USING REMOTE SENSING TECHNIQUES FOR RURAL DEVELOPMENT PLANNING IN KENYA. A STUDY IN MERU DISTRICT.

by

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ABSTRACT

The thesis sets out to examine the utility of remote sensing techniques in helping to define recommendation domains - relatively homogeneous agricultural areas - to act as foci for agricultural development planning in lower Meru, Kenya.

Recommendation domains are used in farming systems research (FSR) for agricultural research and development initiatives enabling greater participation from rural producers within the development process. Recommendation domains are defined by agricultural potential (agro-ecological zones) and farming systems (agro-economic groupings).

A multilevel approach incorporating Landsat MSS data, 1:50,000 stereo panchromatic air photography, large scale aerial colour slide photography and ground surveys is used to collect data on the farming systems of the study area. Relatively homogeneous farming patterns are identified and mapped using a number of different computer software packages. These patterns are related to previously identified zones of agricultural potential (agro-ecological zones) to define recommendation domains for new agricultural development initiatives in the area.

Several domains are identified for specific attention. Recommendations are made which are relevant to both national and district level agricultural planning in Kenya. It is suggested that future development programmes should focus on areas undergoing population movement and cultivation change since without careful planning these changes are likely to detrimentally affect the local farming systems and natural environment.

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LIST OF ACRONYMS

AEG - Agro-economic Grouping

AEZ - Agro-ecological Zone

ASAL - Arid and Semi-arid Lands

BN - Basic Needs

CIMMYT - International Maize and Wheat Improvement Centre, Mexico (Centro Internacional de Mejoramiento de Maiz y Trigo)

DDC - District Development Committee

EMI - Embu-Meru-Isiolo Programme

FCC - False Colour Composite

FMR - Farm Management Research

FSR - Farming Systems Research

FSRAD - Farming Systems Research and Agricultural Development

GDP - Gross Domestic Product

GNP - Gross National Product

IADP - Integrated Agricultural Development Programme

IRD - Integrated Rural Development

KARI - Kenya Agricultural Research Institute

KREMU - Kenya Rangeland Ecological Monitoring Unit

LDCs - Less Developed Countries

LRDC - Land Resources Development Centre

MOALD - Ministries of Agriculture and Livestock Development

NARES - National Agricultural and Extension Services

NFSD - New Farming Systems Development

RRSF - Regional Remote Sensing Facility

SRF - Systematic Reconnaissance Flight

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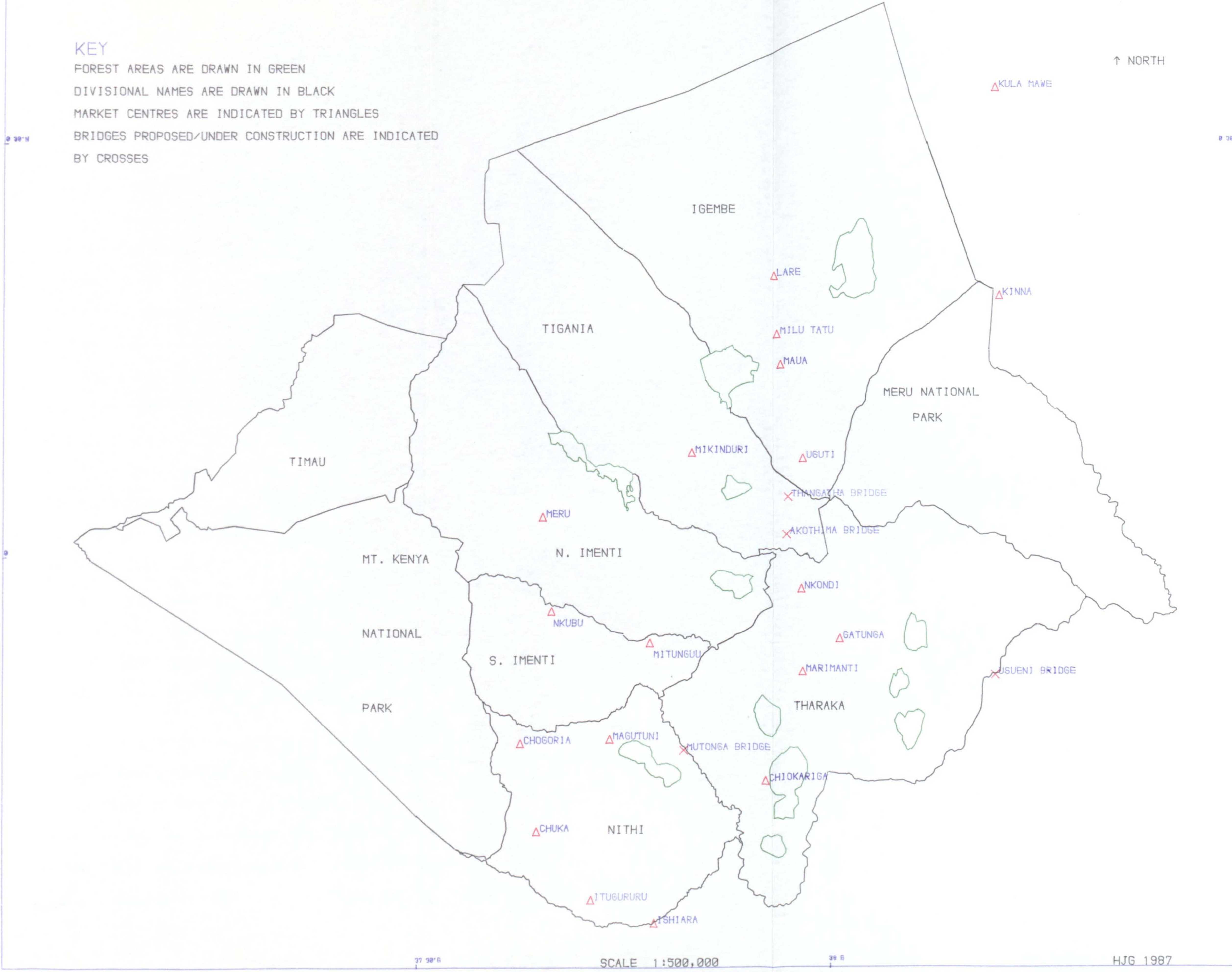
MAP 1 REFERENCE MAP OF MERU DISTRICT



CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND TO STUDY

What are the causes of the poverty we see portrayed so vividly and shamefully on our television screens? Should planners and decision makers tackle poverty by working through existing administrative and organizational structures, or are these, themselves, perhaps part of the problem? Should rural planners be working for, or with, the rural population? Is it more effective to adopt a 'top down' approach to planning, with strategies, goals and objectives being made at the most senior level within an organization, with little or no involvement from those whom the resulting policies are going to affect? Alternatively, would a 'bottom up' planning approach incorporating some participation from rural people be more effective? Should planning be focussed on centralised decision making, or should responsibility be shared, with some decisions being made at regional and district level within a decentralised structure? These are just some of the pertinent questions which are currently facing those in the field of rural development planning.

It is clear however that the quality of the debate concerned with the development of the Third World has declined during the 1980's with few major new initiatives. Part of the reason for this is due to an increasing tendency to generalise across situations which require much more specific treatment and in-depth study. Chambers (1983) has discussed some of the biases which prevent planners from seeing the real problems and needs of rural populations, and which may lead to such generalisations. He aptly groups these under the title of 'rural development tourism', suggesting a comparison with tourists who might visit an area to obtain a superficial and rather optimistic understanding of its people, their priorities and problems.

This study attempts to overcome these criticisms by focussing on the approach of farming systems research (FSR). This argues that the participation of rural people in agricultural development strategies is crucial to the success of such strategies. It also argues that a decentralised organizational structure is most likely to promote improved agricultural production and productivity, although certain elements of agricultural research will have to remain station based rather than farm based. FSR aims to integrate rural people *and* rural knowledge into the development process.

1.1 RELEVANCE OF THE RESEARCH

Public awareness of the African food crisis in the early 1980's has led to rising pressure from both national and international bodies on African governments to develop more effective rural planning strategies. A major limitation of present rural land use planning is the lack of reliable or adequate data on farming groups within the rural environment. Indeed, in many situations agricultural research is conducted with little prior knowledge of the complexity of agricultural land use practices within a given area, and little understanding of why farmers are acting in they way they do. A first priority must be to identify farming groups within the rural environment and to undertake agricultural research *with* such groups in order to understand the resource limitations and development priorities of these rural populations.

Both the agricultural extension services and others involved in rural development practice, recognise that it is increasingly important to be able first, to identify target groups within the smallholder economy and second, to understand the variability within and between such groups. One of the major requirements of such work is that it should be highly location-specific.

The smallholder economy is complex - comprising of a multitude of different crop and livestock practices, variations in farm size, number of farm plots, language groups, length of residency - to name a few characteristics. However, farmers appear to act consistently within any given resource environment and respond consistently to external market stimuli. These facts suggest that it is possible to identify farmer groups within the rural environment, although the internal cohesiveness of such groups may vary from one place to another.

The dissemination of research findings to farmers has traditionally been carried out by the agricultural extension service, and it seems highly likely that this will continue to be the most frequently used channel for transferring technology and information to specific groups within the smallholder sector. The success of agricultural extension however depends to some degree on the validity of the groups identified. Valid groups are defined in this context as: farmers within a given area who have similar resource endowments, access to new technology, market facilities, cropping practices and so on.

The strategy of focussing on target groups has to be economically viable. For technology transfer to occur, it must be adopted on a relatively large number of farms with the same natural and socio-economic environment, similar resource endowments, constraints and opportunities (Collinson, 1982). Clearly, in most developing countries financial resources are also a limiting factor, influencing the amount of public money that can be invested in agricultural research. The success of a new technology is, however, measured in terms of its acceptability and adoption by farmers. Research recommendations therefore need to be timely and appropriate to the particular resource environments of farmers. At the same time if such agricultural development strategies are to gain any national political influence they must be seen to be improving per capita agricultural output and rural employment.

1.2 GEOGRAPHIC FOCUS OF RESEARCH

The research presented here focusses on a marginal and relatively inaccessible area of smallholder farming in Meru, one of the forty districts within Kenya. Kenya is primarily an agricultural producer although approximately 80% of the country is unsuitable for rainfed cultivation. Farming within the country is divided between a large farm sector and a smallholder sector. Both of these play an important role in the national economy by providing foreign exchange through export earnings from cash crops, and in satisfying national food requirements. The study focusses on the smallholder economy since this sector will need to support the fast growing national population, both by satisfying food demand, and in providing employment for an increasing number of young school leavers who will be entering the job market over the next fifteen years. While the large farms and estates account for only about five percent of the agricultural land and already have well developed employment structures, future job creation will almost certainly have to come from within the smallholder sector.

In July 1983 the Government of Kenya launched a new national development programme called, "District Focus for Rural Development" (Republic of Kenya, 1984). The objectives of this programme are: to improve problem identification, to increase the resource mobilization, and to improve project implementation at district level. National ministries are still responsible for overall policy guidelines, but the districts are responsible for the operational aspects of rural planning. This policy recognises that district personnel are in the best position to identify and prioritise projects since they are in close contact with the rural population. In line with this recent policy, the work presented here is limited to Meru district.

Meru district is situated in the centre of the country and encompasses an area stretching from the peaks of Mount Kenya, east to the Tana river, the largest river in the country, north to the dry, arid lands of Isiolo, and south towards the densely-settled Embu district, and more marginal Kitui district (Figure 1.1). Meru is one of the most ecologically diverse areas of the country, and as a result contains a very complex pattern of smallholder production. It is therefore an ideal situation to study since it encompasses a number of different agricultural systems. At the same time there are a number of important cultural differences among the people and this is reflected in the agriculture practiced. Meru is also a region experiencing increasing land pressure, with population increase and internal migration both contributing towards the demand for land. Within the district there is a divide between the relatively prosperous west and north, and the poorer, south and east - in particular between the farmlands of the Mount Kenya and Nyambeni foothills and the lower, drier, pastoral area of Tharaka.

The study concentrates on the medium to marginal agricultural potential land of lower Meru. Much of this region falls within the arid and semi-arid lands programme area (ASAL) which has been identified for special development assistance by the Kenya government. Part of this area is also included in the Embu-Meru-Isiolo soil and water conservation programme which is financed by the UK.

1.3 SCOPE OF RESEARCH

This study aims to identify target groups of farmers by using the crop cover and land cover characteristics of the farming systems within the study region to define relatively homogeneous agricultural areas. Remote sensing techniques are used as an aid to identify farmer groupings. These groupings are called agro-economic groupings (AEGs) and are defined as: smallholder agricultural areas which have similar crop, livestock and off-farm activities which may be distinguished on the basis of the spatial characteristics of the land use under study.

The agricultural homogeneity and heterogeneity of target groupings are related to characteristics of the farm population and to cropping practices undertaken by farmers within such groupings. AEGs are used to define recommendation domains. Recommendation domains are defined as: homogeneous groups of farmers with similar; natural resource endowments, access to markets and socio-economic characteristics. Finally, the identified recommendation domains are used to suggest where new development initiatives should be focussed within the district.

The major objective of the research is:

To test the utility of remote sensing techniques in helping to identify recommendation domains - relatively homogeneous agricultural areas - to act as foci for agricultural research and development initiatives within lower Meru.

In line with this above objective:

To establish the spatial distribution of agro-economic groupings within the lower and eastern areas of Meru district.

To examine the internal consistency of agro-economic groupings in relation to farmer mobility/residency.

There are three main research hypotheses in the study:

The homogeneity of AEGs is related to farmer mobility/residency. AEGs which are most homogeneous tend to include farmers who have been resident longer than farmers residing in AEGs which are more varied internally.

Areas of recent cultivation change are also the areas of greatest population movement.

Farmers within the same agro-ecological zone act consistently and maintain a similar farming system.

1.4 STRUCTURE OF THE THESIS

Following this chapter, Chapter Two has two main sections. In the first, a brief outline of the agricultural sector within Kenya is discussed. The second section is more detailed, and contains a number of subsections. These are used to introduce the reader to the case study area of Meru district.

A literature review is presented in Chapter Three. The first section discusses current views of development planning from a post-Second World War perspective. Section two introduces the systems approach within agricultural research and development. Farming systems research (FSR) and a number of other models are reviewed in the third section. Finally, the use of remote sensing techniques in rural development planning is considered.

The research methodology is discussed in Chapter Four. It contains four main sections. The first section outlines the approach used to identify recommendation domains. Section two discusses the field survey methods, questionnaire, field measurements and the collection of crop statistics. The sample design and sampling strategy are considered in the third section. The final section deals with the methods used to identify areas of land use/cover change in lower Meru using Landsat MSS data and 1:50,000 stereo panchromatic aerial photography.

Chapter Five deals with the data processing and manipulation undertaken prior to analysing the ground and air survey data. There are three sections. The first discusses the methods which were used to derive absolute land cover and crop cover percentage estimates from the three air surveys. The methods of computing similar estimates using the ground survey data are explained in the second section. Finally the techniques which were used to map and display the analysed data are discussed.

Comparisons between the air survey and ground survey data are made in Chapter Six. The chapter is divided into four main sections. The first section examines the nature of the frequency distributions of the data in order to test whether parametric or non-parametric statistical tests can be used in the analysis. In the second section, the areas under selected crop variables identified from the ground survey are compared in order to discuss seasonal variations in crop area. The effects of variations in the ground resolution of the aerial photography are examined in the third section. In the final section crop cover percentage estimates for the major crops in the region are compared across the ground and air survey data sets. Five crops are selected to help identify agro-economic groupings in Chapter Seven.

Agro-economic groupings (AEGs) are identified and defined in Chapter Seven. This is a long chapter and has four main sections. The initial section discusses the manner in which the data are compressed using principal components analysis. Canonical correlation of the air and ground survey data sets is the focus of the second section. In the third section results of a multiple regression analysis on the two data sets are presented. Four AEGs are identified together with a more heterogeneous transitional farming zone. Individual farm data are employed to examine the homogeneity of the identified AEGs in the fourth section.

There are five main sections in Chapter Eight. Discriminant analysis is used to classify all the individual farm data in the first section. The results of this analysis are used to redefine AEGs where necessary. The hypothesis that there is a relationship between farmer mobility/residency and the internal homogeneity of AEGs is examined in section two. In the third section recommendation domains are defined. The stability of the defined domains are discussed by relating these domains to areas of recent cultivation change identified using Landsat MSS data and 1:50,000 panchromatic air photography in section four. Finally, the identified domains are discussed in relation to the need for new agricultural research and development initiatives in lower Meru.

Chapter Nine is the final chapter and has four main sections. The first summarises the findings of the study. In the second the main limitations of the study are described. Recommendations emanating from the study are discussed in the third section. In concluding, suggestions for further research are made.

CHAPTER TWO

DISTRICT FOCUS FOR RURAL DEVELOPMENT - A PROFILE OF MERU

2.0 INTRODUCTION

Before considering the theoretical basis of the approach adopted in this study to identify recommendation domains, it is important to provide an introduction to the geographical area under study. The present chapter starts with a brief review of the position of agriculture within the Kenyan economy and is followed by a more detailed discussion of Meru district, which is the focus of the study. The study region is described and reasons for focussing on the drier and more marginal areas of the district are put forward.

2.1 KENYA - AN AGRICULTURAL ECONOMY

Kenya is about the size of France but despite its expanse, Kenya faces a critical situation in that her natural resources are no longer capable of sustaining her burgeoning population. The total population is estimated to be approximately 20 million and this is expected to grow to some 35 million by the year 2000 - Kenya has one of the fastest growing populations in the world. However, only about 19% of the land area is suitable for rainfed cropping and 85% of the population is therefore concentrated in this area.

The country sub-divides into five main land resource zones. These include the humid west, central highlands, coast, semi-arid uplands and arid lowlands (Figure 2.1). In area, the arid lowlands dominate, accounting for 69% of the country. Potential agricultural production is limited to about 8.6 million hectares and although some 200,000 hectares of the drier zones are estimated to be suitable for irrigation (ODA, 1986) the costs of developing this potential are huge. It is unlikely then that much expansion of the cultivatable area will occur before the end of the century, and even if expansion does occur this will only be a very small addition to the 5.2 million hectares currently devoted to crop and milk production (Republic of Kenya, 1986).

Kenya is a country with an open economy with exports and imports accounting for large shares of the Gross Domestic Product (GDP), although the precise shares vary from year to year depending on world market prices and on export volumes. Since 1974 the share of imports has ranged from a high of 43% to a low of 32% in 1976. Exports have ranged from 31% in 1977 to 23% in 1980, while agriculture over a seven year period from 1974 to 1980 averaged 51% of GDP. Over the same period the share of manufacturing industry was small at an average of just 15% (Hunt, 1984).

Given the structure of her economy Kenya must place future development emphasis on the agricultural sector. The modern wage sector, for example, currently employs only about 1.1 million out of a total workforce of approximately 7.5 million, the remaining 6.4 million being largely rural based and employed in either the informal sector or in non-wage agriculture (Republic of Kenya, 1986). Future employment needs will have to be met from within the rural areas.

High fertility rates in Kenya (estimated to be eight births per adult woman) are compounding the problems facing the country and are leading to mounting pressure on the natural resources, and especially on the available cultivatable land. Rapid subdivision of farm holdings is occuring in many districts (the situation in Meru district will be discussed later) with an increasing threat that holdings will become unviable and will be unable to support the subsistance needs of farm families in the future.

In addition to the above mentioned factors, there has been a tendency towards growing imbalances between the modern and industrial sector on the one hand, and the traditional and informal sectors on the other. As a result, inequalities between the urban and rural areas have become pronounced. In view of this unbalanced growth it is encouraging to note that government development policies since the late 1970's have aimed to redirect attention towards the rural districts.

In July 1983 the Government initiated the District Focus for Rural Development Strategy in an effort to decentralise decision-making and development planning to the districts, and to counter the imbalances which had grown out of the centralised planning structure that had been in operation since Independence in 1963. The main aims of this strategy are to move planning, budgeting and purchasing powers away from Nairobi, the capital, to the regions (Sindiga and Wegulo, 1986). It aims to extend the benefits of development to local people by encouraging local initiative to improve problem identification, resource mobilization and project implementation (Republic of Kenya, 1986). It is a strategy that seeks greater participation from rural people in the belief that this will lead to more rapid development. The emphasis is on rapid rural appraisal techniques which can identify the problems and needs of rural producers quickly and effectively. What are the options open to rural development planners within this new approach?

In general the 'soft options' of expanding the area under cultivation, removing the restrictions that prevented Africans from growing cash crops, and introducing scientifically advanced methods of production on the larger farms no longer exist for Kenya's agriculture (Lofchie, 1985). The recent Sessional Paper (Republic of Kenya, 1986) recognises this and sets out three broad strategies to overcome what some authors have called the 'impending crisis' in the country (e.g. Hunt, 1984; FAO, 1983) as Kenya faces a critical period with declining per capita agricultural output being recorded during the 1970's and early 1980's (Mosley, 1986). In the face of this challenge the three strategies outlined focus on:

1) Encouraging small farmers to adopt more productive practices including the use of improved varieties, fertilizers, and disease and pest control.

2) Undertaking agricultural research into new varieties, especially maize and other grains.

3) Diversifying the production pattern in favour of crops such as tea, coffee and vegetables.

Of the 44.6 million hectares of land in Kenya only 8.6 million hectares are of medium to high agricultural potential (Republic of Kenya, 1986). Maize, dairying, beans, root crops, sorghum and millet account for only 43% of the total value of agricultural commodities yet they occupy almost 84% of the farmland. Coffee, tea and vegetables produce 37% of the total value while covering only 5% of the land (Ibid., 1986). However as Fair (1985, p.23) notes, during the 1979-1983 development plan:

> "smallholdings, averaging 2 hectares each, were occupied by 70 per cent of the Kenyan population, and were responsible for 75 per cent of total employment."

With this background Kenya's small farmers will have to become the focus of the government's rural development strategy if the disparity between her soaring population, and disappointing per capita agricultural output is to be successfully tackled. Greater emphasis on diversifying agricultural research expenditure in favour of traditional food crops rather than the already important cash crops of tea and coffee should be made. Employment generation will in the short to medium term have to come from this sector of the economy. Plantation agriculture although providing employment for the rural landless at the moment (Davies, 1987), cannot be expected to continue to absorb surplus rural labour in the future. Without adequate investment in the smallholder economy there will be no practical alternative to generating the estimated 4.1 million extra jobs which may be needed in the agricultural sector - an increase of 160% over the next twenty years (Livingstone, 1986).

The main thrust of development within the country must then be towards *rural development.* The government recognises that this will involve not only renewed emphasis on smallholder agricultural development, but also a need for strategies on human settlement patterns which promote regional growth and counteract excessive congestion around Nairobi and Mombasa - currently the two main growth poles in the country (Republic of Kenya, 1978). Under this strategy a network of Designated Service Centres is being established to improve the quality of life in the rural areas while still maintaining the development of a few strategically placed Growth Centres, of which Meru town in Meru district is one example.

The research presented in this thesis can be seen as a contribution towards promoting sound, long-term, district agricultural planning. In this regard it supports the government strategies outlined above which are aiming to establish long-term regional growth together with a greater participation for rural people in district development initiatives. The work reported here is of particular relevance to the agricultural research and development services within Kenya. It is especially important that rural development is linked to agricultural research, given the country's heavy reliance on overseas aid within the development budget. Unless this aid is carefully monitored, short-term, high-profile projects may divert funds from the longer term more fundamental development programmes that are required. In this regard it is important to target development assistance towards specific groups of people in the rural environment. Where common needs are recognised research can be undertaken which will be of benefit to many producers.

Since the early 1980's Kenya has become more dependent on external aid sources in terms of overall levels of government expenditure. For the year 1979-80, overseas aid formed 39.9% of government expenditure, while by 1982-83 this had risen dramatically to 84.8% (Duncan, 1986). The government must bargain hard with the international community to see that long term investment of these monies occurs in the agricultural sector. Most of the prime agricultural land is already intensively farmed, and has to date received most of the benefits accruing from agricultural research. In future efforts should focus more on the important food crops being grown predominantly by smallholders.

> "It is precisely in the area of food commodities such as milk, maize, wheat, cassava, pulses, sorghum and millets that Kenya's agricultural performance has been particularly disappointing in recent years and research performance in these areas has been disappointing to match." (Mosley, 1986, p.520)

The agricultural research budget has been under-funded with only half as much spent on maize, the staple African food, as on coffee, and very little on sorghum and millet (Ibid., 1986). This research emphasis on cash crops and exotic foods has long historical roots. The National Cash Crops Policy of 1963 implied that crops which could be neglected from agricultural development included:

> "....a large variety of African food crops. All millets, sorghums, cow-peas, dolichos, sweet potatoes, colocasia etc which are for purely local consumption and have no considerable internal or export market." (Omuse and Adala, 1984, p.11)

The significance of this policy was that it formed the basis of the agricultural planning section of the First Development Plan 1964-1970. Twenty years on from this policy, a shift has occured in the form of the National Food Policy of 1981 which has been underwritten in the current Fifth Development Plan 1984-1988. This ensures a greater role for the smallholder economy within the proposed national agricultural strategy (Ibid., 1984).

These policy shifts do appear to demonstrate a new awareness of the need to undertake agricultural research and development which is of direct relevance to the smallholder. With greater emphasis on rural development and specifically agricultural development, it is essential that development initiatives are effectively targeted, thus ensuring maximum involvement from rural dwellers as well as allowing a *majority* of farmers access to the fruits of such development. In this regard identifying target groups of farmers in lower Meru is one of the primary aims of this research.

Having discussed some of the basic development problems within the country and reviewed recent government policies aimed at overcoming these, the next section introduces the study region of Meru district.

2.2 MERU DISTRICT

The selection of Meru district, Kenya, as a suitable research area for this study must be seen in relation to the overall objective of the study and the current agricultural priorities within the country which have been outlined above. The reader is reminded that the main objective of the research is:

To test the utility of remote sensing techniques in identifying recommendation domains - relatively homogeneous agricultural areas - to use as foci for agricultural research and development initiatives within lower Meru.

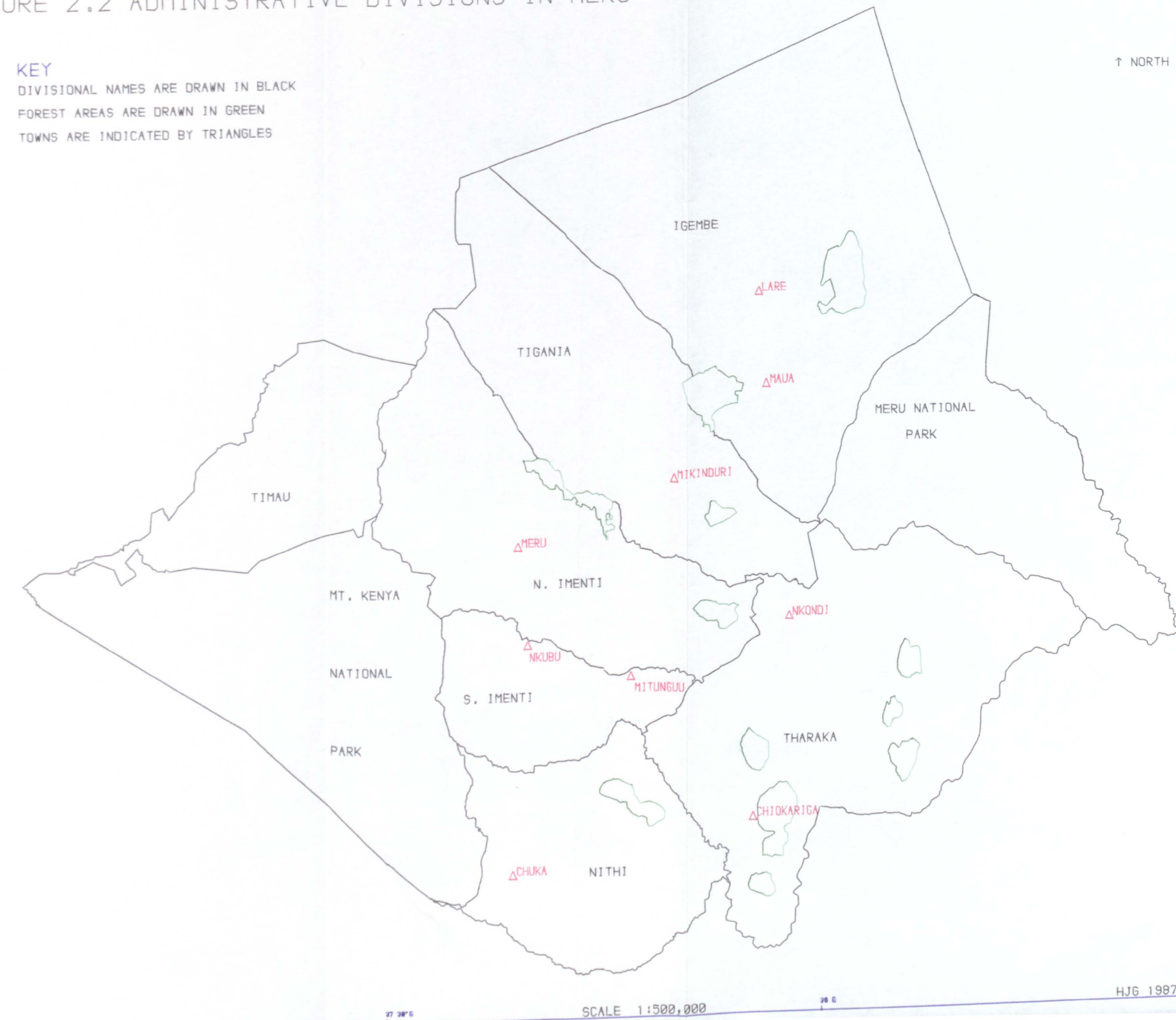
Bearing this in mind, discussion in the following section focusses on the historical and demographic, physical, and agricultural facets of Meru. Reasons for limiting the study to the lower Meru region are explained.

2.2.1 GENERAL BACKGROUND

Meru district is one of forty districts in Kenya and is situated to the east of Mount Kenya in the central region of the country (Figure 1.1). The district headquarters, Meru town, is located about 200km north of Nairobi. Administratively the district is divided into seven divisions of: North Imenti, South Imenti, Tharaka, Nithi, Igembe, Tigania and Timau (Figure 2.2). Each of these divisions is further sub-divided into locations and sub-locations. Politically the district is represented by seven MPs covering the constituencies of Nyambeni North (Igembe), Nyambeni South (Tigania), Meru South (Nithi), Meru South-West (most of North Imenti), Meru North-West (part of North Imenti and Timau), Meru Central (South Imenti) and Meru South-East (Tharaka) (Republic of Kenya, 1983).

The district covers a land area of 9,922 square km. Apart from agricultural land which represents some 5,331 square km, forest reserves cover an area of approximately 1,579 square km and the two National Parks (Meru National Park and Mount Kenya National Park) represent an additional 1,708 square km.

FIGURE 2.2 ADMINISTRATIVE DIVISIONS IN MERU



In terms of national agricultural capacity (derived from monetary estimates of potential annual average yields for the major cash crops) Meru is second in importance to Narok (Republic of Kenya, 1978). It is therefore likely to contribute significantly to the increase in agricultural productivity which will be required to support the country's subsistence needs well into the twenty first century (Figure 2.3). It is perhaps appropriate to select Meru as a focus for the work reported here for this reason alone. However, there are also a number of more specific reasons for this choice and these are presented in the discussion that follows.

2.2.2 HISTORICAL AND DEMOGRAPHIC BACKGROUND

Historically there were eight different peoples in the Meru area - an area which approximates to the boundaries of present-day Meru district. All these groups are recent migrants who have moved from the Tana basin in the last two hundred years or so and include the Chuka, Tharaka, Muthambi, Igoji, Mwimbi, Imenti, Tigania and Igembe. They are all grouped as Bantu although the Tigania have had long historical contact with the Masai (Adamson, 1967). Even today distinctions can be made between the people of Meru which are based on these historical language and cultural differences. The Tharaka people are from the Kamba tribe in neighbouring Kitui district to the south-east of Meru, and may well have been influential in the spread of maize in this region during the mid nineteenth century (Bernard, 1972).

Currently there are estimated to be some 900,000 people in Meru with over 90% of these involved in agriculture (Weekly Review, 1987). At the last census in 1979 50.8% of the population were children under 15 and 19.5% were under five. Table 2.1 below shows the divisional breakdown of the total district population with a projection for 1988.

TABLE 2.1

POPULATION MERU DISTRICT 1979 AND 1988

DIVISION	CENSUS 1979	1988
NORTH IMENTI	198,434	290,404
SOUTH IMENTI	103,543	151,533
TIMAU	23,389	34,229
NITHI	142,288	208,236
TIGANIA	140,651	205,840
THARAKA	50,277	73,579
IGEMBE	171,597	251,129
TOTAL	830,179	1,214,950

Source: Republic of Kenya, 1983, p.7.
Projection is based on an annual population growth rate of 3.91%.

North Imenti continues to have the highest number of people and Timau the lowest number of people. Timau has only recently been scheduled for smallholder settlement as it was formerly an area of large European-owned farms. The figures above give little indication of where more recent population pressure is arising however. It is difficult to obtain reliable estimates at locational level within the district as there have been a number of boundary changes since the 1979 census which makes it impossible to accurately compare figures at this level. Field experience suggests that the most significant population changes are taking place within the eastern and lower regions of Nithi, South Imenti, North Imenti, Tigania, and Igembe divisions, as well as the northern area of Tharaka division to the south and south-west of Meru National Park (Figure 2.4).

This east Meru region forms a major part of the focus of this study. Part of this region is also the focus of the British aid to Kenya, Embu-Meru-Isiolo (EMI) programme, which is concerned with soil and water conservation, forestry and livestock production. Increases in cultivation resulting from population pressure is affecting both the farming systems and the fragile natural environment of the region and the present study should be seen as a contribution to more effective agricultural planning for the area. The research findings are expected to be of interest to those working in the EMI programme.

2.2.3 PHYSICAL CHARACTERISTICS

The physical and climatic characteristics of Meru district are very diverse. One of the main reasons for this lies in its geographic location. The Mount Kenya massif lies in the west and the Nyambeni hills dominate the north while to the east the district stretches as far down as the harsh bushland plains of Tharaka bordering the Tana river. Here the landscape is broken by steep inselbergs protruding from lowland plains dissected by widely spaced rivers and seasonal river courses. The highest point in the district is also the highest in the country and reaches above 5300 metres, while to the south-east of the district the altitude is little more than 300 metres above sea level.

FIGURE 2.4 RECENT AREAS OF POPULATION CHANGE IN LOWER MERU

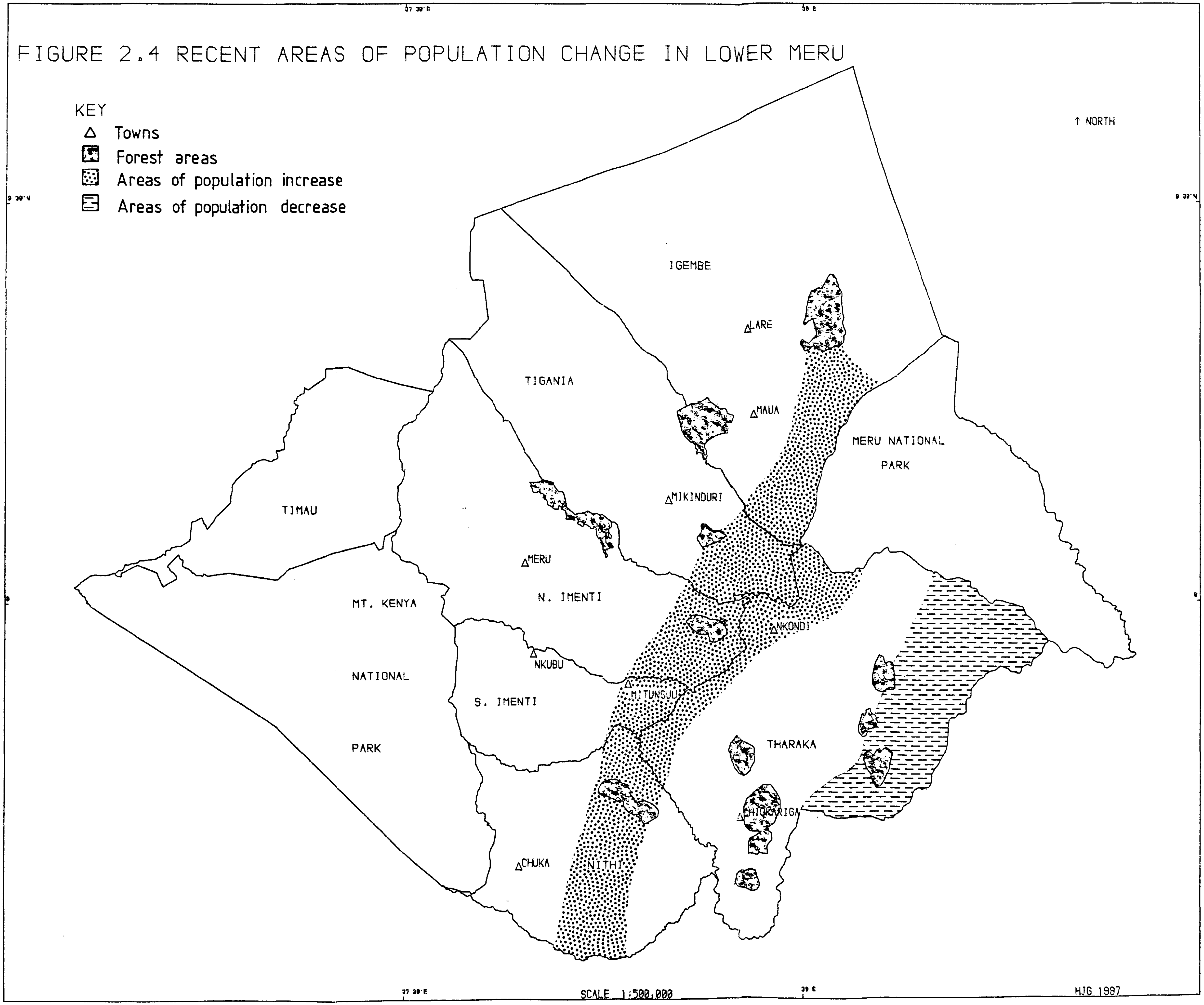


Figure 2.5 shows the altitude range within the study region. Temperatures range correspondingly from the glaciers of Mount Kenya to the dry, baking plains of Isiolo and the harsh, thorn bushland of Tharaka.

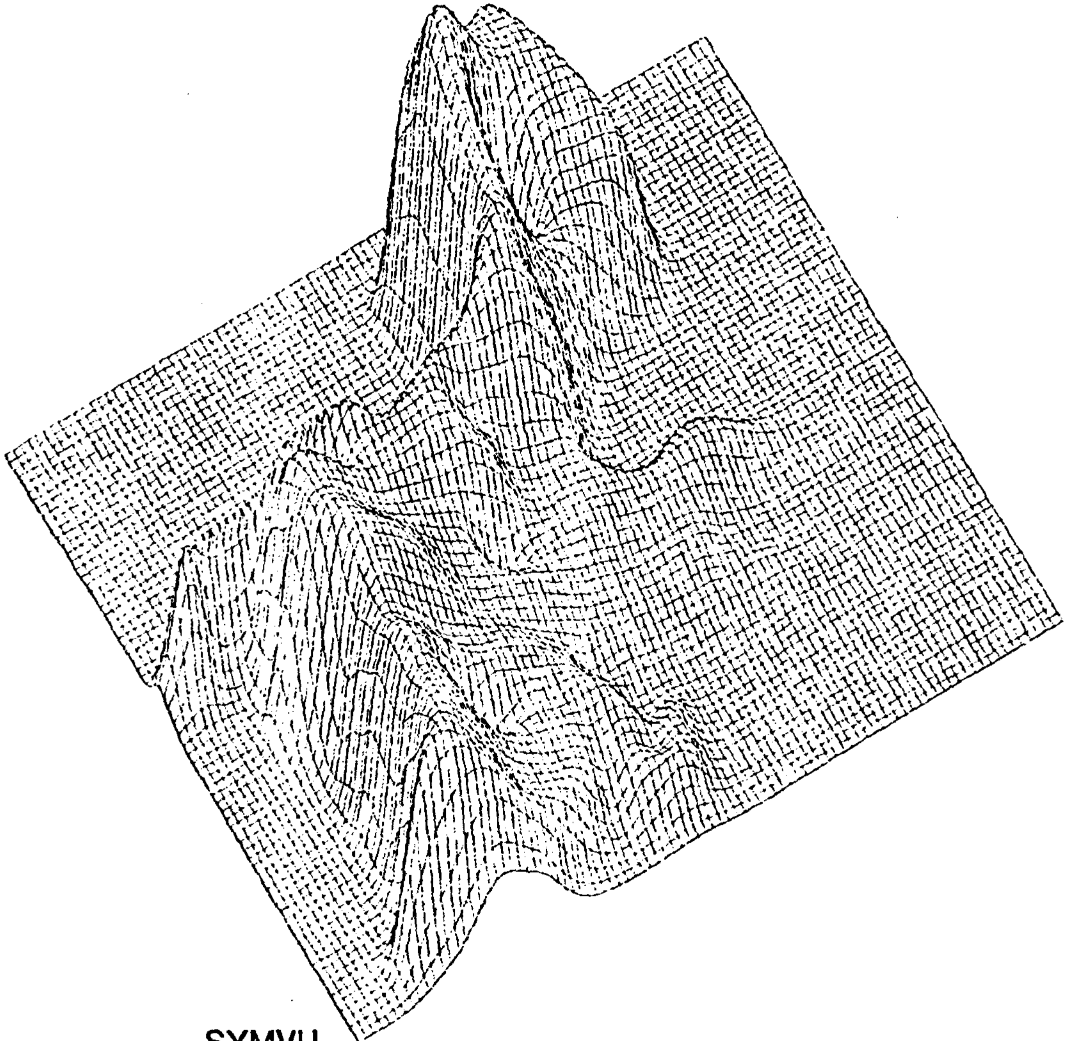
The landscape is very heterogeneous and therefore provides an interesting gradient of agricultural potential for study. The land configuration has a dominant influence on the agriculture of the area. Typically, the presence of the two mountain masses mitigates against high temperatures and rates of evapotranspiration, yet they also provide high levels of rainfall, and the southern and north-western parts of the district receive between 1400 and 2200mm of rainfall annually. This contrasts with an annual rainfall of between 400 and 800mm for the lowland areas to the east and north.

There are two important characteristics which are particularly relevant to a discussion of agriculture in Meru. The first of these is the rainshadow to the north and north-west of the two mountain complexes. Within a matter of a few kilometres, conditions which are ideal for the growing of coffee, tea and pyrethrum change to an environment in which it is too dry for maize growing in many seasons (Jaetzold and Schmidt, 1983). This part of the district is however outside the focus of the present study.

The second main feature is the pronounced decline of rainfall as the district slopes eastwards. Low rainfall together with high temperatures make the eastern border of the district (Tharaka division) very marginal and almost unsuitable for rainfed farming; indeed the agriculture practiced in the area is of a shifting

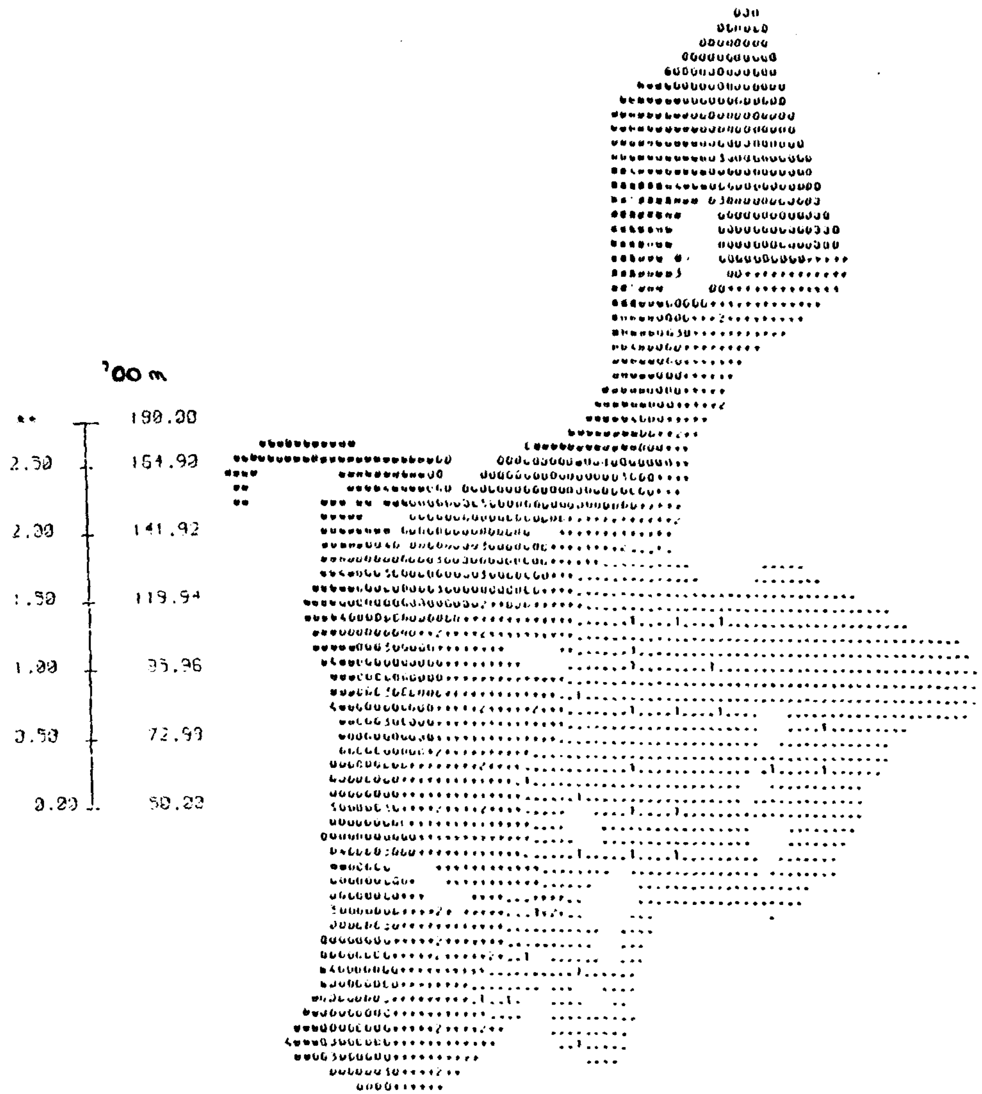
Figure 2.5

3 dimensional spatial distribution



SYMVU

2 dimensional spatial distribution



SYMAP

Dark shading indicates high values

Light shading indicates low values

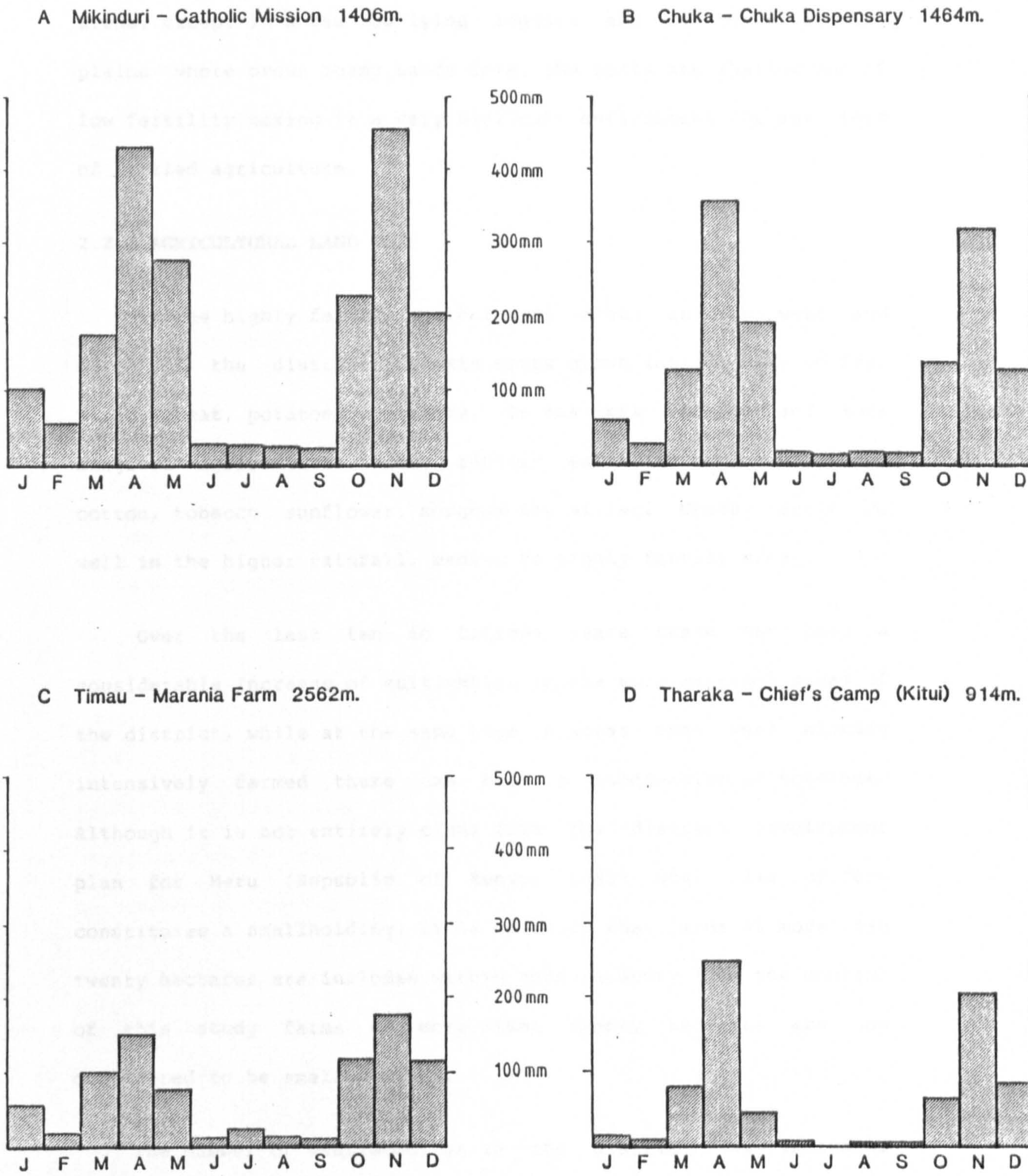
ALTITUDE RANGE WITHIN THE STUDY REGION – LOWER MERU (Scale in metres) type, with farmers moving on to farm a new piece of land after every second or third season. Mean annual rainfall figures mask the variability of rainfall in this part of the country. Thus not only do the lower areas suffer from low rainfall, they cannot even depend from one season to the next on getting the same amount. It is primarily this area which is the focus of study.

Annual rainfall is generally bimodal within the district (Figure 2.6). The longer of the two rainy seasons begins during March and extends well into May and sometimes early June. The second rainy season begins around mid October and persists into late December. These two periods are separated by much drier weather, and the agricultural life in the district revolves around these seasonal patterns - a fact of some significance when using remote sensing techniques to distinguish between agro-economic groupings (farming systems) within the district (see Chapter Six).

Both the climate and soils in the district are closely related to the landforms of the area. Within the area the main difference in soils is between the highlands, based on more recent volcanic materials, and the more ancient basement rocks of the lowlands. The soils of the highlands tend to be more clayey, while those of the basement system are more sandy. It would be a mistake to view the highlands as entirely fertile however, for as Bernard (1972, p.25) notes with respect to the south-eastern and eastern slopes of the mountain massifs:

> "heavy rainfall rapidly leaches out minerals in these (brown loam) soils; most are overacidic, structureless, and weak."

Figure 2.6 Seasonal Rainfall for Selected Stations – Meru.



Adapted From : 1:250,000 Climate and Vegetation Map , Government of Kenya 1976.
Jaetzold and Schmidt , 1983.

Careful crop husbandry, soil conservation and water control are needed to maintain the fertility of such areas. In the lowland areas, except in a few low lying regions and scattered fluvial plains where brown loamy sands form, the soils are shallow and of low fertility making it a very difficult environment for any form of settled agriculture.

2.2.4 AGRICULTURAL LAND USE

In the highly fertile agricultural areas in the west and north of the district the main crops grown include tea, coffee, miraa, wheat, potatoes and maize. In the less fertile and more marginal agricultural areas further east the common crops are cotton, tobacco, sunflower, sorghum and millet. Grade cattle do well in the higher rainfall, medium to highly fertile areas.

Over the last ten to fifteen years there has been a considerable increase of cultivation in the more marginal areas of the district, while at the same time in areas that were already intensively farmed there has been a subdivision of holdings. Although it is not entirely clear from the district development plan for Meru (Republic of Kenya, 1983) what size of farm constitutes a smallholding, it is unlikely that farms of more than twenty hectares are included within this category. In the context of this study farms of more than twenty hectares are not considered to be smallholdings.

The number of smallholdings in the district has increased substantially from an estimated 98,178 in 1976 to 114,243 in 1982 (Republic of Kenya, 1983). There appear to be three reasons for this. First, in Timau division many of the former large farms have been subdivided to create a larger number of smallholdings. Second, some families have been selling land to others who are in need of land. Finally, there has been an increasing trend for families to subdivide their holdings into smaller land parcels to give to their children. Also apparent is an increase in multi-cropping (crop complexes) with an estimated change from 230,200 hectares in 1979 to 422,835 hectares in 1983 (Ibid., 1983).

