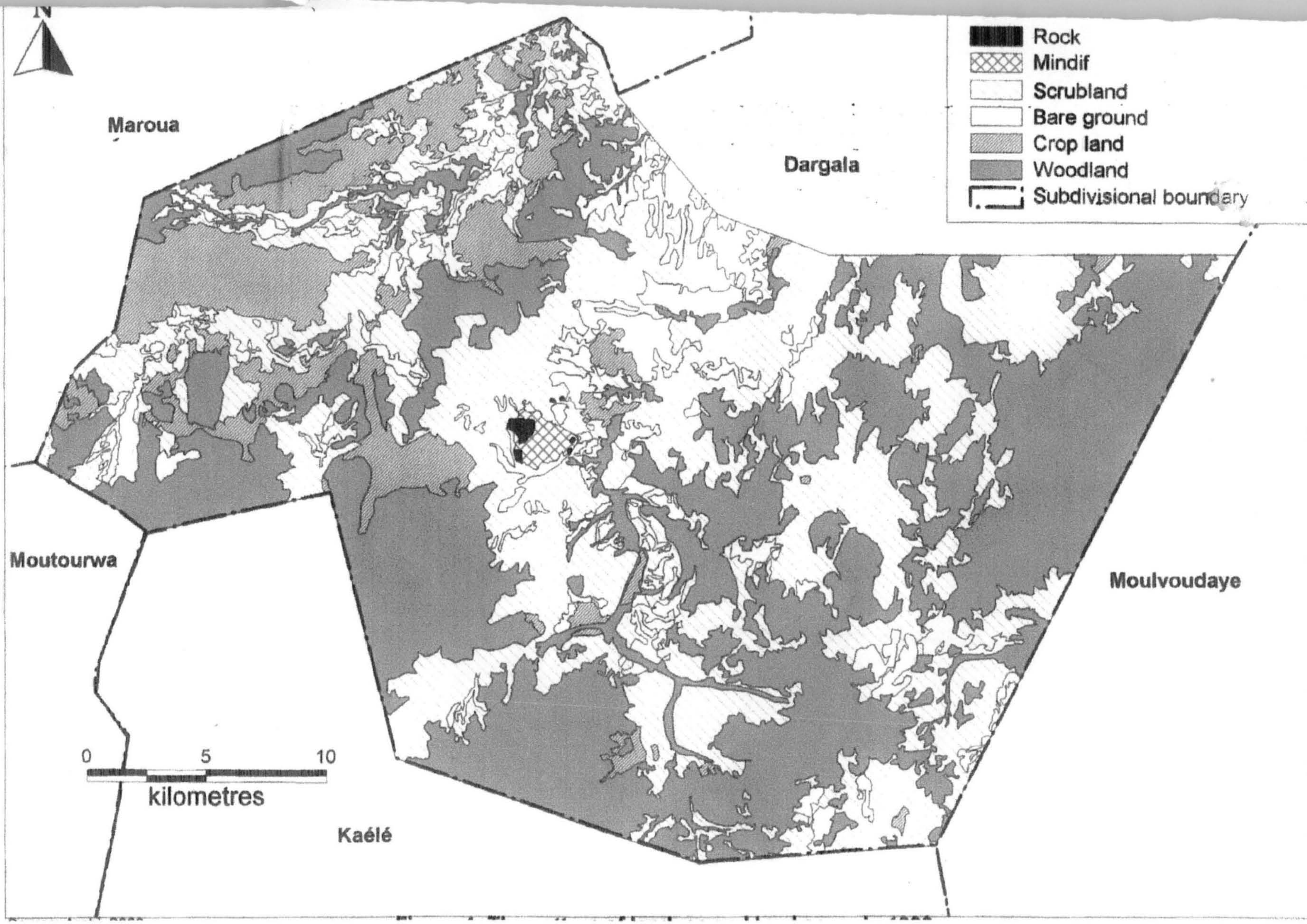


Figure 5: The pattern of landuse and land cover in 1990

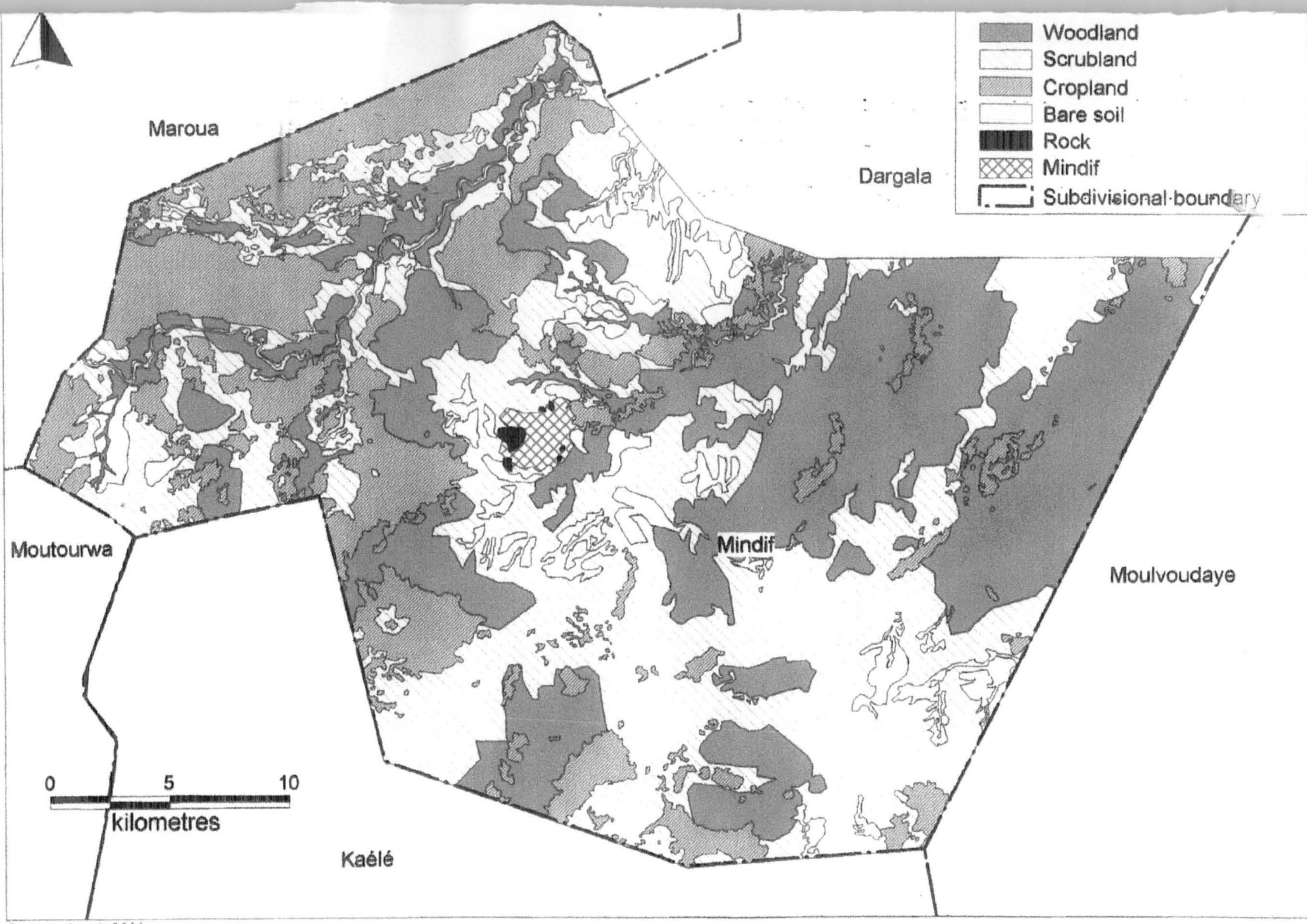


Figure 6: The pattern of landuse and land cover in 2002

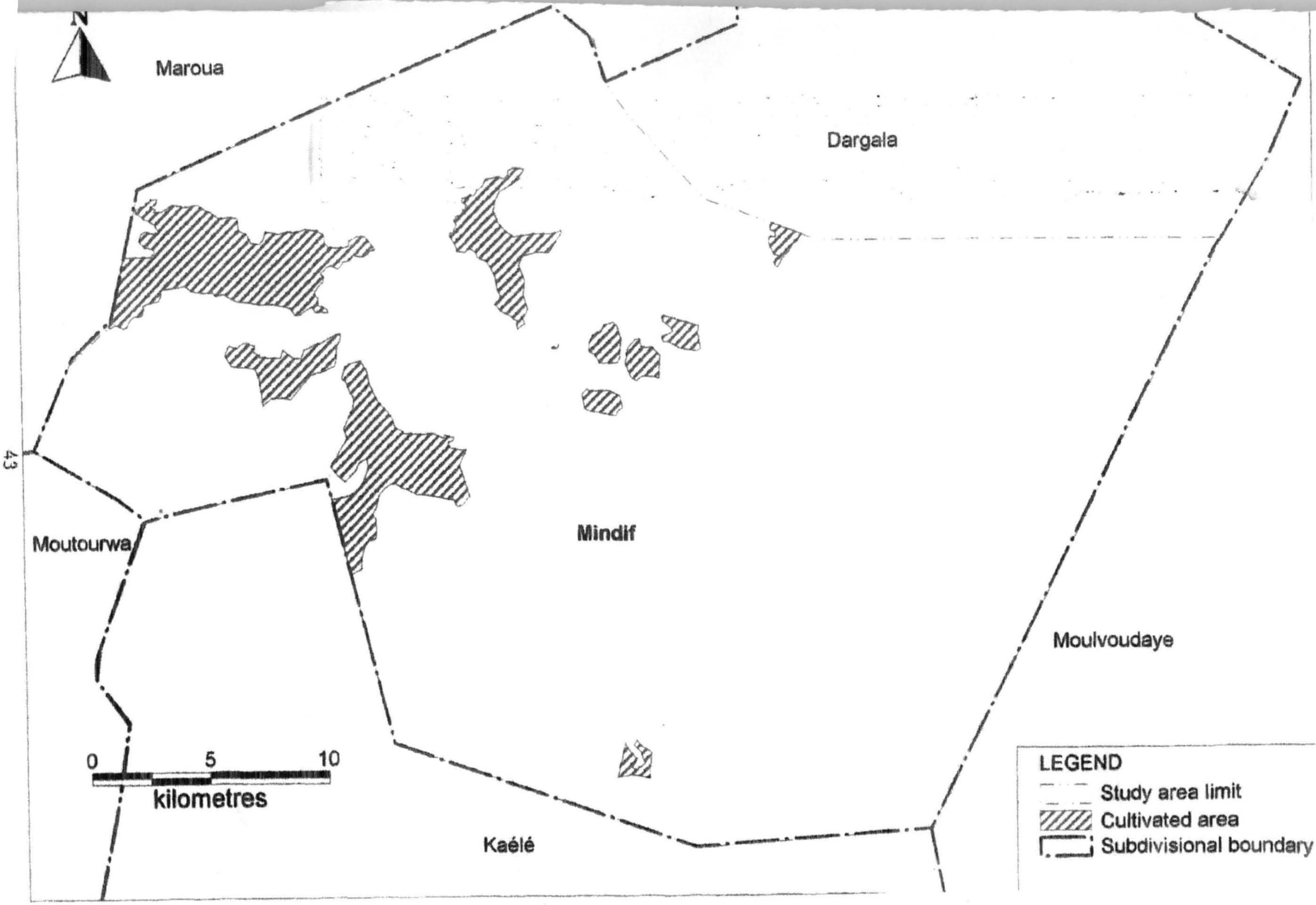


Figure 7: The extent of cultivated area in 1975