As mentioned earlier, it is clear that given this increase in cultivation intensity, both the smallholder farming systems and the local natural environments of these areas of change will be affected. Long-term detrimental changes are likely unless efforts are made to identify the areas most affected so that agricultural research and development initiatives can be undertaken to prevent environmental degradation.

Table 2.2 shows a breakdown of agricultural land potential by division for the district. Agricultural potential is defined according to the probability of meeting the temperature and water requirements of the main crops within particular areas. A full discussion of agro-ecological zones is given in Chapter Four.

Generally speaking the highland and upper midland agro-ecological zones are the most fertile while the lowland zone is very marginal. The upper highland zone is most suitable for pyrethrum, wheat, barley and dairying. Tea, wheat, maize, barley, dairy and sheep are most suited to the lower highland zone. In the upper midland zone coffee, tea, maize, beans, potatoes and sunflower are commonly grown. The lower midland zone is the most important cotton-growing area although millets, sorghums, and sunflower also do well in the relatively higher rainfall areas. Livestock are also important in the lower reaches of this zone. Finally, the lowland zone is most suitable for livestock grazing though some millet is grown.

TABLE 2.2

AGRICULTURAL LAND BY DIVISION AND AGRO-ECOLOGICAL ZONE IN MERU DISTRICT ('00 ha)

DIVISION	UH	LH	UM	LM	L	TOTAL
TIMAU	288	193	211	12	-	704
NORTH IMENTI	43	90	206	325	-	664
SOUTH IMENTI	-	52	171	102	-	325
NITHI	-	20	162	314	2	498
THARAKA	-	-	-	398	896	1294
TIGANIA	-	9	136	316	-	461
IGEMBE	-	6	243	1079	57	1385
ZONE TOTAL	331	370	1129	2546	955	5331

The Table excludes the Tropical Alpine Zone.
UH indicates upper highland, LH indicates lower highland, UM indicates upper midland, LM indicates lower midland, L indicates lowland. Own computations based on information in Jaetzold and Schmidt, 1983.

Clearly the largest percentage of agricultural land falls within the lower midland zone of the district (48%), yet the fertility of this zone is generally only moderate to low (Figure 2.7). As mentioned earlier this area has also experienced a recent population influx. The lower midland zone falls within the arid and semi-arid lands (ASAL) - a region of the country which has been identified for particular development assistance by the government under the ASAL programme. The ASAL region corresponds to areas with between 200-800 mm of annual rainfall and includes 473,000 square kilometres or 82% of Kenya's land area (Republic of Kenya, 1979).

In the context of Meru district, ASAL includes the marginal cotton zone (lower midland zone 4), the livestock-millet zone (lower midland zone 5 and lowland zone 5) and the ranching zone (lowland zone 6) (Figure 2.8).

Within Meru district it is clear that these lower zones have in recent years suffered considerable agricultural decline. Livestock estimates for the period 1977-1982 show that Zebu cattle, goats and sheep have decreased by 69%, 50% and 33% respectively (Republic of Kenya, 1983). These estimates were computed prior to the 1984 drought which has caused further severe hardship. Similarly, production estimates for the major crops in this region indicate a significant decline in output.

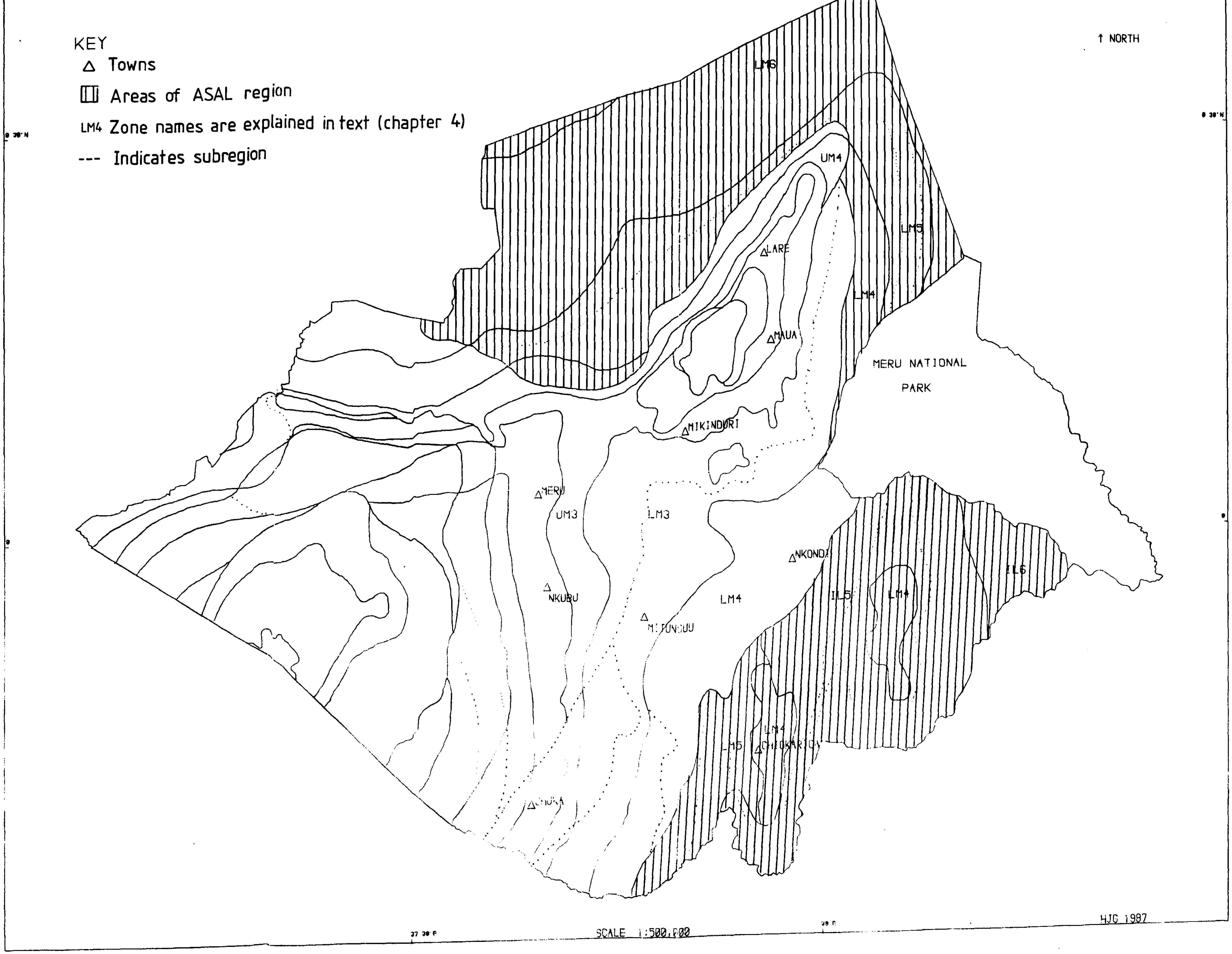
TABLE 2.3

CROP PRODUCTION IN MERU DISTRICT (estimates)

CROP TYPE	HA/TONS	1976	1982	%CHANGE
SUNFLOWER	HECTARES	695	1,725	148
	TONS	2,628.8	1,380	-48
COTTON	HECTARES	12,053	15,313	27
	TONS	3,689	2,100	-43
MILLET/ SORGHUM	HECTARES	6,220	7,900	27
	TONS	8,678	6,675	-23
PIGEON PEA	HECTARES	3,276	3,200	-2
	TONS	1,592	1,920	21

Adapted from: Republic of Kenya, 1983, p.96.
1983 figures unavailable, 1984/5 figures not used due to bias resulting from the 1984/5 drought.

FIGURE 2.8 AEZ MAP OF MERU SHOWING ASAL REGION



The above figures indicate that although the area under sunflower, cotton, millet and sorghum has increased, the overall production for these crops has decreased significantly. Pigeon pea is the only exception to this trend. It is not the objective of the present study to ascertain the reasons behind the decline in agricultural productivity and production shown above. Rather, the figures in Table 2.3 are used to illustrate some of the negative agricultural characteristics of the more marginal areas of the district.

Over the same six year period the more fertile parts of the district showed steady crop production increases. Thus tea and coffee production were up by 29% and 19% respectively, while maize production rose by 136% (Ibid., 1983). These production figures indicate that there is a growing gap between the lowland areas and the relatively prosperous highland zones and clearly show the need for agricultural research and development initiatives in the lower Meru region.

The research presented here covers the lower Meru region which includes these more marginal lands. The research findings are expected to support both the on-going ASAL programme - of which the British EMI programme is part, and the more recent District Focus for Rural Development Strategy of the Kenya government. By identifying target groups of farmers with similar farming systems, natural resource endowments and access to market and government services, the research provides a framework for more effective and participatory agricultural research and development in this area.

2.3 SUMMARY

Some general remarks are made with regard to the position of agriculture within the Kenyan economy in the first part of this chapter. The importance of current government efforts to decentralise planning to the districts and to involve rural people more within the development process is emphasised. Meru district is described in more detail in the second part of the chapter, with particular emphasis being placed on agriculture in the region. The latter part of this second section contains a discussion on some of the characteristics of the more marginal land within Meru and shows that this area needs particular development assistance. It is proposed that recipient groups with similar agricultural problems need to identified to ensure that development monies and personnel are used most effectively.

The next chapter reviews the position of agricultural sector within post Second World War rural development planning. It emphasises the neglect of the role of the farmer in most development planning to date and suggests how a systems approach can be used to establish the farmer as the key actor within the rural environment. It is argued that the farmer must be the central figure in any participatory agricultural development initiative.

CHAPTER THREE

DEVELOPMENT PLANNING, FARMING SYSTEMS RESEARCH AND REMOTE SENSING

3.0 INTRODUCTION

The previous chapter has identified some of the major development problems facing Kenya. It has been argued that the success of the future development of the country is closely linked to agricultural development within the smallholder sector of the economy. In order to ensure that future development initiatives are to succeed in this sector, target groups of farmers must be identified. At the same time it is essential that agricultural research and development personnel work *with* rather than for rural groups. Participatory development is fundamental to the success of rural programmes operating within the smallholder economy.

This chapter begins by reviewing the current position of development planning within the specific context of agricultural development in the tropics. Some of the limitations of past development planning models are discussed. In the second section a systems approach to agricultural development is introduced which, it is argued, provides a suitable framework for understanding the complex agricultural environment of the smallholder. Farming Systems Research (FSR) - the approach adopted in this study, is introduced and compared with a number of other agricultural research and development approaches in the third section. FSR correctly focusses on the central position of the farmer within the rural environment, and in so doing can be used for planning and implementing participatory development.

In the final section the use of remote sensing procedures in rural development planning is discussed. Some comments on satellite remote sensing are made but more particular emphasis is placed on aerial remote sensing, specifically sample colour slide photography, since use of this latter procedure is one of the main foci of this dissertation.

3.1 DEVELOPMENT PLANNING AND AGRICULTURE - CURRENT VIEWS IN PERSPECTIVE

Before discussing the conceptual basis of FSR and how this model of agricultural research and development differs from a number of other somewhat similar approaches, it is important and necessary to provide a more general theoretical background to current development thinking in the Third World. This will show how recent agricultural research and development initiatives have arisen out of a general lack of satisfaction with the results of previous development objectives in the agricultural field.

Development of the 'Less Developed' or 'Third World' countries has become increasingly important to the international community since the Second World War and, although in many instances this interest can be seen as a direct result of political and diplomatic pressures from both East and West on newly-independent states in an attempt to exert superpower influence on a global scale, there have also been many genuine development initiatives.

In the last 40 years much has been written on world development issues, and in particular Third World development. Arising out of these studies there have been two major paradigms of development thought - the economic growth or modernization approach and, more recently since the late 1960's, the socio-political or structural dependency approach. Proponents of both would probably find general agreement in the overall objectives of development planning as defined by the alleviation of poverty, disease and malnutrition. However, it is the understanding of why there is poverty, and how it should be overcome to provide improved living standards, health, opportunities and access to resources (for sustained development), which is where development planners and rural development specialists disagree.

Development can be regarded as a paradox. It does not represent a simple linear progression from undeveloped to developed, non-possession to possession, limitation of choice to freedom of choice. Development is a process of change and agricultural development is a process of change specific to rural contexts. Change may be beneficial or detrimental, it may be selective or general. Change on one farm or in one community may be beneficial to that farmer or community while *at the same time* it may be creating hardship to another farmer or community. This then is the paradox. The challenge for the agricultural planner is to maximise the benefits while at the same time minimising the detrimental effects resulting from any planned intervention in the change process.

If change is such a paradox, how then do development specialists and practitioners approach this problem today? Obviously there have been and still are differing views as to the priority areas for development initiatives (cf. the modernization vs socio-political viewpoints). The influence of such initiatives can be seen when we examine the major development objectives of the international community since the Second World War, and the position of agriculture and the rural community within these.

Clayton (1983) has argued that there have been three main phases in development thinking since the end of the Second World War. Not surprisingly, these have tended to coincide with the major development initiatives undertaken by the United Nations Organization. Since our concern here is not so much to discuss the history of development thinking, nor indeed the development of different paradigms, but rather to consider the influence of these on recent trends within the field of agricultural development, it is convenient to adopt Clayton's three-phase structure. Indeed, since he himself approaches development strategies from an agricultural perspective, the approach adopted is particularly relevant to the present context.

In 1943, the Hot Springs Conference led to the setting up of the Food and Agricultural Organization. For the FAO and its member countries at this time, the purpose of agricultural development was seen to be primarily the alleviation of low standards of living and poor nutrition levels in the rural areas of the countries under their jurisdiction. Agriculture was to contribute to the raising of income levels and gross national product (GNP) in member countries and so lead to an expansion of the world economy. The development objectives of the United Nations at this time therefore were to increase food supplies and farm incomes. As Clayton points out, however, while agricultural production increased significantly, so did the population in the developing countries and so per capita food production was less significant overall. Such population growth was unprecedented in history and quite outside the experience of the developed countries (Ibid., 1983).

In terms of the overall objectives of *agricultural development* (vis: alleviating rural poverty), such attempts towards increasing income and production levels were judged to be inadequate. This is not to say that some countries were much better off ɔy the end of this phase, for example the Near and Far East, but academics, international agencies and development organizations were beginning to argue that to increase GNP was not an adequate objective by itself to sustain the development of these countries. Furthermore, it was suggested that neither was GNP an adequate criterion for measuring development, whether this meant success or failure within a given context. Under these strategies (increasing income and production levels) little distinction was made between producers in rural areas. Generally, the agricultural landscape was seen to be relatively uniform with most rural dwellers being similarly placed to benefit from outside intervention, and with equal access to resources. The idea of the need to target development programmes to meet the needs of specific rural groups was not considered important. Such strategies were often concerned with an 'extractive philosophy' where production of crops for export was the major concern rather than the benefits accruing to the producers (Norman et al., 1982).

Agricultural development strategies arising from the GNP approach came under attack by the early 1960's in particular because of the effects of the Green Revolution in some of the Near

East countries, for example India. Practitioners and academics began to argue that while employment opportunities remained limited, and the distribution of incomes such that they were leading to greater urban/rural disparities, serious attempts to reduce rural poverty would remain hindered (Lipton, 1977).

As a result, by the UN second development decade, emphasis from a priority objective of raising GNP had become redirected towards employment creation and the reduction of income disparities. Influential figures within the development debate argued that development needed to be considered in a wider context - that raising incomes was not an adequate definition of development without also considering the distribution of this increase in wealth (Seers, 1969). Concern arising from the rapid influx of rural migrants into the urban areas of most of the developing countries, brought about a new awareness of the problems of unequal development and urban bias within countries which was leading to volatile situations. Growing unemployment was posed as a politically destabilising force. It was during this second development phase that the socio-political model of development began to have influence within the international community.

More attention was turned towards the reasons and causes of poverty in much of the developing world, rather than simply an acceptance of poverty and the initiation of strategies to tackle this within existing structures. In one sense this was a healthy re-examination, for people began to examine the causes of poverty in terms of processes and change within communities and nations. This led to a more critical appraisal of who was benefitting from projects and programmes in these countries. Employment generation was identified as a major factor in the development process, and development strategies became weighted in favour of programmes geared towards the generation of new jobs. In the context of agriculture, efforts were made to distinguish between those who had benefitted and those who had not done so, but there were enormous problems in measuring these differences. Furthermore, the major problem was still seen in the context of a rural/urban dichotomy with the result that differences within rural communities still tended to be overlooked.

The problem of urban unemployment is often considered to be more important than rural unemployment or under-employment which is typically more seasonal in nature, and less politically sensitive. However, the definition and measurement of unemployment in the context of developing countries has proved to be difficult, with problems of measurement arising due to the importance of the informal sector within both the urban and rural areas of many countries. Some studies recognised the importance of this sector within the less developed countries (LDCs), as for example, the ILO mission to Kenya in 1972 which stated:

> "....we see in the informal sector not only growth and vitality, but also the source of a new strategy of development for Kenya. The workshops of the informal sector can provide a major and essential input for the development of an indigenous capital goods industry, which is a key element in solving the employment problem."(ILO, 1972, p.505)

However, due to the characteristics of this sector there have been severe difficulties in the collection and analysis of data pertaining to these situations. Clayton (op. cit.) argues that as a result of these difficulties (in measuring employment generation and employment levels), emphasis in development planning switched towards income redistribution and poverty.

Whatever the reasons for the change in emphasis what is important here is that, in focussing on income redistribution, there was a change in emphasis away from agriculture. As a result of the move away from employment generation towards income redistribution, the importance of agriculture as the key sector for future employment opportunities became overshadowed by a new concern over the distribution of wealth and income in the less developed countries. The focus became shifted more towards the urban areas where income differences were more obvious and more politically sensitive.

Income distribution, equity, and equality of access and opportunity became the keys to future development in the LDCs. Although ideas concerned with equity, equality of access and opportunity were useful in promoting a wider understanding of the practical problems and barriers affecting rural populations, in the case of ***smallholder agriculture*** there are three main reasons why income redistribution cannot be considered to be the major development objective.

First, within the smallholder sector any evidence of wide per capita income disparities is based on inadequate data. Generally such data can only be ascertained from detailed farm surveys and these need to cover large samples if they are to represent the complex nature of the smallholder economy. There are few such studies and any findings from these cannot be generalised to national situations.

Second, smallholder agriculture by its very nature operates within a free market economy, and this means incomes will inevitably be unequal reflecting the abilities, resources and ambitions of farm families. It should be noted that this does not mean measures towards increasing accessibility and equality of opportunity within this environment have no place within a development strategy. Rather, such measures should not attempt forcibly to redistribute land, since this will not be beneficial to smallholders in a single sector agricultural setting. This has bearing on the third point: the distribution of resources within the agricultural sector. It is useful to examine the Kenyan situation in this regard.

In the Kenyan context, although her agriculture is divided between two sectors - there is both a large farm sector and a smallholder sector - there has been considerable government effort towards sub-division of what were formerly large European-owned farms with the settlement of smallholder farm families on this land. Today most of the large farms are found either in the high potential areas specialising in tea- and coffee-growing for export, or in the marginal areas where beef, sheep and goat farms predominate. The large farm sector occupies a relatively minor percentage of the available agricultural land, although it contributes very significantly to the overall GNP (Republic of Kenya, 1986). The large farm sector in the high agricultural potential land is generally well managed and highly productive.

In assessing the need for land redistribution policies, consideration of farm size in relation to soil fertility and other natural resource endowments, size of farm family, and the importance of off-farm income is important. Studies of this nature are sadly lacking in the literature, and it is questionable whether such policies are appropriate or even possible in the Kenyan context (see Hunt, 1984, for an alternative to this view). In some South American countries (Brazil and Columbia for example) land redistribution is indeed a fundamental stumbling block to smallholder agricultural development, but in most African countries this is not so and detracts from the real issue which is to understand the complex heterogeneity of the rural environment. Such an understanding can only be gained by working together with farmers to discover what constraints they face and to devise solutions which recognise the farmer's key position within the development process. This implies rural development initiatives must be:

1) participatory - involving rural households.

2) directed to meeting the needs of specific groups of people.

By the mid 1970's a third phase, the basic needs approach to development (BN), had become widely documented and discussed. The basic needs approach aims at eradicating the worst aspects of world poverty by the year 2000. Its objectives are to satisfy the minimum clothing, housing, and food requirments of households, and to provide essential services such as water, sanitation, education, health and public transport (Jolly, 1976). The BN approach is a more specific strategy than either of the two previous development objectives discussed above, and has gained popularity from the apparent inability of the previous strategies to tackle the poverty problems of the LDCs. As Hopkins and Hoeven (1983, p.2) state:

> "A concern for meeting basic needs arose from a concern with the problems of mass poverty, unemployment and underemployment coupled with low productivity which have persisted in many Third World countries despite substantial economic growth."

Although many countries had experienced economic growth during the 1960's and 1970's poverty remains a real problem for most Third World nations, and the BN strategy has been put forward to tackle their persistent poverty-linked problems. Hopkins and Hoeven (Ibid., 1983) stress the BN approach has not entirely superceded either of the two previous strategies (income/growth and employment/redistribution). Rather, it has attempted to provide a more specific set of objectives for developing countries to pursue still within the overall context of broad development strategies encompassing economic growth and, organizational and institutional changes at local, national and international levels.

Perhaps the real danger of the three strategies outlined above has been their tendency to generalise to a global level situations which pertain at national or local level. Clayton (op. cit.) has some sobering comments to make in particular regard to the BN approach. However these are equally relevant to any future development strategies.

He argues that one of the main dangers of present agricultural development planning is the extent to which unmeasured and unmeasureable parameters are used in formulating strategies. Thus, for example, much has been written on the growing disparities in farm incomes within LDCs yet very few practical studies have been made which have attempted to address themselves to measuring this, *and* to examining the distribution of such income. In addition to the tendency to substitute measurement with argument, there has been a change from precision to generalization. The implications of this become clear when we consider the complexity of smallholder agricultural development in the LDCs. In the vast majority of LDCs a major percentage of their populations are involved in agricultural production, often comprising of smallholdings which are subject to a number of overriding political and economic constraints. The farmer is the key decision-maker and operator on each smallholding; however, s/he is seldom if ever integrated into development initiatives.

These economic and political constraints have often become subsumed within the development debate, where philosophy and perspective have ruled out definition and practice. For example, agricultural research and development initiatives need to consider the constraints of: high population growth rates, lack of financial resources, problems of technical provision and maintenance, land ownership and farmer participation. These (and many other) parameters will affect the success of any proposed agricultural development strategy. It is not adequate simply to identify these constraints without going further, and attempting to measure their effects on agricultural production.

Recent approaches to development planning have established a broader understanding of the development paradox - in part this has resulted from the recent influence of a more radical social science perspective. Certainly the dependency or socio-political model has widened our perspectives, and helped us to focus on both the positive and negative aspects of development. This more radical perspective has been an important contribution to the development debate (Long, 1977). However, it is clear that there has generally not been a supporting quest for model development or a practical working out of the ideas that have been generated by this debate. In view of this lacuna it is perhaps not surprising that practitioners have sought elsewhere for suitable theoretical models to support them in their search for solutions - agricultural development remains very much a pandora's box full of problems... "that never disappear utterly and cannot be solved once and for all " (Bawden et al., 1985, p.31).

Since the late 1970's many working in the field of agricultural research and development have been calling for more participatory development initiatives (Chambers, 1983, 1986; Richards, 1979; Brokensha et al., 1980; Collinson, 1979). The logic of participatory development is profoundly simple. Over the last three and a half decades the farmer/ smallholder/ peasant, has been the principal 'target' of development efforts involving rural communities. Yet s/he has almost always been the passive recipient of research and development. Participatory development calls for the farmer to be recognised as the key actor in the rural environment. S/he should therefore be a key participant in the development process from its initiation. In the past the farmer has not been involved in the development process except as a recipient of aid and research. S/he has seldom been consulted in the formulation of agricultural development strategies.

In establishing the farmer at the centre of the development 'stage', other 'actors' (academics, planners, politicans, etc.) can provide necessary support and knowledge where this is required to enable the farmer to overcome the limitations of his/her own knowledge and resource base. The role of the planner and policy maker here must be to encourage farmers to produce goods which will help to satisfy their own aspirations, and yet be complementary to the agricultural goals and objectives identified by governments at regional and national levels.

In this study the smallholder is considered to be *the* expert of his/her individual farm unit and local environment, yet it is also recognised that the smallholder is constrained by factors beyond his/her control. The nature and condition of the physical environment, lack of access to resources, limitations of technology, and demographic characteristics of the farm household all impinge on decisions the farmer has to make.

In order to understand why the farmer makes the decisions s/he does, it is necessary to understand the interrelationships of parameters which affect the farm as a managed unit. On gaining such an understanding development workers may then be better placed to assist farmers in overcoming their problems. The lack of understanding of the farm decision environment which has been typical of the previous development strategies outlined above, has been a major obstacle in preventing effective communication of agricultural research within rural environments.

Systems analysis provides a suitable framework for establishing such an understanding. Farming Systems Research (FSR) is one model of agricultural research and development which is built on a systems framework and which is currently being adopted by a number of African governments in their attempts to link large numbers of smallholders with agricultural research.

3.2. A SYSTEMS APPROACH TO AGRICULTURAL RESEARCH AND DEVELOPMENT

Systems analysis is used extensively throughout this research. The FAO agro-ecological zones project (1978) is an example of systems analysis in research at a global scale, while the agro-ecological zones model (AEZ), developed by Jaetzold and Schmidt (1983) in Kenya, is a regional application of this approach and is used here to stratify the study region for sampling purposes. The AEZ model is also used to provide a framework for assessing the physical characteristics of the agro-economic groupings (AEGs) which are identified in the study. Both AEGs and agro-ecological zones contribute to the definition of 'recommendation domains'. Recommendation domains are areas of relative agricultural homogeneity within the rural environment which are used for promoting appropriate agricultural research and development initiatives. They form the basic practical framework for FSR.

Before discussing the FSR model in more detail it is important to discuss some of the general concepts involved in systems analysis within agriculture. This will provide a broad theoretical background in which to situate the FSR model. Systems analysis examines phenomena using a holistic approach. It is able to examine the relation between different parameters within a defined unit area at one or more points in time. Relations between parameters may change over time and their effects on the whole system can be noted. The importance of individual parameters in respect of both their individual and combined effects on a particular situation are assessed, and thus changes occuring in one part of a system can be analysed to show the resulting effect on another part. Any single parameter cannot therefore be fully understood without reference to the other parameters within a system.

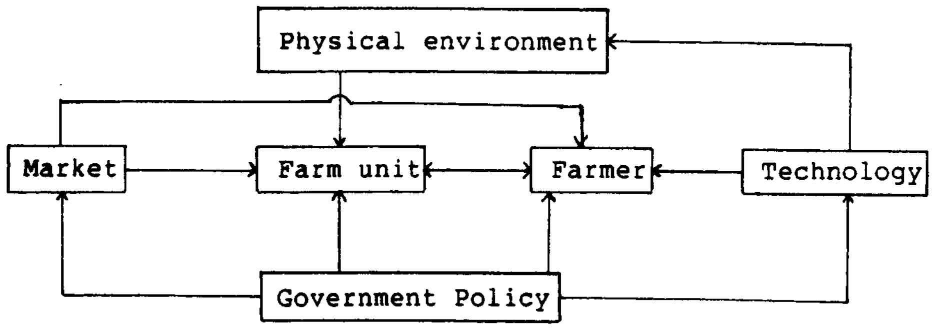
Spedding (1979, p.18) has defined the relation of individual parts within a system to each other, emphasising the importance of the interrelation of the parts to the whole:

> "A system is a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks."

What constitutes a significant feedback will vary according to the subject being studied. In this context we will take it to include any beneficial or detrimental effects resulting from a farmer's actions or decisions on an individual holding within a given geographic area. This may result in changes in the physical characteristics of the area or in the socio-economic conditions of the farmer, and may affect the productive capacity of the farm/farms in question. Figure 3.1 shows this diagrammatically. The main feedback sources are shown to be the market, government policies, technology and the physical environment. These all directly affect the farmer and the farm unit - there may well be other indirect feedbacks (for example, world commodity prices) but these are not shown here.

FIGURE 3.1

FEEDBACK AFFECTING THE FARM SYSTEM



It is important to clarify the purpose of using systems analysis in this study since systems theory has been applied to many different subjects and in many different disciplines. In smallholder agricultural development planning, the focus of this dissertation, there are three main advantages in using a systems approach.

First, since smallholder agriculture is an activity which is traditionally very dependent on a given resource environment, systems theory is a useful tool for initially establishing a framework for understanding the interaction and relation of man's activities on parameters within a given physical environment. Systems theory provides a framework for understanding what the smallholder does and why s/he acts this way.

Second, because it examines the interaction of parts in the context of the whole system, so long as the parts are not considered in isolation from the whole, they can be analysed separately, their connections with other parameters or subsystems being taken into account but not overriding the consideration of the specific part under analysis. This means it becomes possible to simulate the effect of changes in one part of the system on the system as a whole. Thus systems analysis is potentially capable of simulating alternative scenarios for agricultural production and development. This could be especially useful given the importance of the agricultural sector in most developing countries. It allows the agricultural researcher to examine a number of different farmer responses to an innovation and to establish the likely beneficiaries from such innovations. In this way it should be possible to identify those developments which will be most accessible to the target groups in question. A third and more general point is considered below.

Bernstein (1973) has argued that there is a need for an interdisciplinary approach to development within the social sciences which will allow us to view economy, politics and society under a unified approach. He goes on to discount systems theory on the grounds that it is essentially non-historical and attempts to generalise over different situations, aspiring to universal validity by disregarding the distinctions between different modes of social, political and economic organization. However, one of the strengths of systems analysis is that it *is* capable of distinguishing between distinctive social, economic or political situations, for it is not limited by scale, and can therefore become situation-specific.

One system may exist in relation to a number of others within a hierarchy; thus, depending on the objectives of the analysis, it may be examined as a distinctive system on its own, or perhaps as a sub-system of a larger and more complex structure. In considering cross-cultural comparisons, a systems approach is able to contribute to the theoretical development of agricultural planning in the tropics not because of an ability to generalise but, rather, by identifying differences between one situation and another. A systems approach is therefore very suitable for case study research since a case study has a geographic boundary which can be used to define the boundaries of the system. Maxwell (1986a) has emphasised the value of the case study approach within FSR.

3.2.1 AGRICULTURAL SYSTEMS AND DEVELOPMENT

What is the broad objective of systems analysis in agricultural planning? Stated quite simply it is: to provide agricultural researchers, planners and policy makers with adequate information derived from a holistic understanding of the interaction of the farmer with his/her environment which will result in the adoption of technologies leading to optimum land use for an area. At the same time the adoption of such innovations must lead to an improvement in the economic and domestic conditions of the agricultural population if *long-term* development is to be assured.

A systems perspective of agricultural development is based on certain assumptions concerning the physical and human environment. Land evaluation (which considers both human and physical parameters) is therefore fundamental for gaining an understanding of the processes involved in the changing agricultural systems of the tropics.

Beek (1978, p.23) defines the systems approach within land evaluation as:

> "a methodology developed... for describing and predicting the functioning of complex physical entities taking good notice of their internal structure and the cause-effect relations between the elements that are part of it."

If this is examined in the context of smallholder agriculture in the tropics, it is obviously necessary to relate the physical characteristics of an environment to the management functions operating within that same environment in order to define a systems viewpoint. A systems view of agriculture must therefore consider both the environment and man if it is to present a holistic understanding of agricultural activity. Systems analysis within agriculture can be defined in terms of the equation:

$$P = f(E,M) \quad (3.1)$$

where P is agricultural productivity, which is a function of both E, environmental factors, and M, managerial factors.

In using systems analysis to analyse a given agricultural environment, equation (3.1) can be reformulated to take account of the conditions present in this environment thus:

$$P = f_i(M/E_i) \quad (3.2)$$

where the function now describes the relation of the management factors (M) to agricultural productivity (P) for a *specific* environment (Ei) (equations (3.1) and (3.2) are adapted from Zandstra, 1980).

In using a systems approach the dynamic nature of agriculture can be satisfactorily accounted for in contrast to the 'static and descriptive approaches' used by geographers and agronomists in the past (e.g. Duckham and Masefield, 1970). This is particularly useful when dealing with smallholder tropical agriculture, where the farm units are generally small yet highly complex physical and management structures.

A distinction should be made between agricultural, farming, and production systems. Agricultural systems can be considered as the most general of all these categories. Agricultural systems may be juxtaposed with land-use systems identified in land evaluation in order to clarify their definition. A land use system may be defined by a structure comprising of land units and land utilization types (Beek, op. cit.):

LAND USE SYSTEM	
land unit (mapping unit)	land utilization type

A land unit is defined by the physical land conditions of an area, and can be considered to represent E in equation (3.1) above. A land utilization type is defined as a specific way of using the land, actual or potential in terms of a set of key characteristics including produce, capital, management, technology and scale of operation. It is therefore a technical organizational unit defined in the context of a specific socio-economic and institutional setting. It can be represented by M in equation (3.1). The concept of a land use system can be used to define a number of different systems: urban, recreational or agricultural. The land units and land utilization types in each case relate to the major physical and management characteristics of the system in question. An agricultural system then is a land-use system which specifically deals with the agricultural environment.

Farming systems and production systems (within the context of agriculture), can be considered identical in meaning. Generally in agriculture, land use classifications use the individual holding as a basic unit for classification purposes. A farming or production system therefore can be considered as: a collection of distinct functional units, as for example crop and livestock activities, which interact within a given environment using joint inputs to produce outputs which have the common objective of satisfying the farmer's aims. The precise boundaries of the system will depend on circumstances at a given location, and often it will include not only the farm but the farm household as well (see Chapter Four for the operational definition of a farm used in the context of this study).

Although traditionally geographers and agronomists have been more concerned with description of agricultural systems rather than in using a more functional approach giving specific land utilization types with specific land requirements, there is more interest today in understanding the complex combinations of factors which give rise to a particular system (Beek, op. cit.). Land use performance and land suitability depend on the intimate relationship between the land and its use. Traditionally land use classifications have lacked the ability to link the physical and socio-economic aspects of the environment together. Systems analysis however provides a suitable methodology from which models linking both the physical characteristics of the land, and the use to which it is put, can be developed. Both land utilization types and land units can be linked together within the same analytical framework.

In the preceding discussion emphasis has been placed on examining agriculture within a framework which incorporates both the land and its use - in land evaluation terms, land units and land utilization types. Why is it so important to examine this relationship?

Implicit in any discussion on information and technology transfer in tropical agriculture is the assumption that communication takes place between one group of people (agricultural research and development personnel) and another (the farmers) thus enabling a transfer of knowledge, ideas, technology, etc. It is assumed that such groups exist in the first place, and secondly, that technological packages can be developed to suit the needs of these groups, thus promoting agricultural development.

This study addresses the first assumption. Groups of farmers exist within the context of a given physical environment - this being the land which they farm, as well as a given economic and social environment. To define such groups therefore we need to consider both of these aspects. This is where systems analysis is useful. It is also why it is so important to focus attention on the farmer - the manager of this system. FSR attempts to do this by beginning the research process with the farmer - basing innovations on existing farming systems, by working throughout the research and innovation development phases with the farmer.

Development projects are designed with particular groups of receivers in mind. Programmes are directed towards particular geographic locations - 'areas of special need'. This assumes that there is an understanding of the physical and human characteristics of the 'targeted' group and area. Often however it is the very lack of a precise understanding of an agricultural environment which leads to the failure of the project or programme. Vague generalisations are made about the people or the area. Foreign aid programmes or government projects are initiated without an adequate understanding and definition of those groups who it is hoped will benefit (as well as those who may not benefit) from such intervention. Ultimately farmers are ignored and development proceeds without the participation of rural people.

FSR provides a suitable methodology for overcoming some of these criticisms. In the next section FSR is distinguished from a number of other agricultural research and development approaches. The key role of the farmer is emphasised.

3.3 FARMING SYSTEMS RESEARCH

The farming systems research model (FSR) is considered at some length. It is argued that this model provides the most suitable and satisfactory theoretical basis on which to develop future agricultural research and development programmes in the tropics. This model was used to provide a framework for the farm survey and the collection of field data in the study region.

Results obtained from the study will contribute towards strengthening the field methodology of FSR, by helping to identify workable recommendation domains quickly and efficiently using remote sensing techniques. FSR is adopted as a model for the present study since it is considered to be the most fruitful approach to take in seeking to overcome the communication gap between the smallholder and those working in agricultural research and development within the less developed countries. The main beneficiaries of the research are considered to be agricultural research and development institutions at both national and local levels in Kenya. The study aims to emphasise the importance of recognising and using the knowledge held by rural farmers within agricultural development work.

FSR is a recent attempt largely initiated by agricultural economists, to address the disappointing results of traditional agricultural research in influencing tropical agricultural development. Although it has been used in more developed agricultural economies also (see, for example, Remenyi, 1985; Schulman and Garrett, 1986) the discussion here is limited to LDCs in the tropics.

Norman and Collinson (1985) referring to Johnson (1982), state that FSR may have been practised during the 1920's in the USA, but that in respect of the developing world it is a new approach. Unlike traditional agricultural research which is 'top-down' and centred on the researchers and the research establishment, FSR is farmer oriented and farm tested. It is also interdisciplinary, integrating the perceptions of biological scientists and social scientists (Clayton, 1983). FSR is seen as an alternative to the 'top-down' approach of mainstream agricultural research and development (Sands, 1986). However it aims to complement and build on existing institutional structures, although there are far-reaching implications for both institutions and for those working in these environments (Collinson, 1986a).

Conceptually there are four stages within FSR (Norman and Collinson, 1985). The first stage is descriptive or diagnostic. Its aims are to determine the constraints the farmers face and to ascertain any areas of potential flexibility within the farming system. It is at this stage that recommendation domains are identified and refined.

The second stage is the design or planning phase where the range of possible strategies is identified. This involves an evaluation of the technical feasibility of the research, its economic viability, and whether it will be social acceptable.

The third stage involves identifying the most promising strategies through testing. This consists of:

1) researcher-managed but farmer-implemented tests for technical relationships to see if the farmer alters any of these through his/her own management.

2) Farmer-managed and implemented tests conducted when the research team is confident that the research strategy is sound, but the researchers need to evaluate the proposed technologies under local socio-economic conditions.

The fourth stage is the recommendation or dissemination phase. Here, strategies identified and screened during the design and testing stages are implemented. In practice there are no clear boundaries between stages.

The research presented here focusses on the first stage which in many ways is the most important since it is at this stage that target groups of farmers are identified and the operational area of the FSR is defined.

One of the operational problems FSR has experienced has resulted from a lack of definition in the concepts which some of its proponents have employed. These have been subsumed under the general title of FSR and have resulted in a loss of clarity of the procedures involved in the approach. FSR should therefore be distinguished from a number of other agricultural research and development models. This will also provide a suitable opportunity to present reasons for choosing the FSR model in this study in lieu of some of these other approaches.

Perhaps the first important distinction to make is between FSR and farm management research (FMR). FMR unlike FSR does not explain farmers' behaviour in terms of rational decision-making, but rather through inefficient resource use and allocation. Agricultural production problems are therefore seen in terms of sub-optimal use of resources by farmers, and the primary aim of FMR is to focus on the management of farms, rather than on understanding the decision environment of the farmer. The other important point of difference is that FSR is multi-disciplinary, whereas FMR has been very much the preserve of economists. Under FSR farmers are incorporated into the research programme from the initial data collection stage through to the final recommendation and implementation stages of the research. In contrast:

> "The only contact between FMR and small farmers is in a data acquisition context and not as *direct* recipients of the normative propositions of FMR." (Clayton, 1983, p.112).

FMR is not therefore a thoroughbred in terms of participatory agricultural research. FSR is the approach adopted in this study since it begins and ends with the farmer who is the key actor in the rural environment and should therefore be a key participant in any development strategy.

Sands (1986) has provided a useful clarification of a number of agricultural research approaches which use the farming system as the framework of analysis. However, although she proposes that all these approaches should be included under a more general generic term, farming systems perspective, this study will continue to use the term farming systems research since this is a model which is well understood in the East African context. Two further distinctions need to be made: these are between FSR and new farming systems development (NFSD), and between FSR and farming systems research and agricultural development (FSRAD).

NFSD is a term used for programmes which have been initiated in the international agricultural research centres and which aim to create *new* farming systems. It is therefore much more of a 'top-down' approach to agricultural research and development than FSR. Simmonds (1986) coined the term in respect of programmes which are usually characterised by some form of government intervention and adaptation of economics to involve a firm technological approach. In many respects it is the opposite of

FSR, which seeks to promote agricultural change more in terms of cooperation. NFSD seeks revolutionary directed change, rather than evolutionary individual or group change (Sands, 1986). NFSD tends to focus most prominently on the biological and physical characteristics of an area, often leaving out socio-economic analysis in the design and development stages of new technologies.

FSRAD refers to farming system programmes which involve both agricultural research and development strategies. The farming system is placed within the broad context of the economic and policy environment of the programme area. Its objectives are to promote agricultural development through technological as well as institutional and economic reform in the rural environment. FSRAD can really be considered the same as integrated rural development (IRD):

> "(IRD) is even more holistic in scope (than FSR), focussing on projects that go beyond improving agriculture to encompass fish, forest and handcraft production, for off-farm employment, and the provision of health, education and other communal services". (Conway, 1985, p.44).

FSRAD or IRD can be considered a broad based approach to agricultural research and development. They focus more on the district and regional level, and may well comprise of a number of different research strategies which include FSR as one of several relating to agricultural, infrastructural, marketing or perhaps even pricing problems.

The Integrated Agricultural Development Programme (IADP) in Kenya was an example of an IRD approach. This programme aimed to provide smallholder credit and technical advice together with rural infrastructure development. It was initially started in

1976 and was planned to continue over four phases but by 1982 had run into severe difficulties and was abandoned (Hunt, 1984). One of the main reasons for this appears to have been weaknesses in the administration of the programme with long delays in loan dispersal, and the absence of cooperative societies in some farming areas making it impossible to distribute credit to farmers.

Despite the conceptual ambiguity surrounding much of the work carried out in the name of FSR to date, there are a number of fundamental reasons why this model is adopted as the focus of the present study. Most important of these is the position of the farmer in the development process. The smallholder is considered to be *the* expert on local farming (Collinson, 1986b), and therefore has a great deal to offer in the technology development process.

Richards (1985) has shown how small farmers are often involved in initiating their own agricultural revolutions using knowledge derived from indigenous knowledge systems (Brokensha et al., 1980; Chambers, 1979) and founded on empirical testing. So far few research projects have attempted to harness this knowledge source. FSR provides a suitable framework for including such knowledge within a participatory framework of development.

In the East African context participatory processes have recently received wide political acclaim, and in the Kenyan case, the District Focus for Rural Development Strategy has initiated a modest process towards decentralisation of administration and decision making. A major objective of this strategy is to promote more rapid economic growth in the rural areas, and central to this aim is an improvement in the balance between urban and rural development. The main body responsible for district development is the district development committee (DDC).

Projects which are primarily intended to serve one district are to be chosen, planned and implemented at the district level. The significance of this policy is that it now gives authority to the DDC to coordinate all development projects within the confines of a district - that is private, self-help (Harambee) and public initiatives. This should lead to more rapid and effective administration of these projects and more likelihood of participation by rural people.

About 80% of Kenya's land area is arid or semi-arid and supports 20% of the country's population and half its livestock. Kenya's formal development programme for the arid and semi-arid lands (ASAL) was begun in 1979, funded largely by aid donors. Budget rationalisation requires that these programmes be brought more in line with the system operating within the districts and in this regard they are expected to be managed within the system of district focus for rural development in the future (Republic of Kenya, 1986).

The main ingredients of the ASAL programme include livestock development, research on drought-resistant crops and grasses, inexpensive means to control environmental degradation and, to provide fuelwood. In Meru, the British funded Embu-Meru-Isiolo (EMI) programme operates within this remit while similar programmes are operating in other districts (e.g. the E.E.C. funded Machakos Integrated Development Programme). The ASAL programme is seen as an important strategy which the government hopes will support development towards a more balanced regional growth within the country.

Given these developments, FSR is well placed to benefit from such strategies even if its organizational implications remain difficult to accept. FSR argues for more specific strategies to focus agricultural research and development towards improving problem situations. Within the ASAL region new agricultural research problems are confronting agricultural research teams (Government of Kenya, 1979) and FSR is a suitable model to use to tackle such problems.

One of the methodological issues confronting FSR however is the identification and description of recommendation domains. Recommendation domains are defined as:

> "homogeneous categories of farmers with comparable access to resources and markets and a comparable farming system." (Fresco, 1984, p.256).

Inevitably there has to be a trade-off between research for an individual farmer (which is far too expensive in the context of smallholder development in the tropics) and research for groups of farmers, which may lead to some individual farmers benefitting more than others. Farmers are grouped into *relatively homogeneous* groupings based on existing farming systems so as to minimise the number who may be unable to benefit from development initiatives. These groupings are then used for research planning and for identifying priority adaptive research foci (Collinson, 1982). Research experiments are carried out under the operating conditions of the target grouping to ensure that recommendations emanating from the work will be accepted by farmers.

The present study focusses on the more marginal farming groups within Meru district in an attempt to direct research attention to the resource-poor farmers of the region (Chambers and Ghildyal, 1985). Agricultural research and development under the FSR model can be seen as a prototype of what Chambers and Ghildyal (Ibid., 1985) call the Farmer-First-Farmer-Last model. This model is part of a new and fundamental shift in rural development planning - a new professionalism which reverses power relations "....putting the last first." (Chambers, 1986b, p.18).

In practice several types of grouping techniques have been used within FSR to derive and define recommendation domains. Domains have been distinguished using administrative units, agro-ecological zones, soil characteristics, proximity to markets and other criteria. Norman et al. (1982) in a study carried out in Nigeria, used access to urban markets as a grouping factor. Swinton and Samba (1984) working in south-central Niger used soil texture and depth of the water table to distinguish between groups of small farmers. Schulman and Garrett (1986) used socio-economic characteristics and social class to differentiate between tobacco farmers in North Carolina.

However, most of these studies have serious limitations because they take into account only one or two factors in a complex system. Administrative units seldom (unless fortuitously) correspond to differences in smallholder agriculture production systems, while agro-ecological zones account for only the physical/natural factors in a given environment and ignore any socio-economic factors. Clearly there may be many differences between smallholders in a given context and simply identifying one of these is not necessarily going to provide an adequate understanding of the reasons for farmers operating the way they do.

The most satisfactory approach to use in grouping farmers is therefore one which will include as many of the physical, social, economic, cultural, and broader market and political factors which will impinge on farmers' decisions and on their farming environment as possible. This environment is most appropriately described by the farming system itself. The International Maize and Wheat Improvement Centre (CIMMYT), Mexico, has used the farming system as a basis for deriving recommendation domains in its Eastern Africa programme (e.g. Government of Zambia, 1979) and a similar approach is adopted in the present study.

The existing farming system is used here as a basis for initial groupings for four reasons:

1) Farmers operating a similar system have similar problems and development opportunities.

2) The existing farming system is the basis on which new development initiatives have to be built.

3) A farming system is a physical manifestation of a complex interaction between the natural economic and socio-cultural circumstances of the farm family and, their own priorities and capabilities. It therefore reflects better than any other single criterion the balance of factors which are important in distinguishing distinctive groups of farmers within the rural environment (Collinson, 1982).

4) The spatial characteristics of the farming system (crop/land cover variables) can be used to help identify groupings in the smallholder landscape, and this allows both more efficient identification of recommendation domains, and also provides a methodology, using remote sensing techniques to monitor farming system changes over a period of time. In this sense it answers some recent criticism of FSR methodology (Maxwell, 1986b) which suggests that the model does not account sufficiently for the fact that farming systems are in constant flux, and therefore that the 'targeted' group is not static.

In the context of this study in Meru district, Kenya, there is a further reason for adopting the farming system as the basis for identifying recommendation domains. Kenya is fortunate to have considerable expertise and experience in the field of aerial remote sensing. The Kenya Rangeland Ecological Monitoring Unit (KREMU) of the Ministry of Economic Planning and National Development has recently expanded its operational focus to include land use monitoring and mapping in the high agricultural potential lands of the country. The methods used to undertake this monitoring and mapping work are generally suited to identifying relatively homogeneous areas of agricultural activity and can be used to strengthen the field operation of FSR in the country. Aspects of this methodology are used in the present study and are discussed in more detail in Chapter Four.

In the light of the methodology employed in this study the next section reviews the use of remote sensing techniques in rural development planning.

3.4 REMOTE SENSING AND RURAL DEVELOPMENT PLANNING

Remote sensing is concerned with the detection and measurement of electromagnetic radiation from objects at or near the surface of the earth (Sabins, 1978). Remote sensing is discipline dependent and interpretation of its precise meaning will depend on the type of sensor used and the kinds of images of the environment which result within a given field of study (Curran, 1985). Photographic remote sensing, which is the primary source of remotely sensed imagery used in this study, is concerned with the visual and near infra-red wavebands of the electromagnetic spectrum (Colwell, 1983).

Over the last 15 years much research interest has been generated by the technology of satellite remote sensing. As a result the use of more traditional remote sensing techniques, (particularly aircraft remote sensing) may have become regarded as being out of date. Scientists have become increasingly interested in trying out the new computer compatible data provided by satellite remote sensing systems, often on rather narrow technical and academic grounds. Watson (1981, p.5) provides a rather more down-to-earth view:

> "...remote sensing technologies should be evaluated in a wider environment than the purely technical or scientific one.... This requires a consideration of marketing, of the practical conditions of a method's application, including financial, legal, logistical, political, and behavioural aspects, and of the means of applying the results of remote sensing to problem solving."

There are without doubt some significant advantages in satellite remote sensing. The imagery is spatially comprehensive, there is a great deal of flexibility in the data because it is numerical in nature, and there is often considerable scope for rapid and repeat imaging which is very useful for monitoring purposes. However there are also some limitations. Often the cost of the imagery is a limiting factor (this was certainly found to be true in the present study) although it is still significantly cheaper than conventional stereo panchromatic air photography (Allan, 1980). Satellite remote sensing, like conventional aerial remote sensing, is weather dependent and also platform dependent. There is always a large amount of data generated and this may easily lead to too much information requiring expensive analytical, interpretational and presentational technologies (Watson, 1981). New techniques for data manipulation and interpretation generate new training needs yet often one of the constraints facing developing countries is the lack of qualified personnel (Voute, 1982).

Quite apart from the issues outlined above there are of course overriding political considerations in satellite remote sensing. Resolution on the early land resource monitoring satellites was set at the coarse level of 80 metres in recognition of the sensitivity of the security implications of higher resolution systems (Allan, 1980). It is perhaps too early to say how the French SPOT satellite with a ground resolution capability of 10 metres will affect these sensitivities.

A number of studies involving satellite remote sensing applications have taken place over the last ten years. Within the field of land resource management many of these have been addressed to national or regional problems (Van Genderen and Lock, 1976; Hellden, 1981; Schultink et al., 1981; Schultink, 1983; King, 1982; Griffiths and Collins, 1983; Parry and Williams, 1986). Those which have been applied to agricultural problems have tended to concentrate on more uniform agricultural/rangeland activities (Berg and Gregoire, 1982; NASA, 1978a and b; Lamprey, 1985).

Although many of these studies have included a multilevel methodology incorporating both satellite imagery and aerial remote sensing there have been surprisingly few studies which have examined rainfed agriculture in the tropics. Some exceptions to this trend have been recent studies undertaken in a number of the West African sahelian countries and in East Africa (Norton-Griffiths and Hart, 1982; Watson and Tippett, 1981; Dunford et al., 1983; Lambin and Lamy, 1986; Bartholome, 1986; Epp et al., 1983; Ottichilo , 1986; Ottichilo et al., 1986; Mwendwa, 1986). However several of these studies have been undertaken by researchers within KREMU involving land use studies in only one country (Kenya), and it would be wrong to suggest that there is widespread use of this technology outside these regions.

The present study focusses on the methodology used by a number of these latter studies and applies it to the research problem of identifying and describing recommendation domains in lower Meru. The methodology used here involves a multilevel approach which includes Landsat MSS data and 1:50,000 stereo panchromatic aerial photography, although the study focusses on large-scale aerial colour slide photography and detailed sample ground surveys (these are discussed in more detail in Chapter Four).

This methodology differs somewhat from previous FSR field methods in that it uses remote sensing procedures to define relatively homogeneous areas which are then refined using data from selective farm surveys. The approach used is somewhat similar to that adopted by Dunford et al. (1983) in their study of the Arusha region, Tanzania. Their work had the aim of defining target groups around villages and not farming systems. These target groups they called land planning units. In the present study target groups of farmers are defined on the basis of farming systems since, unlike the human settlement pattern in Tanzania which is based around villages, in Kenya farmers live on their own individual farm holdings.

Dunford et al. (op. cit.) used a two-step procedure to collect land resource information. The first step was what they called a rapid reconnaissance exercise which involved using four separate data sources: a) Landsat MSS false colour composites; b) slope angle maps derived from analysis of existing 1:50,000 scale topographic maps; c) low-level aerial survey - systematic reconnaissance flight (SRF); d) existing reports and maps of the area.

The second step (after identifying priority areas for land development or rehabilitation) involved more detailed and accurate (and expensive) aerial survey techniques. For each of the high priority areas, complete vertical aerial photography was flown and extraction of the information from the photographs undertaken with the help of people living in the survey areas.

As one of their conclusions they mention future studies should avoid excessive data collection and focus rather on low-level aerial surveys using a 5-10% sampling intensity with visual counting of point data and vertical sample photography (Ibid., 1983). This suggestion has been practically endorsed by a number of subsequent studies and is also a technique which is used in the work reported here.

In Kenya, KREMU has been using systematic reconnaissance flights (SRF) to undertake natural resource planning. Initially concerned with providing up-to-date estimates on the population and spatial distribution of livestock and wildlife species in the country, KREMU has more recently become involved in collecting and analysing agricultural land use data on a district and national basis (KREMU, 1984). SRF surveys involve flying at a low but constant height, generally between 400- 1000 metres. Vertical sample colour or black and white photographs are taken along a previously determined transect or flight path at systematic intervals.

Although some researchers have argued that too many resources and too much time can be spent on defining target groups in the rural environment (Biggs and Gibbon, 1986) the definition of such groups is critical to both FSR and the extension services. If these do not adequately describe and identify problem areas for similar groups of farmers, the final recommendations of FSR will not be adopted by significant numbers of farmers. Under such circumstances it will not be surprising if criticisms similar to those concerned with the inequitable benefits of the Green Revolution in India are levied against FSR.

The advantages of using light aircraft remote sensing techniques to help define recommendation domains within the existing procedural steps of FSR in Kenya are threefold. These are best explained by outlining the basic steps of FSR as it has been applied by CIMMYT's Economics Programme in Eastern and Southern Africa. Table 3.1 shows the steps involved in FSR in this context (Collinson, 1982, p.7).

TABLE 3.1

PROCEDURAL STEPS IN THE FARMING SYSTEMS RESEARCH CYCLE

STEP	ACTIVITY	TIME REQUIRED
1	Identification of the general region for research and development initiative	) 2-3 months
2	Collation of secondary information on the natural and socio-economic conditions of the area	)
3	Identification of recommendation domains	2-3 months
4	Review of background information on recommendation domains	1 week
5	Informal survey - discussion with farmers	2 weeks
	- conclusions (verification of RDs)	1 week
6	Design of formal survey	2 weeks
7	Enumerator training /questionnaire testing	1-2 weeks
8	Administration of survey to target groups	2 weeks
9	Coding data, tabulation and specification of analyses	1 week
10	Data processing	1 week
11	Data interpretation and experiment planning	2 weeks
12	Selection of representative farmers and sites for on-farm experiments	2 weeks
13-15	Preparation and supervision of experiments Harvesting of experiments	crop cycle
16	Statistical and economic interpretation of data	4-6 weeks
17	Planning for next season's experiments	4-6 weeks

It is immediately clear that most time is spent on the collection of background information and the definition of recommendation domains (up to six months) within the overall approach. It is therefore at steps two and three that savings of time would be most useful and effective in improving the timeliness of research and development initiatives undertaken using the FSR approach.

Light aircraft remote sensing appears to be a technique which could be used to reduce the overall operation time needed to initiate an FSR programme in two ways. First, using SRF techniques it is possible to survey large areas of smallholder agriculture quickly and derive general groupings which can then be verified by selective, detailed ground surveys. Second, by providing repetitive cover (or where this is not possible using previous existing aerial photo cover) it is possible to establish preliminary hypotheses (relating to areas of agricultural change) which can be used to help target the informal survey carried out at step five to examine specific problems. (e.g. soil erosion, forest loss, etc.)

Quite apart from the two possible advantages outlined above, in the Kenyan context there may be a third reason for considering the use of remote sensing techniques in FSR. As mentioned above KREMU is already using light aircraft remote sensing techniques to monitor and collect agricultural data for the high agricultural potential areas of the country. If such data can be shown to be of value in helping to distinguish between farming systems within smallholder agriculture in the country, then this could improve the timeliness of FSR programmes. Yet perhaps more importantly it would give wider institutional backing to FSR programmes and help to improve the influence of the Kenya Agricultural Research Institute (KARI) in the political and policy environment of the country.

KARI was legally recognised by parliament in 1979 as the organization responsible for all crop, livestock and forestry research in the country. Up until 1986 this organization had not received the political and policy support necessary to allow it to undertake the full role given to it by parliament. However, with the restructuring of the research services within Kenya now underway the future looks more certain. In the light of this restructuring FSR is likely to become more important and the blending of FSR and the agricultural extension services may be given greater priority.

3.5 SUMMARY

This chapter began by examining the position of agriculture within rural development planning in the LDCs. In the second section a systems view of agricultural development was introduced. This provides a suitable framework for understanding smallholder tropical farming systems. In the third section, FSR, the model used in this study was considered and compared with a number of other alternative approaches to agricultural research and development. Finally a review of some recent studies involving remote sensing technology has been given. It is suggested that remote sensing techniques can be used to strengthen the field operation of FSR. In the next chapter the specific approach used to identify target groups of farmers in lower Meru is discussed.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.0 INTRODUCTION

This chapter is divided into four main sections. The first section discusses the general approach used to identify recommendation domains in lower Meru. Section two examines the field survey methods undertaken - the questionnaire, field measurements and the collection of crop statistics - in order to provide ground data on the farming systems of the region. Comparisons between the air and ground survey data which involve the use of some of this data - crop cover percentage estimates, are undertaken in Chapter Six and are used to help identify agro-economic groupings (AEGs) in Chapter Seven.

The sample strategy and sample design based on a primary sample from the air surveys are considered in the third section. The final section deals with the methods used to identify areas of land use/cover change in lower Meru using Landsat MSS false colour composites and 1:50,000 stereo panchromatic aerial photography. Recommendation domains are discussed in relation to these areas of change in Chapter Eight in order to identify priority domains for agricultural research and development initiatives. It is suggested that where farmer mobility is high within AEGs these same areas have experienced marked cultivation changes and characterise less stable rural environments.

A multilevel approach is used in this study. However, although both Landsat MSS data and 1:50,000 panchromatic photography were included in this methodology, the work has focussed on remote sensing using light aircraft and ground sample surveys. The use of light aircraft remote sensing in rural development planning in East Africa has already been mentioned in the previous chapter, and many of the techniques involved in this research were originally developed by workers from this region.

4.1 THE APPROACH USED TO IDENTIFY RECOMMENDATION DOMAINS

This study examines the usefulness of remote sensing tools in helping to identify recommendation domains (hereafter referred to as domains) in lower Meru, Kenya. Domains are areas of 'relatively homogeneous agriculture' which include groups of farmers with similar natural resource endowments, access to markets and comparable farming systems. The methodology used to identify domains involves a different set of procedures from those more commonly found in FSR (a number of which were considered in the last chapter).

In this study two stages are used to define domains. First, different farming systems within the study area are distinguished - using data from three air surveys and a ground survey - these are called agro-economic groupings (AEGs). Second, AEGs are related to areas of similar natural resource endowment - agro-ecological zones (AEZs). Together these are then used to define domains. The resulting domains are therefore defined by both the physical land unit qualities of an area and the activities of man within these land units.

AEGs are defined as: smallholder agricultural areas which have similar crop and livestock farming activities which may be distinguished on the basis of the spatial characteristics of the land use/cover under study. An AEG is therefore a generalisation of the farming system in a given area, and is based on the spatial characteristics of this system. They may be entirely compatible with farming systems although their derivation is on the basis of spatial crop and land cover variables rather than detailed data collected via ground surveys. AEGs are not however a substitute for ground survey work, yet they allow more specific and restrictive ground sampling and survey work to be undertaken which will improve the efficiency of practical FSR work in the field.

Agro-ecological zones (AEZs) are an attempt to define natural land use potential using relevant agro-climatic factors. The methodology used to define AEZs involves seven procedures (FAO, 1978):

1. A review of the proposals of the evaluation is made in conjunction with an identification of the basic data and assumptions to be used.

2. Selection of alternative land uses (crops, levels of inputs, etc) is considered.

3. Climatic and soil requirements of the selected alternative land uses is made.

4. Land units (AEZs) are compiled with respect to the land uses identified in stage 2 above.

5. Matching of requirements of 3 with 4 (land units and land inventory) to calculate the anticipated production potential in different agro-ecological zones.

6. Estimation of production costs, and the identification of various suitability classes with their differentiating parameters.

7. Classification of land into various suitability classes for the selected alternative land uses.

Generalized agro-ecological zones were established by the FAO in 1978 using this methodology. AEZs are in effect climatic zones variated by soils (Jaetzold and Kutsch, 1982). In order to provide information to farmers at a district and regional level, a more detailed characterization of these zones is necessary. This needs to show the yield probabilities and risks for growing particular crop types.

In the Kenyan context research workers at the Kenya Soil Survey headquarters, Kabete, have been at the forefront of attempts to define agricultural potential zones for the country (Braun, 1977a and b, 1980; Braun and Mungai, 1981; Mungai , 1983; Sombroek et al., 1982). More recently, building on this previous research, Jaetzold and Schmidt (1983) have defined agro-ecological zones for all districts within Kenya. The zones defined by Jaetzold and Schmidt are used in this study to represent land units of natural potential. Ground survey samples were stratified by AEZ for sampling purposes in the study to ensure that farms were represented in each major zone within the study region (Figure 4.2). The spatial distribution of AEGs are identified in Chapter Seven and these are then overlaid onto a map of the AEZs to define recommendation domains in Chapter Eight.

FIGURE 4.1 AEZ MAP OF MERU

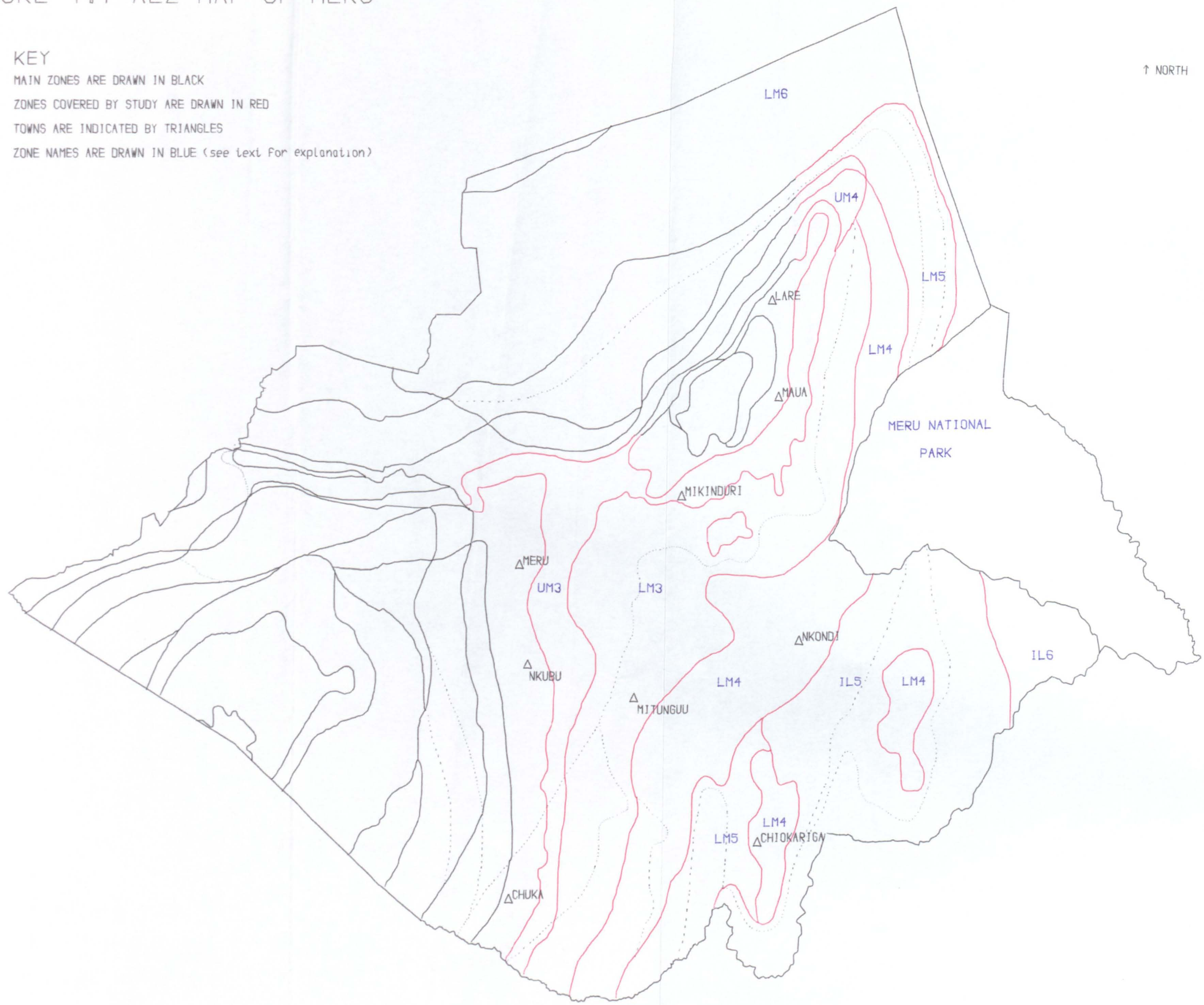
KEY

MAIN ZONES ARE DRAWN IN BLACK

ZONES COVERED BY STUDY ARE DRAWN IN RED

TOWNS ARE INDICATED BY TRIANGLES

ZONE NAMES ARE DRAWN IN BLUE (see text for explanation)



SCALE 1:500,000

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Zone groups are temperature belts defined according to the maximum temperature limits within which the main crops in Kenya can flourish. The highest zone is therefore high altitude rough grazing, while the lowest is lowland nomadism and other forms of transhumance. The main zones are based on their probability of meeting the temperature and water requirements of the main crops. The main zones are subdivided into sub-zones according to the yearly distribution and the lengths of the growing periods on a 60% probability factor, i.e. the length of the growing period should be reached or surpassed in at least six out of ten years. Agro-ecological mosaics within zones may be defined by printing climatic agro-ecological zones on soil maps to show local variations in agricultural potential (Jaetzold and Schmidt, 1983).

Figure 4.1 shows the main AEZs within Meru district. The study region includes seven major zones. Six of these were used to stratify the area for sampling purposes (one contained no settled population) and are described below. These descriptions are derived from Jaetzold and Schmidt (1983).

Extending along the western and northern border of the study region is the marginal coffee zone or upper midland zone 3 (UM3). This is divided into three sub-zones although two of these are very small in extent. Good yield potential exists for crops such as maize, sorghum, beans, sunflower and pineapples. Fair yield potential exists for coffee, cassava, pawpaw, citrus, pasture and forages.

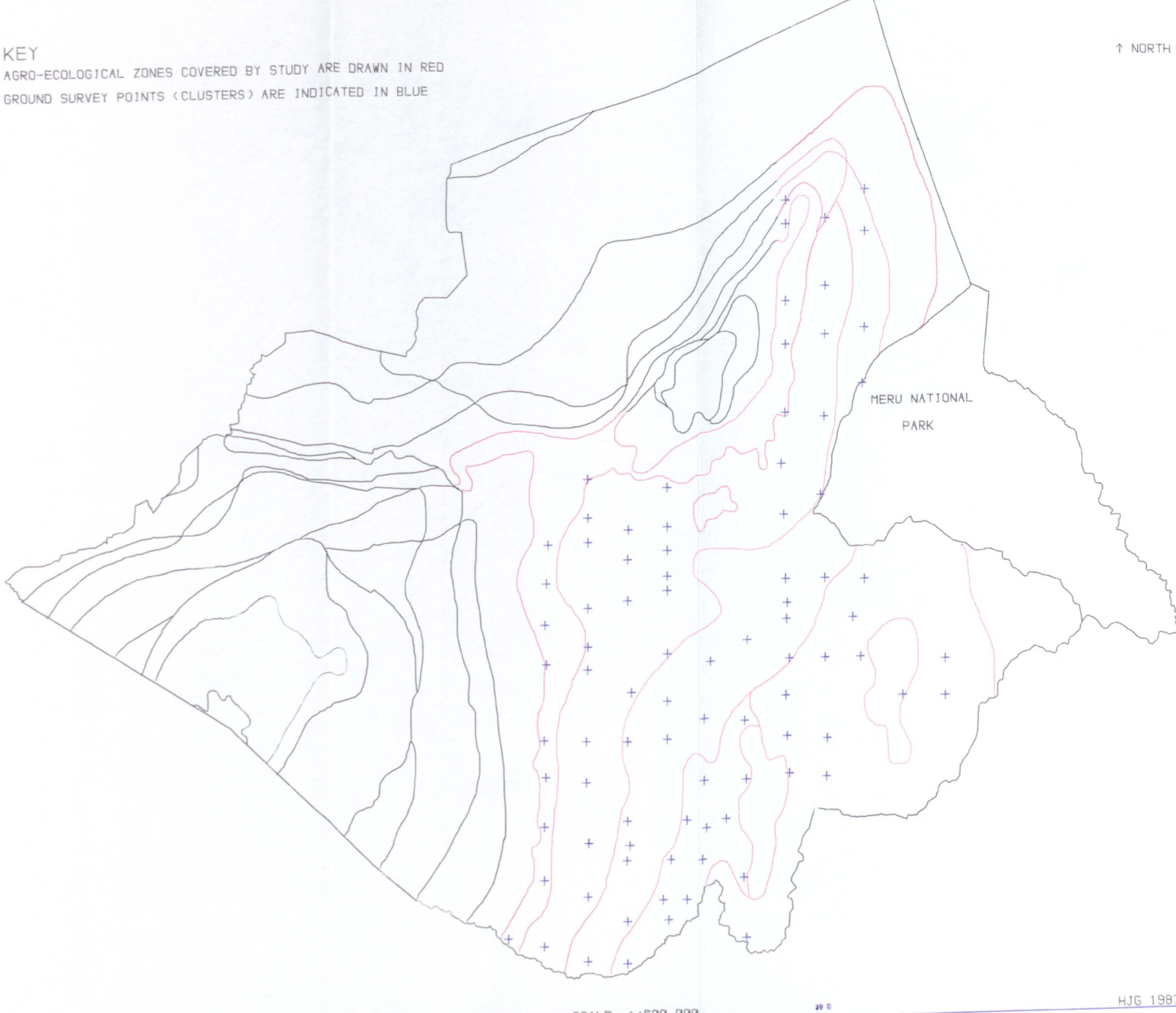


FIGURE 4.2 STRATIFICATION OF GROUND SURVEY POINTS

Near the northern most extreme of the study region a sunflower-maize zone or upper midland zone 4 (UM4) occurs. The area has two short cropping seasons. Best yield potential exists for Katumani maize, early maturing sorghums, beans and sunflower. Other crops may be grown but lower yields are to be expected. Crops such as finger millet, foxtail millet, sweet potato and tobacco are included in this latter category.

Two zones cover the central portions of the study region - the cotton zone (lower midland zone 3 - LM3) and the marginal cotton zone (lower midland zone 4 - LM4). The cotton zone is divided into three sub-zones. Generally in this area early maturing varieties of millet and dwarf sunflower have very good yield potential. Katumani maize, sorghum, chick peas, green gram, early maturing beans, cotton and tobacco all have good yield potential. Castor, mangoes, macadamia nuts and sisal can be grown on a perennial basis.

The marginal cotton zone (LM4) is divided into two sub-zones. Foxtail millet, proso millet and dwarf sunflower all have very good yield potential in this zone. Dryland maize varieties and bullrush millet have good yield potential. Cotton has fair to poor yield potential while sisal can also be grown although at present it is not cultivated in the area.

The lower midland livestock-millet zone or lower midland zone 5 (LM5) has five sub-zones. This zone covers a small area in the centre south of of the region near the village of Chiokariga as well as an area to the north of Meru National Park. Early maturing millets and sunflower have good yield potential. Black and green gram, chickpeas and bambarra groundnuts are some of the crops which have a fair yield potential. Maize however does not do well. Since there is no surface water available in the area to the north of the Park no cultivation occurs here and the area is used for grazing purposes only.

The remaining two zones are both termed inner lowland zones. These are inner lowland zones 5 (IL5) and 6 (IL6) which cover the area to the extreme south-east. Zone 5 has a yield potential similar to that of the lower midland livestock-millet zone (LM5) and similar crops are grcwn in both these two zones. Zone 6 is only suitable for ranching purposes with game ranching giving a higher potential production than cattle. This area has no settled population.

This section has discussed the definition of AEGs and AEZs both of which are used to define domains for agricultural research and development initiatives in Chapter Eight. The next section describes the field methods used to collect data on the farming systems of the study region. These data are used to help define the spatial distribution and describe the characteristics of AEGs in Chapter Seven.

4.2 FIELD SURVEY METHODS

The field survey was undertaken during a six month period from October 1985 to March 1986. The study region was divided into three sub-areas - in each approximately two months fieldwork was undertaken. A base camp was established at a suitable market town in each sub-area which could be moved at short notice when necessary (i.e. to avoid delays during the rainy season when certain survey points became inaccessible) giving versatility to the fieldwork programme. The three base camps used were Marimanti (Sheep and Goat Project), Mitunguu (German Irrigation Scheme) and Maua (Methodist Hospital). At each base camp two local interpreters/enumerators were selected to help carry out the farm questionnaires (4th form and 6th form leavers). This was a deliberate policy. In each of the sub-areas different dialects of Kimeru were spoken, and by selecting local people from each area to help in the survey it was possible to establish a quick and easy rapport with the local farmers.

The fieldwork undertaken consisted of three interrelated components. On each of the 482 farms visited: 1) questionnaires were asked; 2) crop planting history for a four season period was collected; 3) at most of the ground sample points at least one farm measurement was undertaken. In each of the three sub-areas a pilot test of the questionnaire was carried out covering approximately 15 farmers prior to the formal survey. This proved to be especially valuable for two reasons. First, it allowed the researcher to assess the capability of the selected enumerators and to help them to overcome any difficulties in translating the questionnaire into the local vernacular. Secondly, the pilot test led to identifying certain weaknesses in the questionnaire and changes were made accordingly to improve the overall survey prior to visiting the selected farmers.

A number of changes were made as a result of these pilot tests. The layout of the questions was changed to allow more space for the responses. Some questions were re-worded to allow more searching questions to be asked. Vernacular names were introduced wherever this was possible to improve the flow of the survey (rather than Kiswahili names). Local advice on intercropping practices was included in the cropping survey. Some inappropriate questions were eliminated (e.g. farmers were not asked if they practiced zero grazing in the lower zones of the study region) to save time during the questionnaire. Rewording of some questions in the light of the experience of enumerators during the pilot testing was also undertaken.

One day was spent at each farm cluster during the field survey. The selection of farm clusters and the relationship between the ground and air samples are discussed in Section 4.3.1. A questionnaire was undertaken on each farm within the cluster (Appendix 1A) and this was generally completed within an hour. Each questionnaire was divided into seven sections: locational/geographic information, farm information, crop husbandry, livestock husbandry, general farming, family information and finally farmers' future outlook.

Although data were collected on crop yields on each farm in an attempt to estimate the gap between actual and potential production, this data was not analysed. One of the main reasons for this was due to the fact that farmers used different units of measurement for weighing their produce. This meant reliable comparisons between farms/clusters were impossible.

Data from the section on farm information included farm size estimates (farmer estimates) and information on farm tenureship. Farm size estimates are used in Chapter Five together with farm measurements (see below) to calculate crop cover percentage estimates for the ground survey. Crop percentage estimates derived from the air and ground surveys are then compared in

Chapter Six. Data on farm tenureship from the farm information section together with data from the sections on crop and livestock husbandry are used to distinguish between AEGs in Chapters Seven and Eight. Data from the section on family information are used to assess the mobility of farmers within AEGs, while data from the section on general farming are used to examine the need for improved agricultural extension in certain priority areas. Both these data sources are used in Chapter Eight. The sections dealing w.th locational/geographic information and farmers' future outlook are used for more general background purposes in the study.

Cropping history and crop planting methods for a four season period on all the plots on each farm were recorded using a different survey sheet (Appendix 1B). In some cases collecting this information took up to an hour depending on the number of plots and the size of the farm. This crop information is used to assess the accuracy of the air survey crop percentage estimates (using the ground survey as a yardstick for comparison) in Chapter Six. Crop percentage estimates for a selected number of crops are then used to help define AEGs in Chapter Seven.

Finally at most of the ground clusters at least one farm measurement was made. This involved measuring the size of the cultivated area on a farm holding together with separate field measurements for the important cash and food crops as well as crop complexes. Measurements were undertaken using a Smith wheel and prismatic compass following the method devised by Petricevic (1982) (Appendix 2).

In order to allow comparison between the ground survey and air photo data sets (to estimate the validity of using air photography to identify AEGs within the smallholder economy), at each ground point a group of farms (cluster) were covered by the field survey. Originally it had been estimated that it would be possible to cover six farms at each of the 88 ground sample points giving a total of 528 farms. However, the number of farms surveyed at each cluster varied according to the time needed to complete the questionnaires and cropping history on each farm. This meant that at each sample point between four and six farms were covered.

Farm selection at each sample point was undertaken with two criteria in mind. First, farms had to be either entirely visible on the aerial colour slide for a given sample unit, or, if this were not possible (due to the size or spacing of the individual farms) immediately adjoining farms which were only partially visible were chosen. Generally however the selected farms occurred within the area covered by the respective colour slide. Second, farms were selected in order to maximize the difference between these at a given sample point. Thus for example, a farm owned by the brother of a farmer who had been previously interviewed was not included in the farm cluster since it was felt that family ties might lead to a similarity in farm practices.

Generally it was not possible to revisit sample clusters and it was therefore necessary to complete all the farm surveys within one day. Where farmers were absent from one of the selected farms the next nearest farm to the central point of the cluster (defined by the centre of the aerial colour slide) was chosen. On each farm wherever possible both the farmer and his wife were contacted and interviewed since both are considered to be equal participants in the farm economy. The questionnaire was therefore addressed to both parties since it was found during pilot testing of the survey that often women were most knowledgeable about questions relating to cropping practices (since the crops were usually planted by them), while men were usually more able to answer questions relating to financial matters, especially with regard to the sale of cash crops.

For the purposes of this study a farm is defined as: the area under cultivation which is owned, rented or borrowed by one farm family. This is *not* the same as a farm holding which is a broader concept and includes land which is owned, rented or borrowed by a farm family but which is not necessarily all cultivated. Separate areas of cultivation occurring within the confines of a single farm holding were defined as one farm. A farm family is defined by a farmer, his wife and their dependent children.

During the field survey verification of crop cover and land cover types identified on the aerial colour slides was also made to aid in the interpretation of the aerial survey data which was carried out subsequent to the field work (see Chapter Five). For the 1986 air survey this was done by visiting selected fields and identifying the crop types growing. These fields were then used to produce classification keys for classifying other slides from the air surveys which had not been ground checked. Selected natural vegetation land cover types were also ground checked and used to classify other slides in a similar manner.

Having discussed the questionnaire and field methods, the following section explains how the farm clusters were selected.

4.3 SAMPLE STRATEGY

The sampling strategy adopted considers the overall purpose of the survey. The major objectives of the present study are to test the validity of using remote sensing techniques to identify agro-economic groupings (AEGs) in the smallholder economy of lower Meru, and to use these groupings to define recommendation domains for agricultural research and development initiatives in the region.

The design of the sample strategy was considered at some length. It was necessary for some kind of area-based sampling frame to be used so that the air survey crop estimates could be reliably compared with similar estimates obtained from the ground survey. Houseman (1975) has discussed the basic principles of area sampling. One of the key characteristics of this kind of sampling is the physical delineation of areas on the ground which can be used as a sample frame for survey purposes, and which will act as a baseline for any future surveys. The concept is very simple:

> "Divide the total area to be surveyed into N small blocks, without any overlap or omission; select a random sample of n blocks; obtain the desired data for reporting units of the population that are in the sample blocks; and estimate population totals by multiplying the sample totals by N/n." (Houseman, 1975, p.1)

The practical application of these concepts are more complex, and have to be considered in the light of: the available information on the area, the purpose of the survey, the ease with which reporting units (in this case farms) can be associated with the area sampling units and, alternative sampling methods which might be used.

Baseline information on Meru district is better than that of many of the other districts in Kenya. The area is covered by topographic map sheets at 1:50,000 scale, the most recent of which are based on 1980 photography and field checks. This district also has almost complete panchromatic air photo cover at 1:50,000 scale covering a period between 1948-1980, providing comparative air photo cover for the years 1948, 1961, 1967 and 1980. Such baseline information could be used to define an area sampling frame consisting of areas with no overlap or omission over the district, yet there are difficulties with this procedure.

The first problem is that an area sample frame needs to follow physical boundaries wherever possible, so that the sample areas can be easily located in the field. This would not be a problem in the upland areas where there are a large number of streams and roads to help in delineating such areas. However, in the lowland regions of the district the identification of distinctive sample units would be much more problematic. The lowland areas are typically flat, contain little settlement, and their physical characteristics are not of great contrast and so cannot be used to adequately identify sampling units.

One alternative to designing a new area sampling frame for sampling purposes in the district would be to use enumeration areas (EA) as a base for the sample frame. Here again there are problems. In the densely settled and more fertile areas to the west and north (Nyambeni foothills) of the study area, detailed EA maps are available showing the spatial distribution of farms. However, such maps are only available for these more fertile regions of the district (they were the first smallholder areas to have land adjudicated and registered), and most of the lower and more marginal lands, the focus of the present study are not covered by EA maps. Remote sensing using light aircraft provides a satisfactory alternative sampling frame in the light of these difficulties.

Houseman (1975), has shown that there is a smaller sample variance (i.e. variance of an estimate from a sample) when sampling units are widely dispersed and the sample units are small. In other words the degree of inefficiency within an area sample strategy is related to the size of the sample unit, and the number of reporting units (farms) within a sample unit. The physical characteristics of the area are very diverse as described earlier (Section 2.2.3). In Meru farming patterns reflect the changing physical landscape - the farmlands to the west and north are intensively cultivated with closely spaced agricultural holdings, while to the east and south farms are scattered and transhumance is still common. Because of this diversity the sampling strategy should be broad based and should attempt to cover as many of the different natural ecosystems within the area as possible.

Thus, rather than proceeding with a purely random area-based sample, a stratified random or a systematic stratified sample would be more appropriate in this context. Stratification of the area could be undertaken using administrative, or natural physical units (agro-ecological zones) while the selection of sample points within each stratum could be random or systematic. At the same time however it is suggested that farms within the same locality will generally have a stronger tendency to be alike - the degree of likeness being directly related to the physical distance separating them. This factor should be considered within the sample design so that reporting units (farms) are grouped to represent clusters. In the present study the degree of likeness is an important consideration since the objective is to define homogeneous areas within the smallholder economy. The sample design must therefore include stratification as well as some kind of grouping or clustering in order to establish whether there are indeed homogeneous areas within the small farmer communities of the district.

The sample design used in the present study has two key characteristics. First it is based on a principle of stratification: to construct strata which will minimize any differences in variance within strata and maximize differences between their averages. Secondly, it uses the principle of clustering: to maximize variations across farms at any one point, and so identify any significant differences within a locality. Sample colour slide photography undertaken from a light aircraft provides a primary sample frame for selecting farms.

Since the late 1960's, considerable use has been made of light aircraft aerial sampling in East Africa for wildlife and livestock counts and more recently for land use planning (Gwynne and Croze, 1981; Norton-Griffiths, 1981, Dunford et al., 1983; Watson and Tippett, 1981; Watson, 1981; Epp et al., 1983; Ottichilo, 1986). Although there is some controversy between those using systematic positioned sampling strips and those who use randomly positioned ones (Jolly, 1981), the basic methodology is the same (i.e. sampling from a light aircraft) while as Watson (1981) has observed the real issue here is the consumer and not the statistical rigour of the sampling design.

Imagine the survey area is divided into N discrete non-overlapping units each of which is potentially capable of being photographed. These units cover the entire region under study although only a sample are actually photographed under any given sample strategy. In the present study systematic stratified sampling is undertaken with each sample unit being represented by a vertical aerial photograph at regular spaced intervals over the area.

Typically systematic reconnaissance surveys involve flying along a series of orthogonal transects to provide sample photo cover over an area in the form of a grid. In practice this usually involves following the UTM grid coordinate system using a global navigation system (OMEGA/VLF navigation system). A radar altimeter may be used to obtain accurate altitude readings for each sample point to allow hard copy photo products to be registered to a constant scale. One of the major advantages of this approach is its flexibility. Sample intensity can be varied according to the requirements of the study, as can the flying height and the season of the sampling. This enables the survey to be timed to coincide with the most appropriate stages of crop growth. Potentially, the sample can be repeated at some later date to provide data for multi-temporal analysis, although it may not be possible to cover precisely the same sample areas due to variations in aircraft flying speed as well as wind changes (Norton-Griffiths, unpub). However, ground checking could be undertaken to identify any areas of overlap or omission where this was considered critical for multi-temporal comparisons to be made, since the repeat sample units would be very close to the original sample areas.

4.3.1 TWO STAGE SAMPLE

The sampling design adopted here relies on systematic aerial sampling to provide a primary area sample from which a secondary ground cluster sample consisting of 88 farm clusters is selected. Due to financial limitations it was not possible to commission a flight to cover the entire study region in 1986 (to coincide with the ground survey). However with the permission of the Kenya Rangeland Ecological Monitoring Unit (KREMU), Nairobi, it was possible to use air photo data from two previous aerial surveys which had been flown during the period immediately prior to the field study to obtain complete sample cover of the lower Meru area. The 1986 systematic reconnaissance flight (SRF) together with the two previous surveys undertaken by KREMU were used to construct a primary sampling frame comprising of 433 area sample units. Each sample unit was represented by a vertical colour slide.

The first flight was flown in January 1985. Photography was undertaken from a height of 660 metres above ground using a 35mm camera and 20mm lens. This gave colour slides at a scale of 1:30,000. Photographs were taken every 2.5 X 5 km along the UTM grid coordinate system (Figure 4.3). The second flight was undertaken in May 1985 at a flying height of 480 metres using the same camera but with grid sampling every 10 X 1.5 km, giving a photo scale of 1:24,000 (Figure 4.4). The third flight occurred in January 1986. A flying height of 660 metres with the same camera using a 50mm lens and with grid sampling approximately every 1.5 X 5 km, gave a photo scale of 1:12,000 (Figure 4.4).

In order to obtain a widely dispersed ground cluster sample to cover all the farming systems in the region the study area was stratified by agro-ecological zone (AEZ). Sample units (colour slides) from each of the three air survey flights were allocated to one of these strata. Within each stratum samples were randomly selected by allocating a number to each. Based on an original estimation of surveying six farms per sample point, 88 samples were then selected using random number tables. Figure 4.2 shows the distribution of these points. Sample points were selected on the assumption that if the methodology used to identify AEGs proved to be successful then this sample could be expanded to include all 433 air photo samples.

A number of reserve sample photos were also selected within each stratum to provide alternative ground sample clusters where any of the original photo points were found to be inaccessible from the ground. Sample units which were found to be more than one hour's walk from a motorable road were eliminated from

FIGURE 4.3 SAMPLE POINTS OF JANUARY 1985 AIR SURVEY

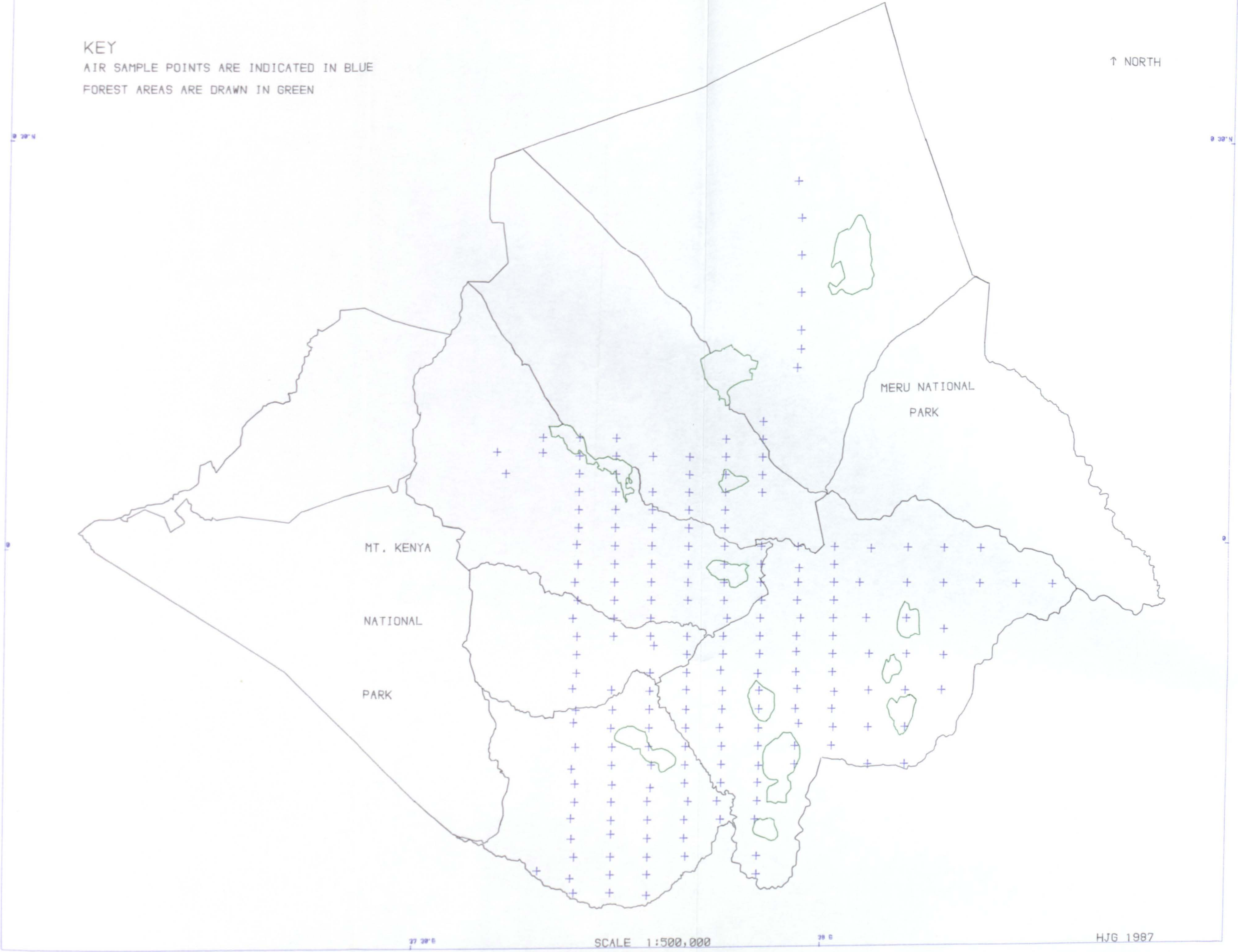
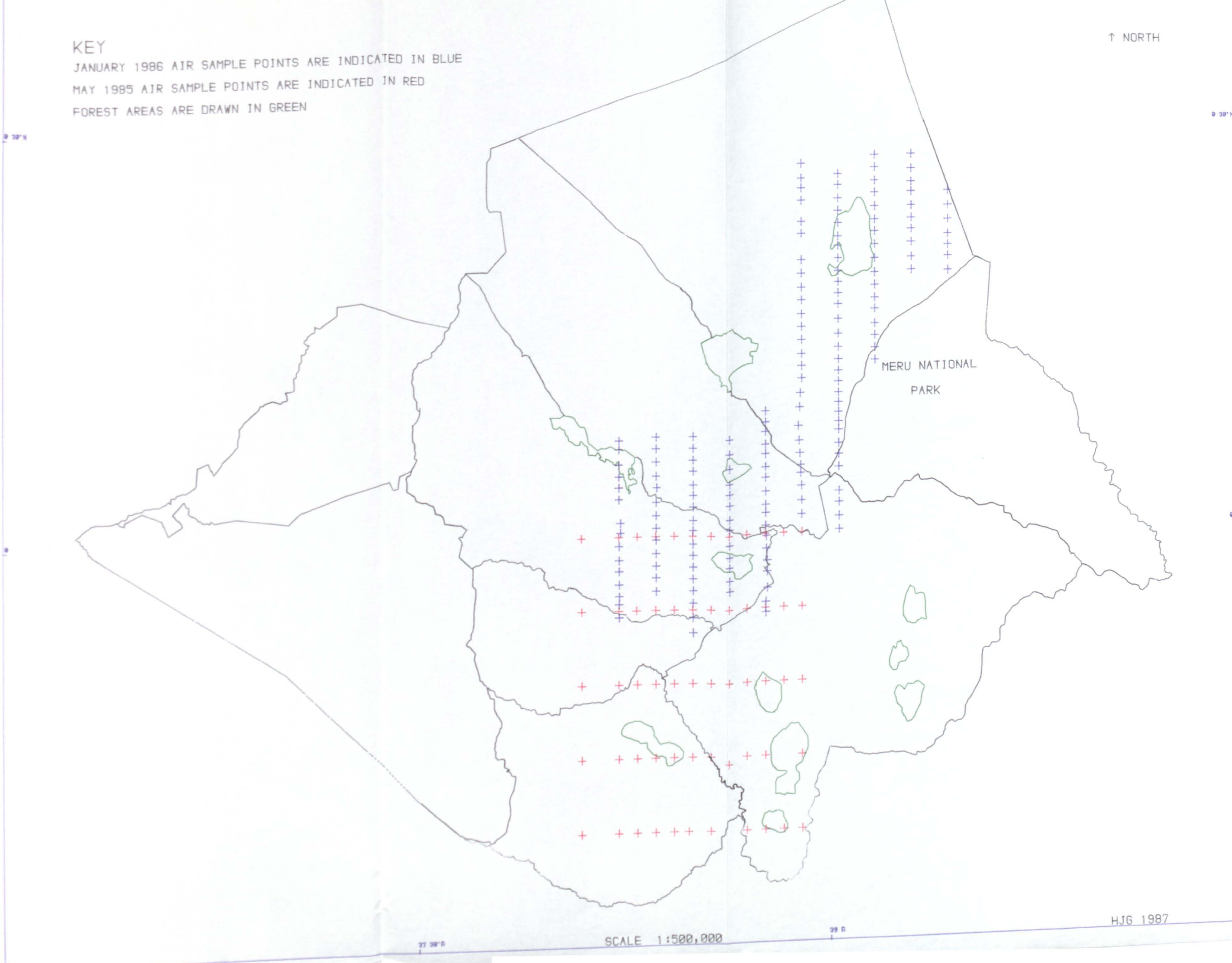


FIGURE 4.4 AIR SURVEY POINTS: JANUARY 1986 AND MAY 1985



selection at this stage since each ground sample point was to be visited only once and time was therefore a limiting factor. In practice this eliminated only areas with no settlement (i.e. the extreme south-east and north-east of the study region) and which were of little interest.

4.3.2 LOCATING THE GROUND SAMPLE CLUSTERS

Having selected the 88 ground sample clusters it was important to minimise the time spent in locating these areas on the ground. Several techniques were devised to help here. First, all the sample clusters were mapped from the air survey flight maps onto 1:50,000 topographic sheets to give an approximate location for each survey area. For the lower, drier areas in the south and east, 1:12,500 stereo panchromatic aerial photography giving complete cover for 1982 available from the Embu-Meru-Isiolo programme (EMI) was used to locate the precise area covered by each colour slide from the SRFs, and this area was then transferred onto a 1:50,000 topographic working map of the district. For the other areas within the study region where such photo cover was not available, 1:50,000 stereo panchromatic aerial photography from 1980 (available from the Survey of Kenya, Nairobi) was used in a similar manner, although it was often only possible to locate the exact area covered by each slide at this scale of photography with detailed examination using a stereoscope.

Having located each ground cluster as precisely as possible on a working map at 1:50,000 scale the area covered by each colour slide was checked in the field during the ground survey by using a portable slide viewer containing the appropriate aerial colour slide. Generally it was possible to locate the ground sample clusters within half an hour to one hour of arriving in the survey area each day - depending of course on the distance of the survey point from the nearest road.

One of the objectives of the research presented here is to identify which recommendation domains have been experiencing marked increases in cultivation in recent years. It is suggested that where cultivation changes are identified, farming systems are in a state of flux and it is in such areas that future agricultural research and development initiatives should focus for it is in these areas that detrimental environmental changes may be occurring. The next section reviews the methods used to identify areas of cultivation change.

4.4 IDENTIFYING CULTIVATION CHANGES

Land use/cover changes were examined using two different remote sensing approaches. Initially Landsat MSS data were analysed to identify broad areas of change for a period between January 1973 and February 1980. Secondly 1:50,000 stereo panchromatic aerial photography was used to define more specific cultivation changes.

Landsat MSS data using a computer compatible tape for the scene of 10th June 1979 which covers the Mount Kenya region (and includes the area under study) was machine processed and classified in preparation for comparison with two similar scenes of 30th January 1973 and 17th February 1980. However, owing to financial limitations it was not possible to purchase computer compatible tapes covering these other scenes. Visual analysis of the 1973 and 1980 scenes was therefore considered and using the services of the Regional Remote Sensing Facility (RRSF), Nairobi, preprocessed false colour composites (FCC) of these two scenes were obtained.

Each FCC was projected onto a 1:250,000 base map covering the study area using a overhead projector. On each FCC areas of similar colour, texture and hue were demarcated using felt marking pens by drawing onto an acetate overlay. Using the 1973 scene as a baseline, broad areas of change between the two scenes were mapped onto a third overlay (Figure 8.10). It was not possible to distinguish precise land use changes however using this imagery.

A second and more detailed examination of areas of land use/cover change was therefore undertaken using two sets of 1:50,000 panchromatic aerial photography for the years 1967 and 1980. Four stages were involved. First, wax crayons were used to delineate areas of similar texture, tone and contrast on each of the sets of photography. Using a zoom transferscope the delineated areas from each set of photography were then mapped onto acetate overlays covering 1:50,000 topographic map sheets at the second stage. Generalised categories of land use/cover change were then identified by comparing the two overlays (using 1967 as the base year) and mapping the results using the same equipment. Specific areas of both cultivation increase and decrease were defined from this analysis. Finally these areas of cultivation change were digitized and mapped.

Using this information, recommendation domains with the most marked cultivation change and/or the greatest farmer mobility are identified in Chapter Eight in order to define priority areas for new agricultural initiatives.

4.5 SUMMARY

This chapter has discussed the general approach used to identify recommendation domains within lower Meru. The questionnaire design, field measurements and crop statistics, all of which are used to distinguish between farming systems in lower Meru, were reviewed in the second section. The third section dealt with the sample strategy and design. A primary sample of 433 air sample points was used to select a secondary ground cluster sample of 88 points. Each ground sample point is covered by a sample colour slide from one of the air surveys. The last section discussed the methods used to identify areas of cultivation change within the study region. These areas of cultivation change are used in Chapter Eight to help select domains for new agricultural development initiatives.

The next chapter discusses the methods and techniques which are used to organize and process the data in preparation for the analysis which is presented in Chapters Six, Seven and Eight.

CHAPTER FIVE

PROCESSING AND ORGANIZATION OF DATA

5.0 INTRODUCTION

In the previous chapter the research methods which were used to collect the ground and air survey data were discussed and the different data sources identified. This chapter is concerned with the processing and organization of the data from these sources. Computer files were generated making the data accessible for analysis using a number of different computer programmes on the Nottingham University VAX 11/780 and ICL 2900 machines.

The chapter is divided into three main sections. The first section discusses the methods which were used to derive absolute land cover and crop cover percentage estimates from the three air surveys and describes the format of these data files. The ground survey data are discussed in the second section. The methods which were used to calculate absolute crop percentage estimates as well as other averaging procedures used to compute summary variables for each farm cluster are presented. The organization of the two ground data files are discussed.

The objective of these first two sections is to show how absolute crop percentage estimates were derived for each data source (ground and air data). These estimates are compared in the next chapter to assess the validity of using remote sensing procedures to help identify AEGs. Finally, the techniques which were used to map and display the analysed data in Chapters Seven and Eight are discussed.

5.1 THE AIR PHOTO DATA

In order to derive relative land cover and crop cover percentage estimates for each of the systematic reconnaissance flights (SRFs), the aerial colour slides were projected onto a dot grid comprised of random point samples. Using a Leitz distortion-free cabin projector slide interpretation was carried out at a scale ranging between 1:400 and 1:1000 according to the scale of the original photography.

Random point sampling has been shown to be one of the most efficacious methods of estimating land use/cover from aerial photographs (Stobbs, 1968) and is easy to use and inexpensive to operate. A large paper sheet consisting of over seven thousand grid squares was prepared and each grid allocated a number. It was decided that agricultural land use categories covering at least 1.5% or more of the total land area were to be estimated with a sampling error of no more than 5%. The formula

$$N = (100-P)\,\frac{38{,}400}{P(E)^2} \qquad (5.1)$$

was used, where N is the total number of sample units (colour slides), P is the percentage of the total land area occupied by the most critical land use category (1.5% in this case), 38,400 is a constant based on Students' t, taken at the 95% level of probability, and E is the percentage error within which the results can be expected to fall in 95% of the cases (equation 5.1 after Stobbs, Ibid.). It was calculated that for 433 sampling units (the number of aerial colour slides included in the study region) it was necessary for each slide to be sampled by a dot grid having at least 233 randomly distributed points. 235 random points were selected. For each of the SRFs a number of land use/cover interpretation classes were defined. For the January 1985 flight 61 classes were distinguished while for the May 1985 and January 1986, 85 and 103 classes respectively were defined (Appendices 3A, B and C).

The number of points falling within each land use/cover interpretation class for each sampling unit was summed. This total was then divided by 235 (the number of random points on the dot grid) and multiplied by 100 to derive a relative percentage figure for each land class at each of the 433 sample units.

In order to check on the accuracy of the slide interpretation undertaken by the researcher a test was devised in which a number of the slides were separately interpreted by a different person. This test is referred to as the Zakary test (named after the person who helped in the test) in the rest of the study. For four of the main agro-ecological zones in the study region (UM3, LM3, LM4 and IL5) seven sample units (slides) were randomly selected to provide a sub-set of 28 sample units. The researcher and one other person then independently interpreted these slides using a previously defined set of land use/cover classes (Appendix 4). A comparison was made between the two sets of results for each of the four agro-ecological zones using the Mann-Whitney U test. The results of these tests are given in Table 5.1 below.

TABLE 5.1

ZAKARY TEST - COMPARISON OF RESULTS

AEZ	CALCULATED U	PROBABILITY P
UM3	920.5	0.6857
LM3	880.5	0.4585
LM4	809.0	0.1445
IL5	962.0	0.9491

AEZ indicates agro-ecological zone, UM3 equals upper midland zone 3, LM3 equals lower midland zone 3, LM4 equals lower midland zone 4, IL5 equals inner lowland zone 5 (for further discussion of these zones see Section 4.1). The critical value of U at the 0.05 level is 733.14.

Details of the Mann-Whitney U statistic are given in Section 6.3; essentially, it is a test of the significance of the observed difference between the medians of two samples. The data are given ranked orderings since this is a non-parametric test. The null hypothesis states that there is no significant difference between the land use/cover percentage estimates of the two samples being compared for any AEZ at the 0.05 level of significance. The null hypothesis is only rejected if the calculated value of U is less than or equal to the critical value of U. The results show that for all AEZs there is no significant difference between the two sample estimates of land use/cover.

In fact it is clear from the individual percentage figures for the two samples that while the overall distribution of estimates is similar, some of the land use/cover estimates are quite different from each other. In particular the estimates for maize, rough grazing, cotton and millet vary significantly between the two samples in some of the AEZs (Appendix 4). The Zakary test shows it is important for the slide interpretation and ground checking to be carried out by the same person. Certain land use/cover classes are difficult to distinguish when the interpreter has not been into the field to verify the interpretation classes for himself. There are a number of reasons for this.

First where crop complexes occur it is particularly difficult to distinguish crop types. Field checks allow workers to identify colours and textures on the slides which can be related to particular crop combinations in the field. Accurate crop description keys can then be produced to help in the interpretation of slides where ground checking has not been possible. Secondly, young cereal crops (e.g. maize and sorghum) can be easily confused by colour and texture with each other or with fallow areas of long grass cover. Here again field checking can minimise interpretation error.

The following sub- section discusses the procedure used to compute absolute crop/land cover percentage estimates from the air survey data.

5.1.1 CALCULATING ABSOLUTE PERCENTAGE ESTIMATES

Absolute crop cover percentage estimates from both the SRF data and the ground survey are used in the analysis presented in this study to help identify AEGs. Chapter Six compares the accuracy of the estimates derived from the air surveys with similar estimates derived from the ground survey. Absolute percentages for the SRF data were computed by multiplying the relative percentage estimates of a crop at a particular sample unit by the total land under cultivation at that sample unit using the formula:

$$A = \frac{p_{ij}C_j}{100} \tag{5.2}$$

where, p indicates relative percentage estimate of crop type i at sample unit j and C indicates the total percentage of land under cultivation in sample unit j.

Both the air and the ground data files were structured so that they could be manipulated, and computations and comparisons performed across the two different data sources using the SPSSx computer package (SPSS Inc, 1986). Sub-section 5.1.2 discusses the organization of the air survey data files.

5.1.2 ORGANIZATION OF AIR SURVEY DATA SETS

The relative land use/cover percentage estimates from the three SRFs were entered into the computer separately to give three data files - one for each of the air surveys. The structure of these files is however the same. Table 5.2 shows their general format.