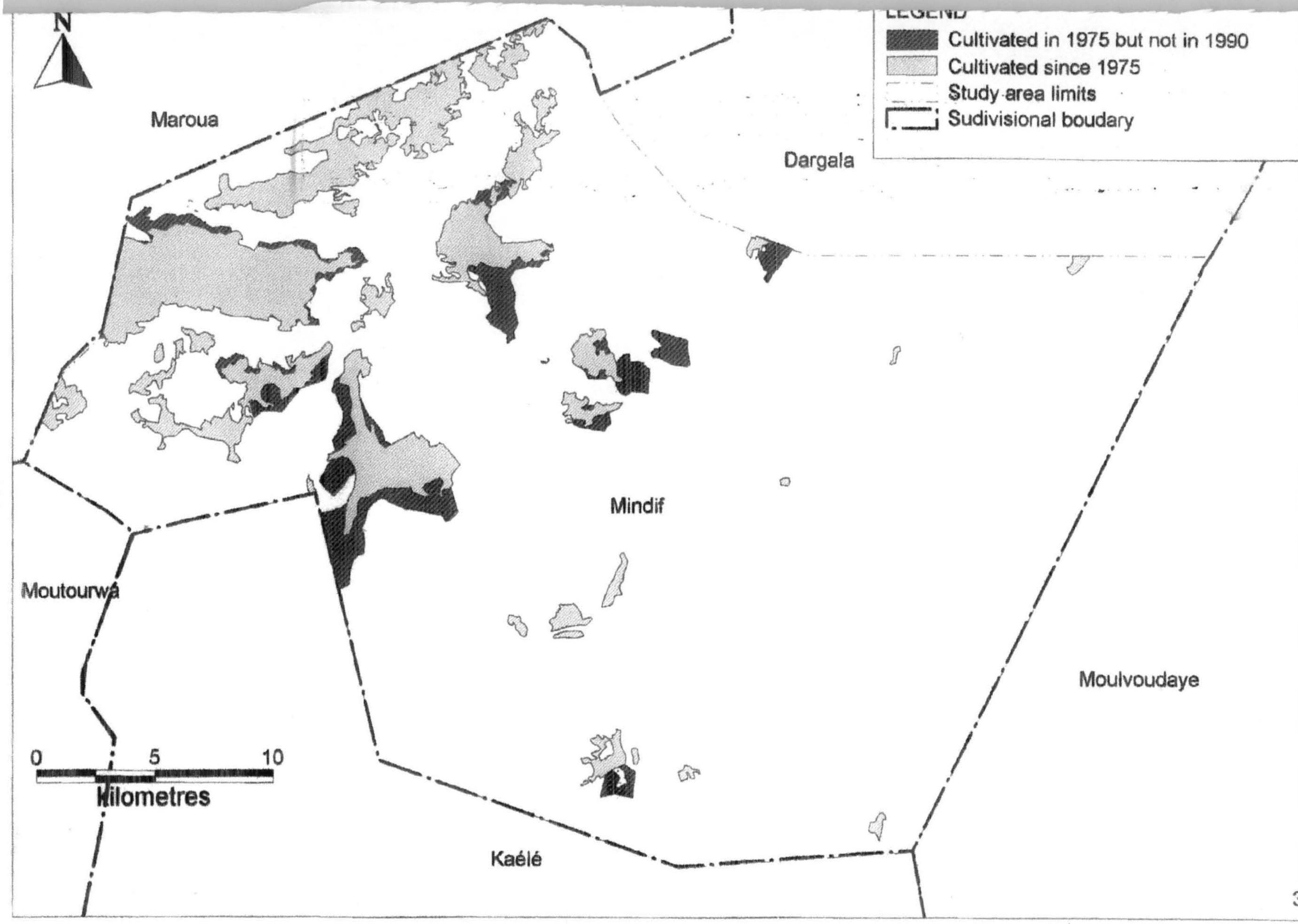


Figure 8: The extent of cultivated area in 1990

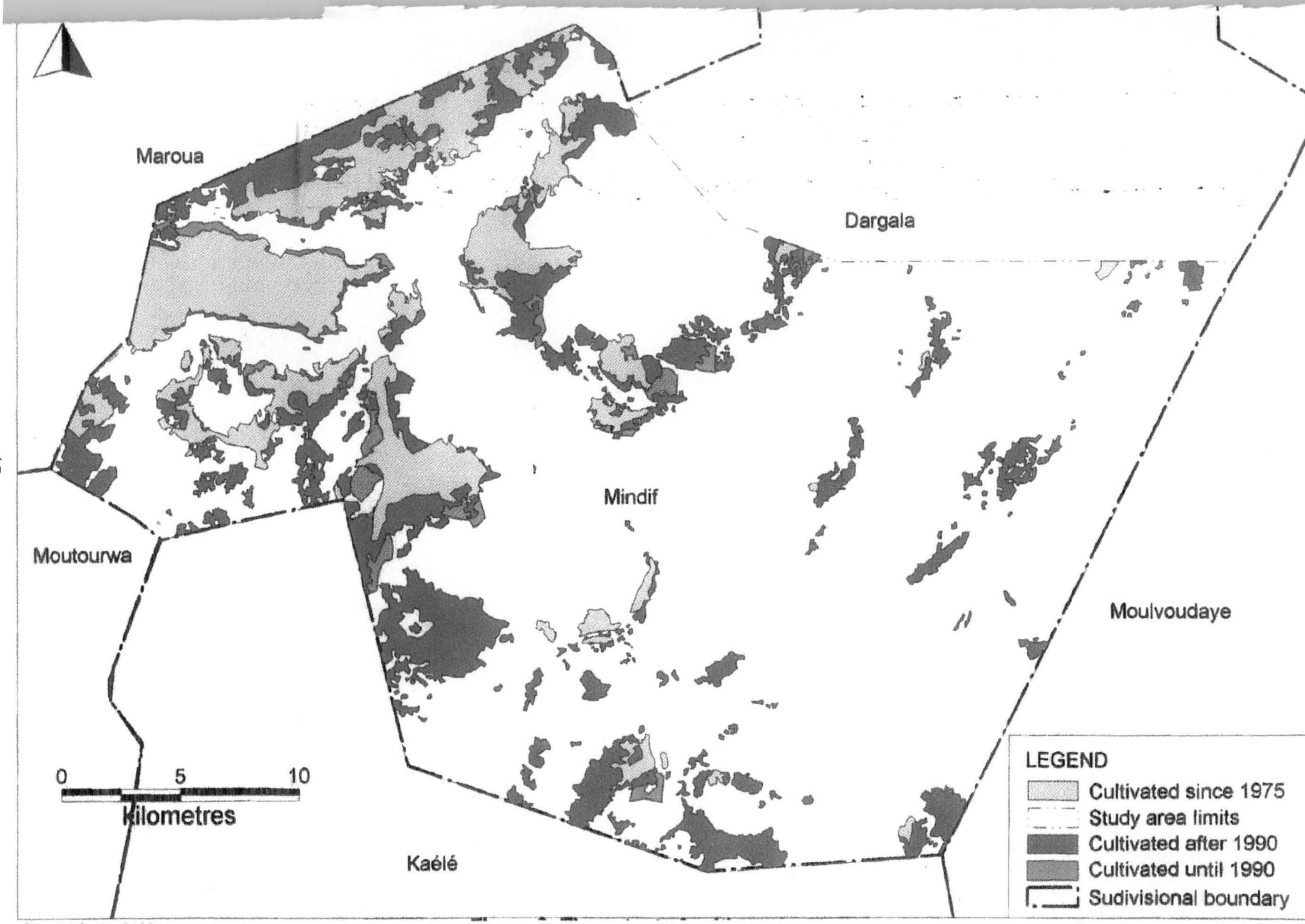


Figure 9: The extent of cultivated area in 2002

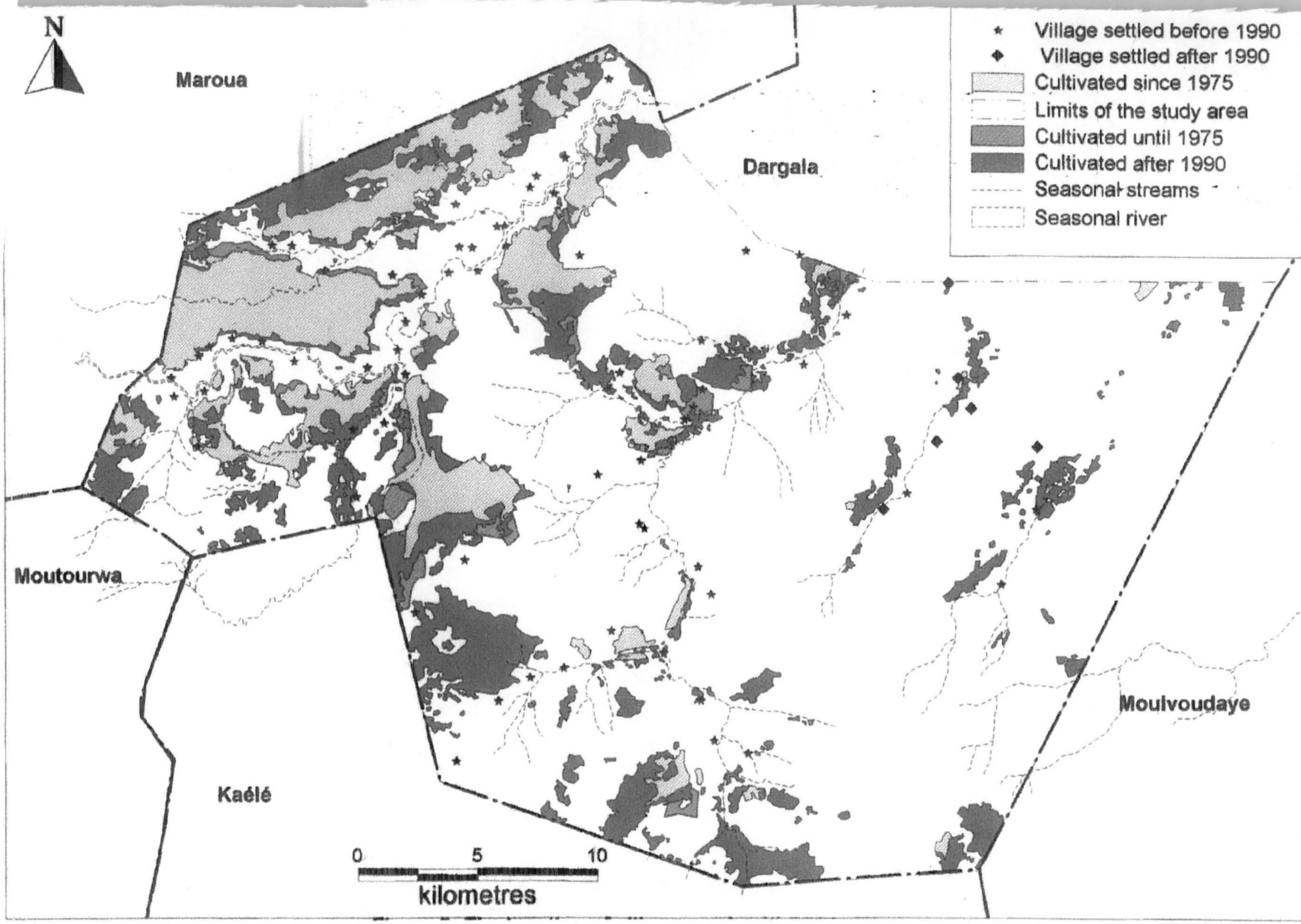


Figure 10: The location of villages and cultivated area

Simple correlation and regression analysis between population and cropland gives a very high positive coefficient of correlation variable is cropland and the independent is population.

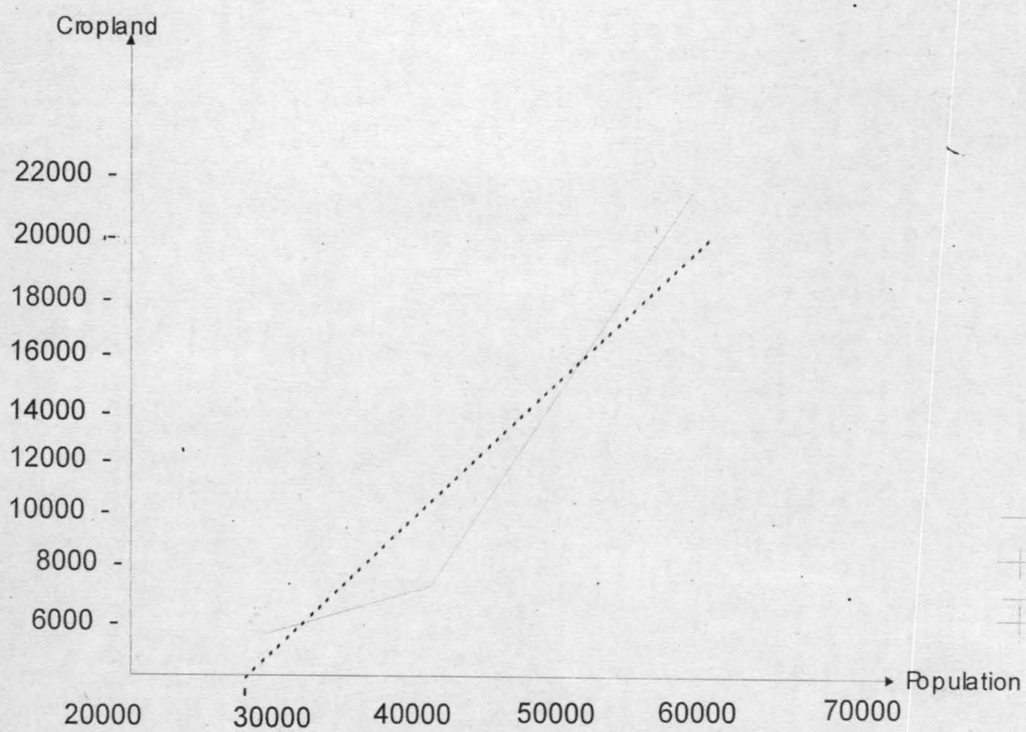


Figure 11: Correlation between croplan and population

Simple regression and correlation analysis between cropland and woodland revealed a perfect liner relationship with a strong negative coefficient R = - 0.95 and a coefficient of determinant R2 of 0.907. The independent variable is cropland and the dependent variable woodland