TABLE 5.2

STRUCTURE OF THE AIR SURVEY DATA FILES

COLUMN NUMBER								
1-3	4-12	13-14	15-16	17-19	20-22	23-27	... 68-70	71-75
X	GRID	LOC	AEZ	ALT	Y1..	Z1..	... Yy...	Zy...

X indicates air photo number, GRID indicates UTM Grid coordinate at centre of slide, LOC indicates administrative location, AEZ indicates agro-ecological zone (from Jaetzold and Schmidt, 1983), ALT indicates height above sea level at the centre of each slide, Y1...Yy indicates the code for land use/cover class one to class y and Z1...Zy indicates the estimated percentage for land use/cover class one to class y. Lists of the land use/cover classes used in these three data sets are given in Appendices 3A, B and C.

Where there were too many land use/cover categories to be accommodated on one record (80 columns) of the data file, the structure of the other records is identical to that of the first although the variables in columns 1-19 are not included in subsequent records. Taken together the air survey computer files include information from three cropping seasons (January 1985, May 1985 and January 1986) and contain a varying number of cases, each case representing a single sample photograph (area sample unit). The January 1985 data file contains 205 cases, the May 1985 file 52 cases, and the January 1986 file, 176 cases. The names of these data files are abbreviated to Jan85, May85 and Jan86 for reference purposes in this study.

Having explained the methods used to calculate absolute crop /land cover percentage estimates using data from the air surveys the discussion now focusses on the methods used to calculate similar estimates from the ground survey data.

5.2 THE GROUND SURVEY DATA

Although many remote sensing studies argue that ground data are essential in order to provide an objective standard against which to compare estimates obtained using remote sensing methods, few studies have examined the methods (and pitfalls) of actually collecting ground data. The field experiences gained in this study suggest that in future more attention needs to be paid to this aspect of research in land resource studies.

Several kinds of error may be included in the ground data collected. First, farmer responses are subject to recall error and this may result in some farmers giving misleading information. Secondly, if ground area measurements are undertaken these will never be precise (a 95% accuracy level was used for farm measurements in the present study) and depending on the landform, such errors may be considerable (e.g. if no account of slope is made for area measurements undertaken in mountainous landscapes). Finally, ground measurements and survey work normally require a considerable amount of time, and there may be a case for accepting slightly lower levels of accuracy if estimates made using remote sensing techniques are more timely. One particular limitation of the ground data presented in this dissertation is considered below.

Although 482 individual farms were visited during the ground survey these were concentrated around 88 farm clusters. Cluster sampling was used since the objective was to establish comparative ground data for verifying the crop estimates obtained from the air surveys. Owing to financial limitations in the study, it was not possible to commission an air survey flight to cover the entire study region during 1986, and therefore data from two previous flights undertaken by KREMU (Jan85 and May85) were also used.

Ideally, the groups of farms surveyed on the ground should cover the same area as the sample colour slides of the SRFs, in order to minimise any error in the crop estimates between these two data sources which might result from variation in the size of the sampled area. However, because the three different SRFs produced different scales of photography, the area sampled by each photograph on each flight varied. On the January 1985 flight each sample photograph covered approximately 72 hectares on the ground. For the May 1985 air survey this decreased to approximately 46 hectares, while for the January 1986 flight each photo covered approximately only 12 hectares. Comparable area sample sizes were only obtained between the January 1986 air survey and the ground sample clusters, since the other two air surveys both covered sample areas which it was not practically possible to cover on the ground using the methods outlined in the previous chapter.

The comparisons between the air and ground data undertaken in Chapter Six rely on the ground data as a yardstick to measure the accuracy of the remotely sensed estimates of crop cover. The discussion presented here illustrates however, that both data sources contain potential sources of error. Greater attention should be paid to estimating the possible effect of errors from *both* ground and air data sources where these are used in future remote sensing applications.

5.2.1 CALCULATING ABSOLUTE PERCENTAGE ESTIMATES

In order to assess the validity of using remote sensing techniques to help identify AEGs in lower Meru, it was necessary to verify the accuracy of the air data sources by comparing the absolute crop cover percentage estimates from both the air data and the ground survey, to see if there was any significant difference between these (Chapter Six). The method used to compute absolute percentages of different crop covers using the air survey data at each area sample unit has been discussed in Section 5.1.1 above. The method used to compute similar estimates from the ground survey data are presented here.

Equation 5.3 below shows how absolute crop cover percentage estimates for the ground survey were computed. At each of the 88 farm clusters:

$$A = \frac{(\ ((F/p)P_i)\ C)}{100} \qquad (5.3)$$

Where, F is the percentage of the area (estimated using farm measurements and farmer estimates) under either pure food crops, pure cash crops or crop complexes. p is the number of plots under one of these three categories at a single ground sample cluster. P is the number of plots planted with crop i, and C is the total percentage of land under crop cultivation estimated from the air surveys.

C is an estimate derived directly from the air surveys and has been discussed above (equation 5.2). P is derived from CROPTAB (CROPTAB and FARMDAT are discussed in Section 5.2.2 below). Aggregating individual farm values or counts for a variable to form a new variable - which is the sum of the original values or counts, to correspond with a ground farm cluster (4-6 farms) was performed very simply using the AGGREGATE procedure in the computer software package SPSSx. This procedure allows one to aggregate values or counts on a variable across different cases as long as each case (farm) has some kind of identifier. In this study all the farms surveyed at the same farm cluster were identified by the same UTM grid coordinate. It was therefore possible to compute the total number of plots under a particular crop at each of the 88 ground clusters using this procedure.

On each of the 482 farms crop variables were grouped into the three categories: pure cash crops; pure food, fodder and forage crops; and crop complexes (farm area measurements had not been undertaken on individual crop plots during the field survey, rather, measurements had been made using the three broader categories outlined above). The number of plots in each of these three categories on each farm was obtained. At each of the 88 farm clusters these plot counts were then aggregated to obtain the total number of plots for each category (p in equation 5.3).

The percentage area estimate (F in equation 5.3) for the three crop categories outlined above at each farm cluster was obtained by using both the field survey farm area measurements, as well as area estimates given by some of the 482 farmers. It was necessary to use both farmer estimates and farm measurements to compute the absolute percentage of land under different crops in the study region, since it had not been possible to undertake crop area measurements on all of the 482 farms covered by the ground survey (Appendix 5).

Farm area measurements were made allowing for a 5% error. However, there was also a potential source of error in the area estimates given by farmers. Not only might this arise from inaccurate assessments of farm areas by farmers, but farmers wishing to appear wealthier than they actually were, may have purposely overestimated the area of land they were cultivating. In order to test the accuracy of the farmer estimates therefore, these were statistically examined by comparing their estimates against actual farm measurements for a sample of 63 of the 482 farms visited (Appendix 6). The results of this comparison are shown in Table 5.3 below.

TABLE 5.3

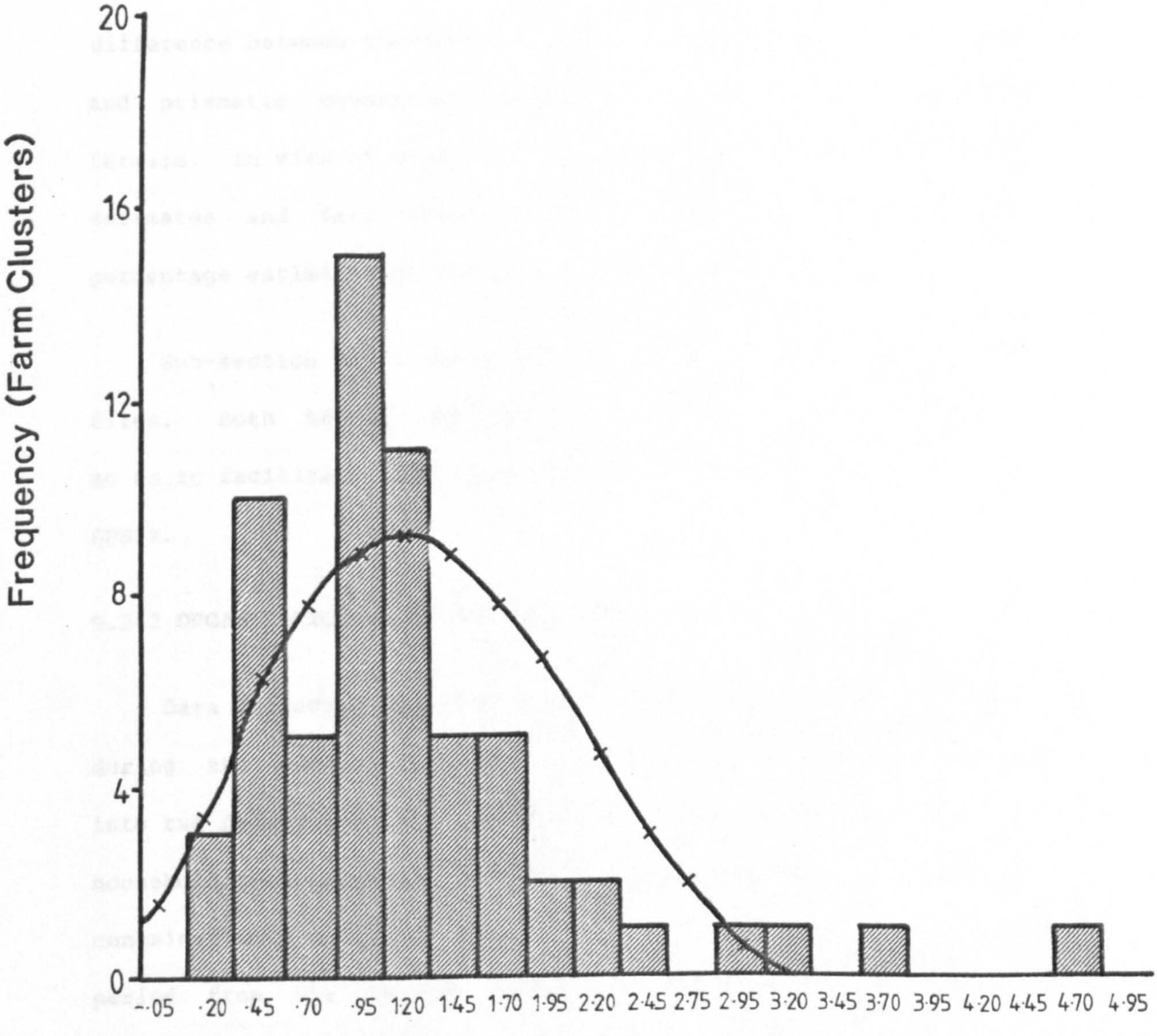
A COMPARISON OF AREA ESTIMATES FIELDWORK MEASUREMENTS AND FARMERS' ESTIMATES

CALCULATED U	CRITICAL U	PROBABILITY
1721.5	1582.79*	0.1991

U indicates the value of the Mann-Whitney U statistic (see text), * at the 0.05 level of significance, 63 farms were used in this comparison.

Farm area measurements and farmers' area estimates were compared using the Mann-Whitney U statistic (further discussion of this statistic may be found in Section 6.3). since plots of the statistical frequency distributions of the data were found to be non-normal (Figure 5.1). The null hypothesis states that there is no significant difference between the area estimates in the two samples, and that any observed difference is due to chance in the sampling process. This hypothesis is rejected only if the calculated value of U is less than or equal to the critical value of U at a chosen level of significance. Using the conventional

Figure 5.1 Farm Cultivated Area - Ground Survey.



Classes represent area cultivated in hectares.

x——x- represents the normal frequency distribution curve.

Negative class values have been computed in order to fit the normal distribution curve.

0.05 level of significance to test for differences between these two samples, the results show that at this level there is no significant difference between the two area estimates.

This indicates that from a sample of 63 farms selected from across the study region, there appears to be no significant difference between the crop areas estimated by using a Smith wheel and prismatic compass and estimates of these same areas given by farmers. In view of this, it is possible to use both farmer estimates and farm measurements to obtain absolute crop cover percentage estimates at each of the 88 farm clusters.

Sub-section 5.2.2 discusses the structure of the ground data files. Both the air and ground survey data files were organized so as to facilitate their use using the computer software package SPSSx.

5.2.2 ORGANIZATION OF GROUND DATA SETS

Data collected from the ground survey which was undertaken during the period from October 1985 to March 1986 was organised into two data files. One of these files contained general farm household/socio-economic and farm livestock data, while the other contained more detailed cropping data covering a four season period from the second season of 1983 to the second season of 1985. These computer files will be referred to as FARMDAT and CROPTAB respectively in this text. Each of these data files has a more complex structure than the air survey data files discussed above, with each file comprising of a number of records of different length. Table 5.4 shows the basic structure of FARMDAT (Appendices 7A and B show these files in more detail).

TABLE 5.4

THE STRUCTURE OF FARMDAT: GROUND DATA

RECORD ONE				COLUMN NUMBER			
1-3	4	5-6	7-8	9-10	11-18	19-39	40-80
FRM	REC	AEZ	LOC	SLOC	GREF	MEAS	GENERAL FARMING

RECORD TWO		COLUMN NUMBER
1-3	4	5-80
FRM	REC	GENERAL FARMING /FAMILY HISTORY/LIVESTOCK

RECORD THREE		COLUMN NUMBER
1-3	4	5-78
FRM	REC	GENERAL FARMING/LIVESTOCK MANAGEMENT/OTHER FARMS

RECORD FOUR		COLUMN NUMBER
1-3	4	5-17
FRM	REC	GENERAL FARMING/OTHER FARMS

FRM indicates farm number, REC indicates the record number, AEZ indicates agro-ecological zone, LOC indicates administrative location, SLOC indicates administrative sublocation, GREF indicates the UTM coordinate reference, MEAS indicates the farm measurments which were undertaken during the survey.

The second ground survey data file (CROPTAB) contains information collected from the farmers on the crop planting practices on each of the 482 farms. The information here covered four cropping seasons. For each farm there were therefore four farm records (4 X record one) corresponding to the four seasons covered by the survey. The number of plot records (record two) varied however according to the number of plots on each farm - the more complex a farm the larger the number of plot records. Table 5.5 below shows the basic outline of CROPTAB.

TABLE 5.5

THE STRUCTURE OF CROPTAB: GROUND DATA

RECORD ONE - FARM					COLUMN NUMBER				
1-3	4-5	6	7-8	9-10	11-12	13-20	21-22	23-24	25
FRM	NPLT	REC	AEZ	LOC	SLOC	GREF	CULTL	CONTL	SEAS

RECORD TWO - PLOT					COLUMN NUMBER		
1-3	4-5	6	7	8-9	10-12	13-14	15
FRM	PLT	REC	SEAS	CRPCOD	COMCOD	PLCODE	NUCOM

FRM indicates farm number, NPLT indicates number of plots on farm, REC indicates the record number, AEZ indicates agro-ecological zone, LOC indicates administrative location, SLOC indicates administrative sublocation, GREF indicates UTM grid coordinate reference, CULTL indicates length of cultivating on present farm, CONTL indicates length to continue cultivating on present farm, SEAS indicates the farming season, CRPCOD indicates the code of the planted crop (Appendix 8), COMCOD indicates the code of each crop complex, PLCODE indicates the method of planting (see Appendix 1B) and NUCOM indicates the number of crops in a crop complex.

Apart from the absolute crop cover percentage estimates derived from the two data sources using the methods outlined above, a number of other variables were computed from the ground data by aggregating the 482 individual farm values to form new summary variables for each of the 88 farm clusters. The number of years growing cash crops, number of years growing food crops, number of sheep, number of goats, number of local cattle (Zebu), number of grade cattle, crop income, livestock income, off-farm income, length of fallows, farm size and number of farms owned by the farm family, were used to compute new variables. The values of these original variables were summed for all farms at a single farm cluster and then divided by the number of farms visited at each cluster (i.e. four, five or six - depending on the number of farms surveyed). The new variables were therefore averages of the the original variables. These averages are used to identify and distinguish AEGs within the study region in Chapters Seven and Eight.

Recall that crop planting data were collected for a four season period (Section 4.2) which enabled valid comparisons to be made between the air and ground data sets, even though the three SRFs were flown during different cropping seasons. In comparing the ground and air data in the next chapter, only the appropriate season of crop data are used for each of the 88 farm clusters. 51 of the farm clusters were chosen from the January 1985 photography and crop data for the second season of 1984 are therefore used in these cases. For the 31 clusters which were chosen from the January 1986 photography crop data for the second season of 1985 are used. Finally, for the remaining 6 sample units derived from the May 1985 air survey, crop data from the first season of 1985 are used.

The first two main sections of this chapter have dealt with the methods used to process and organize the ground and air data. The final section of this chapter discusses the graphical techniques which are used in the analysis of the data and in the presentation of the findings.

5.3 MAPPING AND THE GRAPHICAL DISPLAY OF DATA

There are two objectives in using graphical display and mapping in this study. Firstly, since the analysis presented here is concerned with spatial phenomena - agro-economic groupings (AEGs) and recommendation domains, visual display helps to generate hypotheses and direct discussion. Secondly, since the beneficiaries of this work are likely to be practitioners working in the field, maps will be especially useful to such people in helping them to generate discussion and participation at district level among the lower cadres of the civil service.

Three different computer software packages/routines were used to produce the visual displays and maps which are presented in the study. The GINO-F library of Fortran routines was used to produce all the base maps of Meru district using the interactive program MERUMAP developed by Paul Watson of the Institute of Planning Studies at Nottingham. The GINO-F library is very flexible and is able to call on a large number of subroutines, which allows the user to produce high quality maps easily and efficiently (University of Nottingham, 1983).

The basic map data for input into MERUMAP include administrative boundaries, agro-ecological zones, forest reserves and areas of cultivation change. These were digitised using a System-4 digitiser. The digitised coordinates were transformed to UTM grid coordinates using a small Fortran program. Using MERUMAP graphical output files were then created and plotted on a 4-pen Benson plotter.

SYMAP (Dougenik and Sheehan, 1975) is the second computer software package used in the study. All the map overlays were created using this package. It was used primarily as an analytical tool to map the component scores of the principal components analyses undertaken in Chapter Seven, and to map the distributions of homogeneous agricultural areas resulting from discriminant analysis performed in Chapter Eight. In order to run SYMAP the digitised line data mentioned above and the UTM grid coordinate points of the 88 farm clusters were transformed to fit the SYMAP coordinate system.

One advantage of SYMAP is that output can be sent directly to a line printer which allows inexpensive graphical output (raster) to be produced. Map overlays can be generated by photocopying the line printer output onto acetate film. The scale of the printed output can be controlled by selecting the appropriate elective within a SYMAP run.

Another advantage of using SYMAP lies in the different map options within this computer package. One of these options allows the user to compute a continuously differentiable and regularly spaced data surface from a series of irregularly spaced data points (Schmidt and Zafft, 1975). Using this option it was possible to produce contour maps (without drawing the actual contour boundaries) from the 88 irregularly spaced farm clusters. The spatial distribution of these data points was examined using elective 28 (point distribution coefficient) of SYMAP. This provides the user with a measure of the reliability of the interpolated surface based on the spatial distribution of sample points. The coefficient is based on the nearest neighbour statistic and ranges from 0, when all the points are clustered at the same location, to 2.15 when they have maximum spacing (Dougenik and Sheehan, op. cit.). The point distribution coefficient for the 88 sample clusters was found to be 1.27. This conforms to a random to uniform distribution of points which shows that the interpolated surfaces are reliable.

The final computer graphics package used in the study is the SYMVU program. This allows the user to produce three-dimensional perspectives of a surface on a pen plotter (e.g. Figure 2.5). SYMVU can display contour, choropleth or proximal maps of greater precision and quality than SYMAP although the program requires regularly spaced data values as input (Muxworthy, 1977).

A regular data surface however can be generated using SYMAP and this can be later used for input into SYMVU. This was the procedure adopted in the present study. SYMVU can display continuous data and so allows the user to show more of the detail of the data than is possible using a two dimensional view. Both SYMVU and SYMAP are used to help to distinguish AEGs and recommendation domains within the study region.

5.4 SUMMARY

This chapter has discussed the methods used to compute absolute crop cover percentage estimates from both the air and ground data sources. In undertaking comparisons between remotely sensed data and ground data it has been suggested that in future greater consideration should be given to possible sources of error in the data collection procedures involved in both aerial and ground surveys.

The methods used to aggregate variables on each of the 482 individual farm holdings to form new summary variables at each of the 88 farm clusters have also been reviewed. In addition, the organization of the data files for both the ground and air data has been described. Finally, the three computer graphics software programmes which are used in data analysis and data presentation in the study have been discussed.

Absolute crop cover percentage estimates from the ground survey are used in the next chapter to assess the accuracy of similar estimates derived from light aircraft remote sensing. Several parameters which are likely to influence the accuracy of the latter including the season and the scale of the photography are considered.

CHAPTER SIX

GROUND AND AIR SURVEY DATA - CHARACTERISTICS AND COMPARISONS

6.0 INTRODUCTION

Chapter Four described the methods used to collect the data in this study. Chapter Five focussed on the processing and organization of the data prior to analysis. This and the two following chapters discuss the analysis and findings of the study. The chapter identifies which of the main crop cover estimates from the air surveys correspond to similar estimates derived from the ground survey. These crop cover estimates are then used to help define and distinguish agro-economic groupings (AEGs) in Chapter Seven.

In attempting to identify areas of relative agricultural homogeneity, it is clear that there is a great degree of variation in land use and agricultural practice in the smallholder economy of the region. Mention was made in Chapter Three of the practical problems involved in identifying suitable criteria for distinguishing between recommendation domains. Field experience shows that areas of relative agricultural homogeneity exist, the problem remains however - given the great diversity and complexity of smallholder tropical agriculture, how easily can these areas be distinguished using remote sensing techniques and on what basis can such distinctions be made? Furthermore, bearing in mind the dynamic nature of the rural environment (Maxwell, 1986b), how stable are these groupings over time?

One assumption of the work reported here is that AEGs (farming systems) can be differentiated on the basis of their spatial characteristics and, more specifically, on the basis of the cropping patterns within farming systems. It is important therefore to examine parameters which may influence the accurate identification of these patterns. Two such parameters are considered here - the seasonality of the cropping patterns and the ground resolution of the aerial photography being used to identify these patterns.

Before considering these parameters, however, it is first necessary to decide whether parametric or non-parametric statistical tests can be used in the analysis. The nature of the frequency distributions of the land use/cover variables used to help define AEGs in the January 1985 and 1986 air surveys and the 1985/6 ground survey are examined in section one. Owing to non-normality in the frequency distributions of the selected variables non-parametric statistical tests are subsequently used in this chapter.

The second section of the chapter considers the seasonality of cropping patterns within the study region. The ground survey data are used for this purpose. Absolute percentages of land planted under the main crop types occuring in lower Meru are compared over a three season period.

Ground resolution of the aerial photography is considered in the third section. Comparisons are undertaken between the crop cover percentage estimates of the major pure crop types and a number of crop complexes identified on the January 1985 and January 1986 air surveys with similar estimates derived from the ground survey. Crop cover percentage estimates from the larger scale January 1986 photography appear to be more accurate than those of the January 1985 air survey.

Having discussed the accuracy of the data from the two January air surveys in section three, the final section compares absolute crop cover percentage estimates for major crop types in the region using all 88 sample points from the combined air data set (51 from the January 1985 flight, 31 from the January 1986 flight and 6 from the May 1985 flight) with the corresponding ground survey estimates. Five of these crop types are subsequently used to help identify AEGs in the analysis undertaken in Chapter Seven.

6.1 THE FREQUENCY DISTRIBUTION OF VARIABLES IN THE STUDY AREA

It is important to examine the statistical distributions of the data at the outset in order to decide whether comparisons between the different data sources can be made using parametric or non-parametric statistical procedures.

Since the study area encompasses a very varied topography with a considerable climatic range, the distribution of crops is not uniform. In the higher, and more fertile, west and north-west areas, coffee, maize and beans are commonly grown, while in the east and south-east, millets, sorghums and cotton are more common. In order to examine the statistical frequency distributions of each of these crops, distributions of the major crop and land cover types were plotted with the normal distribution curve superimposed.

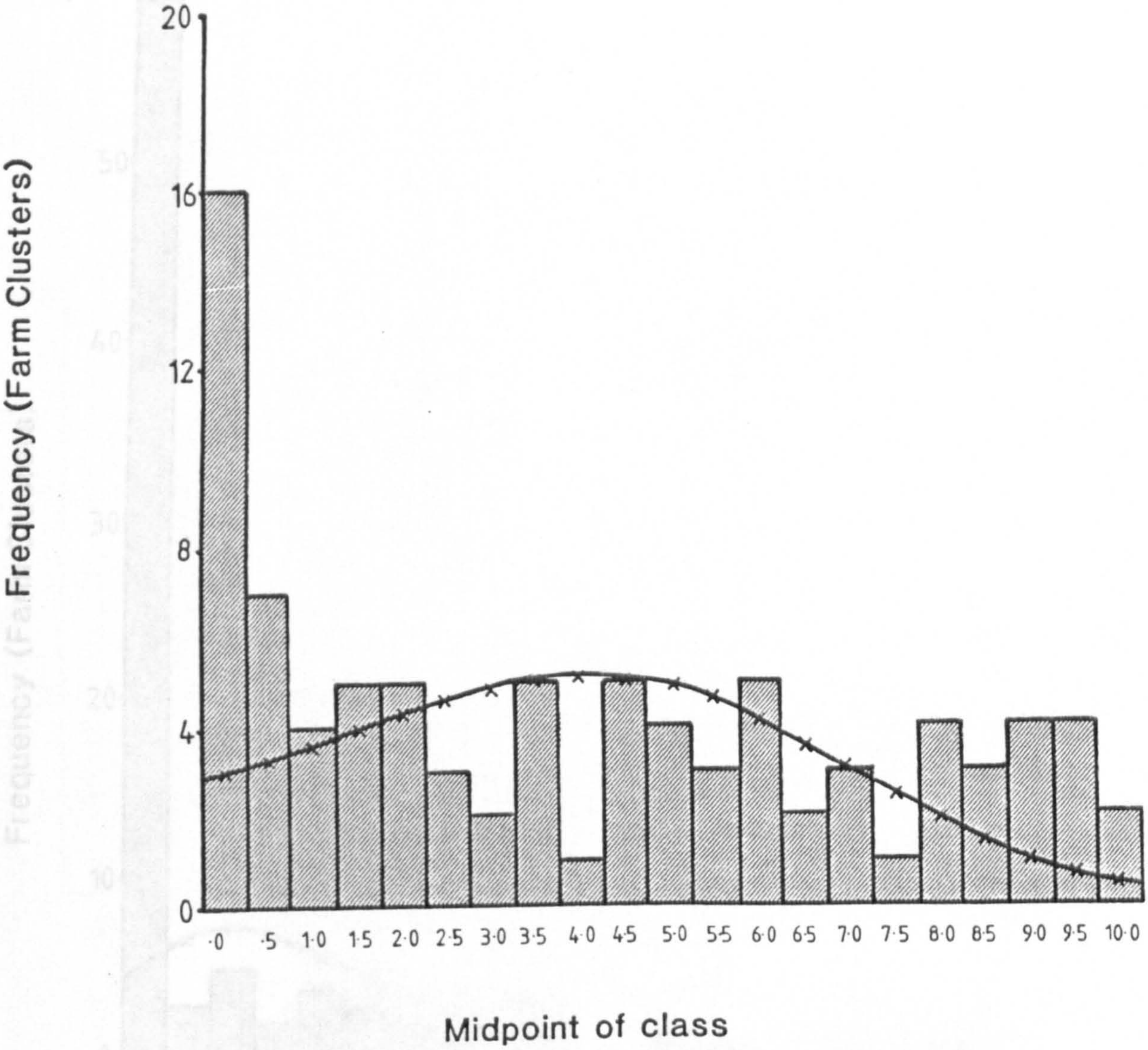
Figures 6.1 to 6.3 show the histograms of some of the variables used to define AEGs with the normal distribution curve superimposed. These frequency distributions are used as examples, and are selected from both the ground and air survey data sets. Visual examination of the distributions shows the data are not normally distributed, and it is therefore not possible to use the Student t statistic to compare the means of the data sets. In this study the Mann-Whitney U test is used for comparisons involving two sets of data, while the Kruskal-Wallis H test is used where three data sets are compared. Each of these methods will be introduced where relevant within this chapter.

6.2 SEASONAL VARIATIONS IN CROPPING PRACTICES - GROUND SURVEY DATA

All the air surveys were flown during different seasons spanning a 12 month period. In defining AEGs with the aid of remote sensing techniques it is important to be able to assess the stability of the observed spatial patterns of cropping and other agricultural land uses. If there are marked variations in the area planted under particular crop types, or if the spatial distribution of such crops vary significantly from one season to the next, their use in helping to define AEGs must be reconsidered.

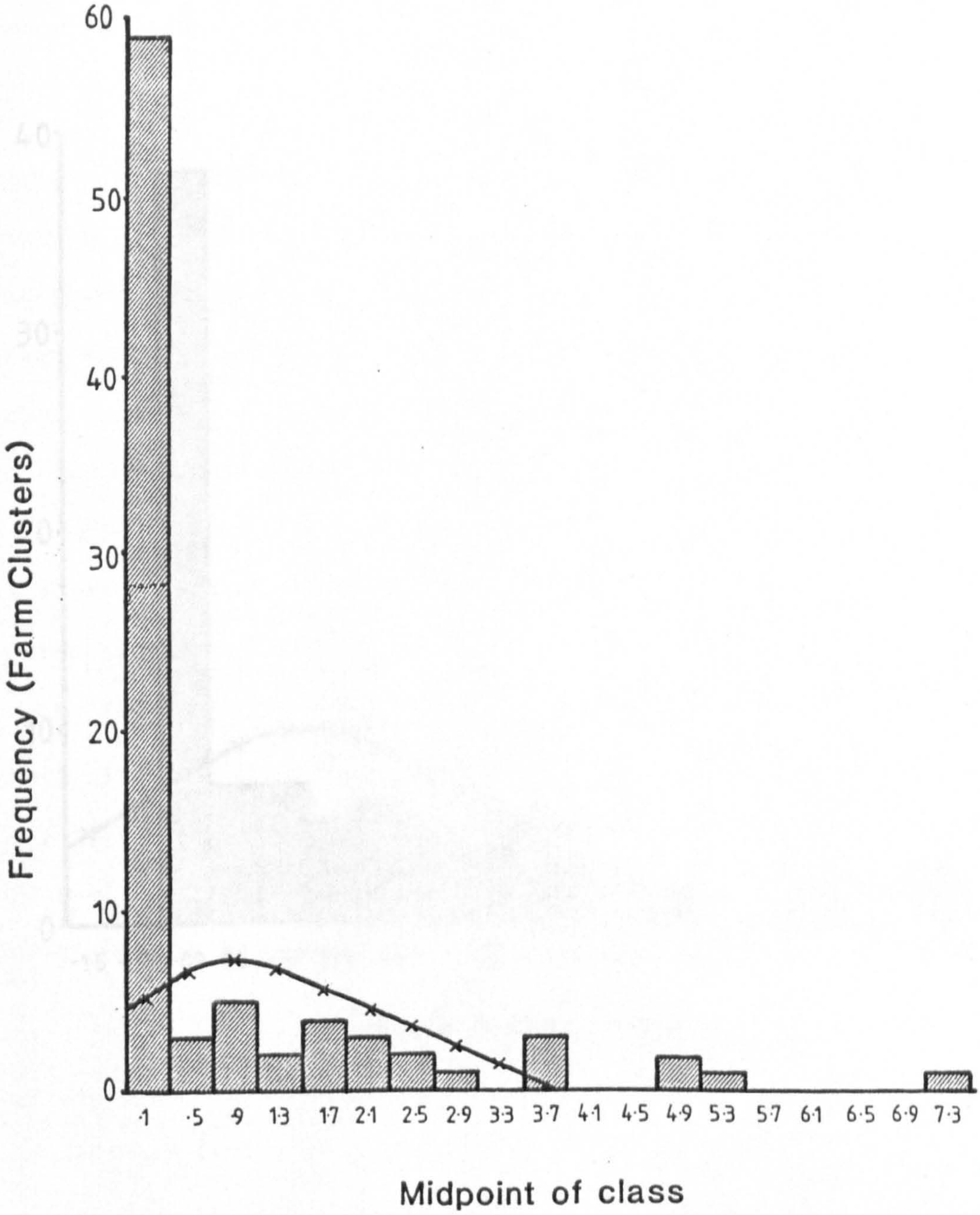
The ground survey was undertaken over a two-season period during 1985/1986, but crop statistics were collected from farmers for four seasons covering a period from October 1983 to January 1986, spanning two long and two short cropping seasons. Since even a two-year time period is too short for examining long-term agricultural changes, this analysis will consider only seasonal

Figure 6.1 Percentage of Maize (All Categories) - Ground Survey.



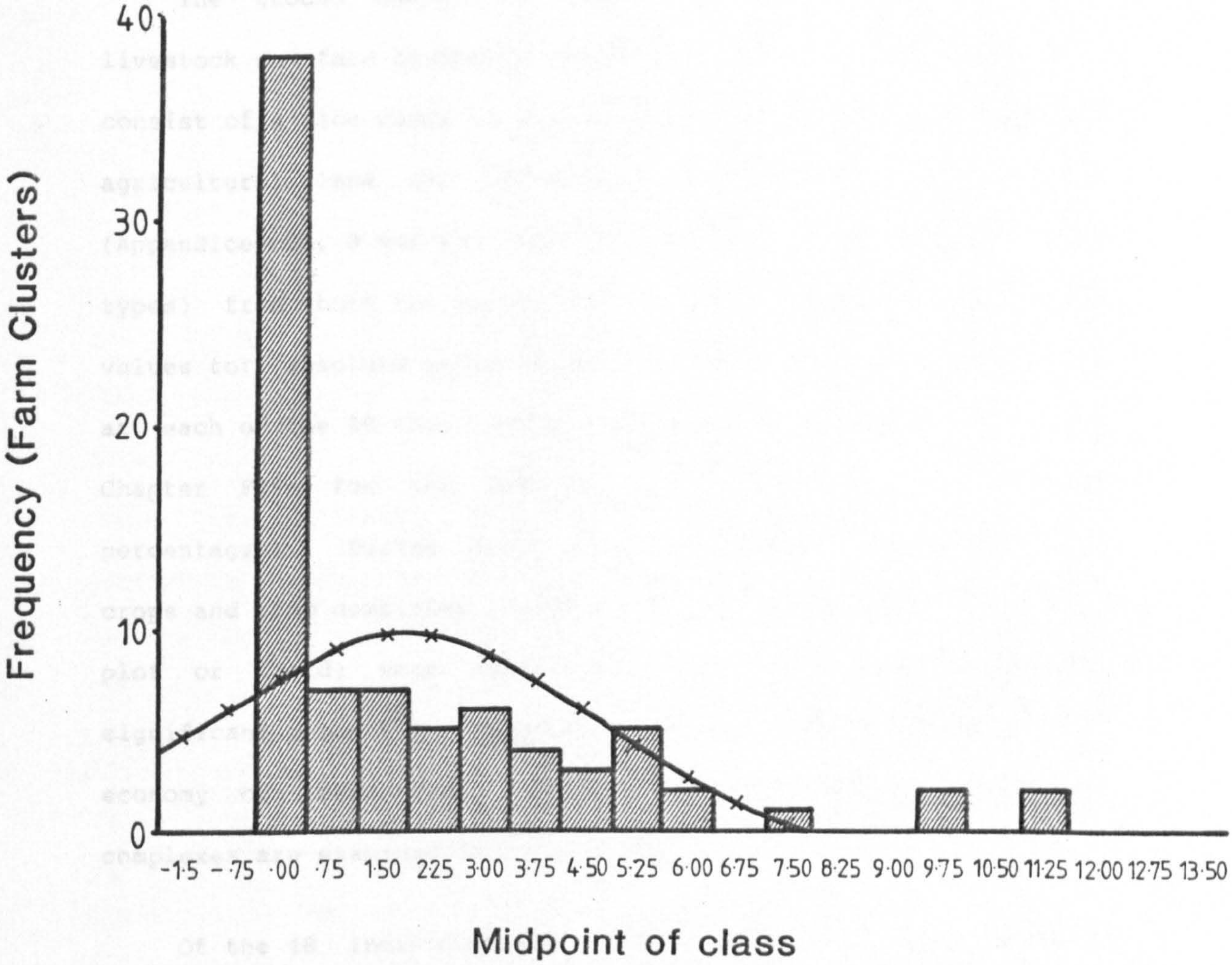
Classes represent percentage of land under maize at each farm cluster
x——x- represents the normal frequency distribution curve.

Figure 6.2 Percentage of Beans (Pure and Complexes) – Air Survey.



Classes represent percentage of land under beans at each farm cluster.
x——x- represents the normal frequency distribution curve.

Figure 6.3 Total Percentage Millet – Ground Survey.



Classes represent the percentage of land under millet at each farm cluster.
x——x represents the normal distribution curve.
Negative class values have been computed in order to fit the normal distribution curve.

changes. Rapid changes appear to be occuring in some of the smallholder areas within the study region (Chapter Eight). It will be important therefore to update any survey findings from time to time, irrespective of whether the data were originally obtained from the air or the ground.

The ground survey data sets consist of detailed crop, livestock and farm household statistics. The air survey data sets consist of a wide range of land use/cover types, of which only the agricultural land use variables are considered in this analysis (Appendices 3A, B and C). Agricultural land use variables (crop types) from both the ground and air surveys represent calculated values for (absolute percentages) land under particular crop types at each of the 88 farm clusters visited during the fieldwork (see Chapter Five for the methods used to calculate absolute percentages). During both the ground and the air surveys, pure crops and crop complexes (crops which are intercropped in the same plot or field) were identified. Since crop complexes cover a significant percentage of agricultural land within the smallholder economy of lower Meru (Appendix 9), both pure crops and crop complexes are examined in this section.

Of the 48 individual crop types identified and recorded within the study region (Appendix 8) only a few cover a significant land area. These are: coffee, cotton, beans, maize, millet and miraa. Other crops which commonly occur (sorghum, bananas, grams, pigeon pea, cowpea, cassava and sweet potato) are usually found intercropped with one or more of the main crops mentioned above, and are therefore examined as crop complexes in this analysis (Appendix 10 shows the crop complexes identified during the field survey). Because miraa and coffee are perennial tree crops it is not appropriate to examine seasonal changes in the area planted under these crops.

Data for four pure crops and four crop complexes were analysed using the Kruskal-Wallis H test. Comparisons were made over a three season period to include one long season and two short cropping seasons. Cropping seasons in Kenya coincide with the rainy periods. The main cropping season in lower Meru is from mid March to the end of May while the minor season stretches from early October to the end of December (Jaetzold and Schmidt, 1983).

The Kruskal-Wallis H test is a test of a null hypothesis that the samples have been taken from populations with identical distributions. It is used to examine differences between three or more samples (Ebdon, 1977). It can be applied to ranked data, therefore interval data must first be ranked before using this statistic.

The data for all samples were aggregated and ranked in order from lowest to highest. The ranking therefore represents an overall ranking, and not rankings of the individual samples being compared. Identical rankings were given the mean of the ranking they would otherwise have received. The sum of the ranks was found for each sample. These sums were then used to compute H from the following equation:

$$H = \frac{12}{N(N+1)} \sum \frac{R^2}{n} - 3(N+1) \qquad (6.1)$$

Where N indicates total number of individuals in all the samples,

R^2 indicates the sum of the ranks within a sample squared (one for each sample), n indicates the number of individuals within a sample.

In this case, the null hypothesis for the crops being compared over three seasons is: there is no difference in the area planted under these crops between the three seasons, and any differences that are observed in the sample distributions are due to random variation in the sampling. Conventionally a significance level of 0.05 is used in hypothesis testing. This means that there is a five percent chance that the statistically derived outcome is incorrect or, that there is a 95 percent chance that the outcome of a test is correct. A significance level of 0.05 is used throughout this analysis.

Table 6.1 shows the results of the comparisons performed on the four pure crop variables - beans, cotton, maize and millet for the three seasons corresponding to the January 1985, May 1985 and January 1986 air surveys. The data used is from the ground survey.

TABLE 6.1

KRUSKAL-WALLIS H TEST- RESULTS OF SEASONAL COMPARISONS GROUND SURVEY DATA - PURE CROP STANDS

CROP TYPE	H VALUE	SIGNIFICANCE
BEANS	0.6233	0.7322
COTTON	10.1417	0.0063
MAIZE	0.5150	0.7730
MILLET	4.0955	0.1290

Critical value of H (at 0.05 level) = 5.99.
N = 264 (total number of farmers growing these crops).

The null hypothesis is rejected if the calculated value of H is *greater* than the critical value at a given level of significance. The table above shows that for all crops except cotton this hypothesis is accepted at the 0.05 level. The results indicate that there is little seasonal variation in the area planted under the above specified crop types within the study region except in the case of cotton.

Field experience showed that cotton tended to be planted on an annual basis with a break of a season or more before further cultivation. Confirmatory analysis of this trend would require data over a larger number of seasons, however. Several farmers also commented on the lack of up-to-date payments for their cotton harvests and this may have been a further reason for the seasonal variation in the area planted under this particular crop. It suggests that maladministration within the Cotton Board may be influencing the pattern of cotton growing. For the three main food crops in the area (beans, maize and millet) no significant change is noted between the three seasons.

In deciding which spatial variables (crop and land cover percentage data) to use to help define AEGs using a methodology incorporating remote sensing techniques it is important to know which variables are subject to seasonal change. The above findings (based on a three season time period) show that the land area planted under cotton does vary. Since cotton is the most important cash crop to farmers in the lower areas of the region however, it is included as one of the five main crop variables which are used to help define AEGs in the analysis presented in the following two chapters.

Intercropping is practised over a significant area within the study region (Appendix 9) and further comparisons using the ground survey data were made across the three seasons using the four main crop complex groups beans, cotton, maize and millet. The objective was to establish if the planted area under any of these crop complexes varied from one season to the next. Coffee complexes were not included in the analysis since coffee is seldom planted with other crops; indeed, the agricultural extension service actively dissuades farmers from intercropping coffee. Table 6.2 below shows the results of a three season comparison using four major crop complexes.

TABLE 6.2

KRUSKAL-WALLIS H TEST. RESULTS OF SEASONAL COMPARISONS GROUND SURVEY DATA - CROP COMPLEXES

COMPLEX TYPE	H VALUE	SIGNIFICANCE
BEANS	16.8940	0.0002
COTTON	13.5375	0.0011
MAIZE	1.3673	0.5048
MILLET	0.5669	0.7532

Critical value of H (at 0.05 level) = 5.99.
N = 264 (total number of farmers growing these crop complexes).

The null hypothesis states that there is no significant difference between the sample distributions of the crop complexes over the three seasons (January 1985, May 1985 and January 1986) under examination. The results show that for bean and cotton complexes this hypothesis is rejected at the 0.05 level, suggesting that there are significant seasonal differences in the land area cropped under these two complexes.

From these results it appears that some crop complexes may be more suitable to use as variables to help identify AEGs within the smallholder economy than others. Those where the cropped area does not appear to show any great variation from one season to the next could be considered the most stable and the most suitable to use in identifying relatively homogeneous agricultural areas. The crop complexes falling in this category include maize and millet.

There are obvious difficulties in trying to recognise crop complexes from the air, however. The scale of the photography is an important consideration here and is discussed further in Section 6.3 below. Owing to the very complex nature of smallholder agriculture in Meru district, if accurate and meaningful crop complex variables are to be identified, it will be necessary to undertake aerial surveys which will provide a ground resolution good enough to separate and identify individual crops from each other even when these occur together in plots of perhaps no more than 0.1 of a hectare.

There are perhaps two other main difficulties in using crop complexes to help identify AEGs. First there are practical difficulties in accurately defining crop complexes. A complex is defined by the occurrence of more than one crop in the same plot or field. Sometimes however this may include up to eight different crops within the same complex (Appendix 10). In this situation it may be difficult to decide whether to include all crops, or only those occurring most frequently in a complex.

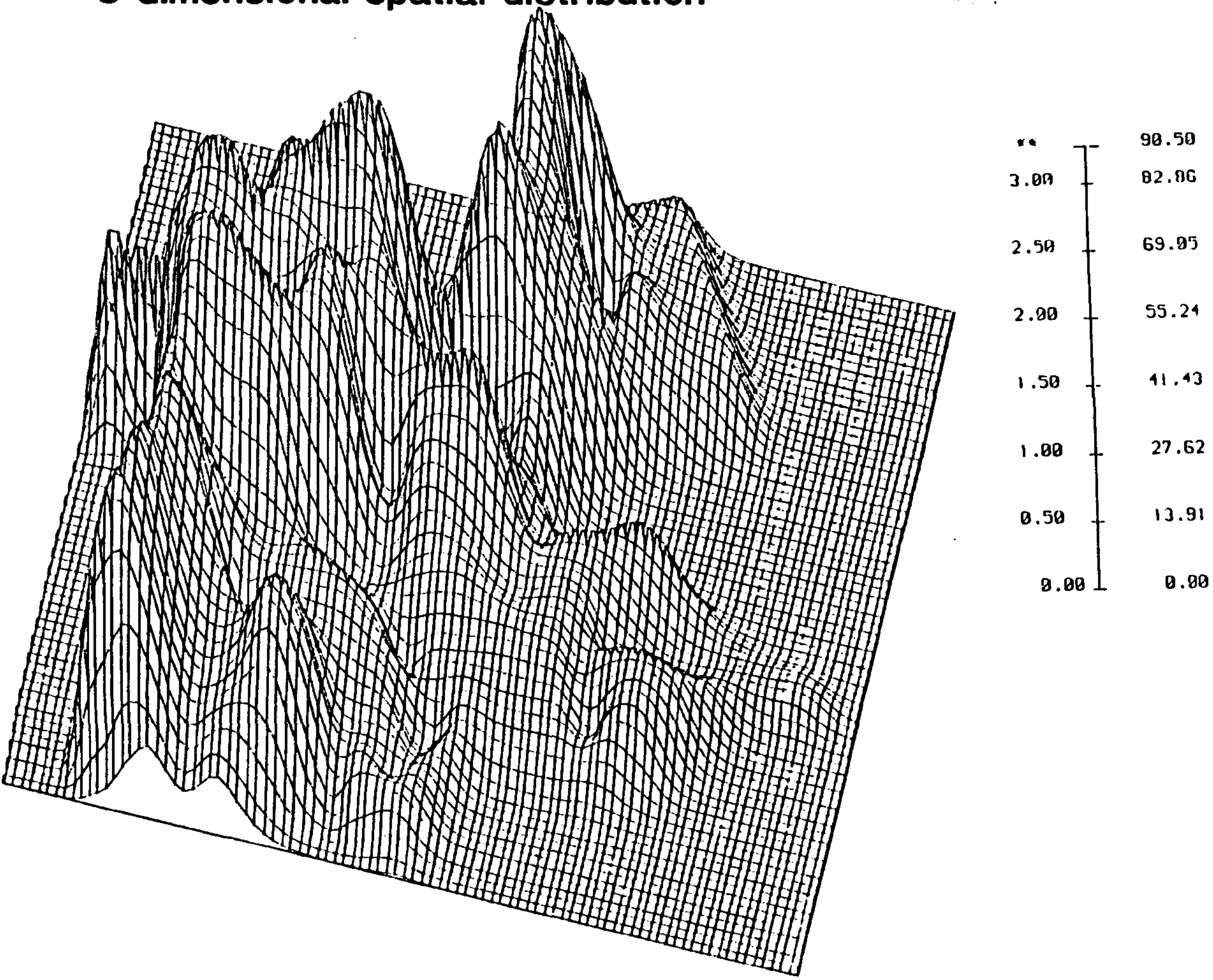
Secondly, the land area under a crop complex cannot be easily related to the area that any one crop in a complex may occupy. To ascertain the area occupied by a particular crop it will be necessary to identify the planting methods used. These are likely to vary from one area to another and may well be influenced by social, cultural and economic factors. Thus the importance of a single crop (for example maize, within a maize complex) may well vary between two areas so that the occurrence of a (maize) complex in both locations may well disguise the real importance of the single crop (maize) within each area owing to differences in the spacing between individual plants.

Where cultivation occurs in the lower and more marginal areas of the district it is more difficult to distinguish AEGs purely on the basis of crop variables (whether these are pure crop stands or crop complexes) since only a small percentage of the land is cultivated (Figure 6.4). It may be useful in such areas to use natural vegetation categories to help distinguish AEGs. Such categories can be used as surrogate agricultural variables. Rough grazing is an example of one such category which is used in the present study to help distinguish the livestock-rearing farms in the south-east of the region.

This section has shown that the planted area for one of the pure crops (cotton) and two of the crop complexes (cotton and beans) vary significantly between different seasons. In choosing crop/land cover variables to help distinguish AEGs it is important to try and select variables which occupy a constant land area across different seasons. Any AEGs which are subsequently identified should then accurately reflect the nature of the

Figure 6.4

3 dimensional spatial distribution



SYMVU

PERCENTAGE OF AREA UNDER CULTIVATION - LOWER MERU (Scale in percent)

2 dimensional spatial distribution

Dark shading indicates high values

Light shading indicates low values

SYMAP

farming systems which they are summarising. Furthermore, in choosing variables which do occupy a constant land area any changes in the spatial dimension of AEGs over a period of time cannot then be attributed to ephemeral variations in the land area planted under a particular crop.

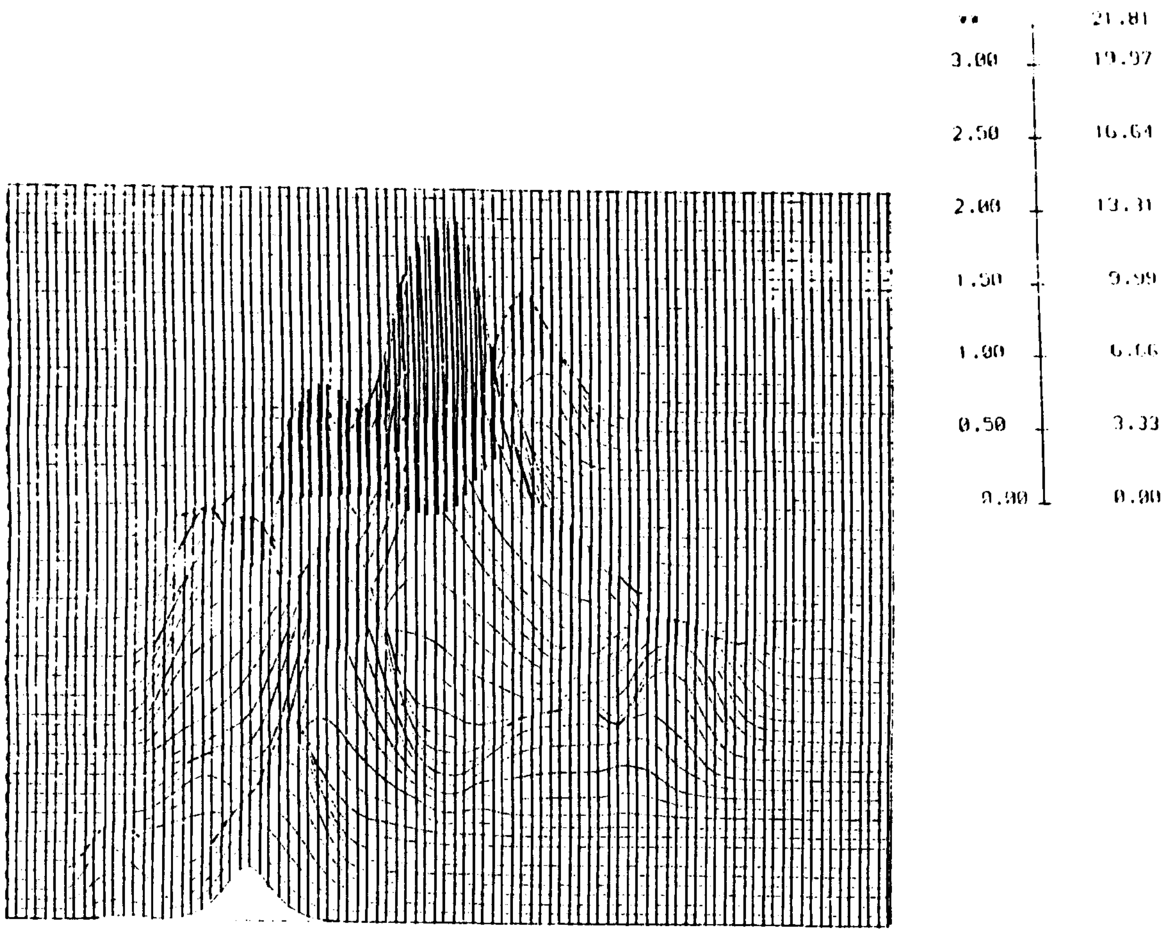
It should be emphasised that spatial differences in the area under specific crop types have not been examined in this section. Rather, the focus has been on the variation in cropped area, i.e. the overall area under a particular crop, and not the crop distribution within this area. Figures 6.5 to 6.10 show that there is some conformity however in the spatial pattern of crops across seasons.