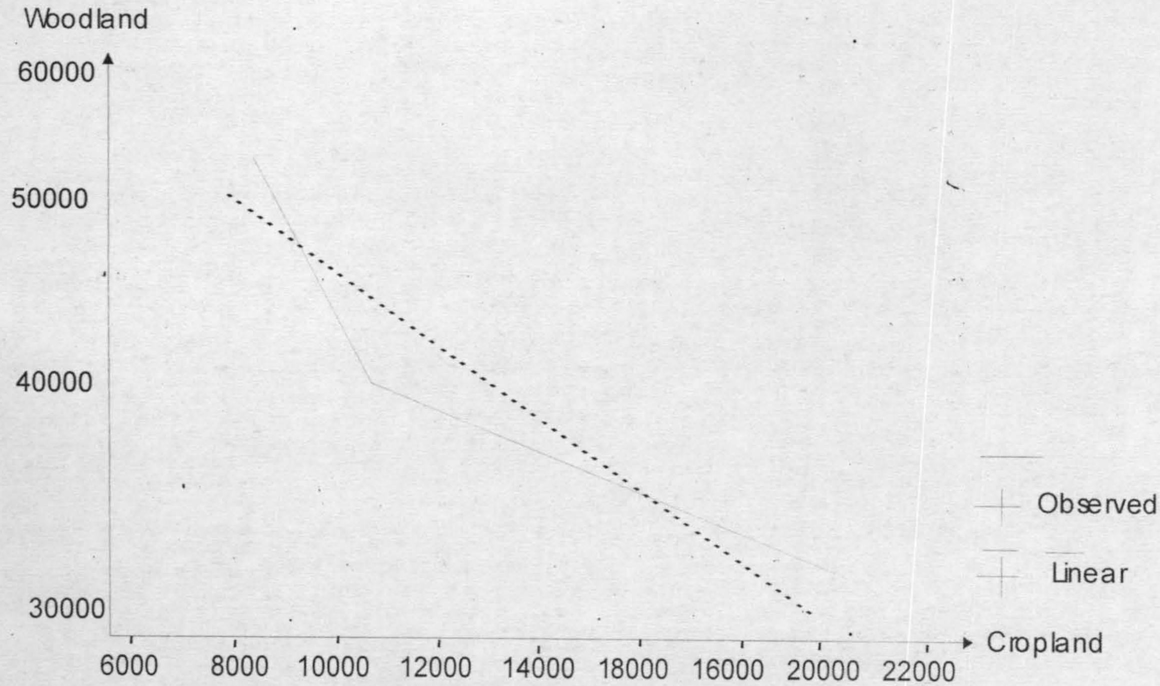


Figure 12: Correlation between woodland and cropland

4.2 DISCUSSION

4.2.1 The Dynamic of Land use and Land Cover

The analysis of satellite images reveals that settled area increased from 214 hectares in 1975 to about 602 hectares in 2002. Cropland increased from 7,291 about 7.5% of the total area in 1975 hectares to 20,222 hectares about 21% in 2002, while woodland decreased from 50,872 hectares about 52.2 % of the study area in 1975 to 32,580 hectares about 33% in 2002. Scrubland increased from 33,728 hectares in 1975 to 36,904 hectares in 2002, and bare ground increased from 5, 249 hectares in 1975 to 9,118 hectares in 1990 and decreased to 7,032 hectares in 2002.

It can be observed that Cropland witnessed a total increment of 12941 hectares, of which 82.2% occurred between 1990 and 2002 and 17.8% between 1975 and 1990, while woodland witnessed a total decrease of 18,292 hectares, of which 50.7% occurred between 1990 and 2002, and 49.3% occurred between 1975 and 1990. As it appears in Table 5, there was an important conversion of woodland to cropland of about 12,942 hectares.

The remaining 5,350 hectares of woodland decrease have been probably converted to either scrubland or bare ground due to fuelwood collection, which is a very important activity. It was found during the interviews that, people used to come from Maroua where the demand is very high with trucks and motorbikes to collect Fuel wood. This has become a lucrative commercial activity initially centered on the village of Gagadje. Recently, after the clearing of the area around Gagadje, the activity was transferred to the surrounding of the villages of Doyang, Modjombodi and Mborora. The collection of fuelwood does not involve villages only, but wealthy business men use to recruit people who are paid to collect the wood for them. The local population find themselves frustrated since they can neither stop those who cut down trees nor receive any financial compensation while their own wood remain unsold.

Malthus theory which says that an increase of land under cultivation is the direct response of population pressure is proven in this study. Although agriculture might be expanding into inferior land quality, the average land productivity might not decrease due to the technological advances.

The observations of Walker (1996) that human demand for land is a key factor to environmental changes also apply to our study area.

According to the investigation, the increment of cropland is attributed to the natural population increase and in-migration. The population of the study area increased from 28,950 inhabitants in 1975 to 61,800 in habitants in 2002 that gave an increase of 32,850 inhabitants since 1975. An increase of 53.1% was observed between 1990 and 2002, while the increase from 1975 to1990 was about 46.9%. New immigrants coming essentially from the neighboring Kaele subdivision have been found in villages around Gagadje, resulting in the creation of many farms during the last 10 years.

The extensive conversion of the vegetal cover in the region is the direct result of the inability of the traditional system of land use (slash and burn tenurial system in this case) to adapt to the forces of increasing population growth, urbanization and the monetization of the economy as stated by Agyepon (1996).

Direct effect of land cover and land use changes in the study area are soil erosion, loss of bio-diversity and these lead to the immigration of the population and the creation of new villages, just as observed by Ladeke and Plochl (1996).

The results in this study confirmed Walker (1996) earlier observations that agricultural and urban encroachment of natural area whether leading to outright conversion or modification of land cover. These lead to the flora and fauna, emission of carbon dioxide at local, regional and global level.

4.2.2 Population and Land use change

Simple correlation and regression analysis between population and cropland gives a very high positive coefficient R O.96, and a coefficient of determination R 0.921 this means there is a perfect relationship between population growth and cropland. Increase in population therefore strongly determines increase in cropland and that about 92% of cropland increase results from increase in population.

The field work revealed that the rapid multiplication of farms since 1990 was due to a recent massive use of plough in the farming activities and a change of mentality among the farmers during the last 10 years. The farmers engage themselves more and more in commercial agriculture. There was also the development if onion due to the advent of a recently created co-operative of onion producers that gives credits to farmers. The development of beams, potatoes and cotton cultivation was attributed to economics reasons because of a growing demand.

The statement that population pressure on land use are likely to be felt through changes in the tenure arrangement by Bilsborrow and Ogenda (1992) is also applicable to the study area. The last 10 years witnessed a huge transformation of the areas, both in terms of infrastructures and population, which in turn accelerated demand of agricultural products. Land is being cleared to establish new farms. For younger farmers, access to land is vital if they are to be gainfully employed.

4.2.3 Farming and Land cover change

Simple regression and correlation analysis between cropland and woodland revealed a perfect linear relation with a strong negative correlation – 0.952 and a coefficient of determination R of 0.907. This observation means that the increase in cropland is at the detriment of woodland, and that about 90% woodland degradation is due to the creation of new farms. This corresponds to the expansion of agriculture into inferior land as viewed by Malthus. People will therefore continue creating new farms since land is still available. The remaining 10% of woodland degradation can be attributed to fuel wood collection activities.

And increment in scrubland was also observed. It appears however that as the scrubland increases, the woodland decreases. The increment of scrubland probably results from the degradation of woodland .this is probably due to the collection of fuel wood that takes place in the study area to supply the growing energy demand in Maroua with a population of about 200,000 inhabitants located at about 25KM away from the study area.

The soil quality and the vegetation density and factors such as transportation network are the key determinants of deforestation rate and few farms creations (Plaff, 1999)

4.2.4 People's response to land covers change

Every body in the area agrees that the woodland is dramatically degrading but no one does anything to stop the situation. Immediate personal interests are the preoccupation of farmers and fuel wood collectors. The farmers also progressively abandon the cultivation of groundnut and engage themselves much in the cultivation of onion, beans, potatoes and cotton because of the economic profitability. It could be normally expected that people plant trees but nothing is done to compensate the disappearance of the woody layer, instead once a fuel wood collection site is cleared, another one is located and the activity continuous on the new site until it is cleared. This is for example what happens when the area around Gagadje was cleared; a new site was created around Doyang, and Modjombodi.

Some of the observations made with the traditional agricultural system is the disappearance of fallow period that use to last up to four years, and the creation of new farm. People go up to five to six kilometers from the village to start new farms since those at close proximity are occupied.

The creation of these new farms is strongly related to the fact that some new crops were introduced (commercial in nature) and the affluence of migrants to the region, in search of new land for farming. From all indications, as with Wood and Skole (1998) and Plaff (1999), population density per se did not have a significant effect on the clearing of land.

4.2.5 Spatial distribution of land use and cover

Figures 7, 8, & 9 show that almost all the cultivated land are concentrated around densely settled area. The villages are mostly located along streams and valleys, bare ground are generally found on gentle slopes towards the streams and rivers, and scrublands are generally found the immediate surrounding of the villages.

The distribution of woodland shows that this class dominates in areas where there is almost not village. New settlements have been found around Gagadje and a formerly abandoned village has been recently settled. This certainly explains the creation of many new farms. The rate of conversion was found to be higher in areas of high village density than in areas where settlements are very few. Such observations were made by Boren *et al* (1997) in the United State when they stated that land in high density rural population was subject to more intensive management practices. It is also observed that the spatial dynamics of cultivated areas follows an east to west direction, from densely settled area towards less settled area.

It can be observed that cropland moves northward and westward pushing back the woodland and scrubland. Some areas cultivated in 1975 have become scrubland in 1990 but cultivated in 2002. This observation can be attributed to the practice of fallow in the past. Almost all the cultivated areas in 1975 are cultivated in 2002; small areas that are not cultivated have been converted to either scrubland or bare soil. The entire cultivated areas of 1990 are cultivated in 2002; this observation testifies the disappearance of fallow in the study area.

Based on the social processes of land clearing and the spatial patterns of deforestation that appear on the ground, the study area is a typical Smallholder, traditional subsistence agriculture model called diffuse model (Geist and Lambin, 2001). This model is associated in particular with shifting cultivation and permanent cultivation by small holders

CHAPTER FIVE

CONCLUTION, SUMMARY AND RECOMMENDATIONS

5.1 Summary

The study focused on Mindif, located in the extreme northern province of Cameroun with the aim of analyzing temporal dynamics and identifies the driving forces of land use and land cover change between 1975 and 2002. This was done through a combination of field method such as interview schedule, GIS and remote sensing analysis. Satellite data available for 1975, 1990 and 2002 were used to map land use and land cover pattern using digital and visual image processing techniques. The resulting images were converted to vector and combined with other data layers obtained from the topographical map. Information collected from the interviews were used to explained and understand the digital results.

It was found that the study area witnessed an important conversion of woodland to cropland, and the more population grows, the more land is reclaimed for agriculture. The increment of cropland between 1990 and 2002 was more than 80% of what was observed between 1975 and 1990, while scrubland slightly increased as woodland decreases. The coefficient of correlation of $r = 0.96$ shows that the increase of cropland comes from the increase in population, and $r = 0.952$ shows that the decrease of woodland is strongly caused by the creation of new farms. Farming is mostly concentrated in areas of dense settlements mainly around the villages that are located along rivers and streams.

5.2 Conclusion

This study reveals that human population growth logically caused the increase of cultivated land, leading to the degradation and eventually the disappearance of woodland. Thus uncontrolled expansion of new farms was found to be the main driving force responsible for the degradation of woodland resulting from the increase in human population. It is likely that if the present tendency continues, all the area will be converted to cropland. Suprisingly however, even though everybody is aware that the woodland is being degraded, no body does anything to stop the situation. As it was observed, the scale and rate of change between 1975 and 1990 when population density was low was far below the change that occurred between 1990 and 2002 when the density becomes higher. The study also shows that satellite data if available at different times can be a powerful tool for the assessment of environmental change and that the combination of visual digital analysis produces better results.

5.3 Recommendations

This study shows a high risk of environmental degradation in the study area. In other therefore to reverse the tendency, important measures have to be taken and implemented. It is in this regards that recommendations are made.

The creation of new farms and the collection of fuel wood in the study area should be carefully monitored. A detailed assessment should be carried out on regular basis using images of greater resolution such as 20 or 10m spot. Such a monitoring will allow decision makers take the appropriate measures at the right time to prevent environmental degradation in the study area. The increase of cultivated area threatens the existence of pastures in the area while the number of animals grows every day. A study should be carried out to assess the sustainability of the pastures. The management and the production of these pastures could also be modeled to derive a suitable management approach.

It would also be important to adopt and implement appropriate strategies aiming at reducing the rate at which new farms are created. This may include subsidising the access to fertilizers and improved seeds to allow the farmers produce more on the same land. Access to credit should also be facilitated to rural people such that they could engage themselves in other revenue generation activities, thus avoiding the cutting of trees as a lucrative occupation. The government and non governmental organizations could organize large scale sensitization to draw the attention of the population towards the risks of environmental degradation. The sensitization should equally include the need for planting trees.

The land use in the study area should be carefully planned. Planning of land use by allocating different zones to different uses will avoid the creation of new farms any how. This will also help the control fuel wood collection, thus minimizing decline of natural vegetation cover.

APPENDIX 1: Interview Guide:

Village:

Latitude:

Longitude:

Altitude:

Respondent:

Age:

Sex

Marital Status:

Number of Children:

Native or Migrant?

Number of years spent in the Village:

Why did you migrate?