Marked variations in the spatial distribution of particular crop variables may affect the reliability of the AEGs which are identified. Wherever possible perennial or tree crops should be used to define AEGs since these crops will have a more uniform spatial distribution from one season to the next. However, in more marginal areas where seasonal crops are more characteristic of the farming system, these will have to be included in the analysis. In such areas surrogate agricultural variables (for example, rough grazing) may be important in helping to distinguish between AEGs.

This section has examined seasonal variations in the land area under key crop variables (comprised of pure crops and crop complexes) in the study region. It has established the importance of selecting stable land use/cover variables to help identify AEGs. Section 6.3 compares the two January air survey crop cover percentage estimates with corresponding estimates obtained from

Figure 6.5

3 dimensional spatial distribution



SYMVU

PERCENTAGE OF AREA UNDER COTTON - SEASON ONE (Scale in percent)

2 dimensional spatial distribution

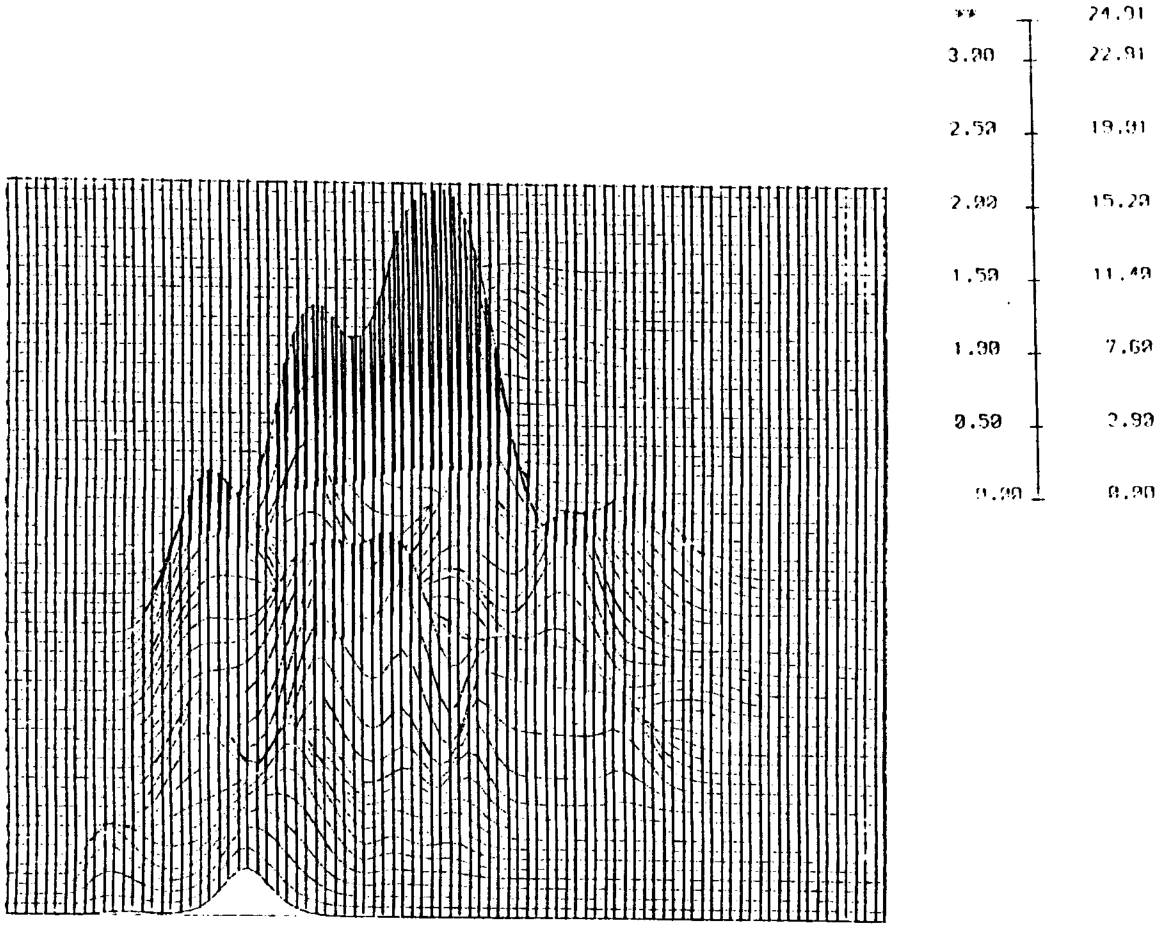
SYMAP

Dark shading indicates high values

Light shading indicates low values

Figure 6.6

3 dimensional spatial distribution



SYMVU

PERCENTAGE OF AREA UNDER COTTON - SEASON TWO (Scale in percent)

2 dimensional spatial distribution

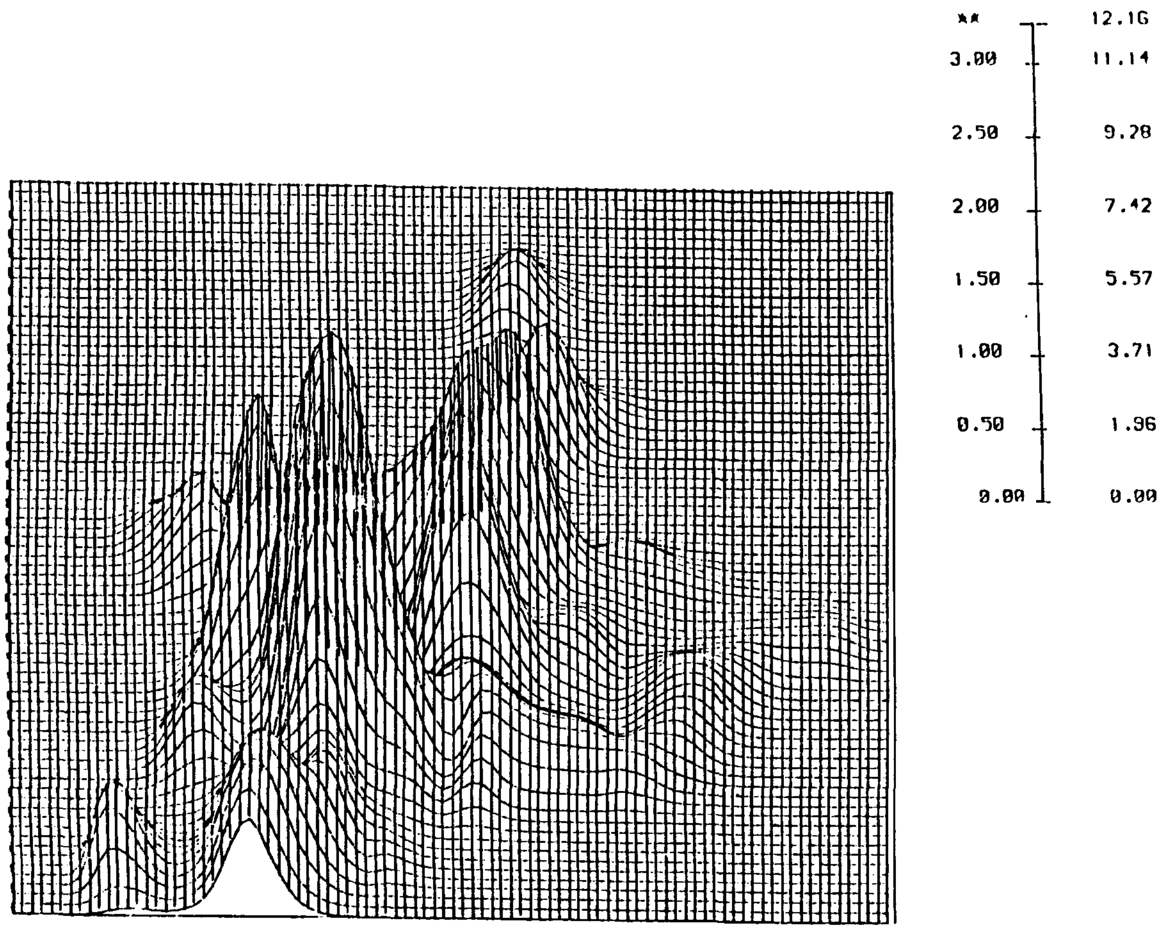
Dark shading indicates high values

Light shading indicates low values

SYMAP

Figure 6.7

3 dimensional spatial distribution



SYMVU

PERCENTAGE OF AREA UNDER COTTON - SEASON THREE (Scale in percent)

2 dimensional spatial distribution

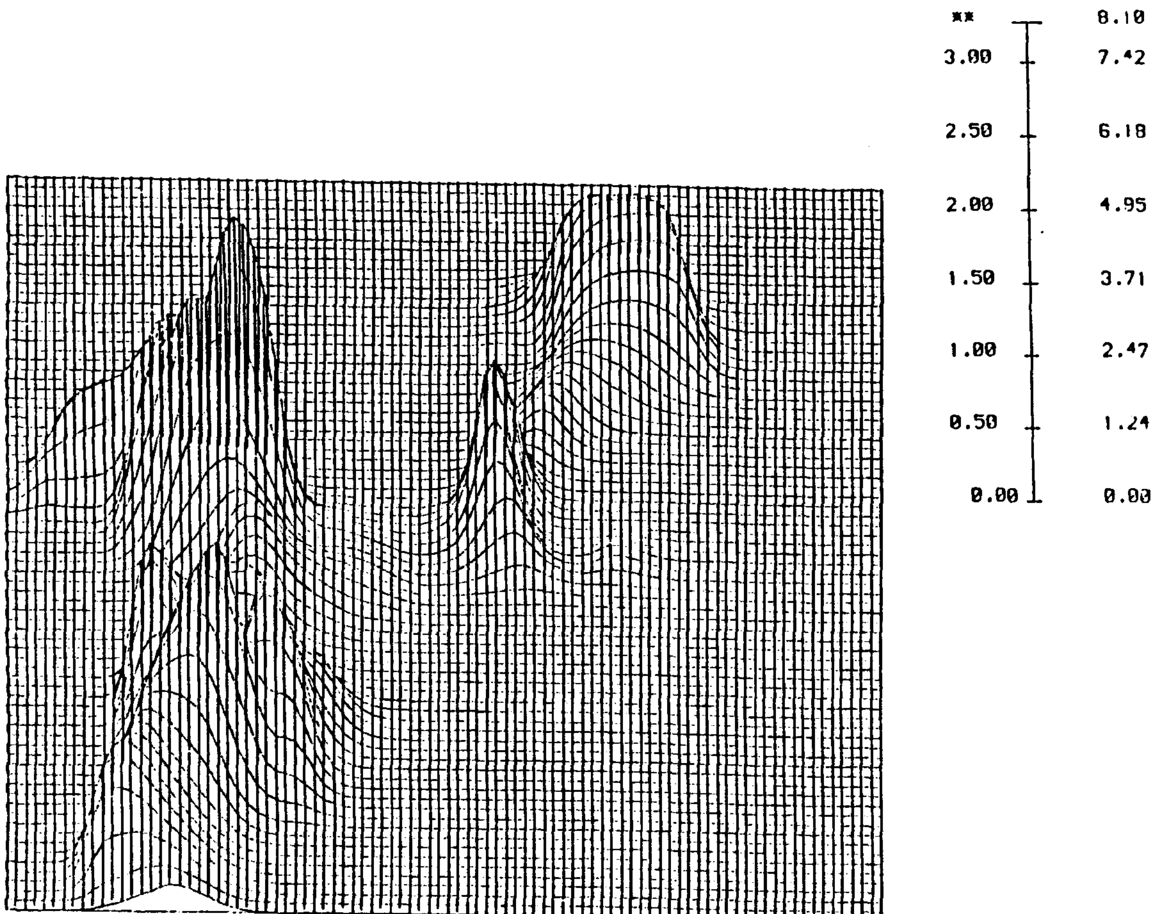
SYMAP

Dark shading indicates high values

Light shading indicates low values

Figure 6.8

3 dimensional spatial distribution



SYMVU

PERCENTAGE OF AREA UNDER BEANS - SEASON ONE (Scale in percent)

2 dimensional spatial distribution

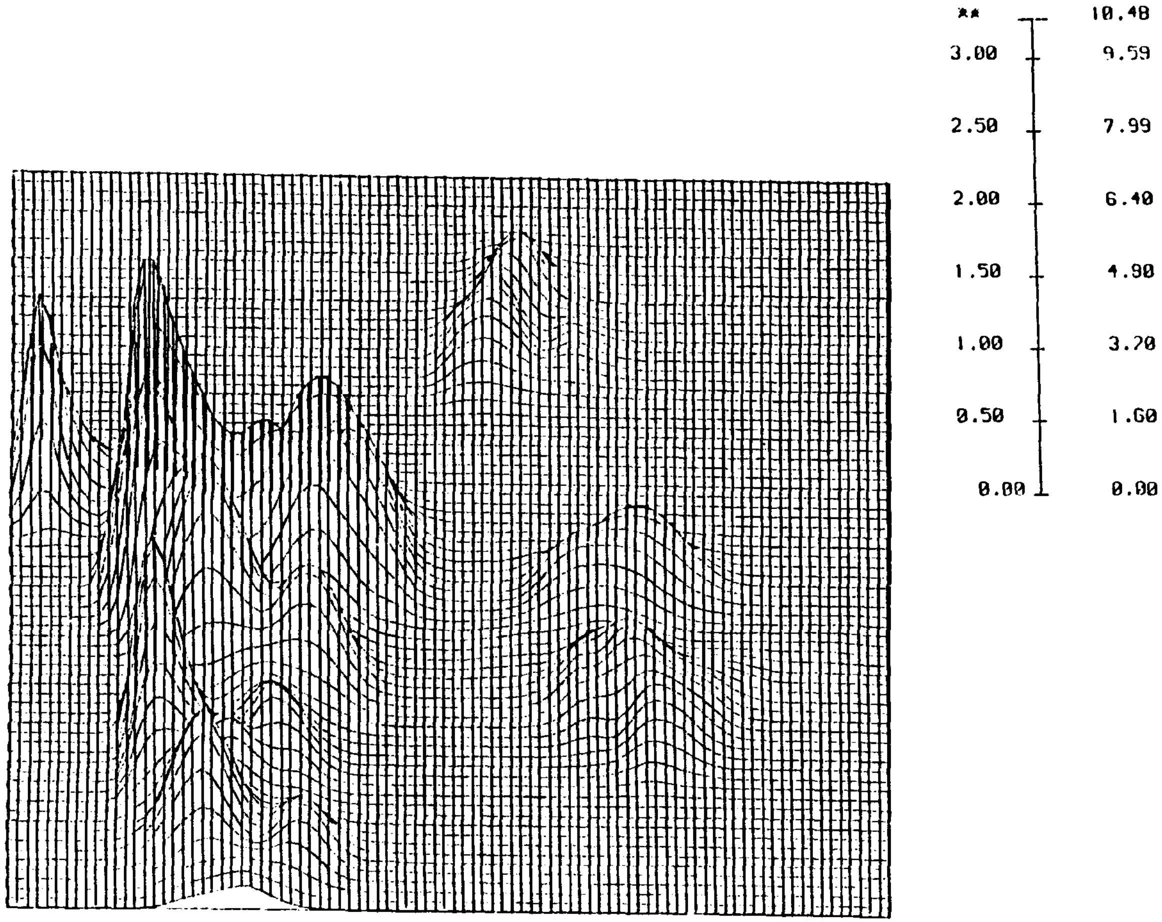
SYMAP

Dark shading indicates high values

Light shading indicates low values

Figure 6.9

3 dimensional spatial distribution



SYMVU

PERCENTAGE OF AREA UNDER BEANS - SEASON TWO (Scale in percent)

2 dimensional spatial distribution

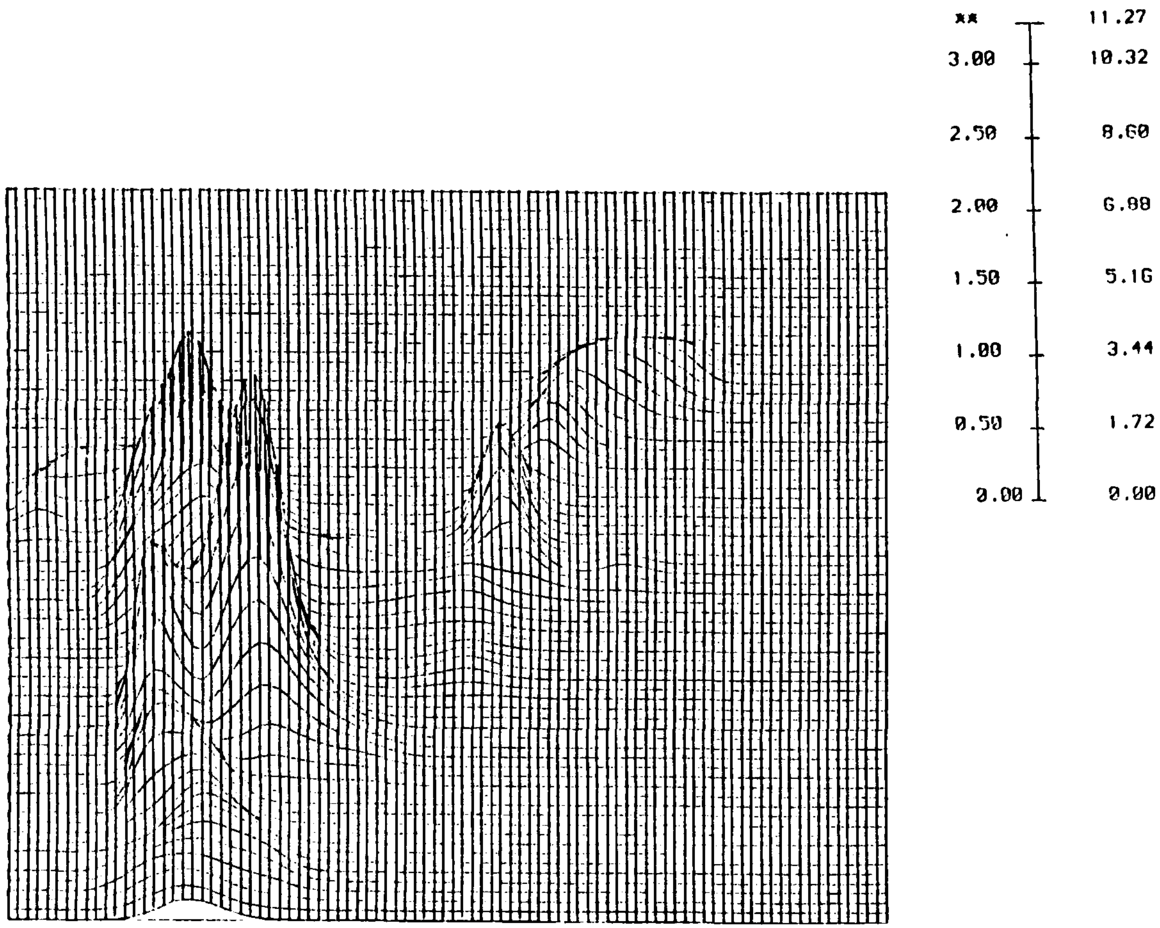
SYMAP

Dark shading indicates high values

Light shading indicates low values

Figure 6.10

3 dimensional spatial distribution



SYMVU

PERCENTAGE OF AREA UNDER BEANS - SEASON THREE (Scale in percent)

2 dimensional spatial distribution

SYMAP

Dark shading indicates high values

Light shading indicates low values

the ground survey. Discussion focusses on the ground resolution of the colour slide aerial photography.

6.3 COMPARING THE JANUARY AIR SURVEYS WITH THE GROUND SURVEY

In the context of this study remote sensing procedures are seen as a set of tools which can be used to develop a greater understanding of the complex nature of smallholder agriculture and the decision environment of the small farmer in the tropics. These tools however need to be assessed in terms of their reliability and accuracy, and this is one of the aims of the analysis presented in this section.

Owing to financial limitations it was not possible to commission an air survey over the whole study region during 1986. Two air surveys were however undertaken during 1985 by the Kenya Rangeland Ecological Monitoring Unit (KREMU) in Meru district, and these covered the central and southern parts of the study area. Absolute crop/land cover percentage estimates calculated from colour slide photography at each of the 88 sample units from both the KREMU air surveys and the 1986 survey are used in the study to define AEGs. Each of the air surveys was undertaken at a different flying height and gave a different scale of photography. Since only six of the May 1985 air survey sample units are used in the analysis, the crop cover percentage estimates from this air survey are not included in the comparisons undertaken in this section. The majority of the 88 sample units (82 out of 88) used in Chapter Seven to help define AEGs are chosen from the January air surveys.

This section will examine the accuracy of the crop cover estimates from the two January air surveys against similar estimates from the ground survey. Absolute crop cover percentage estimates for the main crop types occurring in lower Meru are compared for each air survey separately using the ground survey as a yardstick for these comparisons.

In testing for discrepancies there are two objectives. The first objective is to identify which of the air surveys most accurately confirms the ground survey results, and therefore which is most suitable in providing estimates of crop/land cover which can be used to help identify AEGs. The second and related objective is, to establish which crop cover estimates consistently conform with the ground survey results over both air surveys. In satisfying this second objective it will be possible to identify the crop cover types which can be accurately estimated on either of the air surveys (i.e. estimates which are not significantly different from those of the ground survey). These crop variables can then be used to help identify AEGs in the next chapter.

Crop categories are compared using the Mann-Whitney U test and differences between the two air surveys and the ground survey are discussed. The Mann-Whitney U test is a non-parametric test, and makes no assumptions about the statistical frequency distribution of the data (Ebdon, 1977). It may be applied to ordinal data, but since interval data can easily be converted to ordinal form, this is not a problem. The Mann-Whitney U test is used here to test for a significant difference (at the 0.05 level) between the absolute percentages of land under different crop types identified by the two January air surveys and the ground survey. This difference is measured by comparing the medians of the samples on each of the measured crop variables. The following formula is used to calculate U:

$$U = \frac{n_x n_y}{2} - z \sqrt{\frac{n_x n_y (n_x + n_y + 1)}{12}} \qquad (6.2)$$

Where z is the critical value of a standard normal deviate at the desired significance level (0.05 level), and n_x and n_y are the sizes of the two samples (equations 6.1 and 6.2 after Ebdon, 1977).

In all the comparisons undertaken here a null hypothesis is presented which states: there is no significant difference in the percentages of crop cover identified over the study area between the two data sets being examined, the two samples being taken from the same common population. An alternative hypothesis is also proposed: that there is a significant difference between the two data sets in the percentages of crop cover identified over the study area, and that this difference cannot be explained by chance. In deciding whether to reject the null hypothesis at a chosen level of significance, the calculated value of U must be *less than or equal to* a critical value of U. A low calculated value of U is produced when there is a large difference between the data sets.

Since the ground survey data were collected over a period of six months with crop planting history recorded over a four season period during the farm survey at each sample cluster, it is possible to undertake separate comparisons using the ground estimates with similar estimates obtained from both the January 1985 and 1986 air surveys.

Crop cover percentage estimates from the sample data sets were ranked using the NPAR TESTS M-W procedure within the SPSSx computer package (SPSS Inc, 1986) and comparisons between data sets undertaken. Tables 6.3 and 6.4 show the results of comparing the ground data using the Mann-Whitney U test with the January 1985 and January 1986 data for a selected number of key crop types. The tables clearly show that the 1986 data compare better with the ground survey estimates than the 1985 data. In 1986, the null hypothesis is accepted at the 0.05 significance level for all eight crop variables, while for 1985 the null hypothesis is rejected for the variables pulse, total maize and millet.

TABLE 6.3

RESULTS OF SAMPLE COMPARISONS USING MANN-WHITNEY U JANUARY 1985 AIR SURVEY DATA AND GROUND DATA

CROP TYPES	CALC U	PROBABILITY P
BEANS	1170.0	0.2247
COFFEE TOTAL	1297.5	0.9785
COFFEE PURE	1295.0	0.9605
COTTON	1118.0	0.1981
MAIZE PURE	1123.5	0.1844
MAIZE TOTAL	964.0	0.0205
MILLET	673.0	0.0000
PULSE	673.0	0.0000

N = 51 (the number of the 88 ground sample clusters covered by the January 1985 air survey).
Critical value of U at 0.05 significance level = 1007.6.
Value of z (standard normal deviate) at 0.05 significance level = 1.960

The crop variables: beans, maize (pure), cotton, millet and coffee (pure), are the same variables which were used for the analysis presented in Section 6.2 above. In addition to these three other compound crop variables were included: total coffee, total maize and pulse. A compound crop variable is defined as, the total percentage of land estimated within a given area (being equivalent to a ground sample cluster) to be under a particular crop type and comprising of both pure stands and crop complexes. Total maize for example, represents the total percentage of land on which maize is growing (both as a pure stand and as a crop complex) at each of the 88 ground sample clusters in the study region. Pulse is a compound crop variable which covers pure stands and crop complexes for all the leguminous crops.

TABLE 6.4

RESULTS OF COMPARISONS USING MANN-WHITNEY U JANUARY 1986 AIR SURVEY DATA AND GROUND SURVEY

CROP TYPES	CALC U	PROBABILITY P
BEANS	465.0	0.8036
COFFEE TOTAL	365.5	0.0710
COFFEE PURE	375.0	0.0866
COTTON	468.0	0.8346
MAIZE PURE	395.0	0.2219
MAIZE TOTAL	417.0	0.3711
MILLET	434.5	0.4549
PULSE	404.5	0.2702

N = 31 (the number of the 88 ground sample clusters covered by the January 1986 air survey).
Critical value of U at 0.05 significance level = 341.3.
Value of z (standard normal deviate) at 0.05 significance level = 1.960.

A number of reasons can be proposed to explain the variation in the results obtained from comparing the crop cover estimates of two air surveys and the ground survey (Tables 6.3 and 6.4). Both the January air survey flights produced different scales of photography and were undertaken using different photo sample intensities (Section 4.3.1). The colour slides resulting from the January 1985 survey had a scale of approximately 1:30,000. The January 1986 survey slides had an approximate scale of 1:12,000. It is reasonable to argue that the increased ground resolution of the latter survey enabled greater accuracy in crop identification with this being reflected in the results presented above. Crop cover percentage estimates over the study area are shown to be significantly different (at the 0.05 level) for two of the compound crop variables (maize and pulse) when the 1985 January air survey and ground survey are compared. Since no significant difference in crop cover estimates over the study area are found for the pure crop variables maize and beans when these two surveys are compared (Table 6.3), this suggests that crop complexes are not being accurately identified in the January 1985 air survey.

The two January air surveys did not cover entirely the same ground area within the study region, and it is difficult to provide evidence that sampling intensity is contributing to the differences observed here. It would be necessary to fly over the same area at the same height (to obtain photo products of the same scale) with different sampling intensities in order to satisfactorily examine this assertion.

It should be noted that of the three crop variables millet, maize and pulse which have significant differences in cropped area between the January 1985 and ground survey data, two of these (millet and pulses) are grown predominantly in the lower, more marginal lands of the region. This finding is important in that it confirms the resolution limitations of the photography particularly in regard to distinguishing crop variables in the drier regions of the district. On the 1985 photography both millets and pulses were often very difficult to distinguish from natural grass cover which was common on fallow land.

It is also important to notice (Section 6.2, Table 6.1) that the area planted under one of the major cash crops of the lower region of the district, namely cotton, exhibits a significant seasonal variation. In attempting to identify AEGs in the lower, more marginal area it would seem essential then to use high resolution colour photography to overcome both the lack of natural contrast in the landscape of the area, and to identify any seasonal changes which may affect the delineation of AEGs when these are based on crop/land use patterns. In this respect the January 1986 air survey appears to be more reliable for identifying cropping patterns. However, since it was not possible to fly over the entire study area in 1986, both the January air data sets are used in this analysis.

The ground area covered by a single sample photograph in the January 1985 survey is approximately six times that of the 1986 survey (76 ha compared with 12 ha), and identification of crops using the 1985 photography is more difficult. Crop complexes were distinguished for a greater number of crops using the 1986 air survey data than was possible with the 1985 air data since areas of intercropping were easier to pick out on the lat er survey (Appendices 3A and C). Intercropping is an important characteristic of smallholder farming in the area (complexes account for between 7.2% and 96.2% of total cultivation at the selected sample units - Appendix 9) and, if crop complex variables can be accurately distinguished using light aircraft remote sensing, this should aid the search for identifying areas of 'relatively homogeneous' agriculture and distinguishing between different farming systems.

Grid sampling intensity in the 1986 survey was approximately every 1.5 by 5km, and compares to a similar grid sample every 2.5 by 5km used for the 1985 survey. Intensive sampling coupled with high resolution colour photography would provide a detailed land-use mosaic of the densely settled farmlands in the north and west of the study area. Using this photography it would be possible to make accurate estimates on the area planted under crop complexes. Such a strategy would also be suitable for identifying cropping patterns in the medium and low agricultural potential land areas where difficulty in distinguishing certain crops from the naturally occuring vegetation was experienced when using the 1985 air survey data.

The difficulty of distinguishing certain crops in the lowland areas of the district may be due, in part, to recent seasonal and climatic variations in the area. Two factors are important here. Firstly, the 1985 air survey was flown at the end of a period of severe drought in the district. This meant that many of the identified field crops in the lower regions were crop failures, and were often difficult to separate from natural grass vegetation occuring on recent fallows (fallows of less than five years).

Secondly, ground checking for the 1985 photography was not possible, since this flight was undertaken during the season immediately prior to the ground survey, which began in August 1985. The ground crop cover estimates which correspond to the

1985 flight were based on farmer responses, and are therefore subject to response error which was not the case in the 1986 survey which was verified by ground work within a few weeks of being flown. Some of the observed differences between the 1985 air survey and the ground survey crop cover estimates may therefore be due to farmer response errors, and not entirely result from errors in crop identification on the photography from this air survey.

However, bearing in mind the differences identified in the estimates of crop complexes between the ground survey and the January 1985 air survey within the study region, it was decided that crop complex variables should not be used to help define AEGs in this study.

The comparisons in this chapter and Chapter Seven are based on the 88 farm clusters visited during the field survey. At each farm cluster between four and six farms were visited and surveyed. In total 482 individual farms were visited. For each ground sample cluster there is a corresponding aerial colour slide (Chapter Five discussed the methods which were used to aggregate the 482 individual farms into 88 farm clusters). Section 6.4 compares absolute crop cover percentage estimates from the 88 ground survey clusters with similar estimates from the 88 corresponding air survey sample units which are selected from all three air surveys. Five key crop variables are chosen to help identify AEGs in the next chapter.

6.4 COMPARISON OF GROUND AND COMPOSITE AIR DATA SETS

Using the 88 ground samples as one sample data set, and the corresponding 88 sample units from the air surveys as a second data set, crop cover estimates were compared across the six major crop categories in the study area. These comparisons were made using only pure crop stands. Table 6.5 shows the results:

TABLE 6.5

RESULTS OF MANN-WHITNEY U TEST
88 SAMPLE UNITS - GROUND AND AIR SURVEY DATA

CROP TYPES	CALC U	PROBABILITY P
BEANS	3369.0	0.0632
COFFEE	3617.5	0.3335
COTTON	3347.0	0.0958
MAIZE	3790.0	0.7948
MILLET	2570.5*	0.0000
MIRAA	3822.0	0.7600

N = 88 (total number of sample units in study). Critical value of z (standard normal deviate) at the 0.05 significance level = 1.960. Critical value of U at the 0.05 significance level = 3209.6. * indicates statistically significant difference.

The null hypothesis that there is no significant difference in the crop cover percentage estimates over the study area between the two samples can only be rejected if the calculated value of U is less than, or equal to, the critical value at a chosen level of significance. Table 6.5 indicates that at the 0.05 significance level, the null hypothesis can be accepted for all the crop variables except millet. The percentage values for millet between the two data sets remains significantly different even at the 0.1 significance level. A number of possible reasons for the difficulty of identifying crops using air survey methods in the lower regions of Meru district have already been mentioned, and it has been suggested that improvements in the accuracy of identification of crops in these areas can be met by increased photo resolution, comparable to the 1986 survey, combined with detailed ground sample checks *at the time* of the air survey.

This section has examined the consistency of crop cover percentage estimates between the ground survey farm clusters and samples from the three combined air surveys. It has shown that for five of the six main crops in the region there is no significant difference between the two data sets at the 0.05 significance level. Because there appears to be a significant difference in the crop cover estimates for millet between the two sets of data, this crop variable is not used in any further analysis presented in the dissertation.

6.5 SUMMARY

In summary, this chapter has been concerned with establishing the accuracy of the air survey data sets against the ground data. It has been possible to show that for a number of the major crop variables in the study area crop cover percentage estimates from both data sources are consistent with each other.

Four main points have been noted. First, the area under certain crops (e.g. cotton) may vary from one season to the next and therefore wherever possible reliance on such crops to distinguish between farming systems should be avoided. Secondly, spatial differences in the distribution of crops from one season to another, although not marked in this particular study area, indicate that the definition of AEGs should not be dependent on single crop/land cover variables. Thirdly, the resolution limitations of the January 1985 colour slide aerial photography prevented an accurate estimation of the area under crop complexes in 51 of the 88 sample units. Due to this finding, crop complexes are not used to help define AEGs in this study. Finally, crop cover percentage estimates for five of the major crop types growing in lower Meru were shown to be comparable on both the air and ground surveys.

In demonstrating that there is consistency between the two data sources on a number of key crop types, it would in future be unnecessary to collect duplicate ground survey data for these variables. Rather, studies which use aerial colour slide photography to help identify AEGs for agricultural research and development initiatives will be able to use larger air sample survey data sets, without the need for expensive and time-consuming duplicate ground surveys. Chapter Seven uses the crop variables examined in this chapter, together with a number of other important variables from both data sources, to define and distinguish between AEGs (farming systems) in the study region.

CHAPTER SEVEN

IDENTIFYING AND DEFINING AGRO-ECONOMIC GROUPINGS

7.0 INTRODUCTION

As noted in Chapter One, one of the main objectives of the work reported here is to define the spatial distribution, and examine the internal structure of AEGs within the lower region of Meru district. The crop variables which were shown to have consistent values over both the ground and air surveys in Chapter Six are included in the analysis presented here to help identify AEGs. AEGs are used together with zones of agricultural potential (AEZs) to define recommendation domains for agricultural research and development in Chapter Eight.

In this chapter the statistical procedures used to identify AEGs are described and the findings of the analysis are discussed. The results show that relatively homogeneous agricultural groupings can be identified. The chapter is divided into four sections. The first discusses the manner in which the data are compressed using principal components analysis into new compound variables. Both the ground and air survey data sets are analysed separately. Component scores for the principal components of both the ground and air data sets are mapped using the computer software package SYMAP (Dougenik and Sheehan, 1975).

The second section uses a canonical correlation procedure to relate the air and ground survey data sets to each other in order to identify correlations between the components of each data set. Section three discusses the results of a multiple regression analysis which is used to identify further significant correlations between the two data sets. Four AEGs are identified together with a more heterogeneous transitional farming zone. AEGs represent areas which are identified to be consistently homogeneous on both the air and ground surveys. Section four examines the homogeneity of the AEGs using individual farm data by employing cluster analysis. Crop planting practices are used to distinguish between AEGs on a farm-by-farm basis.

In the last chapter the statistical frequency distributions of key variables which are used in the analysis were examined. It was established that because the raw data do not approximate to a normal distribution it is not appropriate to use parametric statistics. For this reason appropriate non-parametric tests are used wherever possible. However, where it has been possible to transform the raw data into a form which conforms more closely to a normal frequency distribution (for example by using Euclidean distances and component loadings), this has been done to allow the data to be subjected to a number of powerful multivariate statistical techniques. In interpreting the results of this analysis the reader should keep in mind the assumptions being made in respect of the statistical nature of the data.

In order to test the validity of using remote sensing procedures to help identify AEGs, data from both sources - the ground and air surveys - are analysed separately in the first section. The reader should refer to Chapter Five for a full discussion of the computational methods used to manipulate and organize the sample air survey data and sample ground cluster data in preparation for the analyses presented here. The analyses reported in the first three sections of this chapter are based on the 88 sample units (ground and air). In this respect the ground sample is comprised of average farm values. Averaging was necessary in order to summarise the variation between farms at each farm cluster visited during the fieldwork (each cluster comprised of between 4 and 6 farms). Section 7.4 assesses the homogeneity of the identified AEGs using the 192 farms included in these groupings on a farm-by-farm basis.

7.1 PRINCIPAL COMPONENTS ANALYSIS - THE GROUND AND AIR SURVEYS

In trying to understand the complex patterns presented by the smallholder agriculture of lower Meru, it was felt necessary to compress the farm survey and air survey variables into a more manageable and hopefully more meaningful form, so that a fewer number of compound variables could be analysed. The variables used in the analysis from the air survey data set are largely spatial descriptors of the farming systems within the study region. Since smallholder agriculture is comprised of many different crop and livestock activities, identifying a single crop or land cover type will not be an adequate surrogate for describing a farming system. In order to establish a more satisfactory measure for describing farming systems, single variables can be combined to summarise the information present on each variable. New compound variables containing information from each of the original variables are thus derived.

One technique which allows us to do this is principal components analysis. This technique identifies groups of inter-correlated variables from within large data sets. In using principal components analysis a new set of variables are generated, based on a set of components. These components are used to replace the original set of variables. The relationships between these new variables and the original set become the focus of the analysis. Two indices are extracted during principal components analysis: the angle between the component and the original variables (the correlation coefficient is the cosine of that angle) and the squared correlation which indicates the proportion of variance associated with the component. Component loadings are the correlations between the original variables and the extracted components. The square of these correlations indicates the proportion of the variance in each individual variable which can be associated with each component. Each squared component loading (correlation) shows the degree to which the new variable subsumes or replaces the original variable, i.e. what proportion of the original variable is correlated with the component. The sum of the squared loadings indicates the total variance accounted for by a component. This is known as the eigenvalue.

Component scores are values for the observations on the new variables (components) and reflect their values on the original variables. Thus the larger the value an observation has on an original variable, which has high loadings on a component, the higher the score on the new variable (Johnson, 1978).

To test the hypothesis that there are areas of relatively homogeneous agricultural activity within the smallholder economy of lower Meru principal components analysis was used to define areas of agricultural consistency. Separate analyses were performed on each of the two data sets (ground and air survey), and a number of principal components were derived for each set.

10 key variables were included for analysis from the three air surveys, while 17 were used from the ground survey. These variables are listed in Tables 7.1 and 7.2 below. The variables chosen were selected on the basis of their estimated importance in distinguishing between farms within the study area, their inclusion being a direct result of field experience and observation. Norman and Collinson (1985) have argued that recommendation domains should be based on farming systems. In the present study AEGs are considered to be simplifications of farming systems. AEGs are used to help define recommendation domains in the Chapter Eight.

Five of the most widely-grown crops were included in both data sets. These were coffee, cotton, maize, miraa and beans (millets were excluded from the analysis as estimates of the land area under this crop had been shown to differ significantly between the ground and air sample data sets in the initial stages of the analysis - Section 6.4). All these crop variables represent pure crop categories.

To recap, the distinction between pure crops, crop complexes and crop combinations is as follows: a pure crop is defined as a single crop planted in a stand without any other crops. A stand may vary in size from a small plot of perhaps 0.1 hectare to a field of over 1.0 hectare. A crop complex on the other hand is a collection of crops found growing within the same plot or field. Crop combinations are used and define a larger of category of crops. In this respect they may represent agglomerations of pure crops or crop complexes and can therefore represent collections of plots or fields. For example, beans may be grown as a pure stand, in which case they are categorised as a pure crop; as a complex, growing with other crops in the same field, or as a combination where fields of beans or bean complexes are grouped with other legumes to define a larger category covering pulses.

The selection of certain variables which were common to both data sets was deliberate since the objective was to examine the value of using light aircraft remote sensing to distinguish AEGs in lower Meru. Thus the farming patterns generated from analysis of the air survey data could be compared and regressed against those generated from analysis of the ground data. Farming patterns that were common to both could then be used to define AEGs.

Other important variables in the air survey data included categories relating to the intensity of land use within the area. Variables included here were: the percentage of land under cultivation, rough grazing, improved grazing and land under fallows. Height above sea level for each sample point was also included as a variable to help distinguish between areas of high and low terrain. Cropping patterns in the study area are related to terrain (Jaetzold and Schmidt, 1983) and it was felt that this characteristic would be helpful in distinguishing between farming systems.

Variables included in the ground survey were: the major crop and livestock types, income levels associated with these (as well as off-farm income), farm size (cultivated area), length of fallows, the number of farms cultivated by the farm family, and the number of years the farm family had been growing food and cash crops. These variables were selected because they were considered to be key parameters of smallholder agriculture in the study region and could be used to distinguish between farming systems in the area. For example, in the drier areas to the south and east of the study region the farming system is based on a bush fallow/shifting cultivation type of agriculture, where cash cropping is less significant than in the more fertile west and north. By contrast, in the north the farming system is characterised by very small parcels of land with one farm family often owning more than one farm. All of these variables had also been measured on an interval scale and therefore represented data which were suited to multivariate statistical analysis.

Table 7.1 below shows two groups of land use variables and a distinction needs to be made between these. Both groups of variables are derived from the total land use/cover observed at a sample point and therefore represent absolute values. However, the first group is more general in nature and includes the variables: total percentage of land under cultivation, fallows and rough grazing. The second group are all related to the general variable: total percentage of land under cultivation, crop variables from this second group represent only the most important of the crop types identified during the air surveys. Individually however they still represent a significant percentage of the cropped land area within the study region and are also important sources of farm income.

TABLE 7.1

PRINCIPAL COMPONENTS ANALYSIS - AIR SURVEY VARIABLES

TOTAL LAND USE/COVER		OTHER
% LAND USE *	% LAND USE	
CULTIVATED FALLOWS ROUGH GRAZING	COTTON COFFEE MAIZE BEANS MIRAA IMPROVED GRAZING	HEIGHT OF SAMPLE POINT ABOVE SEA LEVEL

* signifies more general land use categories not specific crop types (see text).

Table 7.2 shows the 17 variables which were included in the second principal components analysis using data from the ground survey. The variable farm size does not represent the size of the farm holding rather, it represents only the area under cultivation on this holding.

TABLE 7.2

PRINCIPAL COMPONENTS ANALYSIS - GROUND SURVEY VARIABLES

FARM CLUSTER				
AVERAGE NO OF YEARS	AVERAGE NO L/STOCK	AVERAGE INCOME	PERCENTAGE LAND UNDER	OTHER VARIABLES
CASH CROPS GROWN FOOD CROPS GROWN	SHEEP GOATS GRADE/ CATTLE LOCAL/ CATTLE	CROP LIVESTOCK OFF-FARM	COTTON MAIZE COFFEE BEANS MIRAA	FALLOWS * FARM + FARM SIZE

* Average length of fallows in years.
+ Average number of farms owned by the farm family.

Separate principal components analyses were performed on the two data sets. There were two objectives to the analyses. The first aimed to examine whether it was possible to establish new variables which could summarise the complex information contained in the original variables in such a way as to distinguish between different farming systems in the study region. The second objective aimed to establish whether the spatial variables of the air data set could be used as surrogate measures of the variables from the ground survey. In other words to test that although the data from the air surveys were largely describing the crop/land cover characteristics of the study region, the patterns identified would generally correspond to those revealed by the more detailed ground data.

Three components were extracted from the air survey data set in the first analysis, and these accounted for 62.7 % of the variance of the 10 original variables. A second analysis using the ground survey data set produced six components accounting for 70.8 % of the variance of the 17 original variables. Statistics from these analyses are shown in Tables 7.3 and 7.4 below.

TABLE 7.3

PRINCIPAL COMPONENT STATISTICS - AIR SAMPLE DATA

COMPONENT NO	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENTAGE
1	3.60292	36.0	36.0
2	1.48201	14.8	50.8
3	1.18625	11.9	62.7

Conventionally, only eigenvalues of more than or equal to 1.0 are included in interpreting the results of principal components analyses since eigenvalues below this value tend to account for very little of the original variance in a data set. On the one hand, when extracting only those components with high eigenvalues quite a significant percentage of the original information in the data set may be lost from the analysis. Conversely, interpretation of components with low eigenvalues is difficult with no clear pattern emerging from the component loadings. In the analysis presented here only components with eigenvalues of 1.0 or greater are discussed.

TABLE 7.4

PRINCIPAL COMPONENT STATISTICS - GROUND SAMPLE DATA

COMPONENT NO	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENTAGE
1	4.04249	23.8	23.8
2	2.70754	15.9	39.7
3	1.61436	9.5	49.2
4	1.41987	8.4	57.2
5	1.23288	7.3	64.8
6	1.02529	6.0	70.8

In order to obtain the best possible grouping of variables on the components and to facilitate the interpretation of the results, the component axes were rotated using a varimax rotation procedure. The basic principle here is to define a hypothetical component structure to which the real data set is moved as close as possible. This ideal is known as *simple structure* and the methods of moving towards it as rotation of the axes (Johnston, 1978).

Varimax rotation is an orthogonal procedure. It is by far the most widely used rotation procedure and is distinguished from a number of other rotation methods as it retains the constraint that the components must be uncorrelated. Varimax rotation aims to maximise the variance in the loadings. For every variable the components are rotated as close to the simple structure ideal as possible. The aim is for each variable to have a loading of either +1.0 or -1.0 on one component, and 0.0 on all the others. However, groups of variables are never completely correlated among themselves and completely uncorrelated between themselves, yet, if there is a lot of shared common variance then varimax rotation should discover this. The objective is for each group of intercorrelated variables to be represented by a single factor or component. For both data sets eight iterations were performed before obtaining the closest approximation to the simple structure.

Sub-sections 7.1.1 and 7.1.2 discuss the results of this varimax rotation and the mapping of the component scores. Tables 7.5 and 7.6 show the component loadings for each data set after varimax rotation.

7.1.1 MAPPING AND INTERPRETATION OF THE COMPONENT SCORES

Using the SYMAP computer program the component scores (for the 88 sample points) resulting from principal components analysis were mapped for both the air and ground survey data sets. Classes were divided into quantiles, representing equal frequencies, the higher values being shown with darker symbolism and negative values in lighter symbolism.

The advantage of using the SYMAP programme is that the interpolation algorithm allows one to define an isopleth surface with or without contouring (Schmidt and Zafft, 1975). In the present study this versatility is especially useful since the smallholder farming economy is not comprised of a series of distinct farming units which are clearly delineated from each other. Rather, there is a continuous gradient in the farming pattern and using SYMAP this can be reproduced using the "no contour" option. All the maps included in this section have been produced using this algorithm. Figures 7.1 to 7.9 show the spatial distributions of the nine components resulting from the two principal component analyses. These analyses are now described in more detail.

7.1.2 THE AIR SURVEY COMPONENTS

TABLE 7.5

AIR SURVEY DATA : COMPONENT LOADINGS AFTER VARIMAX ROTATION

VARIABLES	COMPONENT LOADINGS		
	1	2	3
LAND CULTIVATED	.9096	.0914	.2689
ROUGH GRAZING	-.8234	-.0181	-.2570
HEIGHT OF POINT *	.7812	.3284	-.1118
COFFEE	.6886	-.2236	-.4794
MAIZE	.6666	.2767	.0239
MIRAA	.2142	.8294	.1090
IMPROVED GRAZING	.4338	.5359	-.1840
BEANS	.2404	-.3768	.3692
FALLOW	.0352	.1921	.7787
COTTON	.1199	-.2636	.5432

* Height of sample point above sea level.

Five of the original variables have high loadings on the first component. Ranked in order of importance they are: land under cultivation, rough grazing, height of sample point above sea level, coffee and maize. The category rough grazing is the only variable with a high negative loading on this component. Component one accounts for 36.0% of the variance within the data. This component very clearly distinguishes between the two main farming systems in the study region:

A) Variables with high positive values are grouped together and represent the higher agricultural potential land within the study region. Field survey work showed the land in the west and north-western part of the study to be intensively farmed (high values for the variable land under cultivation, and low values for the variable fallow), indicating an area where there is little land lying fallow or uncultivated (Figure 7.1). Farmers here grow cash crops, particularly coffee. Maize is still an important crop and it is significant that both the variables maize and coffee have high loadings on this component. It is therefore an important food and cash crop growing area. The area receives the highest rainfall within the study region (Jaetzold and Schmidt, 1983) and represents the highest terrain which includes the Mount Kenya and Nyambeni foothills.

B) The variable rough grazing with a high negative value represents the lowland livestock-rearing area in the north-east, east and south of the district (light shading in Figure 7.1). It is a surrogate measure for the livestock variables included in the ground survey data and can be compared with the area depicted by component two from the ground survey (Figure 7.5).

FIGURE 7.1 AIR SURVEY - COMPONENT ONE

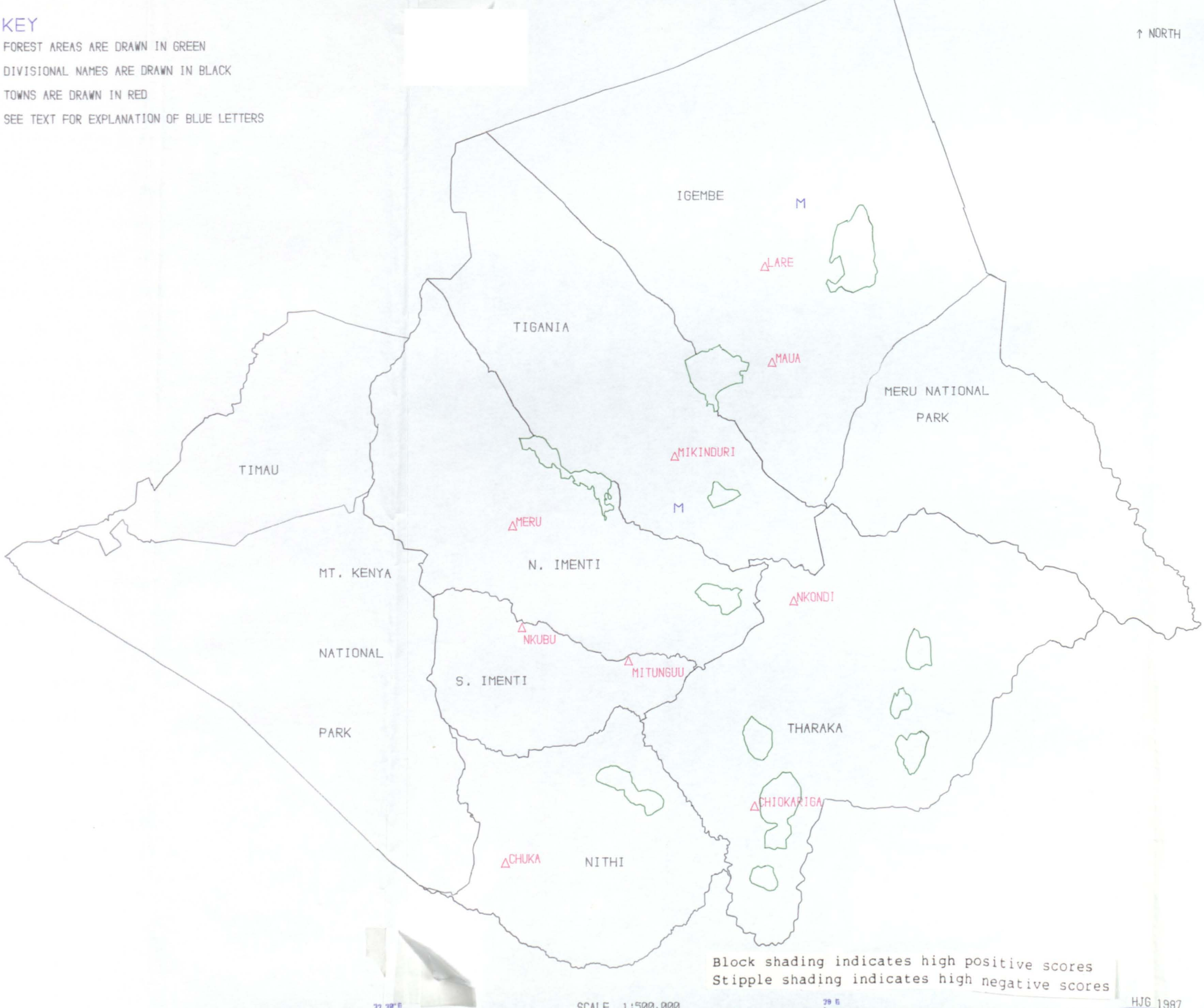


FIGURE 7.1 AIR SURVEY - COMPONENT ONE

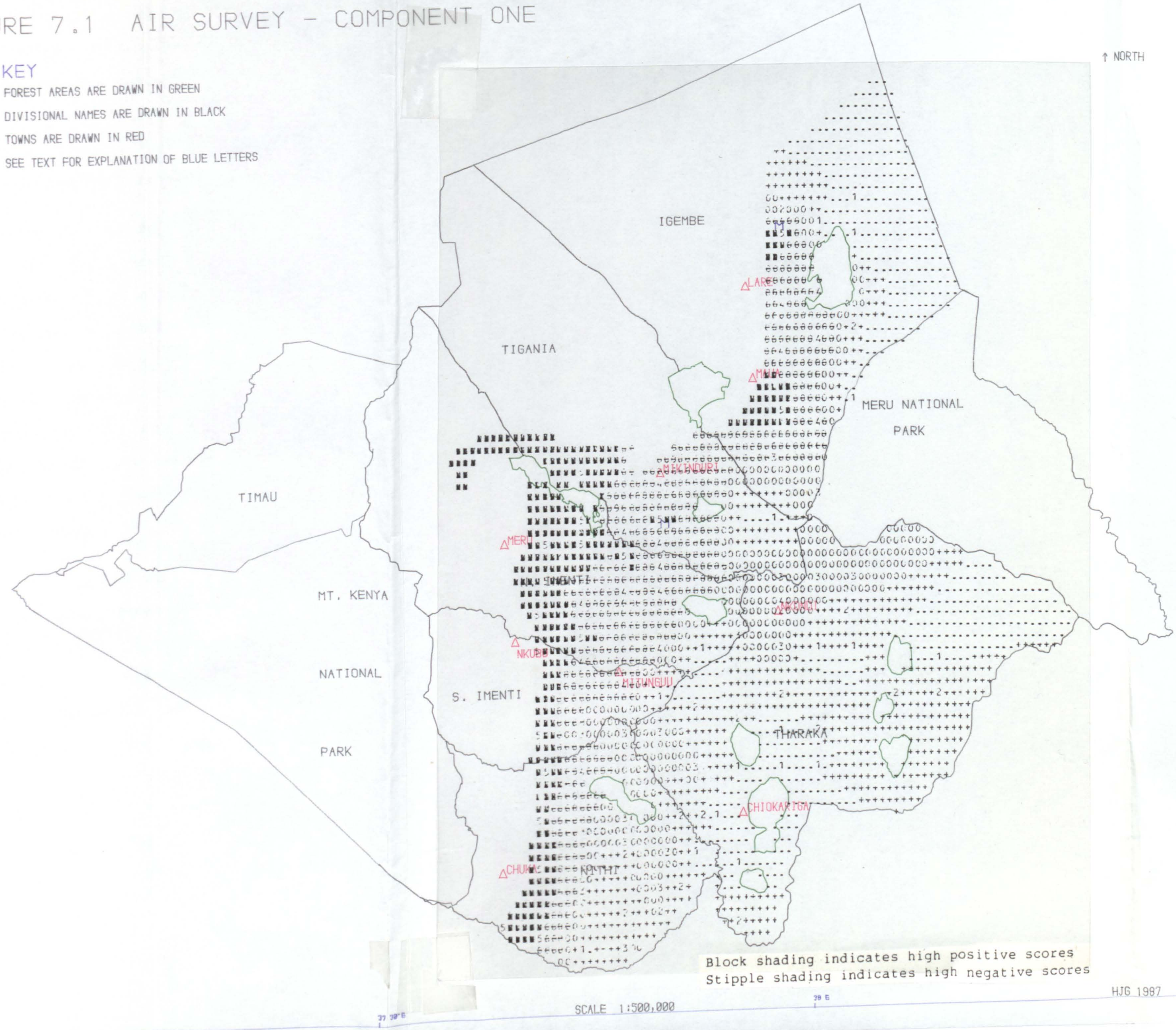
KEY

FOREST AREAS ARE DRAWN IN GREEN

DIVISIONAL NAMES ARE DRAWN IN BLACK

TOWNS ARE DRAWN IN RED

SEE TEXT FOR EXPLANATION OF BLUE LETTERS



In summary component one is portraying two types of agricultural landscape: one which is intensively farmed, has the highest terrain, and receives the highest rainfall of any area within the focus of this study. The other, represents the marginal lowland, livestock-rearing areas which include the southern and eastern lands of lower Meru.