Occupation:

Agriculture:

Distance from the village to the farm:

Size of the farm:

Type of crop cultivated:

Stools:

Fallows Period:

Farming Method:

Variation of farm size:

Fertility of the farm:

Use of fertilizer:

Farm yield:

Access to credit:

Animal Husbandry:

Grazing area availability, location, variation:

Size, quality of grazing land:

Vegetal species preferred by animals:

Quantity of animals:

Environment:

Fuel wood collection:

Other use of the vegetal cover:

Vegetal cover degradation:

Tree planting:

Disappearance of certain trees species:

APPENDIX 2: Landscape observation guide:

Natural vegetation:

- Density and continuity
- Spot man-made effects

Human settlement:

- Location, size, density
- Pattern of distribution
- Key infrastructures

Land use:

Not cultivated:

- Gathering
- Grazing
- Vegetal cover distribution

Cultivated:

- Shape, size of plots, nature boundaries
- Type of crops and their distribution
- Observed farmers practices

Main Landscape:

- Dominating mode of artificialization of the ecosystem

Diversity of socio-economic origin:

- Variability of farmers practices (inputs and farm equipment)
- Variability of cattle raising practices

Evolution of agricultural production system:

Means of production

Agricultural techniques

Productions

Evolution of social and economic components

Demographic pressure

Marketing conditions

Rural credit

Land tenure

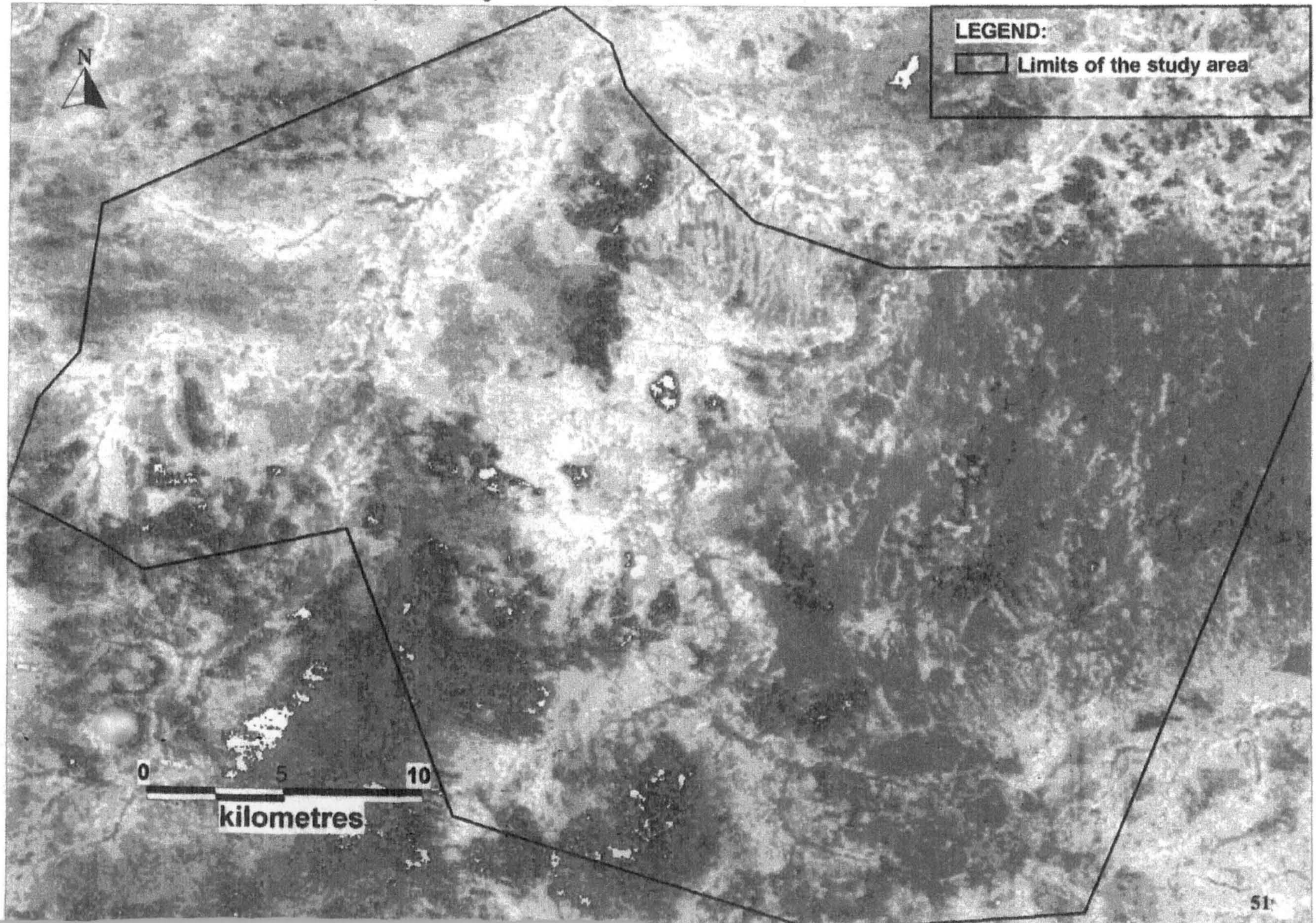
Labour market

Social infrastructures

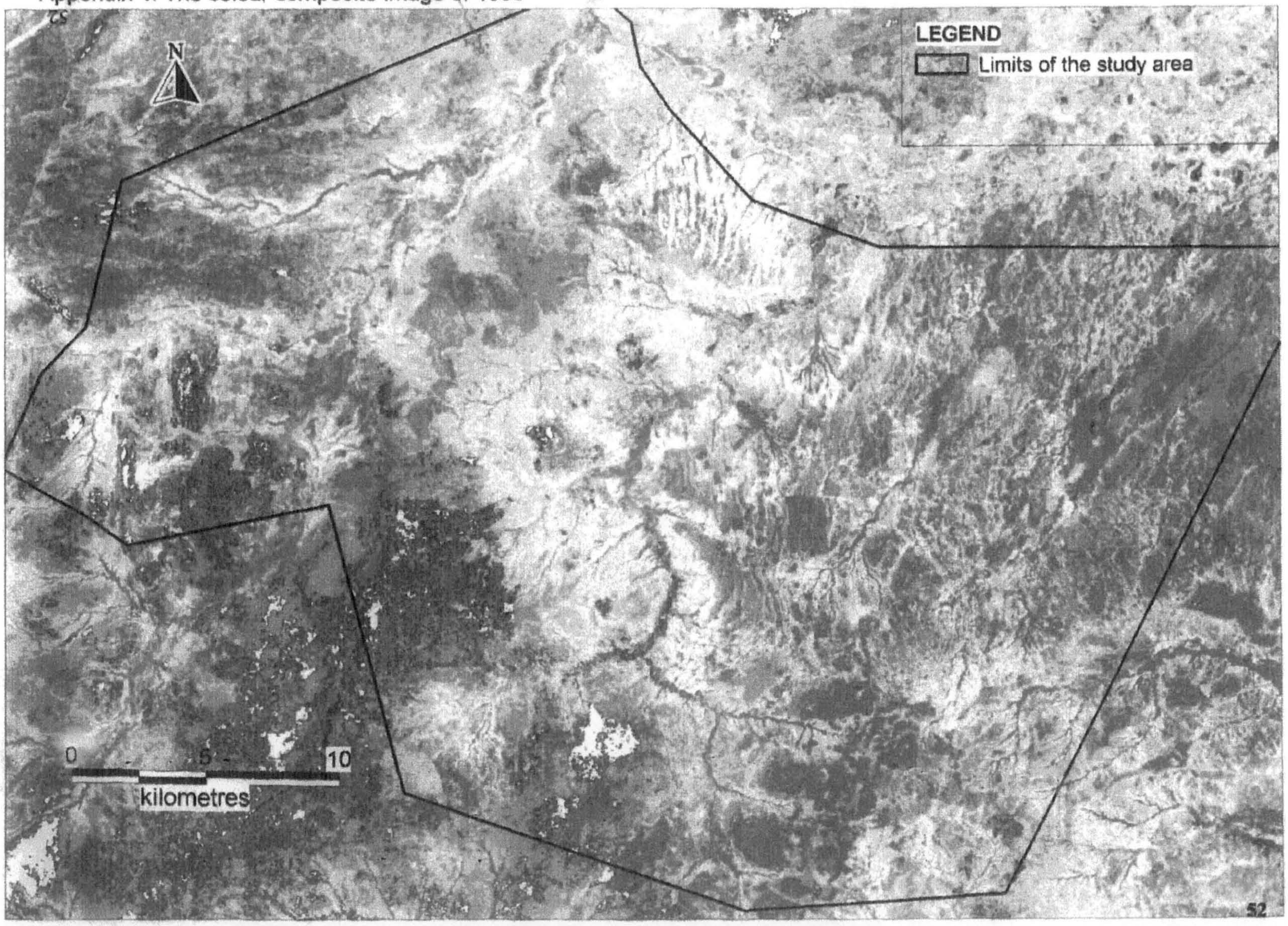
State intervention

Farmer's income, productivity

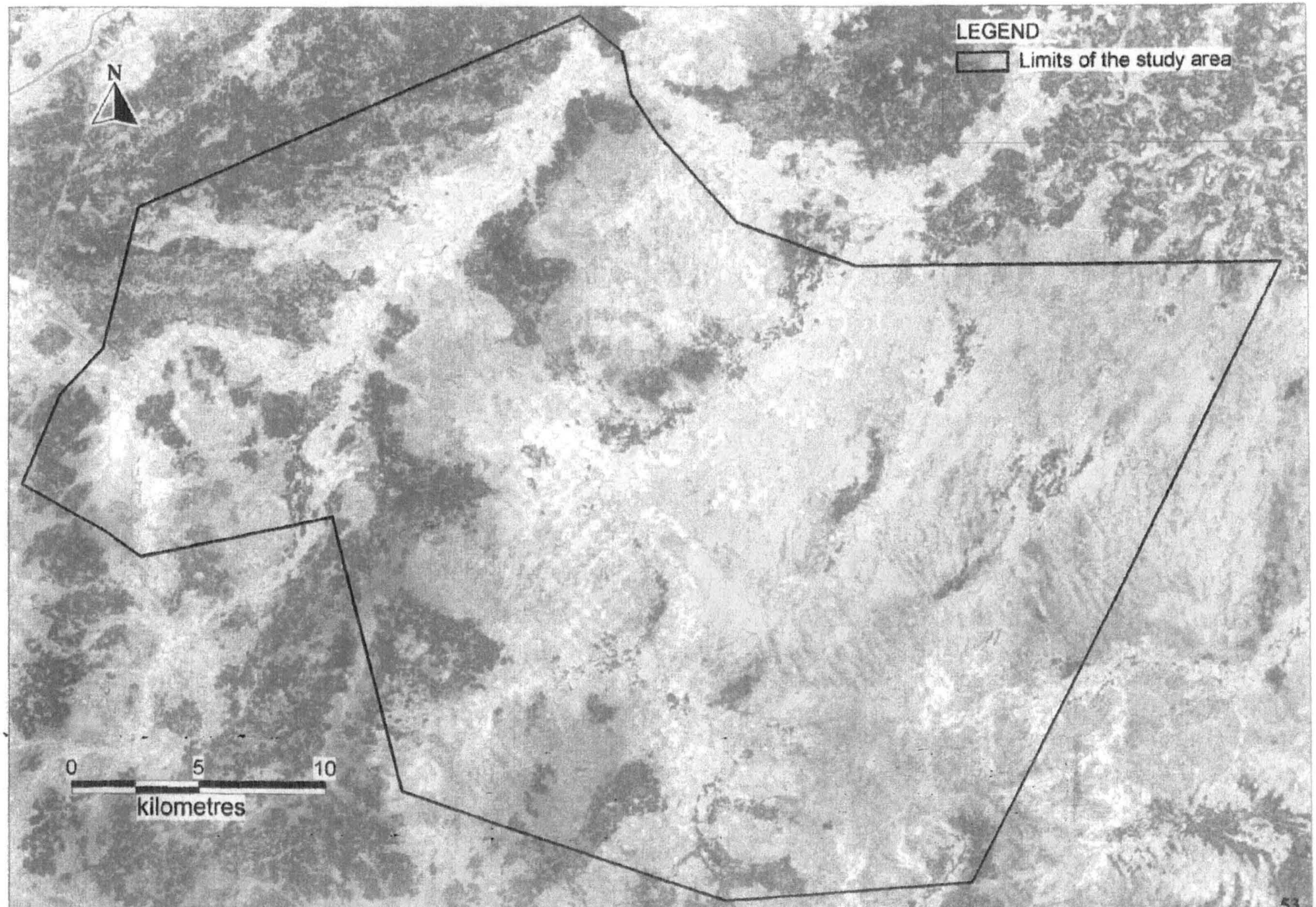
Appendix 3: the colour composite image of 1975



Appendix 4: The colour composite image of 1990



Appendix 5: The colour composite image of 2002



LIST OF ABBREVIATIONS & TECHNICAL TERMS

ACT	Anthropological Centre for Training
CIESIN	Centre for International Earth Science Information Network
DMSP	Defense Metrological Satellite Program
ESP	Ecological Services Products
GDP	Gross Domestic Product
GIS	Geographical Information System
GPS	Ground Positioning System
IDRISSI	GIS Software
IKONOS	Satellite
IUCN	International Union for Nature Conservation
LAND SAT	Satellite
LUCC	Land Use and Land Cover Change
MapInfo	GIS software
MINEPAT	Ministry of Environment, Cameroun
MINEREST	Ministry of Mineral resources, Cameroun
MSS	Multi Spectral Scanner
OLS	Operation Line Scan
PIXEL	Smallest element of an image displayed on a screen
R/S	Remote Sensing
SAR	Satellite
SPSS	Statistics Package for Social Sciences
TM	Thematic Mapper (Satellite)

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