There are two outlying points which do not appear to conform to this interpretation (indicated by M on Figure 7.1). On examination of the raw survey data both of these points were found to represent significant maize-growing areas. Due to this both of the points are associated with the general landscape pattern summarised above. There are in fact some important differences between these points and the other homogeneous areas identified by component one and these will be discussed below. First however the two remaining components derived from the air data set are considered.

On the second component, two of the original variables have higher than average loadings (miraa, and improved grazing). The most significant of these is the variable miraa (Figure 7.2 shows the high values represented by this variable in dark symbolism). The area defined by this component identifies the distinctive miraa-growing part of the district to the north of the study region. It is an area of relatively high altitude and high rainfall, with a significant number of farmers keeping dairy cattle (high loading on the variable improved grazing). 14.8% of the variance within the original data is accounted for by this component.

FIGURE 7.2 AIR SURVEY - COMPONENT TWO

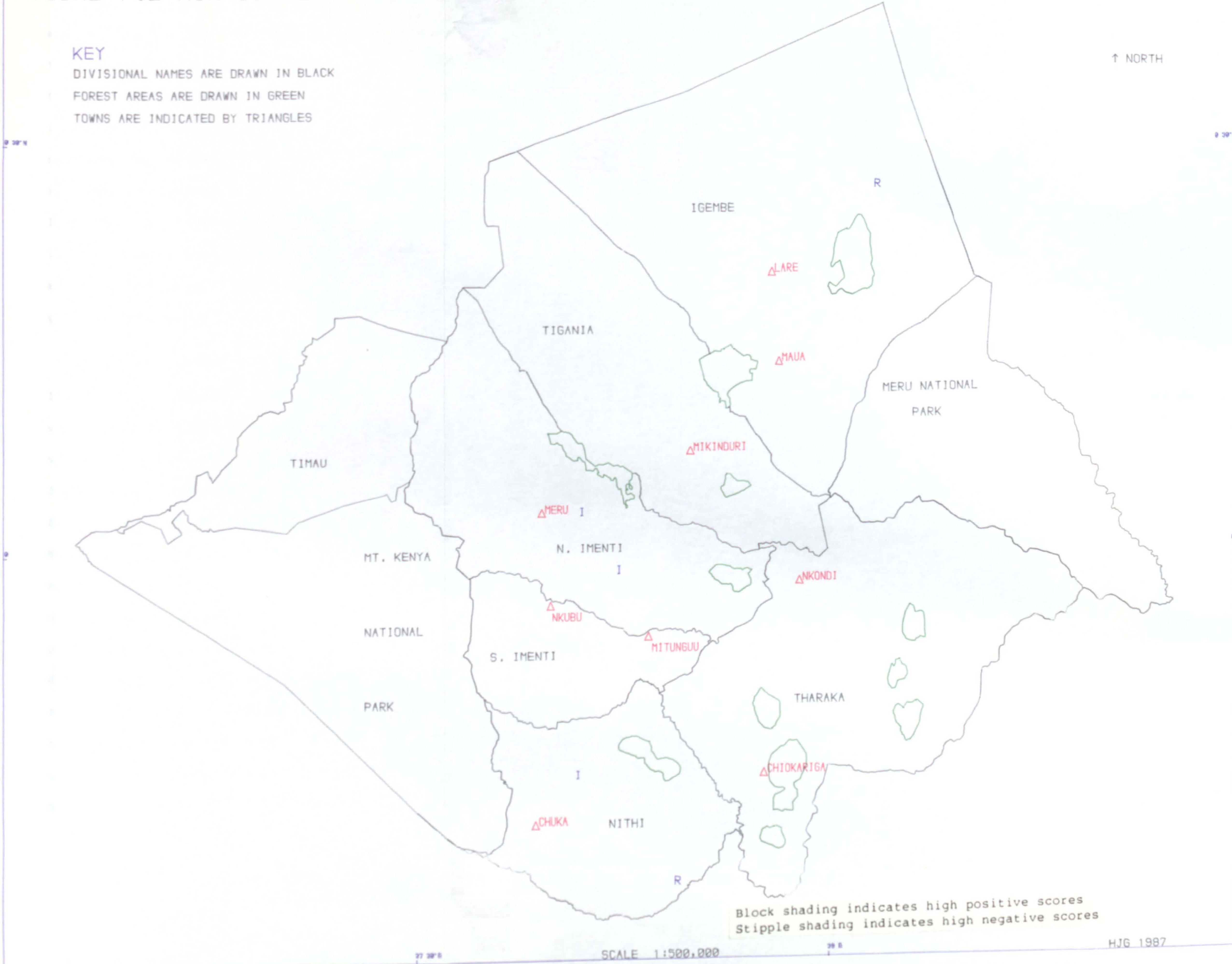
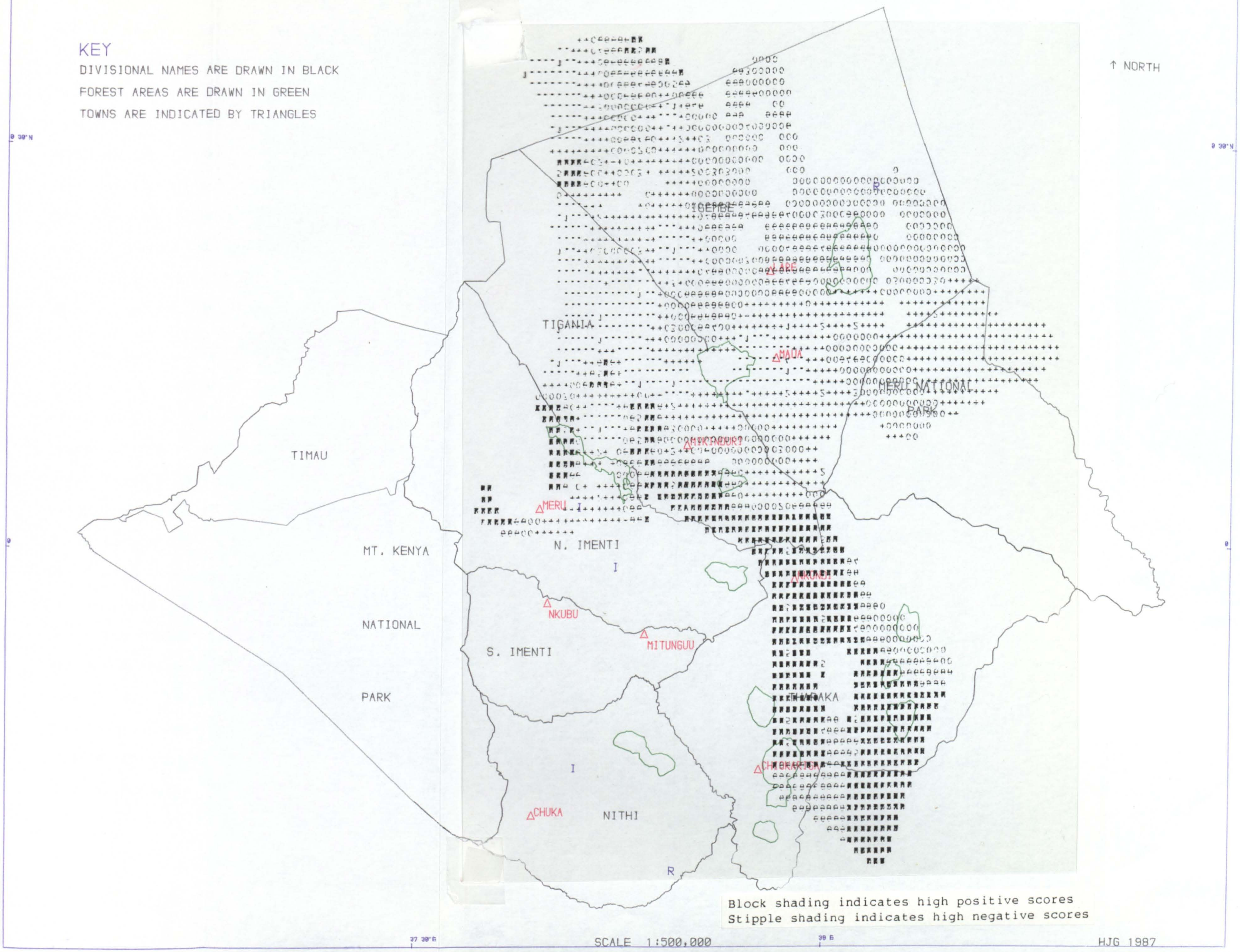


FIGURE 7.2 AIR SURVEY - COMPONENT TWO



There are a number of isolated homogeneous areas to the south and in the far north-east of the study region which are outside the miraa-growing area (field work showed the miraa-growing area to be less extensive) but which have a high value on the component (indicated by I and R respectively on Figure 7.2). The original data show that at some of these points (indicated by I) there is a significant percentage of land under improved grazing with some land also under rough grazing. Because of the association between improved grazing and rough grazing at these points, some lowland areas with very significant percentages of land under rough grazing (indicated by R) have high component scores.

The last component derived from the air survey accounts for 11.9% of the overall variance in the data. Two of the original variables are strongly positively weighted. These include the variables cotton and fallow land. (Figure 7.3 shows the spatial distribution of the component scores). Perhaps the most important feature depicted by this distribution is that it identifies the Nkondi farming area in the central region of the study (indicated by N) which is quite distinct from the area to the south and north. Farms in this area are generally larger and more productive than the surrounding farmlands. The soils are quite distinctive with better water retention capacities than those in surrounding areas. Both cash and food crops are important within the farming system. The coffee-growing area to the west is also clearly identified (light stippled shading indicating high negative scores).

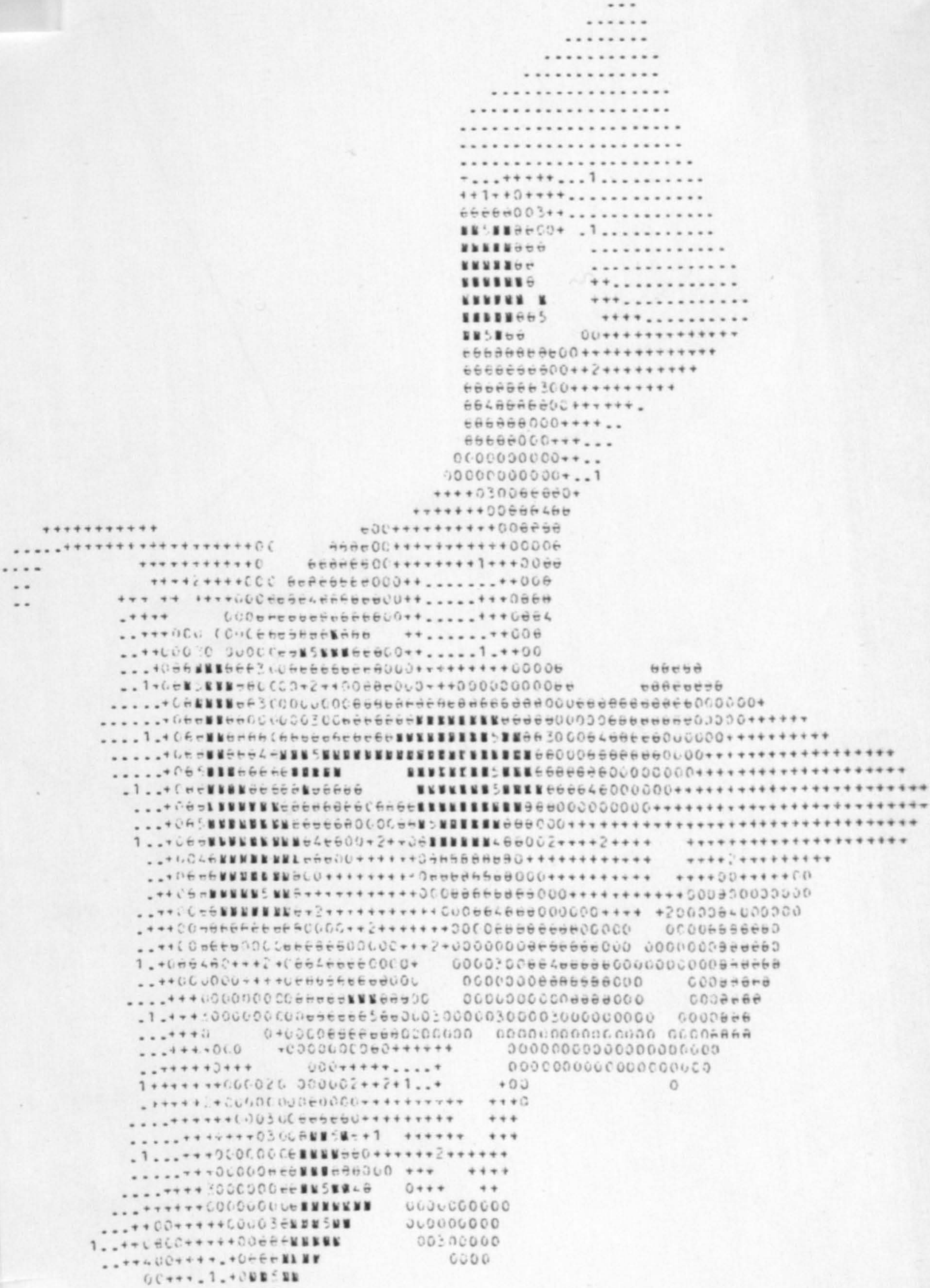


FIGURE 7.3 AIR SURVEY - COMPONENT THREE

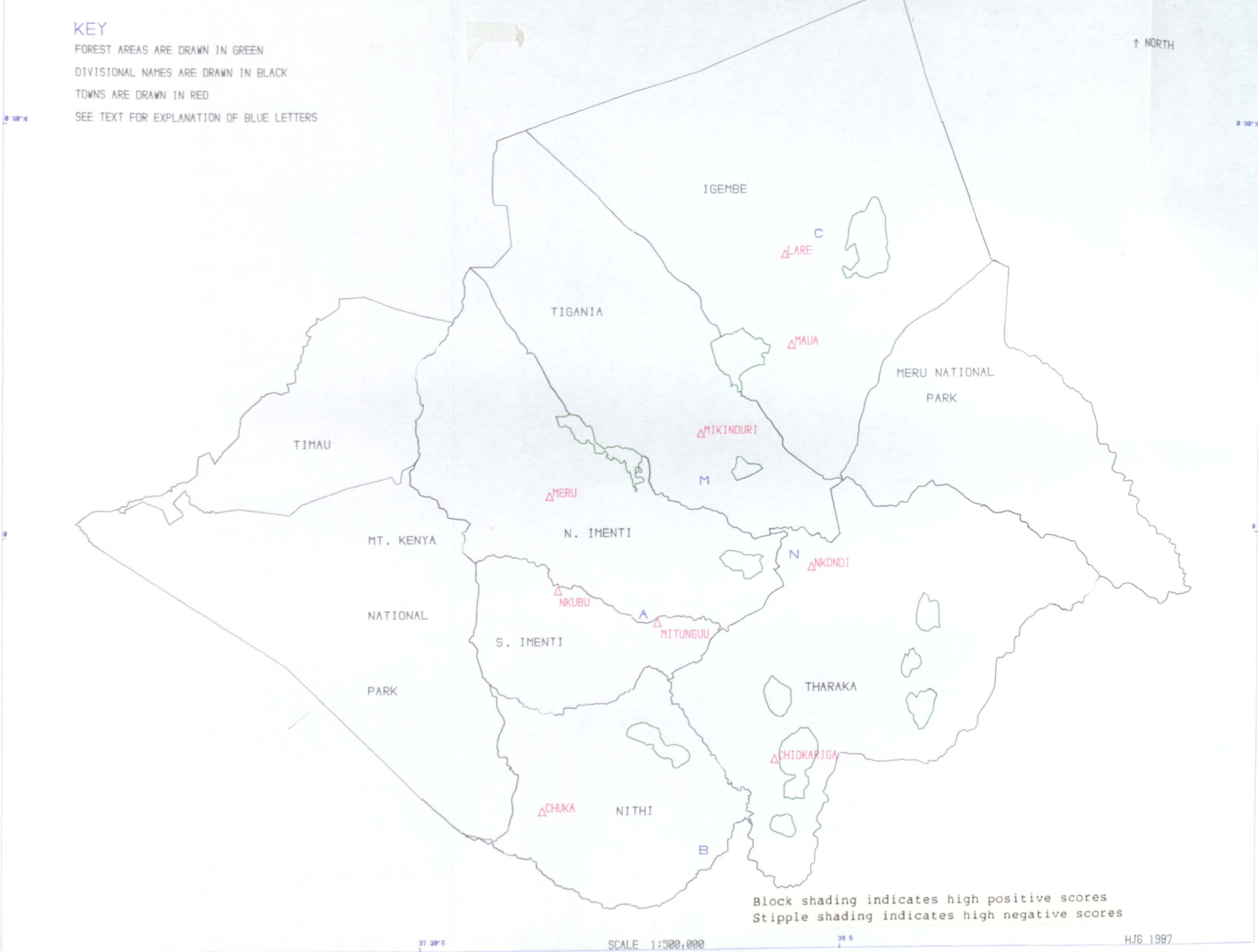


FIGURE 7.3 AIR SURVEY - COMPONENT THREE

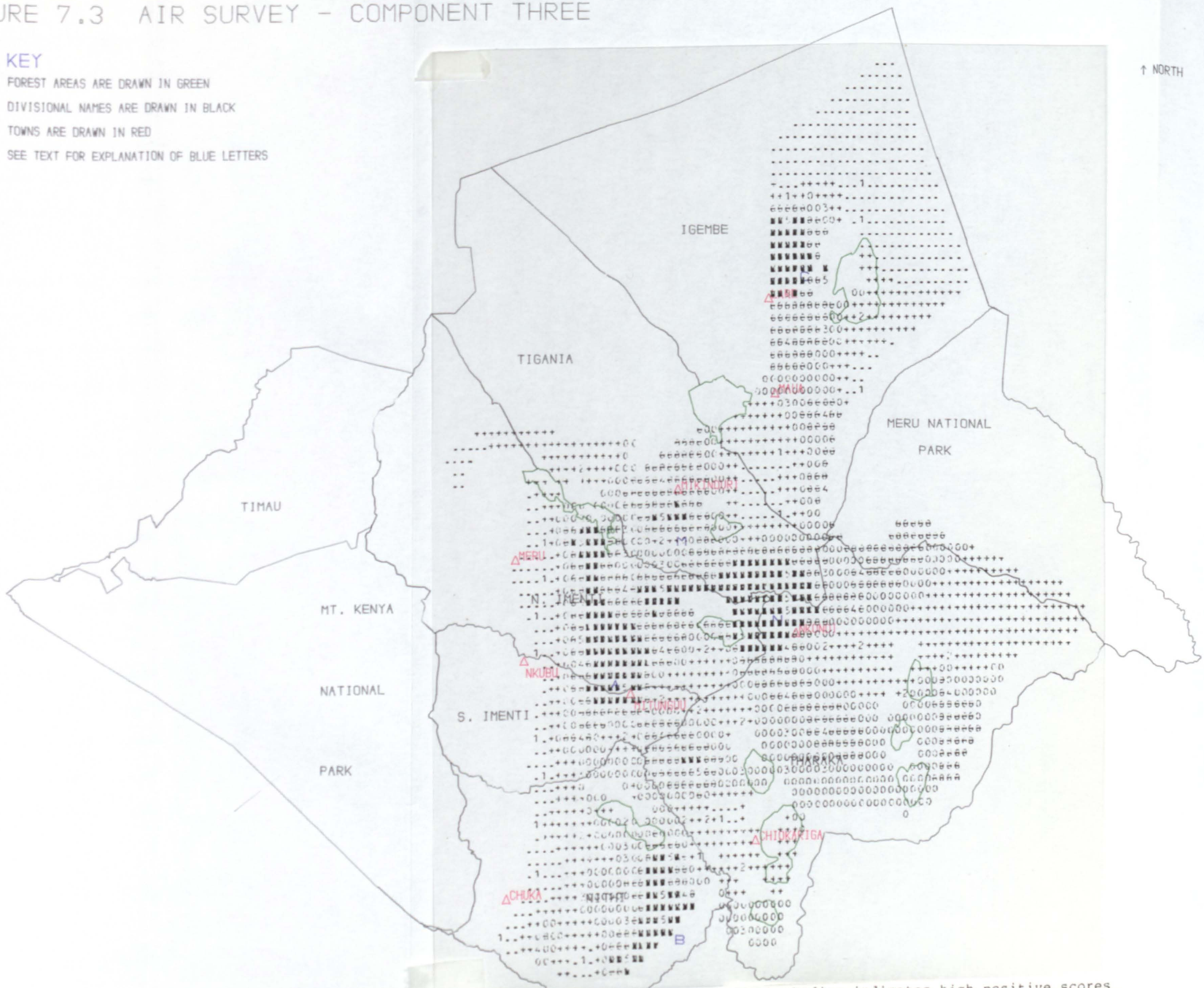
KEY

FOREST AREAS ARE DRAWN IN GREEN

DIVISIONAL NAMES ARE DRAWN IN BLACK

TOWNS ARE DRAWN IN RED

SEE TEXT FOR EXPLANATION OF BLUE LETTERS



Block shading indicates high positive scores
Stipple shading indicates high negative scores

SCALE 1:500,000

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There are however three other significant groupings on this component (these are marked by the letters A, B and C). Examination of the original data reveal that the first area (represented by the letter A) is identified to have significant percentages of land under cotton, fallow land and rough grazing. Because of the association between cotton and fallow land on the component, the area to the south near the district boundary with Embu (B) is also picked out by this component. This area was previously identified by component number two as having high percentages of land under rough grazing. The third area (C) is also identified by component number two. It is part of the miraa-growing area (17% of the land area was planted with miraa at one of the sample points), yet fallow land is also a characteristic of the area (15.7% of the land area was lying fallow at one of the sample points).

In summary the third component has identified areas of significant cotton growing which are also associated with farming systems where fallowing is practised and where there are still significant areas of rough grazing. Two rather spurious associations have been identified by the component however. One is in the north of the study region (C). This is really part of the miraa-growing area and is characterised by a farming system which is quite different from the other groupings picked out by this component. It should therefore be associated with component two.

The second, concerns the area to the north-west of Nkondi (indicated by M). This area was also associated with component one. On both component maps (Figure 7.1 and 7.3) it is spatially distinct from the other groupings. It has already been mentioned that this area is important for maize growing (17.4% of the land area was under this crop) although it represents only a small yet distinctive grouping. More detailed field surveys would be necessary in order to clarify whether it could be considered to represent a distinctive AEG.

7.1.3 THE GROUND SURVEY COMPONENTS

The six components from the ground survey are now discussed before examining the areas which are consistent over both the analyses. Homogeneous areas which are consistently identified on both analyses are used to define AEGs. 70.8% of the total variance is explained by six main components in this analysis. Table 7.6 shows the results of principal components analysis using the ground survey data.

The first component is composed of six main variables with high loadings. Ranked in order of importance these are: number of years growing cash crops, grade cattle, coffee, goats, crop income and maize (Figure 7.4). The loadings are most easily interpreted by grouping all the high values together. Like component one of the air survey, the more intensively farmed, higher altitude, cash crop farmlands within the study region are represented by the component. In this area coffee is the dominant cash crop although income from the sale of milk is also important and is reflected by the high loading for grade cattle. The variable goats has a significant negative value and is shown by the light stippled shading. Typically goats are found in the drier, more marginal livestock-rearing zones to the south, east and north-east of the district. Negative values for the variables

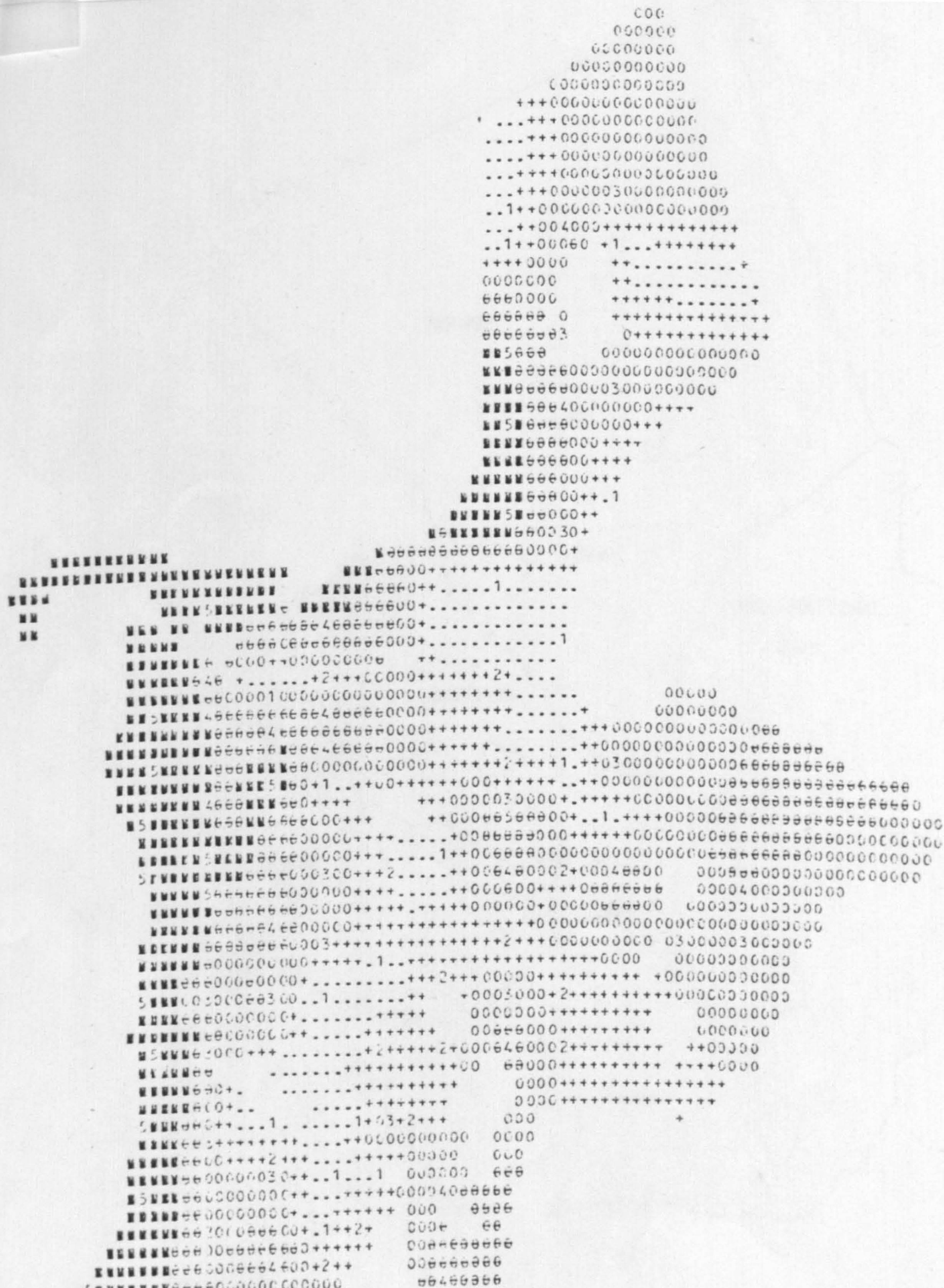

FIGURE 7.4 GROUND SURVEY - COMPONENT ONE

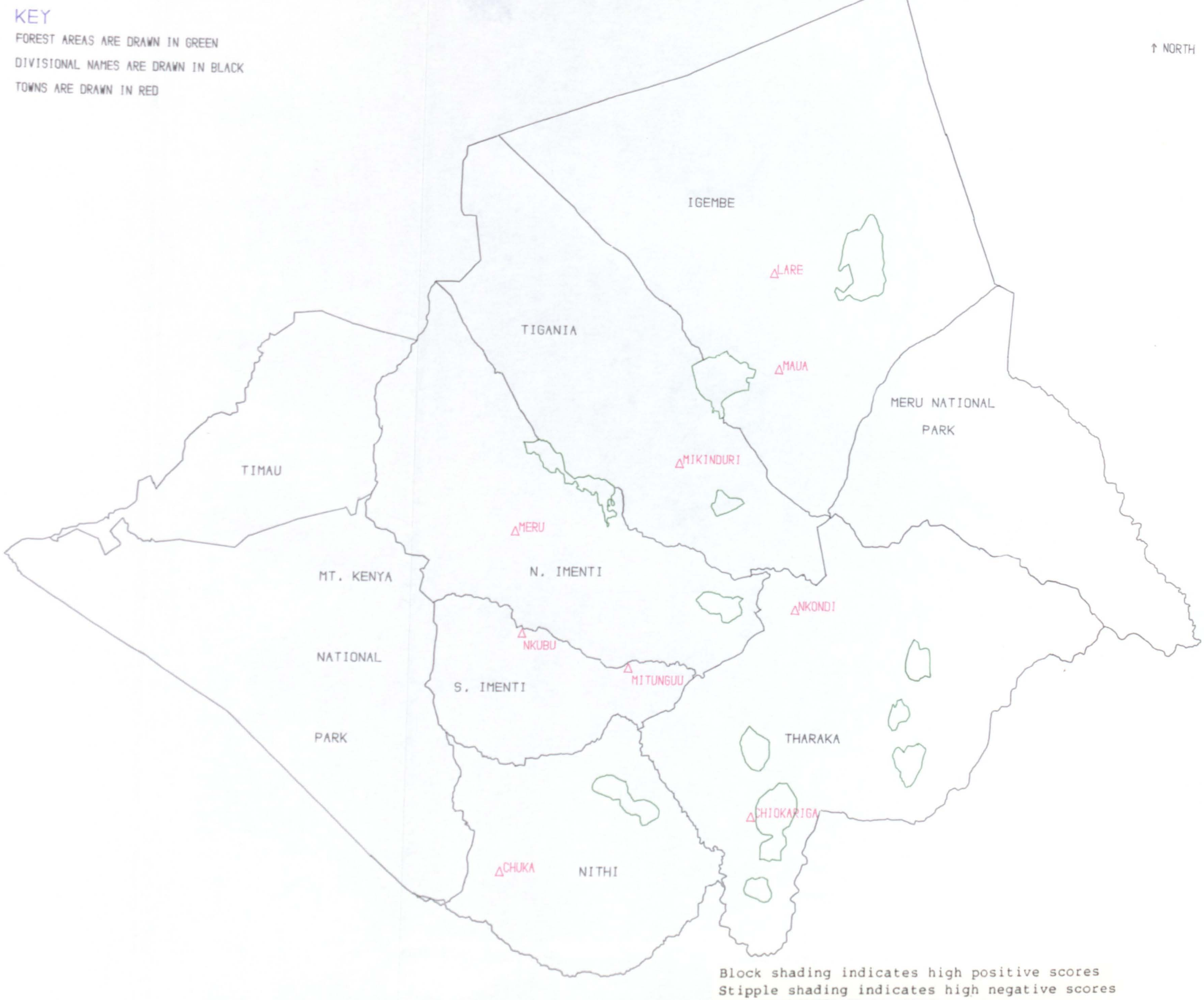

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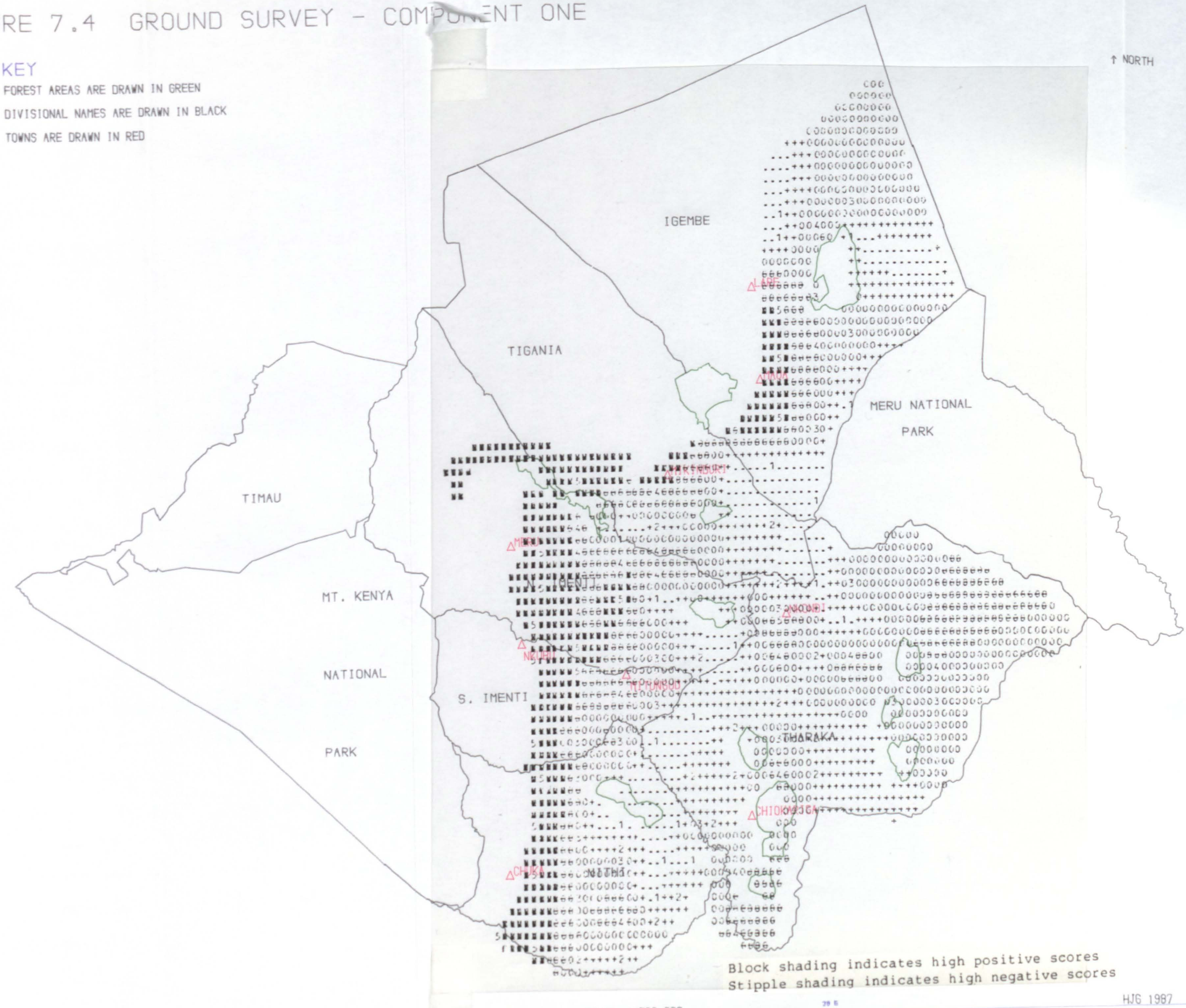
FIGURE 7.4 GROUND SURVEY - COMPONENT ONE

KEY

FOREST AREAS ARE DRAWN IN GREEN

DIVISIONAL NAMES ARE DRAWN IN BLACK

TOWNS ARE DRAWN IN RED



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local cattle and sheep confirm this interpretation. The component accounts for 24.7% of the total variance in the data set.

TABLE 7.6

GROUND SURVEY DATA: COMPONENT LOADINGS AFTER VARIMAX ROTATION

VARIABLES	COMPONENT LOADINGS 1	2	3	4	5	6
YEARS CASH CRP	.8525	.1609	.2351	.1846	-.0479	-.0863
GRADE CATTLE	.8233	.0590	.1155	.0681	.3095	-.2141
COFFEE	.7101	-.1413	.3422	.1647	.2468	-.2168
GOATS	-.6214	.4769	.2476	.1212	.3688	.0406
CROP INCOME	.5681	.4937	.1918	.1759	-.3627	-.0303
MAIZE	.5471	.1767	-.5158	-.0399	.2556	.2699
LOCAL CATTLE	-.3220	.6233	.2000	-.1643	.0831	.0530
FARM SIZE	.4221	.5703	-.2599	.1710	-.1736	-.2028
LIVESTOCK INC	.1006	.5701	.1332	-.4965	-.2689	.0991
SHEEP	-.4950	.5198	.2823	.0390	.4252	-.0638
LENGTH FALLOW	-.3874	.4934	-.2154	.3969	-.0569	.0079
BEANS	.4536	.0486	-.4938	-.2258	.3792	.4552
MIRAA	.1634	-.2930	.4478	.2028	-.2696	.2900
YEARS FOOD CRP	.2893	.4597	-.0387	.6237	.0882	.0518
OFF-FARM INC	.2891	.4017	.1875	-.5239	.0708	-.0315
COTTON	-.1316	.3706	-.3879	.2048	-.4592	.0006
NO OF FARMS	.1462	.0718	.4262	.2181	-.0868	.7048

The second component is clearly picking out the livestock-rearing/marginal agricultural area to the south-east of the district (Figure 7.5). High values on the variables: local cattle, livestock income, and sheep demonstrate this appropriately. It is interesting to note however, that there is a considerable spread of the weightings on this component across a number of other variables. The most significant weightings occur on the variables: farm size, length of fallows, crop income, goats, number of years growing food crops and off-farm income.

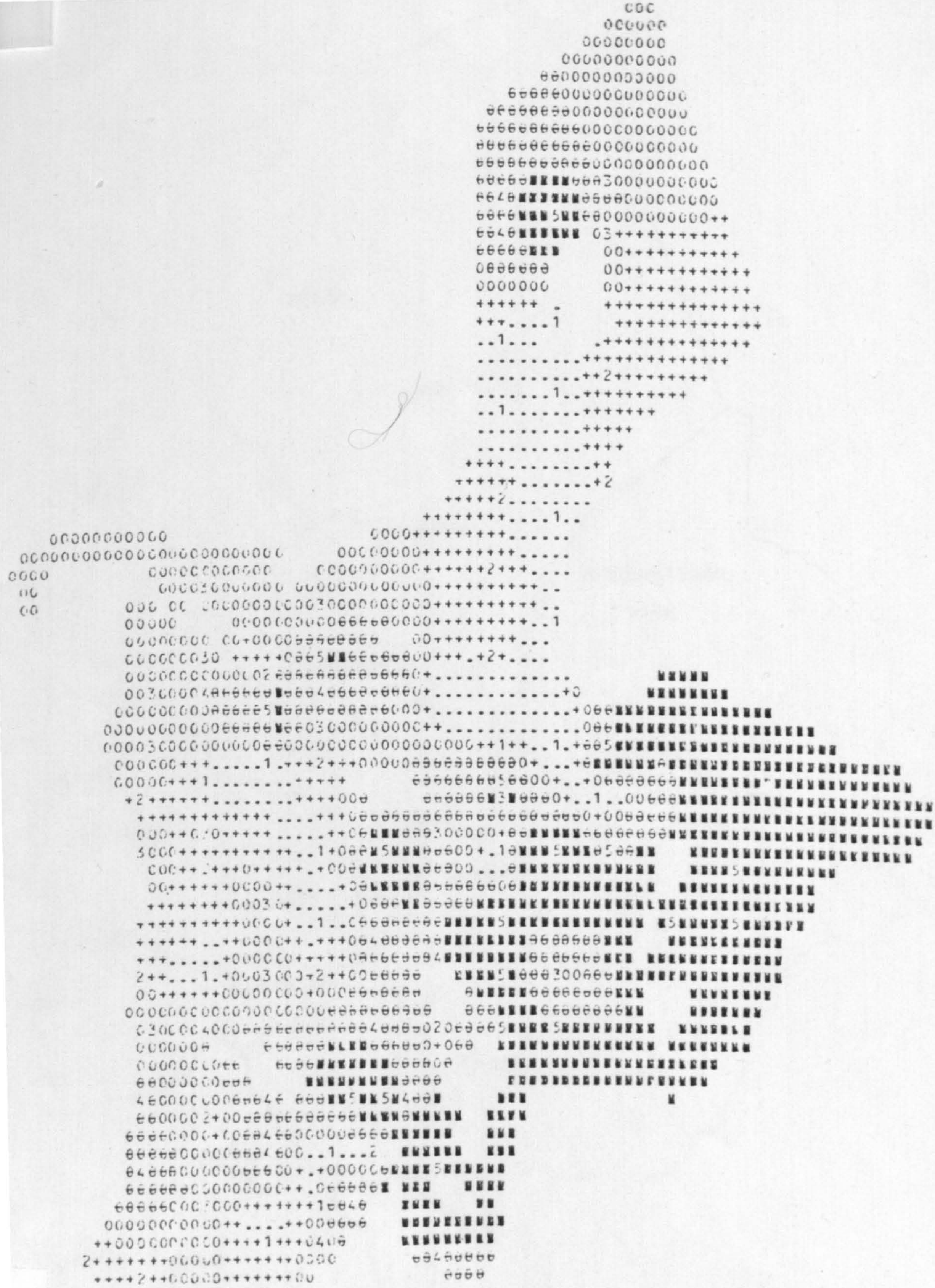


FIGURE 7.5 GROUND SURVEY - COMPONENT TWO

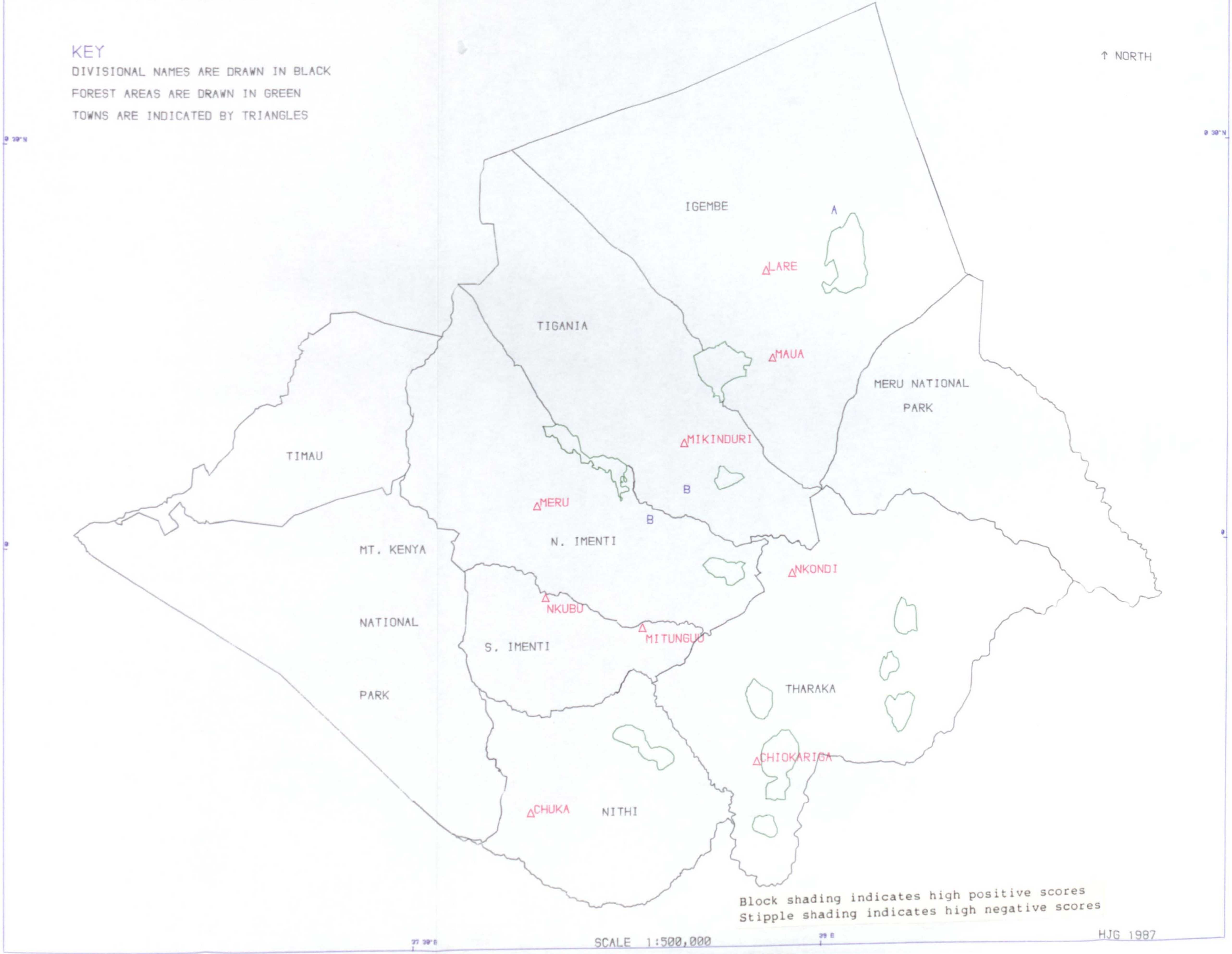
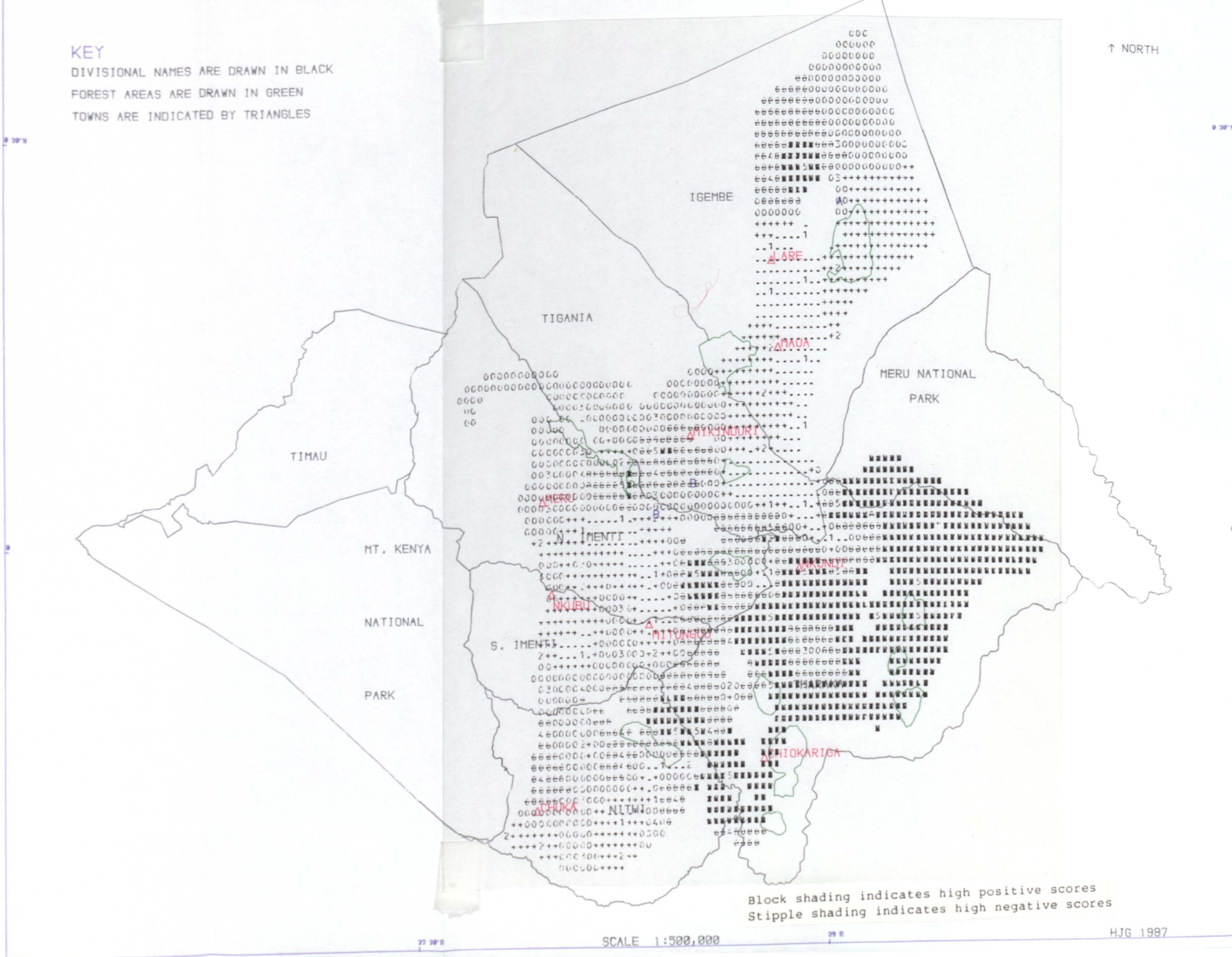


FIGURE 7.5 GROUND SURVEY - COMPONENT TWO



These weightings imply that although the region is perhaps primarily a livestock-rearing area, crop farming is still important within the farming system. A mid range value on the variable off-farm income also implies that farmers in this area rely on other sources of income to support their families apart from that accruing from crop and livestock farming. There are however two other groupings which are defined by this component but which are spatially distinct from the main livestock-rearing zone (indicated by A and B on Figure 7.5).

Area A to the north of the district is associated with the livestock zone mainly on account of the variable local cattle, although like some of the sample points in the livestock zone it also has a high weighting on the variable crop income. However, this area is within the main miraa-growing region and should be included with similar sample points from the area since it has a higher weighting for the variable miraa (ground component six). Area B to the north-west of the livestock zone although less distinctive, has high values on the variables local cattle, livestock income and crop income. It represents an area with mixed crop/livestock farms and where *both* represent an important source of income to the farm household. In this respect it is similar to the farms identified by component three and should be associated with these farms (see below). 9% of the total variance is accounted for by this component.

The third component accounts for 9.5% of the total variance (Figure 7.6). None of the original variables have particularly high positive or negative loadings, and although the variables miraa and number of farms have the highest positive values, the

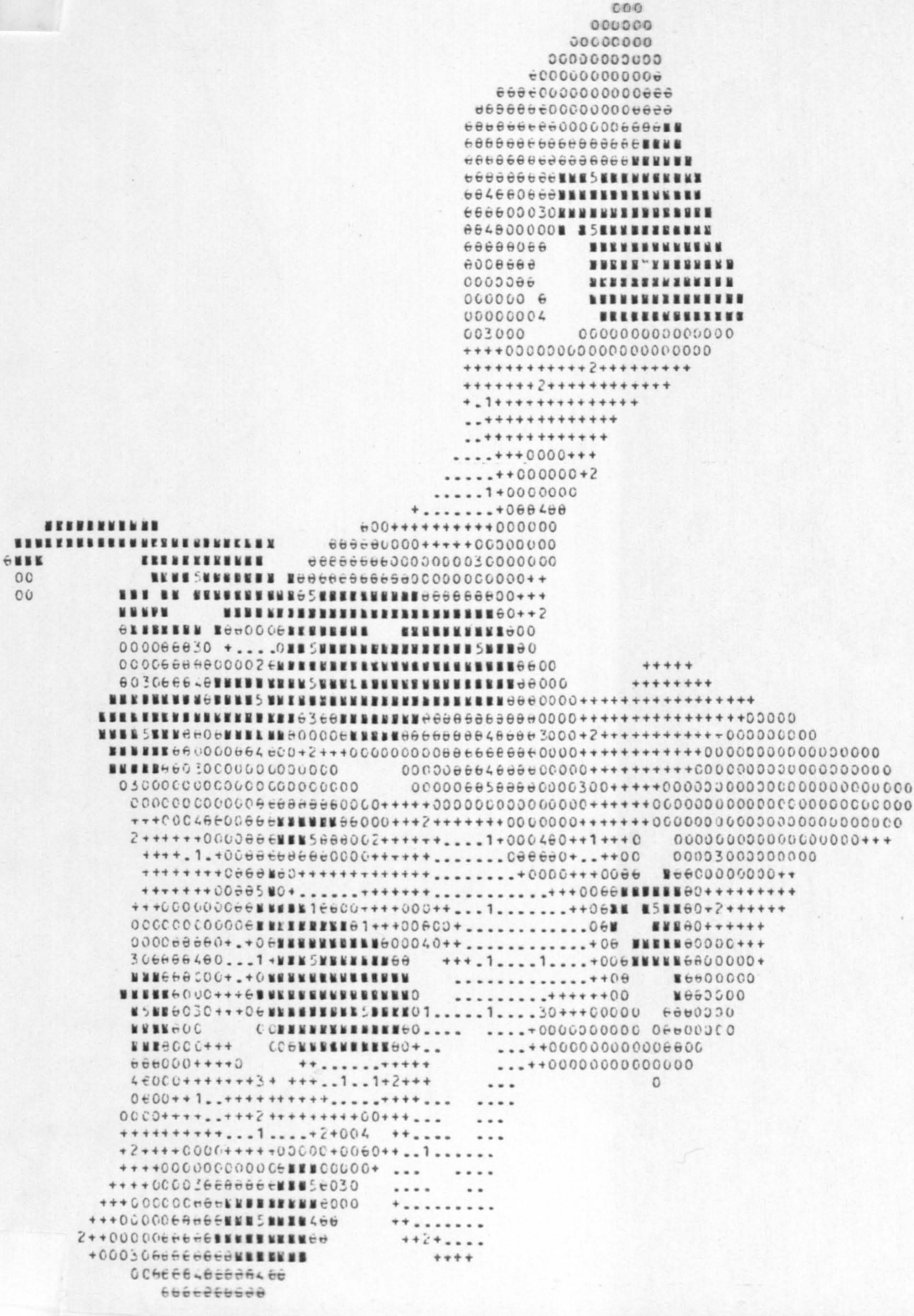


FIGURE 7.6 GROUND SURVEY - COMPONENT THREE

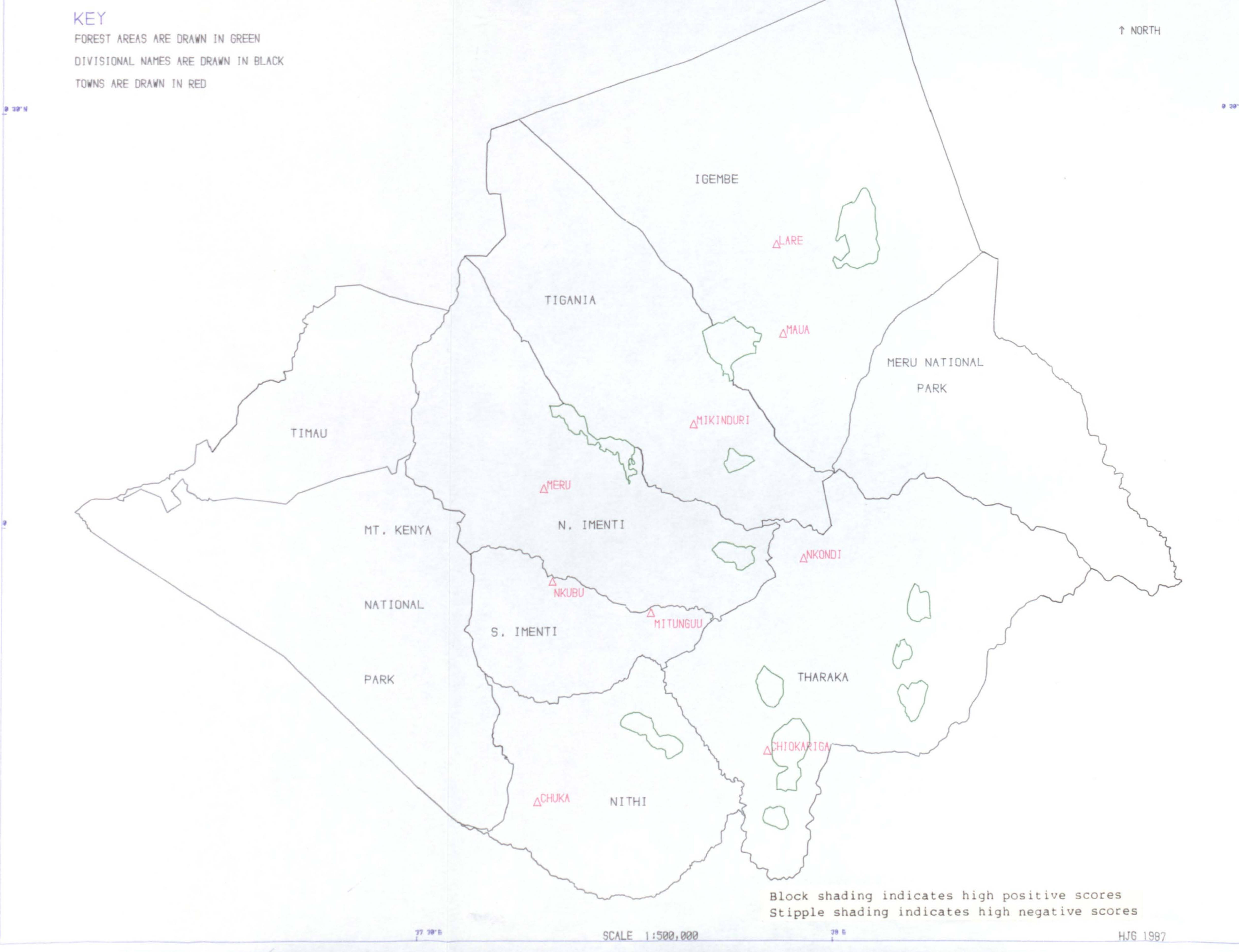
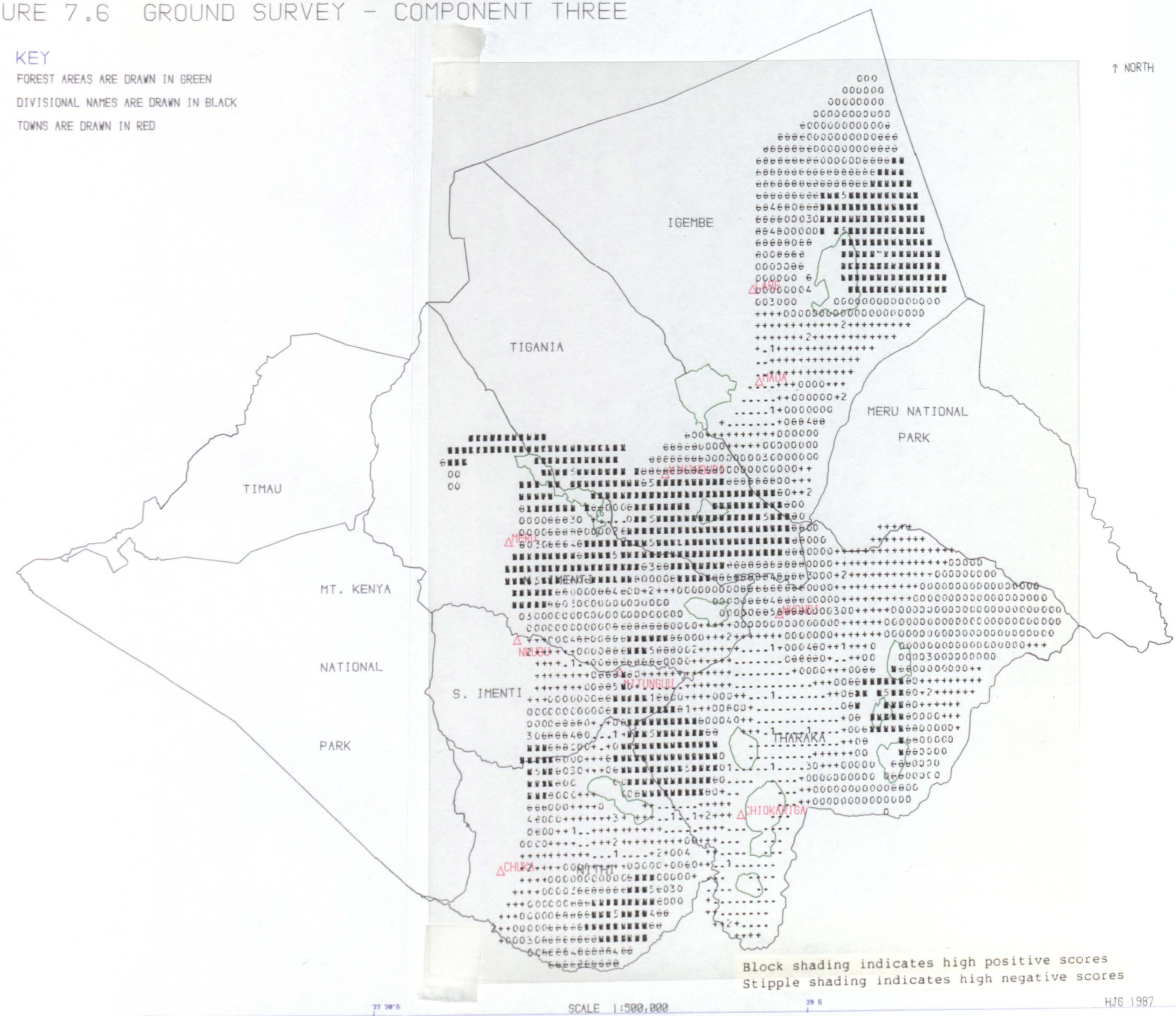


FIGURE 7.6 GROUND SURVEY - COMPONENT THREE



miraa-growing area in the north of the study region is not distinguished. One reason for this may be due to the fact that field investigations showed miraa to be often intercropped with other crops in the same field, and as a result in the farm survey miraa was categorised as a crop complex. In the air surveys it was more difficult to identify such complexes, and miraa was more often classed as a pure crop. In the analysis presented here the variable miraa (for both the ground and air surveys) includes only pure stands of this crop, which may explain why the quite distinctive characteristics of the miraa-growing area have not been emphasised by this component.

On examining the raw data from the ground survey it becomes clear that this component is picking out mixed farm groupings where both livestock and crop activities are contributing significantly to the farm household income. In the original data set approximately 72% of the sample farm clusters also have high values for the variable off-farm income, suggesting that farmers in these groupings have important alternative sources of income quite apart from their traditional crop and livestock activities. Most of this income is derived from the sale of honey although two farmers owned small businesses (livestock buying/selling and a beer shop).

Three variables have significant loadings on the fourth component; these are: number of years growing food crops, off-farm income and livestock income (Figure 7.7). The variable number of years growing food crops, is the only variable with a high positive loading. The Nkondi area is easily distinguished in the central region of the study on this component, as it was on

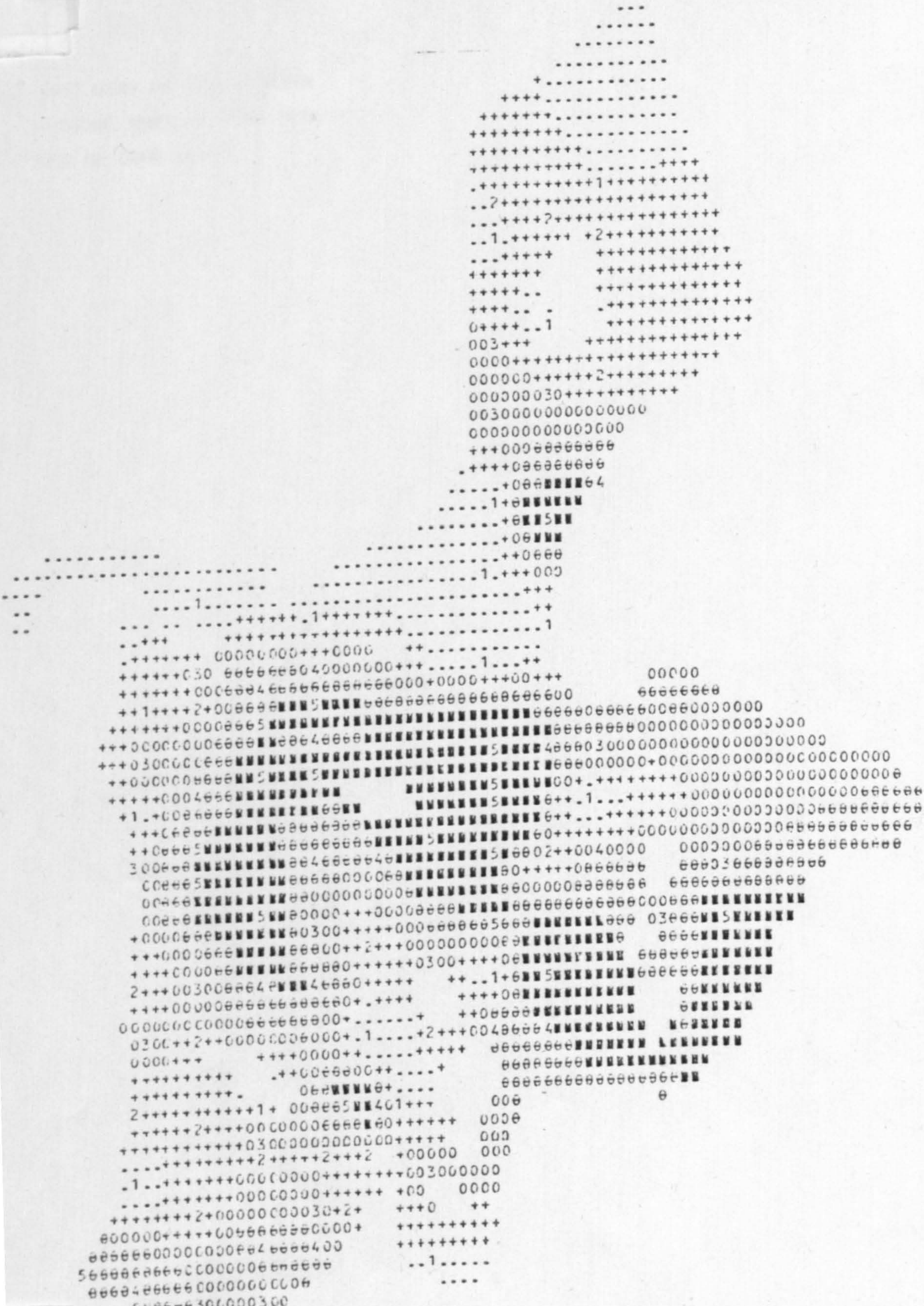


FIGURE 7.7 GROUND SURVEY - COMPONENT FOUR

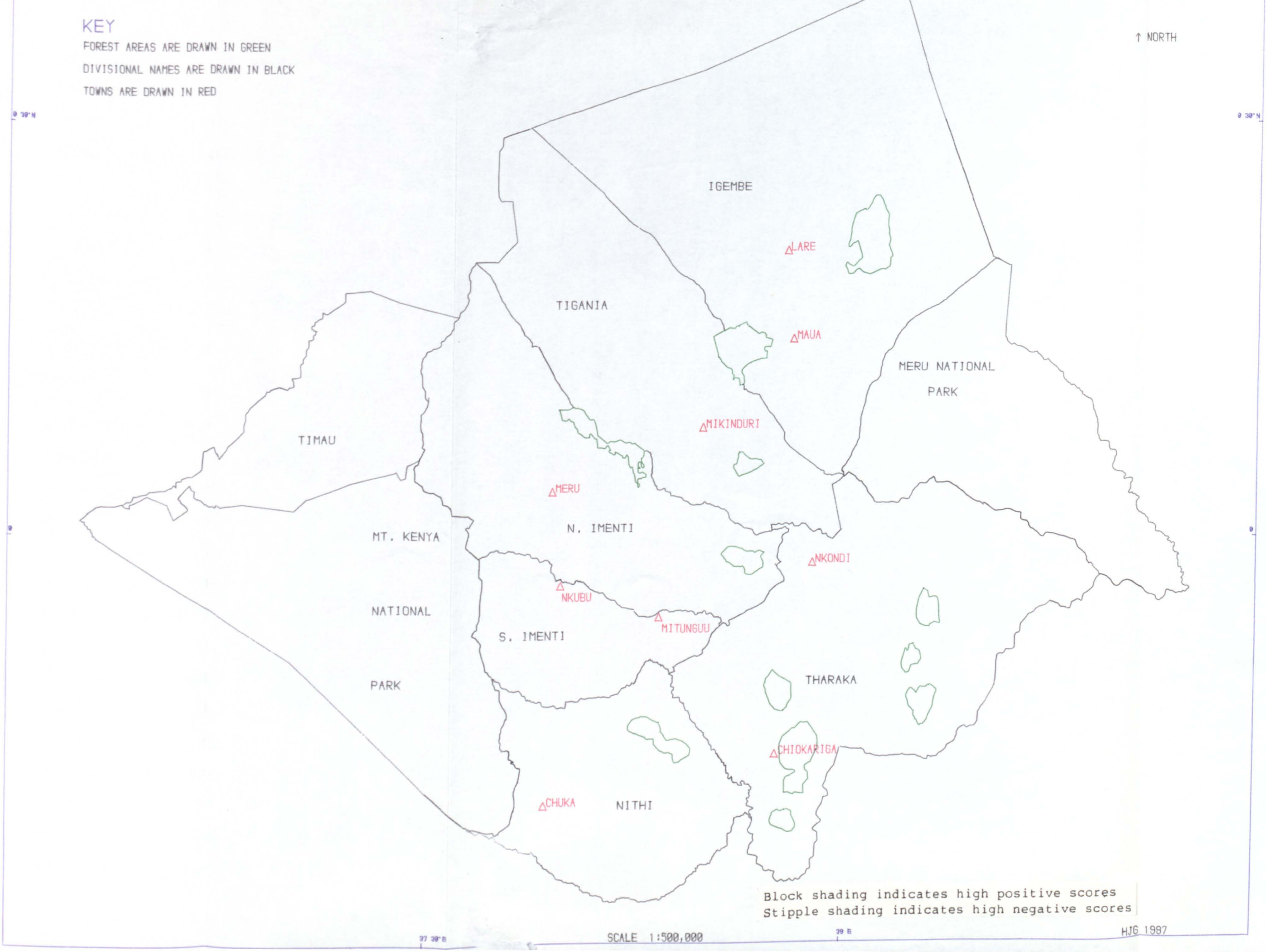
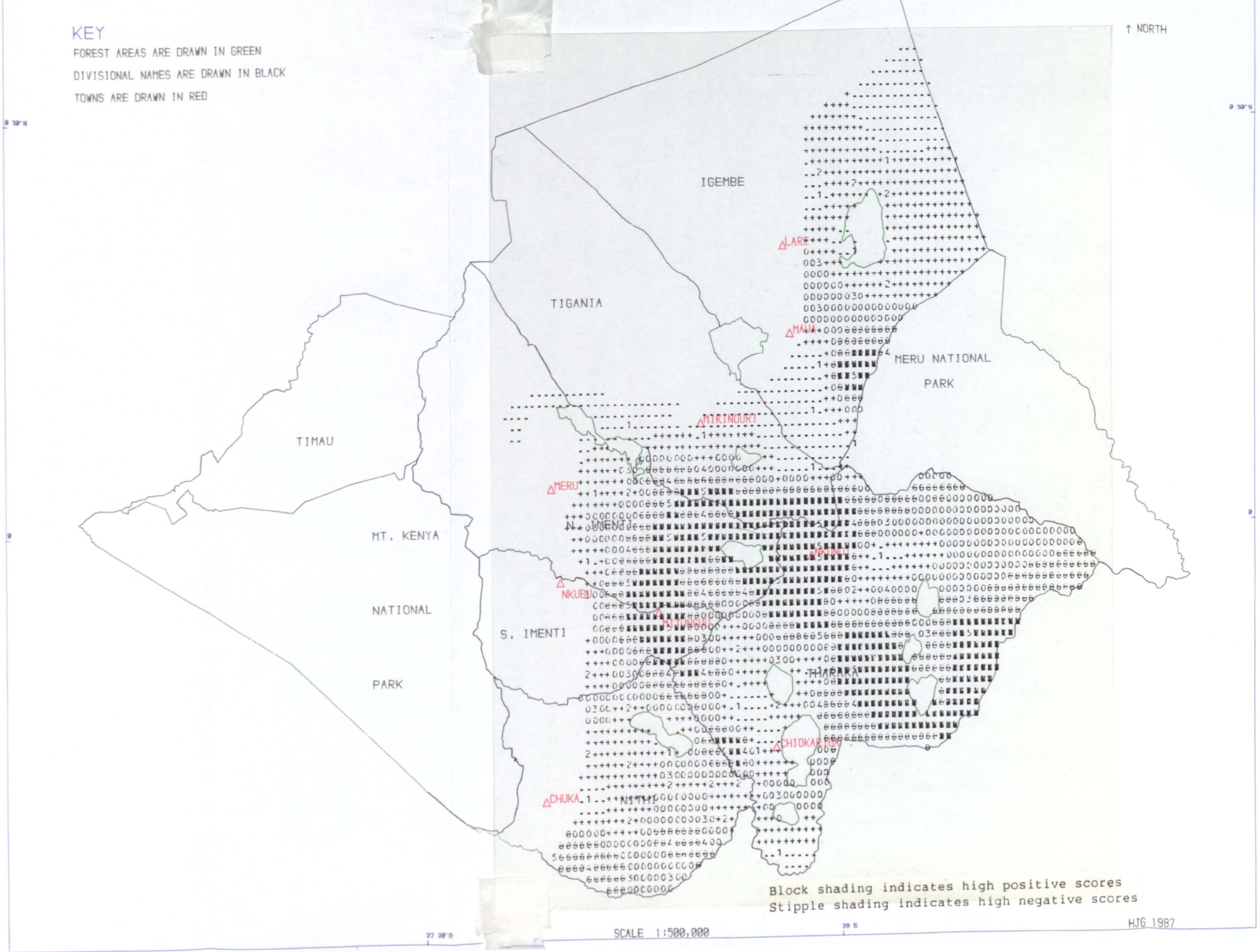


FIGURE 7.7 GROUND SURVEY - COMPONENT FOUR



component three of the air survey data. The fact that the component has a high loading on the variable number of years growing food crops suggests the Nkondi area is an important food growing region. It should also be observed however that the variable cotton had a significant loading on component three of the air survey (which helped to distinguish the Nkondi area from the surrounding farmland), and suggests that cash crop cultivation is important in this region as well. This fact is confirmed when the original ground survey data are examined. 94% of the farms are identified to have cotton growing on them (pure and mixed stands). The groupings on Figure 7.7 appear to be showing the important cotton and food crop growing areas although the variable cotton does not have a high loading on the component.

Figure 7.8 shows the scores for component five. The distribution of weightings across a number of the original variables makes interpretation of the spatial pattern difficult. The original data were examined to help provide an explanation for the observed patterns yet no particular trends in the data were noted. Some of the sample farm clusters had already been associated with groupings on one or more of the previous components and it was decided these could not be reallocated to new groupings. The remaining sample farm clusters appear to represent a transition between the coffee-growing areas to the west and the cotton and livestock-rearing zones in the east. Results of a multiple regression analysis which was performed on the data (Table 7.8 below) in order to identify any important relationships between the two sets of components confirm this interpretation. The component is not significantly correlated to any of the three air components at the 0.05 level. The variance

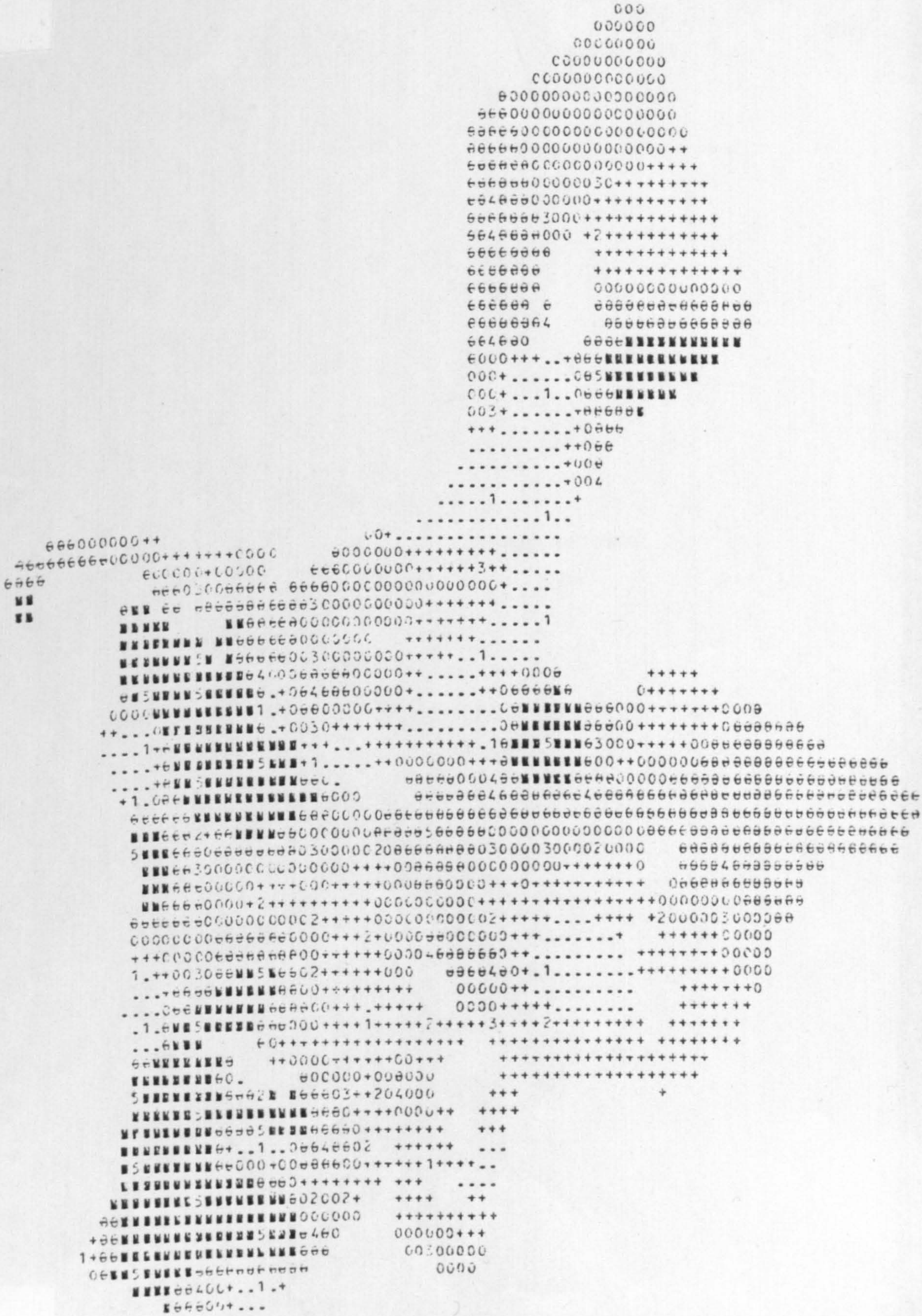


FIGURE 7.8 GROUND SURVEY - COMPONENT FIVE

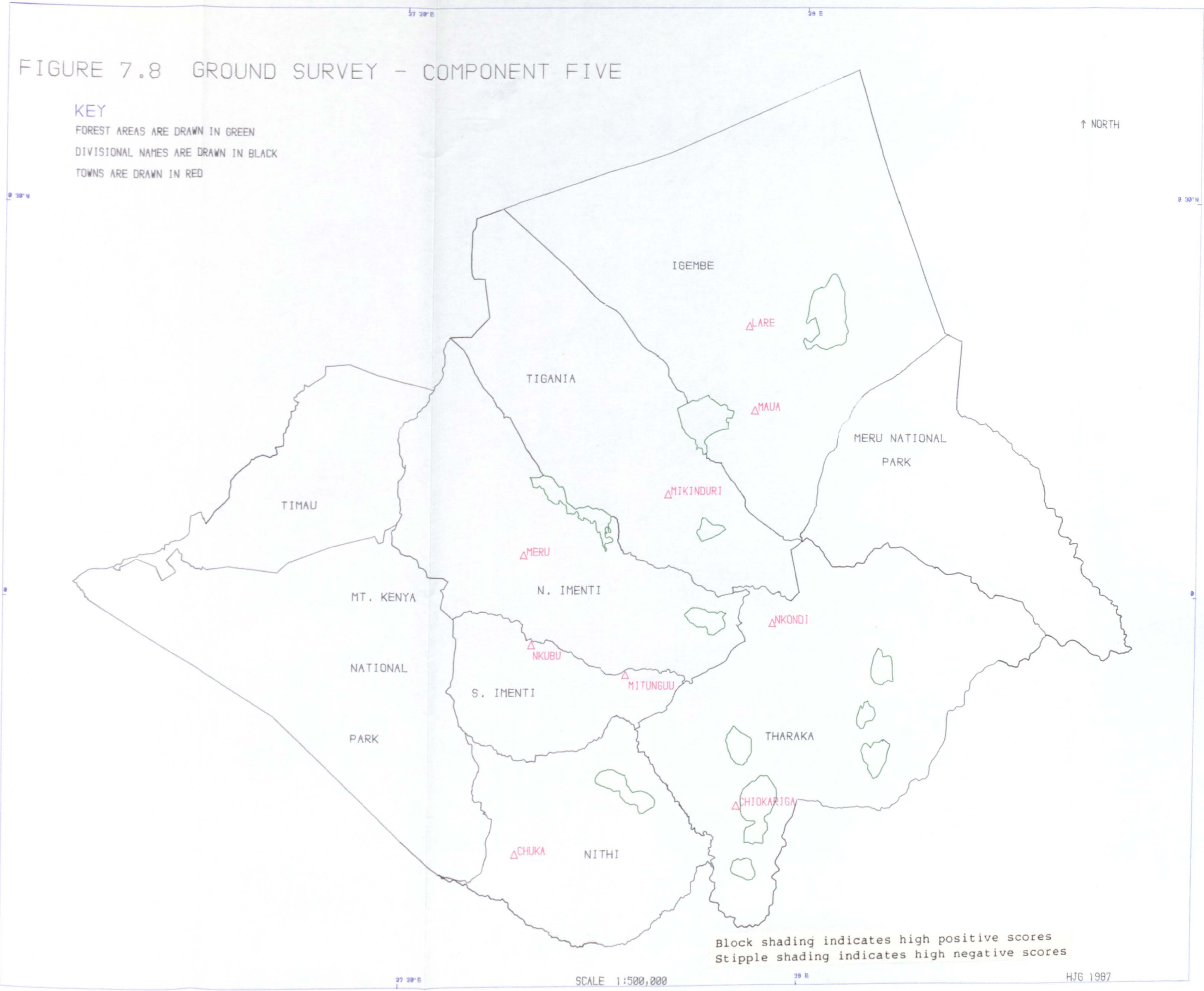
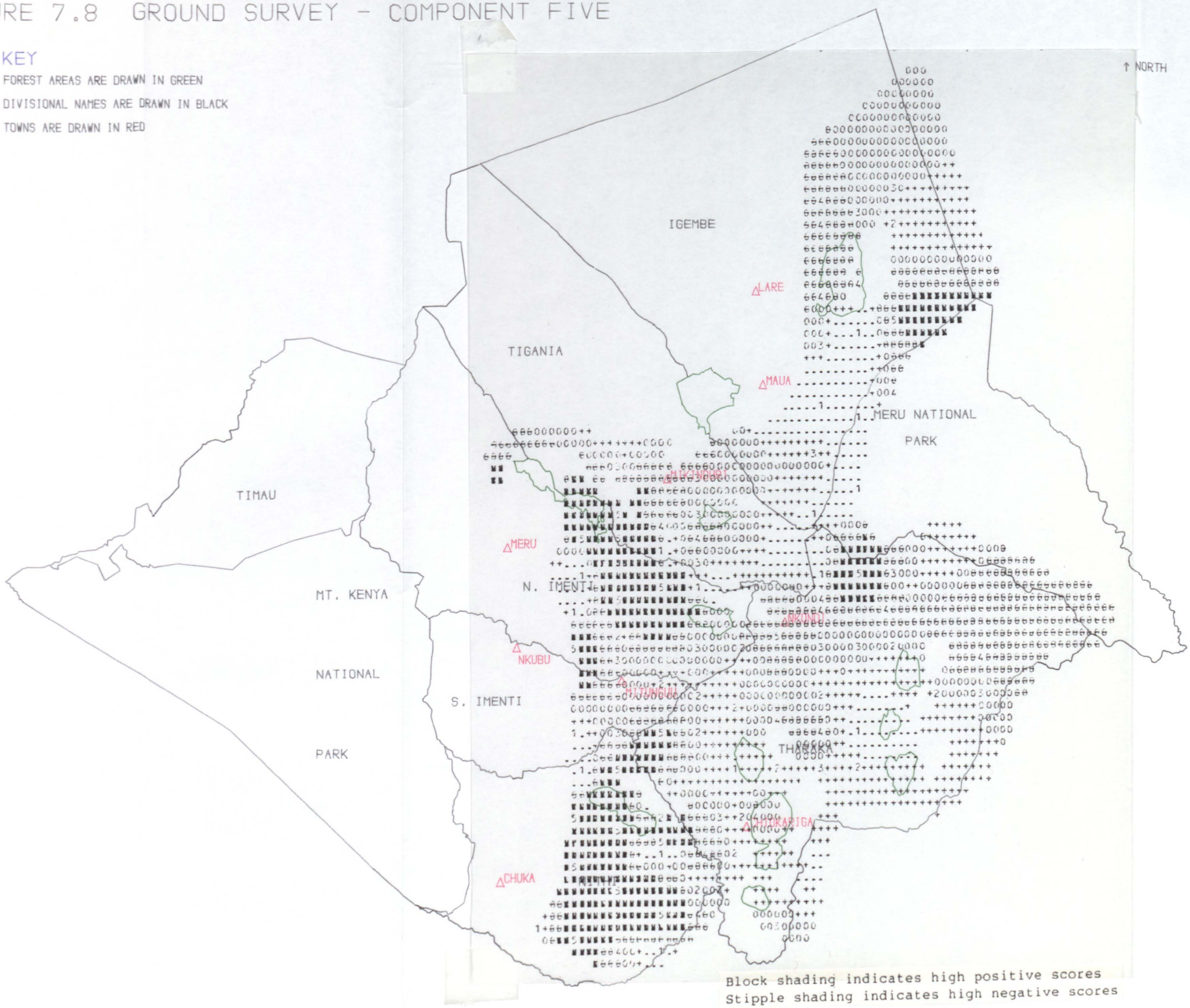


FIGURE 7.8 GROUND SURVEY - COMPONENT FIVE



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accounted for by this component is small and is only 7.3% of the total.

The last component derived from the ground data accounts for 6.0% of the total variance (Figure 7.9). The most significant variable, with a high positive loading is, number of farms. Like component two of the air survey data, this component clearly distinguishes the main miraa-growing area from the rest of the study region. It is significant that both data sets have distinguished this northern zone although this distinction has been made using different variables. However, both these variables (miraa and the number of farms) are important and define the key characteristics of this part of the district. Farms of the area are generally small, with each farm household often owning more than one farm. Typically most farmers also cultivate some miraa, this being one of the main cash crops in the area (tea and coffee are also important).

This section of Chapter Seven has shown that new summary variables (components) can be used to identify areas of relative homogeneity within the smallholder agricultural farming systems of lower Meru. Spatial variables from a combined data set derived from three air surveys have been used to define areas of relative agricultural homogeneity. Variables which include both spatial crop characteristics and more detailed livestock and farm income information from the ground survey have been used in a similar manner. However, although there is general conformity between the major spatial farming patterns which have been identified using these two different data sources, several dissimilarities have also been noted.

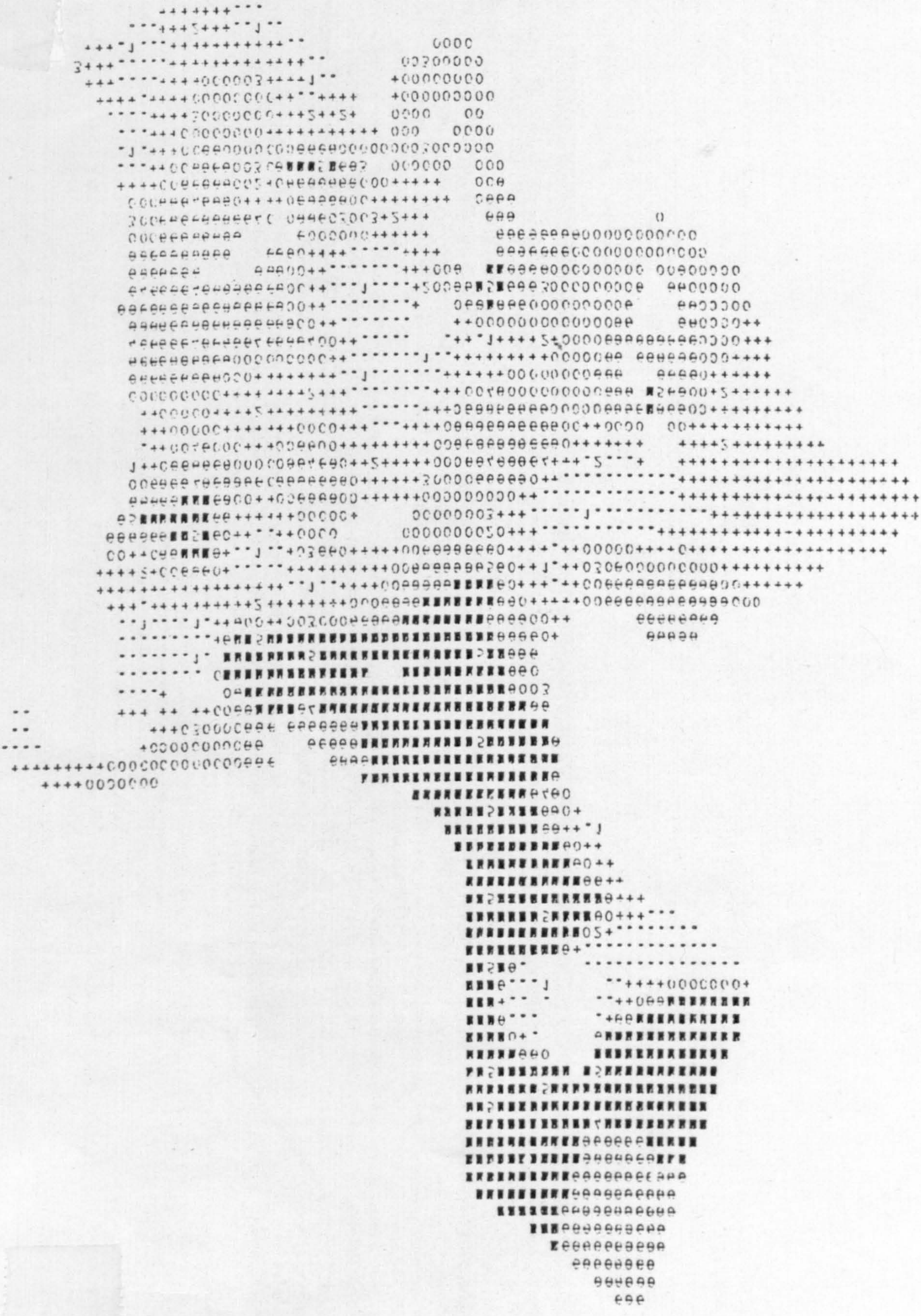


FIGURE 7.9 GROUND SURVEY - COMPONENT SIX

KEY

FOREST AREAS ARE DRAWN IN GREEN

DIVISIONAL NAMES ARE DRAWN IN BLACK

TOWNS ARE DRAWN IN RED

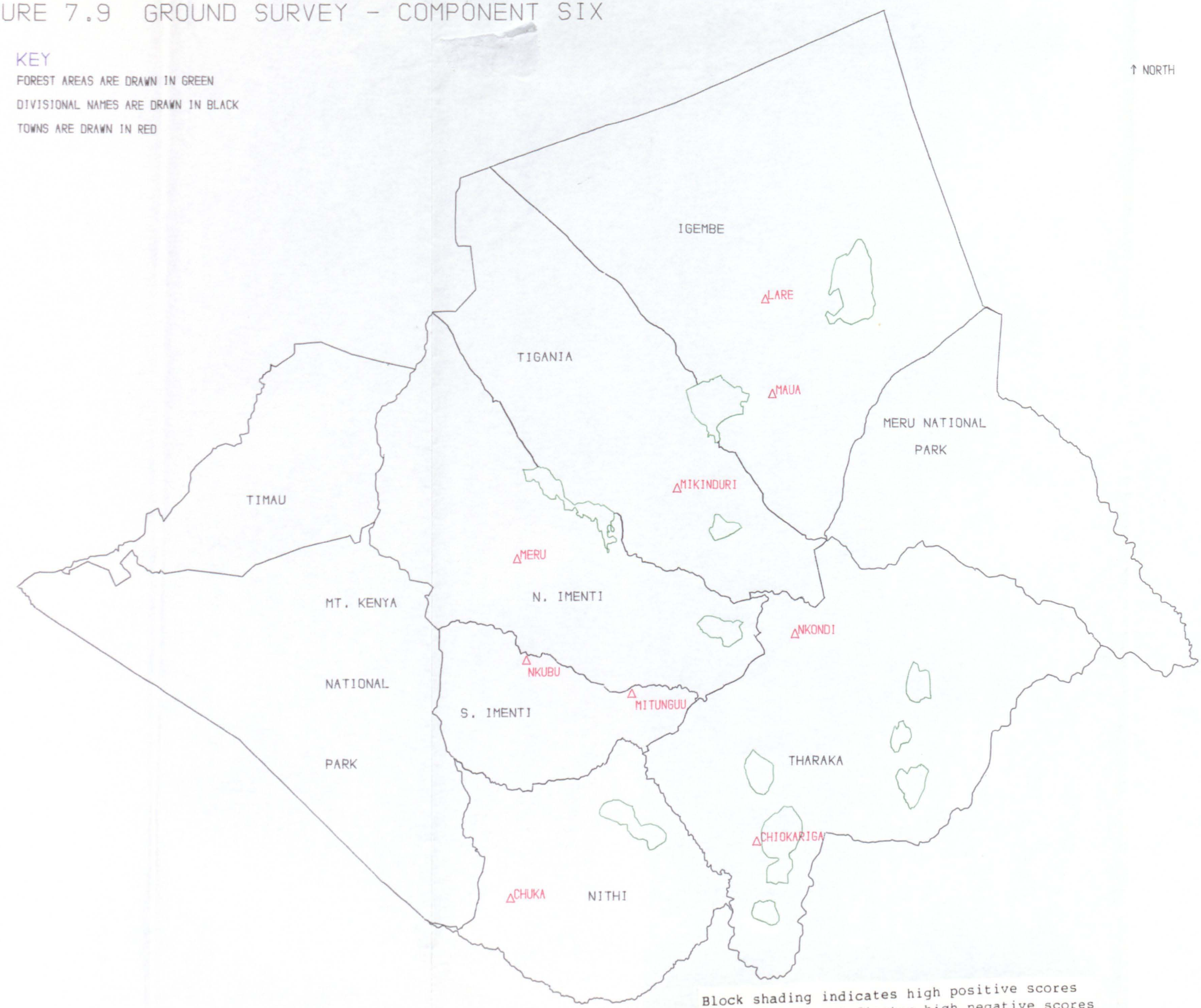
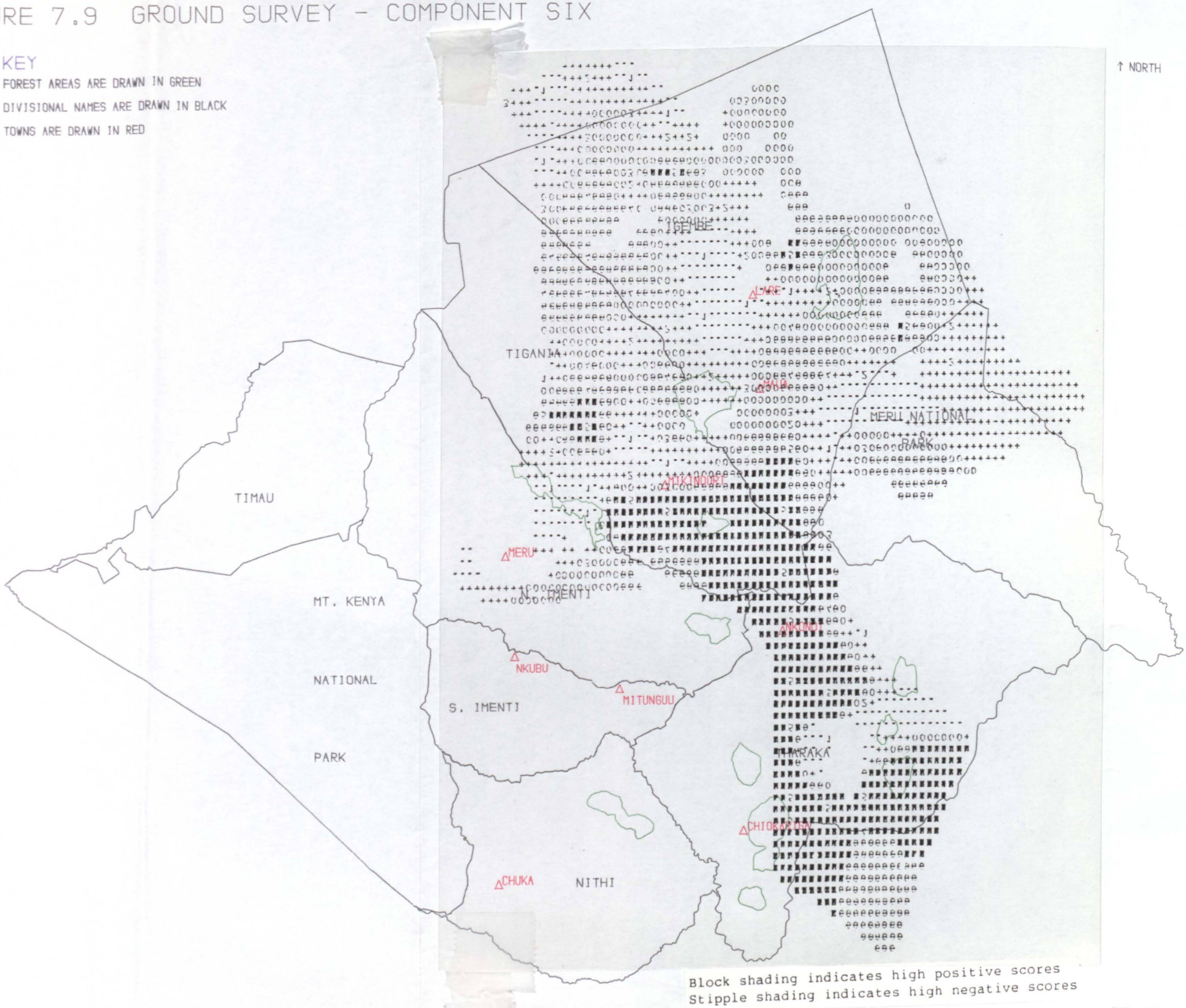


FIGURE 7.9 GROUND SURVEY - COMPONENT SIX



It is clear that analysis of the ground data has identified more detailed farming patterns than was possible when using the air survey data. In many instances these distinctions are made on the basis of farm income variables (crop, livestock and off-farm income) which suggests that income is an important parameter in helping to distinguish between farming systems in lower Meru. In both analyses it has been observed that the components do not always identify distinctive areas and some overlap may occur. Field verification to check on areas of overlap can be carried out where necessary.

Using the components derived from both the ground and air surveys, Section 7.2 sets out to establish which spatial farming patterns are consistent over both data sets. These areas are then used to define AEGs in accordance with the main objectives of the study.

7.2 CANONICAL CORRELATION OF PRINCIPAL COMPONENTS

The previous section has described and discussed the significance of the principal components generated from the two data sources (ground and air). Figures 7.1 to 7.9 show the spatial farming patterns which have been identified from the foregoing analysis. In assessing which of these spatial groupings are most consistent and can therefore be used to define AEGs, the two component sets are related to one another. One method which can be used to do this is canonical correlation analysis.

There are now two sets of data composed of composite variables - principal components. In order to examine the relation between these, the components of the two data sets can be regressed against each other. The resulting correlations are used to decide which components, and therefore which patterns, are most similar.

Canonical correlation is a procedure for relating groups of inter-related variables. The basic principles are the same as in principal components analysis. The data comprise a set of observations for each of which measurements are available on the two sets of variables (components). From a correlation matrix of these variables orthogonal canonical vectors are extracted so as to maximise the correlations between the two sets of variables. Each subsequent vector is similarly located among the residual correlations (Johnston, 1978). The correlations between two variables are known as canonical roots which are interpreted like correlation coefficients.

Using the MANOVA procedure in the SPSSx computer package (SPSS Inc, 1986) correlations between both sets of variables were computed. Because the canonical vectors are orthogonal, problems of interpretation arising as a result of collinearity between variables is eliminated. It should be remembered however that the variables (components) used here are composites of a number of the originally intercorrelated variables. Canonical correlation analysis is concerned with *three* sets of inter-relationships, two within-group relationships and one between-group relationship (the canonical equation relates one set of inter-related predictor variables to another set of inter-related criteria variables). When the sets of variables are composed of principal component scores the within-group relationships are destroyed. This is because each set of scores comprises mutually orthogonal vectors.

Johnston (1978, p.197) argues this can lead to misleading results since:

> "because within each set all of the variables are orthogonal, then only one variable in each set can have a high canonical weight on any one vector."

In order to overcome this possible limitation a separate multiple regression analysis was also performed on the two component sets to establish the significant relationships between them. These results are discussed below in Section 7.3.

In carrying out canonical correlation analysis the components generated from the ground data set were used as the dependent variables, and the components generated from the air data set as the covariate variables. Table 7.7 shows the resulting statistics.

TABLE 7.7

CANONICAL CORRELATION ANALYSIS

VARIABLE	CANONICAL VECTOR 1	2	3
GROUND 1	.84401	.23275	.16439
GROUND 2	-.35964	.02411	.58089
GROUND 3	.03679	.14811	-.07590
GROUND 4	-.29997	.46026	-.62856
GROUND 5	.15439	.52777	-.11598
GROUND 6	.20768	-.65797	-.47037
AIR 1	.91094	.25952	-.32067
AIR 2	.12364	-.91670	-.37998
AIR 3	-.39824	.30602	-.86473

GROUND indicates components generated from the ground survey data, AIR indicates components generated from the air survey data.

There appear to be three main correlations in the above table which show the groupings which are strongly correlated to each other: on canonical vector one, ground component one and air component one; on the second canonical vector, ground components five and six and air component two and, on the third canonical vector, ground components two and four and air component three.

These three correlations are generally what we would expect, and can be explained by the weightings of the original variables on the principal components derived from the ground and air surveys. The correlations strengthen the validity of the interpretation given to the results of the principal component analyses undertaken in Section 7.1. Component one of both the data sets reflects high values for complementary categories. Thus the variables: grade cattle, coffee, maize and number of years growing cash crops, on the ground data overlap with and, in the case of coffee and maize are duplicated by the variables: maize, altitude, percentage of land under cultivation, and coffee from the air survey.

Ground component six has a high positive loading on the variable number of farms and a reasonably large positive loading on the variable beans. On the second air component however the variable miraa has the highest loading followed by the variable improved grazing. It has already been observed that two important characteristics of the northern area of the district - the area identified by these two components are; the small fragmented farm holdings and the cultivation of miraa as a cash crop. The correlation between these two variables appears to explain most of the relationship between the two components. The strong correlation of ground component five is difficult to explain and the problems of interpreting this component have already been mentioned in Section 7.1.

Component four of the ground survey data set has highest loadings on the variables: years growing food crops, off-farm income and livestock income, although the latter two variables are negatively weighted. Component three of the air data set has highest loadings on the variables: fallows, cotton and coffee with the latter being negatively weighted. Interestingly the variables which are common to both data sets (coffee, cotton, beans, miraa and maize) do not appear to be contributing much to the strength of this correlation, although the Nkondi farming area is picked out by both components. As observed earlier (Section 7.1) an examination of field notes taken during the farm survey for this area revealed that it is both an important food and cash crop growing region. It would appear that identification of this particular farming system is possible by using variables which measure either one of these characteristics.

The second ground component is also correlated to the third canonical vector (positively, in contrast with ground component four and air component three) which can be explained by the fact that this vector appears to be distinguishing the lower, drier, agricultural land areas in the south and east from the northern and western areas of the study region. Nkondi in particular is excluded from the drier zone.

7.3 REGRESSION ANALYSIS ON THE PRINCIPAL COMPONENTS

Assuming the preceding principal components analyses have not identified simple structure (Section 7.1 - if this were the case the interpretation of the canonical vectors may be more straightforward) it is necessary to clarify other possible significant correlations between the ground and air components. To do this a multiple regression analysis was performed on the data. The results were tested for significance at the 0.05 level using the t statistic. Table 7.8 shows the values of t for the dependent (ground survey) and covariate (air survey) variables (components) resulting from this regression analysis.

TABLE 7.8

REGRESSION ANALYSIS - GROUND AND AIR COMPONENTS

AIR COMPONENTS	GROUND COMPONENTS 1	2	3	4	5	6
1	.000 *	.000 *	.566	.363	.035	.171
2	.455	.150	.566	.070	.019	.000 *
3	.000 *	.433	.707	.000 *	.430	.835

* significant at the 0.05 level.

The table shows that component one from the air data set is significantly correlated with both component one and two of the ground data set, while component three from the air survey is correlated with both component one and four from the ground data set. Two other significant correlations are revealed: between component six of the ground survey and component two of the air survey, and between component four (ground survey) and component three (air survey).

The results above reveal two new correlations in the data set which were not apparent from the canonical correlation analysis results. Both of these can be explained with reference to the component loadings on the original variables of the principal components discussed in Section 7.1. To recall, it was mentioned in Section 7.1 that component one of the air data set appeared to be identifying two main farming systems in the study region - the marginal coffee zone to the west and the dry livestock-rearing zone in the east and south. This is confirmed by the regression analysis where this component is found to be significantly correlated to both components one and two of the ground survey. Component one of the ground survey is identifying the marginal coffee zone, while component two is identifying the livestock-rearing zone.

The second new association is between component three (air survey) and component one (ground survey). Figures 7.3 and 7.4 show the spatial farming patterns derived from these two components. While it is true that there are obvious differences between these two figures there is some conformity along the eastern margin of the marginal coffee zone (the central-west area of the study) and in the Nkondi area. However, unlike the correlation between component one (air survey) and component two (ground survey) the relationship between these two components does not define a new spatial grouping, since the area of consistency on the Figures (7.3 and 7.4) is not very great.

Using the results from the canonical correlation and multiple regression analyses the maps of the two component sets were visually compared (Figures 7.1 to 7.9), and the significant

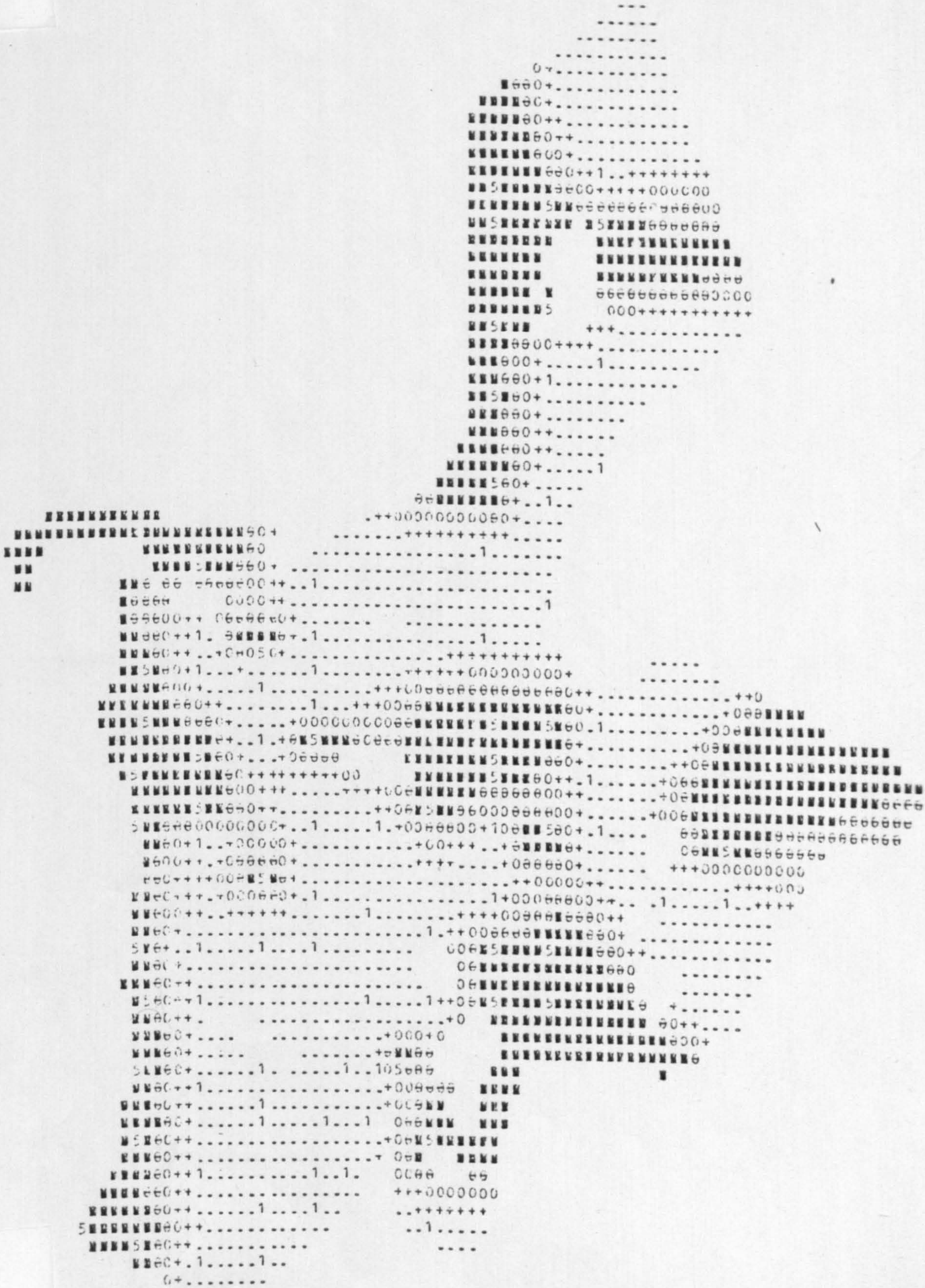


FIGURE 7.10 AGRO-ECONOMIC GROUPINGS IN LOWER MERU

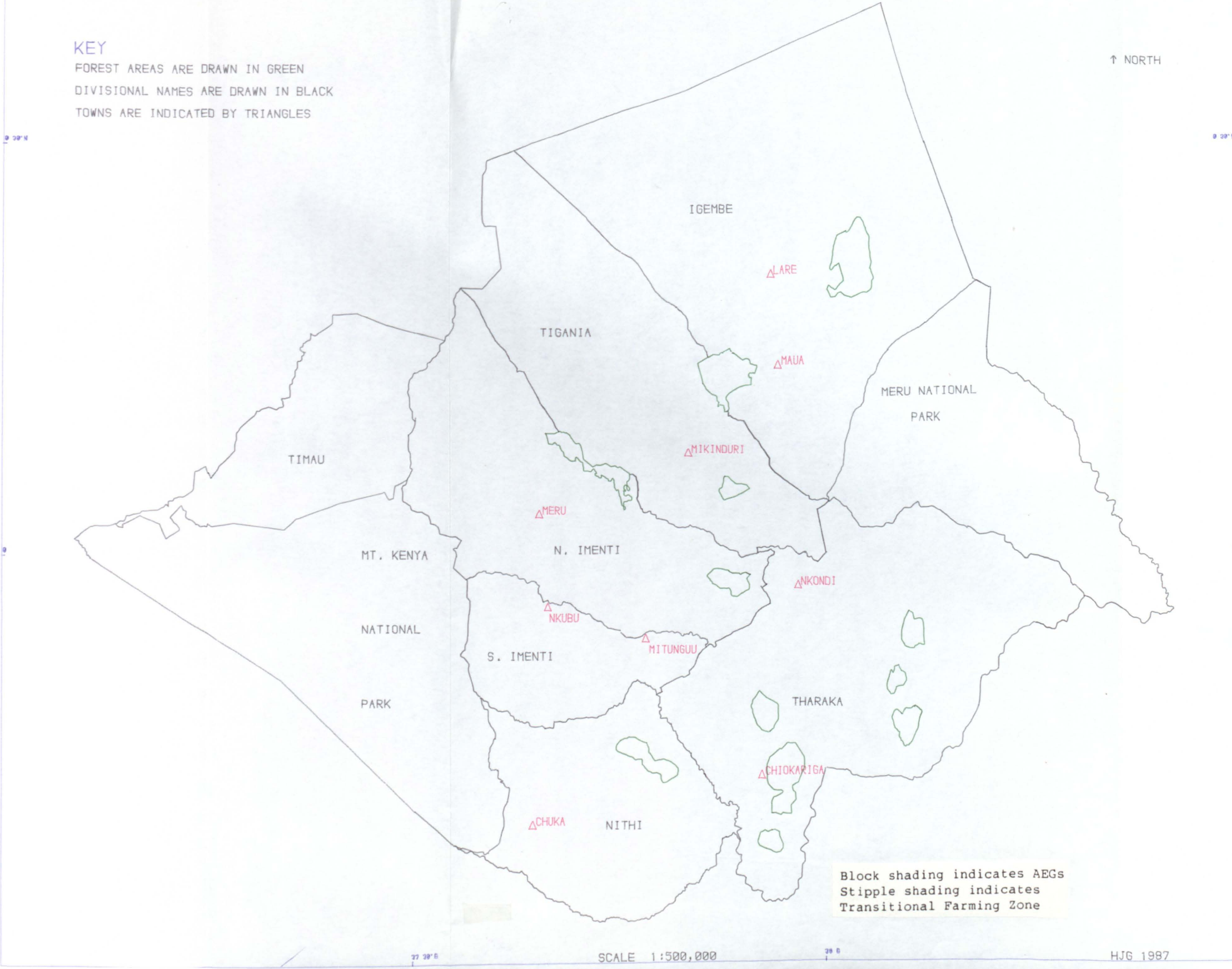
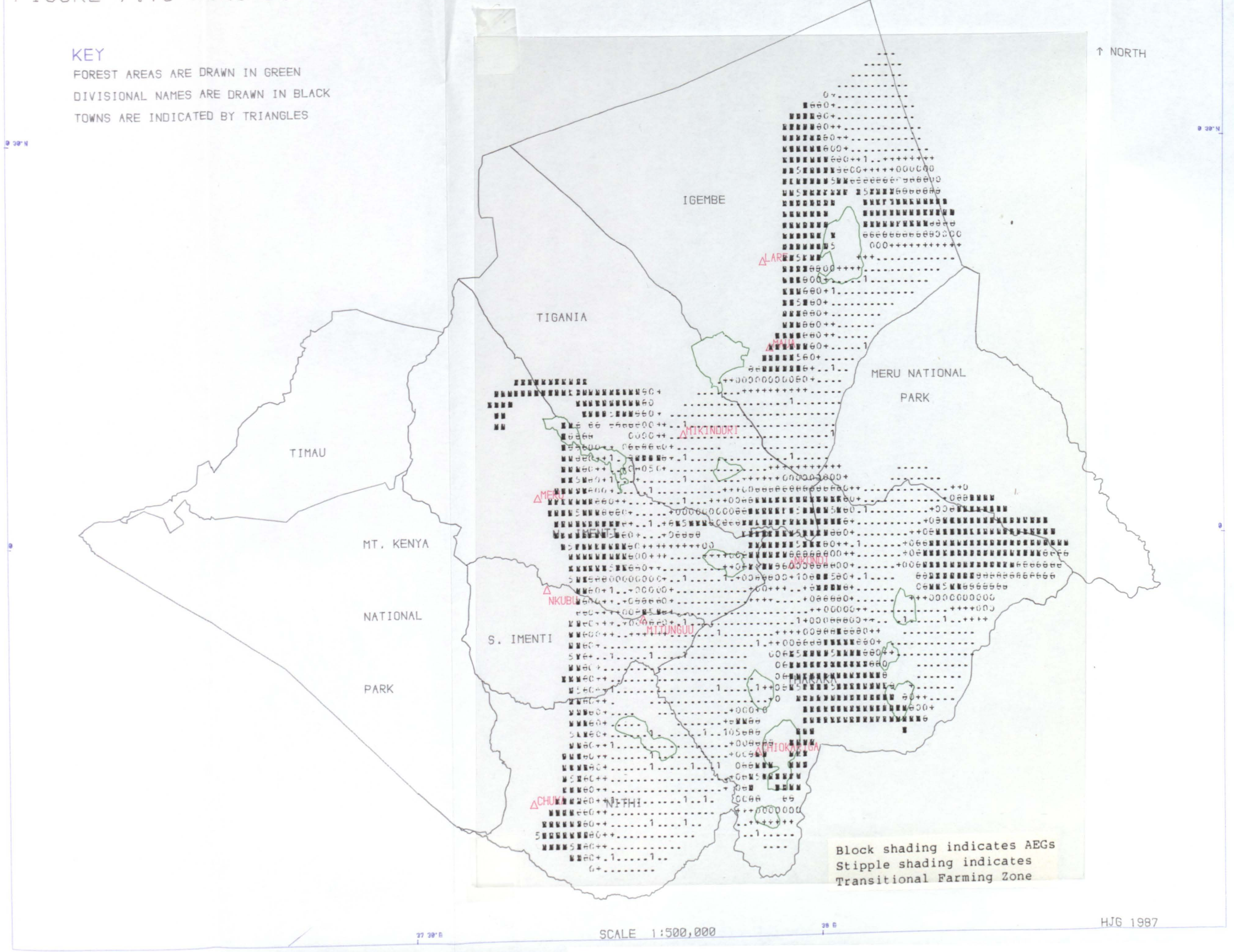


FIGURE 7.10 AGRO-ECONOMIC GROUPINGS IN LOWER MERU



spatial relationships between the two were identified. Conformant and non-conformant spatial areas were established. For each of the identified correlations the respective component score maps were overlain onto each other. All sample points (88 in total) falling within the same quantile range (i.e. having the same symbolism) over both data sets were allocated to the same grouping. Such groupings were designated to be AEGs. These areas were considered to be relatively homogeneous agricultural groupings with distinctive farming systems.

All sample points falling into different quantile ranges over the two data sets were allocated to a floating group. Unless such points later became included in a subsequent AEG they remained in the floating group. After defining all four AEGs, the remaining sample points (i.e.the floating group) were included into a new fifth grouping (the transitional farming zone). Areas which were consistent over both data sets were considered to be the most stable, and it was presumed that these were also the most homogeneous internally. Figure 7.10 shows the distribution of AEGs within the study area.

To summarise, four main groupings have now been defined. These relate to the areas which are consistent over both data sets. The consistent areas are called agro-economic groupings (AEGs). The first AEG has been defined by the relationship between the first two components of the data sets, it represents the intensively farmed marginal coffee zone. The second AEG has been defined by component one (air survey) and component two (ground survey), it represents the dry livestock-rearing and bush fallow cultivation zone and is sub-divided in two. The third AEG is represented by components six (ground survey) and two (air survey). This is the miraa-growing region to the north of the district. The final AEG is defined by components four (ground survey) and three (air survey). This covers the quite distinctive Nkondi farming system and other important food and cash crop growing areas to the west of Nkondi (one of these includes the Mitunguu area).

The reader is reminded that AEGs have been defined on the basis of the farming patterns that have been consistently observed between both the ground and air data. Some of the more complex farming patterns identified using the ground data have therefore been excluded. The reliability of the identified AEGs is however tested using individual farm data from the ground survey in Chapter Eight.

Areas which are not included in any of the above mentioned AEGs are defined as transitional, and include regions where it has not been possible to identify any significant internal consistency within the smallholder agricultural economy. The planning implications for such areas may well be different from the relatively homogeneous AEGs. Agricultural research and development initiatives will need to be considered here most carefully prior to any implementation. In subsequent discussion and analysis the transitional area is referred to as the transitional farming zone.

This section has established a procedure for mapping and identifying AEGs from complex crop and farm data. In the next section the internal homogeneity of the AEGs is examined. Individual farms falling within these groupings are input into a cluster analysis to examine the homogeneity of AEGs at farm level. The defined AEGs have been derived in part from averages at each ground sample cluster, each cluster being composed of between four and six farms.

7.4 EXAMINING THE INTERNAL STRUCTURE OF AGRO-ECONOMIC GROUPINGS

Using the 192 individual farms which were included in the four AEGs identified above (290 farms were included in the transitional farming zone), a cluster analysis was performed to examine the internal homogeneity of each AEG. Before undertaking such analysis however it was necessary to calculate a measure of dissimilarity between farms. This measure could then be used to differentiate between farms and to allocate farms to clusters. Sokal and Sneath (1973) have discussed various numerical methods for estimating the resemblance or dissimilarity between taxa or groups. One commonly used measure is the Euclidean distance, and this is adopted here. The Euclidean distance between two cases (farms) is the square root of the sum of the squared differences in values over n variables, and can be expressed by the equation:

$$D_{xy} = \sqrt{\sum_{i}^{n} (X_i - Y_i)^2} \qquad (7.1)$$

Where D_{xy} is the Euclidean distance, and X_i and Y_i are the values on each variable which are squared and then summed for any two cases.

To estimate the differences between cases the data are arranged in the form of a matrix and the differences between pairs of rows (farms) measured over a number of variables (17 in this case since this number of variables were originally used to distinguish between farm clusters using the ground data set - Table 7.2). Before computing the distance matrix the 17 variables were standardised to z-scores having a zero mean and unit standard deviation using the SPSSx computer software package (SPSS Inc, 1986). This was done in order to avoid any problems arising from gross differences in size of any of the variable values (Sokal and Sneath, 1973).

Using the SPSSx CLUSTER procedure, the Euclidean distance matrix (computed using the SPSSx PROXIMITIES procedure) for 192 farms was input into a hierarchical clustering algorithm using complete linkage or furthest neighbour methods to link clusters. The basic principles involved are as follows. A case (farm) is allocated to a particular group on the basis of its similarity to that cluster, defined as its similarity to the *farthest* member within the cluster. Thus when two clusters join, it is on the basis of the similarity that exists between the two farthest pair of members, one in each cluster (Sokal and Sneath, op. cit.). This method contrasts with single linkage or nearest neighbour clustering, where a case is allocated to a group on the basis of its similarity to the *closest* member within the cluster.

In the present situation it was considered to be more appropriate that farms should be grouped with other farms only if they were more similar to the most outlying members of this group than with respect to any other farm group. This it was felt would tend to maintain distinctions between clusters longer within the agglomeration procedure and therefore help to identify distinct groupings more easily. Results from the cluster analysis are shown below:

TABLE 7.9

NUMBER OF FARMS REMAINING IN ORIGINAL AEGs
CLASSIFICATION RESULTS FROM CLUSTER ANALYSIS

CLUSTER	AGRO-ECONOMIC GROUPINGS (AEGs) GROUP 1	GROUP 2	GROUP 3	GROUP 4
GROUP 1	49%	23.5%	34%	33.4%
GROUP 2	4%	41%	15%	22.2%
GROUP 3	27%	23.5%	46%	22.2%
GROUP 4	20%	12%	5%	22.2%
TOTAL FRMS	99	41	34	18

The table clearly shows that there is considerable variance within the AEGs at individual farm level although three of the AEGs remain quite distinct (groups one to three). The analysis was limited to a four cluster solution to enable a direct comparison to be made with the AEGs obtained from principal components analysis. The four cluster groups are therefore equivalent to the four AEGs.

AEG one (farms within the marginal coffee zone) is quite distinct from AEG two (farms in the livestock-rearing zone). 49% of farms within the marginal coffee zone remain in this group while only 4% of these farms are included in the second cluster group which represents farms in the livestock-rearing zone. 27% and 20% of farms are included in cluster groups (AEGs) three and four respectively for the first AEG. This demonstrates there are some similarities between these three original AEGs (AEG three represents the miraa-growing zone and AEG four represents the Nkondi and associated farming zone).

In AEG two, depicting the livestock-rearing zone, 41% of farms remain within this group although a significant number of farms are also associated with AEGs one and three (23.5% in both cases). Only 12% of farms from this AEG are included in the fourth cluster group. The classification of a considerable number of farms from AEG two with farms in AEGs one and three is somewhat surprising, and acts as a reminder that the smallholder economy of the study area is very heterogeneous. Although the AEGs defined in this study have been based on existing land use (i.e. farming systems) the above results demonstrate a need for relating AEGs to physical land qualities (agro-ecological zones) in order to define recommendation domains. This will help to distinguish between areas on the basis of farming systems *and* agricultural land potential. Clearly where farmers are recently settled in an area they are unlikely to have detailed knowledge about their environment. In such situations it would be unwise to emphasise the importance of existing farming systems (AEGs) over and above natural land potential (AEZs). Rather, both AEZs and AEGs should be used to define recommendation domains.

46% of farms in AEG three (the miraa-growing zone) remain in this grouping. 34% of farms are however included in the first cluster group which represents the marginal coffee zone. This finding is hardly surprising since both of these farming systems occur in regions with similar physical and economic resource bases. They are also the most densely settled areas within the study region and in both coffee is an important cash crop. To distinguish between these AEGs using light aircraft remote sensing will therefore be difficult.

AEG four, representing the Nkondi and associated region, is confirmed as the most internally variable, with a significant number of farms in each of the other three groups. In fact the most significant percentage of farms (33.4%) are included in the first cluster grouping (representing the marginal coffee zone). Analysis of the original data show that the Nkondi farms are grouped with other high income farms from the marginal coffee zone and explain this association. The results suggest that this AEG is not identifying a distinctive farming system and should not therefore be used in helping to define recommendation domains for agricultural research and development.

However, field experience suggested that the area depicted by AEG four was quite distinct with crop planting and farm management practices which differed from those in the surrounding farmland areas (Crop planting practices are related to differences in the use of technology and labour on farms (Norman and Collinson, 1985; Zandstra, 1980) and can be used to distinguish between different farming systems).

In order to test this field observation the four AEGs and the transitional farming zone were examined using data collected on crop planting methods (Section 4.2). Crop planting practices were examined initially to determine whether crops were planted in a random or ordered (rows) manner. From Table 7.10 it is clear that AEG four is quite distinct from the other AEGs and the transition zone with over 95% of crops in this AEG being planted in rows.

This finding confirms field experience that the farms around Nkondi are larger than many in the surrounding farmlands with tractors often being used for ploughing and with planting occuring along the plough ridges. AEG three is distinct from the other AEGs and the transition zone with nearly 70% of crops being planted in a random fashion. These figures show that there are real differences in the cropping practices between the farming systems identified by the AEGs, and that these groupings do reflect differences in the smallholder agricultural landscape.

TABLE 7.10

RANDOM AND ORDERED CROP PLANTING PRACTICES BY AGRO-ECONOMIC GROUPING (AEG)

AGRO-ECONOMIC GROUPING	PLANTING PRACTICE		NUMBER OF PLOTS
	ROW	RANDOM	
AEG ONE	208 49.6%	211 50.4%	419
AEG TWO	50 49.5%	51 50.5%	101
AEG THREE	50 30.7%	113 69.3%	163
AEG FOUR	140 95.9%	6 4.1%	146
TRANSITION ZONE	511 51%	489 49%	1000

One reason why it is difficult to identify discrete groupings in the smallholder economy (Table 7.9) using only pure crop stands (as in this analysis) may be due to the importance of intercropping across the study region and within individual AEGs. Owing to the resolution limitations of the January 1985 air survey (Section 6.3) it was not possible to include crop complexes in the analysis presented here. It is essential that in any future research work involving light aircraft remote sensing to identify recommendation domains, both pure crops as well as crop complexes should be included. Table 7.11 shows the percentage of pure crops and crop complexes (intercropping) in each of the AEGs and in the transitional farming zone.

TABLE 7.11

CROP PLANTING PRACTICES

AGRO-ECONOMIC GROUPING	PLANTING CODES					NUMBER OF PLOTS
	1	2	3	4	5	
AEG ONE	194 43.9%	223 50.5%	1 0.2%	1 0.2%	23 5.2%	442
AEG TWO	80 63%	29 22.8%	16 12.6%	0	2 1.6%	127
AEG THREE	62 33.2%	113 60.4%	0	0	12 6.4%	187
AEG FOUR	100 62.9%	45 28.3%	1 0.6%	0	13 8.2%	159
TRANSITION ZONE	398 37.8%	572 54.3%	41 3.9%	11 1%	31 3%	1053

1 signifies single crops.
2 signifies mixed crops.
3 signifies mixed crop stands.
4 signifies single + mixed crop stands.
5 signifies plots not under cultivation.

Distinctions between the AEGs are less clear when the figures in the above table are examined. AEG two and four have a larger number of pure crop stands than the other AEGs although the differences between these two AEGs and the remaining groupings are not entirely clear with all groups having a significant percentage of plots planted under pure crops. AEG two is the only grouping with more than 10% of plots planted with mixed stands, a characteristic which was noted during the field survey in lower Meru and which is typical of the farming system of this livestock-rearing zone.

In summary, four AEGs have been distinguished and examined using individual farm data to assess their internal structure. Crop planting practices have been used to help distinguish between these groupings on the assumption that planting practices reflect real differences in farming systems within the smallholder farm economy. Although all four groupings are recognised to have some internal heterogeneity each grouping remains distinguishable from the transition farming zone which is the most heterogeneous farming area in the study region. AEG four is the most internally inconsistent while AEG one is the most consistent (Table 7.9).

7.5 SUMMARY

The analysis presented in this chapter has defined four AEGs and a transitional farming zone within the smallholder economy of lower Meru. Although the ground survey was able to identify more detailed farming patterns within the smallholder economy than the air surveys, homogeneous agricultural areas of a similar nature were distinguished by both sets of data. Generally it has been possible to distinguish between farming systems using spatial variables generated from the air surveys.

Within these relatively homogeneous agricultural areas considerable heterogeneity was found to exist when individual farm data were examine using a cluster analysis. In order to verify the distinctiveness of the AEGs which had been identified, crop planting practices within each grouping were examined. This analysis confirmed that there were distinct differences between the AEGs.

For some areas of the smallholder economy in lower Meru it has not been possible to identify any consistent agricultural patterns (farming systems). These areas were grouped into a transitional farming zone. It is suggested that such areas may represent regions of recent settlement or, farming systems and natural environments that are undergoing rapid change.

Chapter Eight uses discriminant analysis to test the validity of the identified AEGs and the transitional farming zone. Recommendation domains are defined and these are then related to areas of land use/cover change identified using Landsat MSS data and 1:50,000 panchromatic air photography. Areas within the smallholder economy which appear to require particular agricultural research and development attention are discussed.

CHAPTER EIGHT

VALIDATING THE OBSERVED FARMING PATTERNS (AEGs) AND DEFINING RECOMMENDATION DOMAINS

8.0 INTRODUCTION

The previous chapter was concerned with the identification of AEGs and a description of their internal structure. Before AEGs can be used to derive recommendation domains - target areas for agricultural research and development initiatives - they need to be examined using individual farm data from the ground survey in order to validate their accuracy.

If agricultural planning is to be successful changes occurring in the farming systems within these target areas must be thoroughly understood in order for development initiatives to proceed smoothly. One of the hypotheses of the research is that where AEGs are most homogeneous farm populations will be least mobile, while AEGs which are more heterogeneous will have more mobile populations. Only once both the validity of the AEGs has been verified and, an assessment has been made on the stability of their human populations can they be realistically used to define target areas for development assistance. These target areas are called recommendation domains and form the primary framework of farming systems research (FSR).

There are five sections in the present chapter. The first section uses discriminant analysis to classify all the individual farms which were surveyed during fieldwork undertaken in 1985/6 (27 farms were eliminated from the analysis due to missing data). This classification is used to establish whether there are any areas of agricultural homogeneity which have not yet been adequately differentiated within the study area. Note that, in the previous chapter only farm clusters which were consistently identified on both the ground survey and air survey data component maps (Section 7.3) were designated as areas of relative agricultural homogeneity (AEGs). Farm clusters which were identified as being relatively homogeneous on only *one* of these data sets were allocated to a floating group (the transitional farming zone) which included 290 farms.

By classifying all the surveyed farms (455) into four groups and mapping the results it is possible to identify core areas of consistency on a farm-by-farm basis. Homogeneous agricultural areas distinguished at individual farm level are examined using the 17 original variables which were included in the ground data set introduced in Chapter Seven. These homogeneous areas are related to the previously identified spatial distributions of AEGs in order to redefine AEGs where the individual farm data show this to be necessary.

The second section examines the hypothesis that there is a relationship between farmer mobility/residency and the internal homogeneity of AEGs. A number of variables from the ground survey are used to assess the degree of mobility among farmers within each of the AEGs.

In the third section the maps of AEGs (redefined where appropriate) are overlain onto a map of the agro-ecological zones in the district (AEZs) to establish recommendation domains based on AEGs and agricultural potential (AEZs). The relationship between AEGs and AEZs is discussed in line with the third research hypothesis - farmers within the same agro-ecological zone act consistently and maintain a similar farming system.

In the fourth section the stability of the identified recommendation domains is discussed by relating these to areas of land use/cover change identified using Landsat MSS data and 1:50,000 panchromatic air photography. Finally, in section five, recommendation domains in which there has been a considerable increase in cultivation or, where the farmer population appears to have been recently mobile are identified as areas of focus for agricultural research and development assistance.

8.1 DISCRIMINANT ANALYSIS, THE CLASSIFICATION OF INDIVIDUAL FARMS

Discriminant analysis is a technique in which linear combinations of variables are used to distinguish between two or more categories of cases (farms). It is concerned with the problem of assigning an unknown observation to a group with a low error rate. The linear discriminant function is a function of n variables which separates cases so that the weights of cases in one group have high values, and as many as possible of the cases in another group have low values. In other words it attempts to provide the best separation between two groups of samples. Discriminant functions are analogous to components, factors and canonical vectors - each of the original variables has a loading on each of the discriminant functions. The basic equation for a discriminant function is similar to a multiple regression equation and has the form:

$$D = B_o + B_1X_1 + B_2X_2 + \ldots\ldots B_pX_p \qquad (8.1)$$

Where B_0 is a constant, the B's are coefficients estimated from the independent variables and, the X's are the values of the independent variables.

The individual observations have scores on the discriminant functions (similar to component and canonical scores) and these are usually derived in standardised form with a mean score being computed for each group of observations (group centroid). Coefficients are chosen so that their values on the discriminant function differ as much as possible between groups, or that for the discriminant scores the ratio

$$\frac{\text{Between-group sum of squares}}{\text{Within-group sum of squares}}$$

is maximum. A "good" discriminant function is one that has much between-group variability when compared to within-group variability. Any other combination of the independent variables will have a smaller ratio. The number of discriminant functions calculated depends on the number of groups to distinguish between. The first function has the largest ratio of between-group to within-group sum of squares. The second is uncorrelated to the first and has the next largest ratio. Any subsequent discriminant functions are extracted orthogonal to the preceding ones, each function being located so as to maximise the F ratio (between-group to within-group variances) in the residuals remaining from the derivation of earlier functions.

Discriminant analysis can be used for estimating the values of observations from other samples by using a primary sample to compute discriminant functions which are then used to classify the target sample. The 192 farms which were used to define AEGs in the preceding chapter were used as a primary sample. A stepwise discriminant analysis was performed in order to derive discriminant coefficients for each farm grouping which could then be used to classify the remaining sample farms (290 farms out of the original 482 farms were excluded from the four AEGs identified in the previous chapter). Based on these coefficients discriminant scores were then calculated for each case (farm) - one score for each discriminant function. These scores were then mapped using a similar procedure to that described in Chapter Seven for the component scores.

Using the SPSSx CLUSTER procedure (SPSS Inc, 1986) cluster membership of the 192 farms were saved for a four cluster solution (corresponding to the four AEGs). These cluster groups were then used in a stepwise discriminant analysis (SPSSx DISCRIMINANT procedure, Ibid.) to derive discriminant coefficients for each group. The coefficients were used to classify the remaining non-grouped farms from the ground survey.

A stepwise method was used to select one farm at a time, with farms which minimised the within-group variance being selected in the analysis. Wilk's lambda (Λ) was used as a statistic to test within-group variance. The larger the value of lambda, the greater the within-group to between-group ratio and the less successful the separation of groups. Wilk's lambda is the ratio of within-groups cross-products to the total cross-products along the discriminant function and is expressed by the following formula:

$$\Lambda = \frac{\sum_{i=1}^{N} (X_{Di}-\bar{X}_{DG})^2}{\sum_{i=1}^{N} (X_{Di}-\bar{X}_{DT})^2} \qquad (8.2)$$

where: X_{Di} is the score for observation i on the discriminant function D.
$\bar{X}_{DG}$ is the mean score on the discriminant function for observations in the group of which i is a member.
$\bar{X}_{DT}$ is the mean score on the discriminant function for all observations.

Discriminant analysis on the four clusters (farm groupings) showed that the majority of the 192 farms were being distinguished accurately into four groupings (Table 8.1 below). In order to determine the spatial distribution of the groupings resulting from discriminant analysis (and to be able to compare these with the distribution of AEGs), the group membership of each farm was used to determine the homogeneity/heterogeneity of the farming system at each of the 88 sample farm clusters.

Where all farms at a single ground cluster were allocated to the same grouping, the farming system was considered to be most homogeneous. Conversely, where farms were allocated across all four groupings at a single ground cluster the farming system was considered to be most heterogeneous. The computer program SYMAP was used to map the results of the classification. Classes were divided into equal value ranges so as to maximise the difference between groups in order to pick out areas of maximum conformity (Dark symbolism was used to distinguish the areas of greatest homogeneity in a farming system on the discriminant score maps).

TABLE 8.1

DISCRIMINANT CLASSIFICATION RESULTS - ANALYSIS USING FARM MEMBERSHIP FROM CLUSTER ANALYSIS ON 192 FARMS

ACTUAL GROUP	N	PREDICTED GROUPS GROUP 1	GROUP 2	GROUP 3	GROUP 4
1	41	85.4%	0.0%	4.9%	9.8%
2	99	0.0%	98.0%	2.0%	0.0%
3	18	0.0%	5.6%	94.4%	0.0%
4	34	0.0%	0.0%	0.0%	100.0%

N signifies number of farms in each grouping.
Overall accuracy = 95.31%.

Figures 8.1 to 8.4 show the four maps resulting from the classification procedure outlined above. These are now discussed with reference to Figure 7.10 which shows the spatial distribution of AEGs within the study area. It should be pointed out that low values at sample points (light stippled shading) represent the most heterogeneous farming areas, while high values (blocked shading) represent the most homogeneous farming areas.

Figure 8.1 shows the homogeneous farming areas picked out by the first discriminant function. All of these sample farms are associated with AEG two (Figure 8.6) which represents the livestock-rearing and bush fallow farming system. In contrast to Figure 8.4 (which identifies the subsistence livestock farmers) most of the farmers (92%) identified in this grouping are involved in the cash economy in some way. Figure 8.2 shows the high income cash crop farms in the study region while Figure 8.3 represents a further collection of high income farms which are situated outside the marginal coffee-growing area. Unlike the farms in group two however, livestock are not a significant income source for these

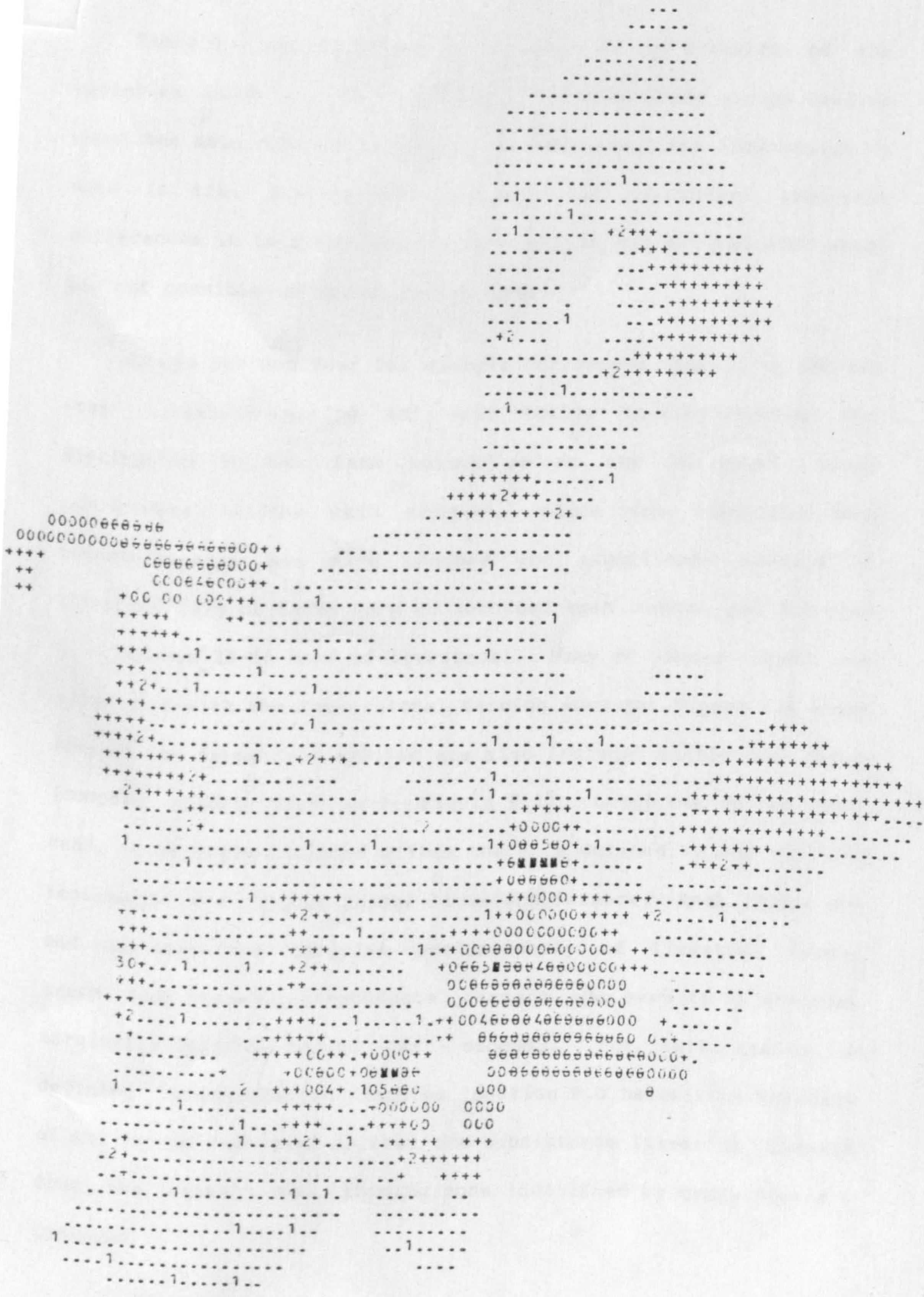


FIGURE 8.1 DISCRIMINANT SCORES: GROUP ONE - ALL FARMS

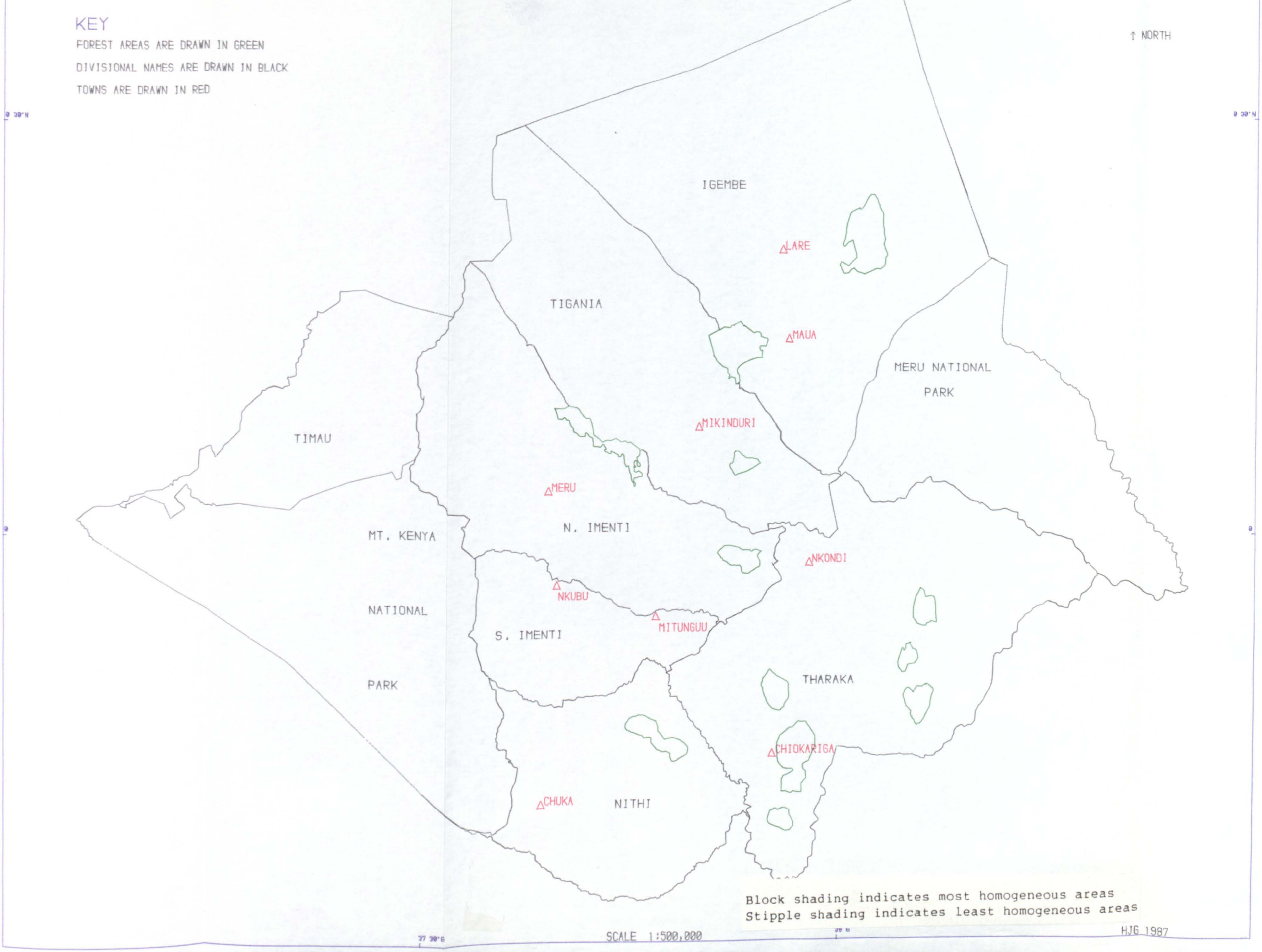
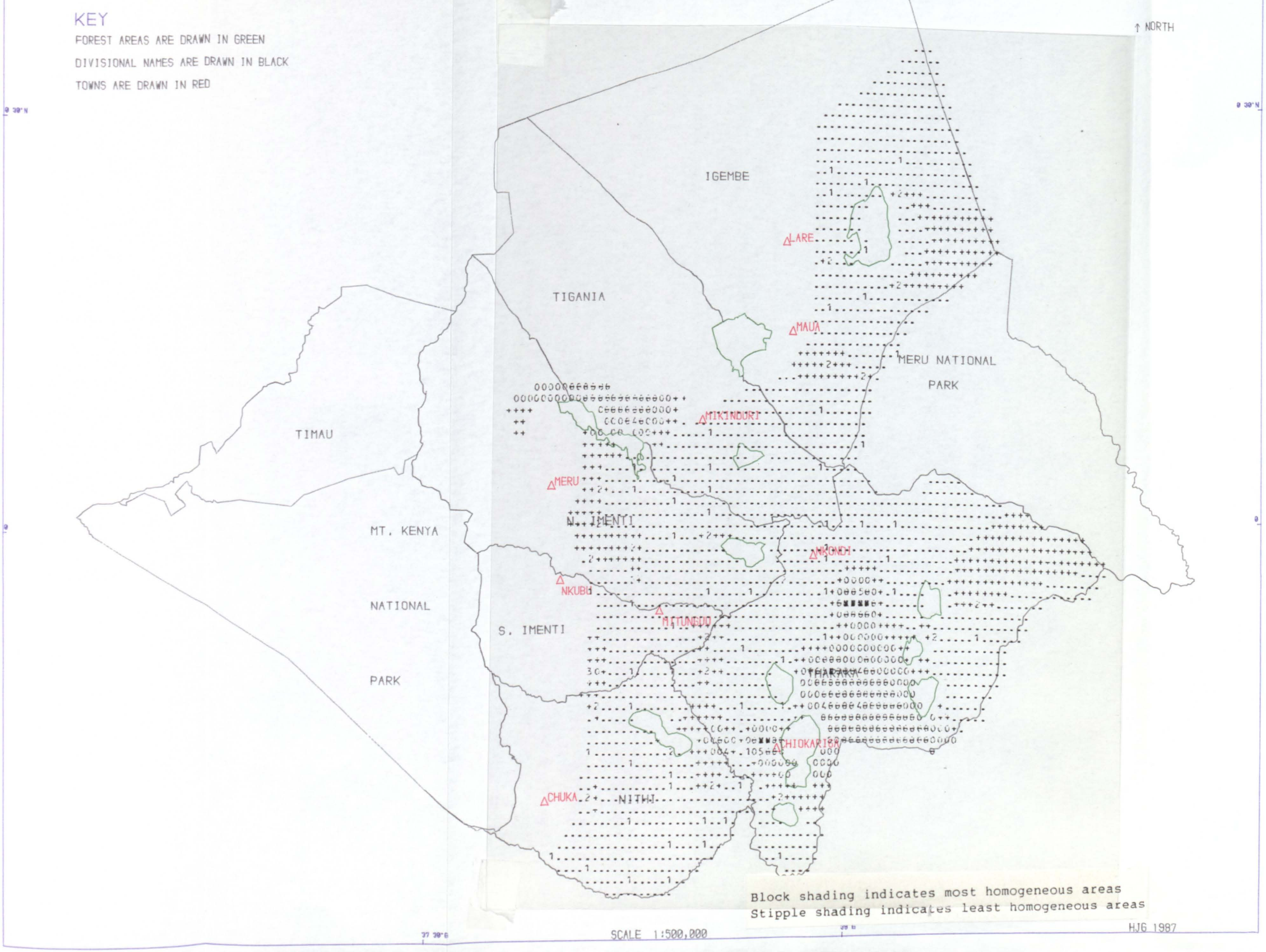


FIGURE 8.1 DISCRIMINANT SCORES: GROUP ONE - ALL FARMS



farmers.

Table 8.2 compares these farm groups across a number of the variables used in the analysis. What do these groups tell us about the AEGs defined in Chapter Seven? The first observation to make is that discriminant analysis has identified important differences in farm household income within and between AEGs which was not possible using the aerial data.

Groups one and four for example correspond closely to AEG two (the livestock-rearing and bush fallow farming system) but distinguish between farm households on the basis of their involvement in the cash economy. Group four identifies farm households with low farm incomes yet significant numbers of livestock (37% of farms have no recorded cash income, yet 37% also have between 20-50 head of livestock). Many of these farms are associated with the transitional farming zone yet Figure 8.4 shows some of the farms from AEG two are also included within this group (compare Figure 7.10 with Figure 8.1). Group one on the other hand, is entirely included within the area defined by AEG two and represents the higher income livestock farmers. Both groups one and four therefore comprise predominantly of livestock farms, group four however represents farmers who seem to be somewhat marginally involved in the cash economy. For this reason in defining recommendation domains (Section 8.3 below) the boundary of AEG two is redefined so that the subsistance livestock farmers from the transitional farming zone identified by group four are included.

TABLE 8.2

A COMPARISON OF THE DISCRIMINANT GROUPINGS DERIVED FROM INDIVIDUAL FARM DATA

VARIABLE NAME		GROUP 1		GROUP 2		GROUP 3		GROUP 4	
		N	%	N	%	N	%	N	%
CROP	NIL	10	71	2	6	1	6	17	89
INCOME	<1000	3	21	4	11	4	23	2	11
	>1000	1	8	30	83	12	71	0	0
CASH	COFFEE	0	0	13	36	0	0	0	0
CROPPING	MIRAA	0	0	2	6	3	18	0	0
	COTTON	3	21	15	41	6	35	2	11
YEARS OF	<10	13	93	14	39	10	59	0	0
CASH CROPPING	>10	1	7	22	61	7	41	0	0
FARMS WITH NO CASH INCOME		1	7	1	3	1	6	7	37
LIVESTOCK	<20	2	16	22	71	14	93	8	50
NUMBERS	20-50	5	42	9	29	0	0	6	37
	>50	5	42	0	0	1	7	2	13
LIVESTOCK	NIL	5	36	13	36	14	82	14	74
INCOME	<1000	7	50	16	44	1	6	5	26
	>1000	2	14	7	20	2	12	0	0

N signifies number of farms in group, % signifies percentage, income is in Kenyan shillings.

Figure 8.2 represents farms with high incomes and includes areas where there is significant cash crop cultivation occuring. These high income farms fall within a number of the originally defined AEGs and indicate that the highly prosperous farms are not restricted to the marginal coffee-growing areas to the west of the study region - for example, farms in the Nkondi region are included in this group and account for most of the cotton farmers (41%).

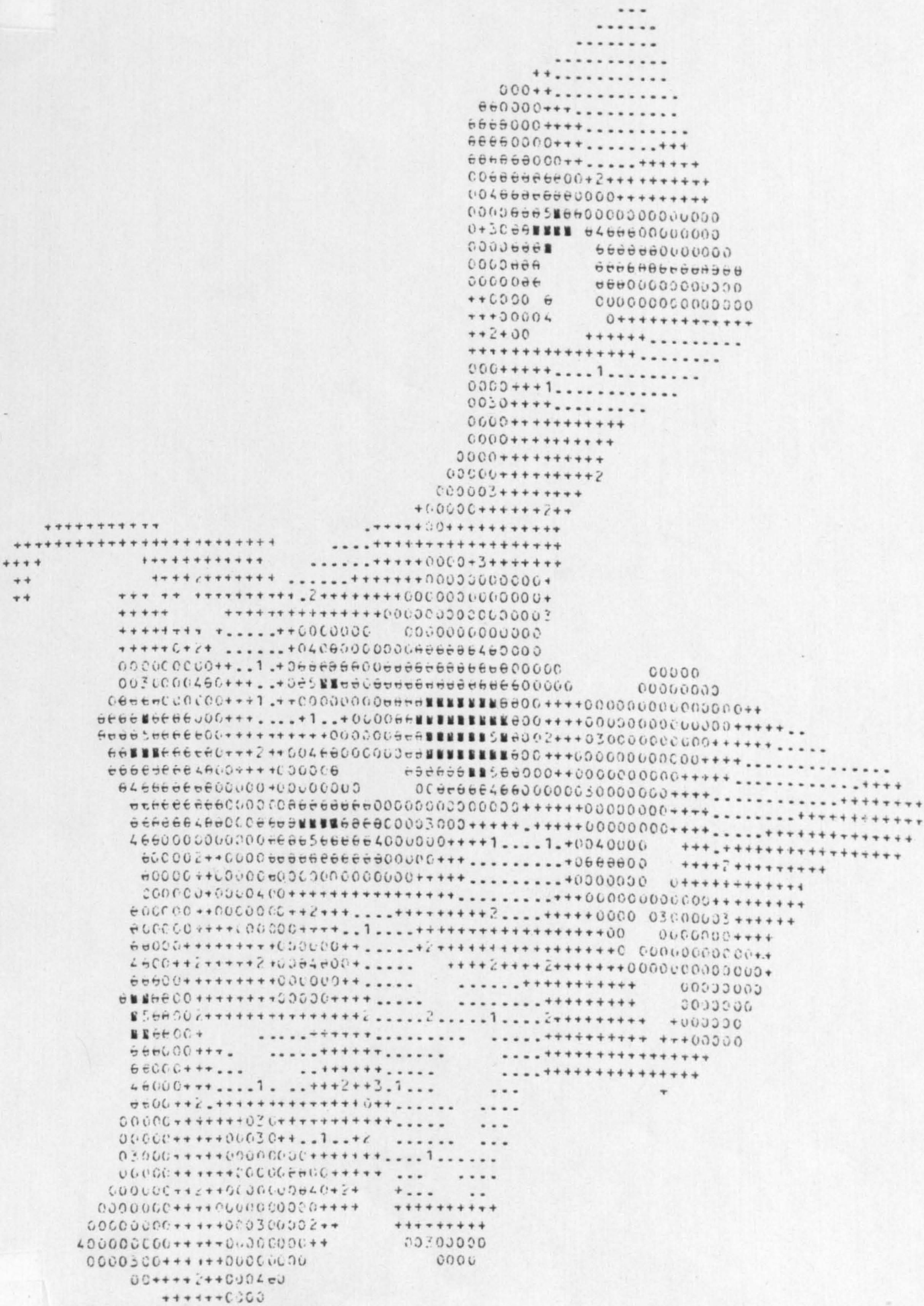


FIGURE 8.2 DISCRIMINANT SCORES : GROUP TWO - ALL FARMS

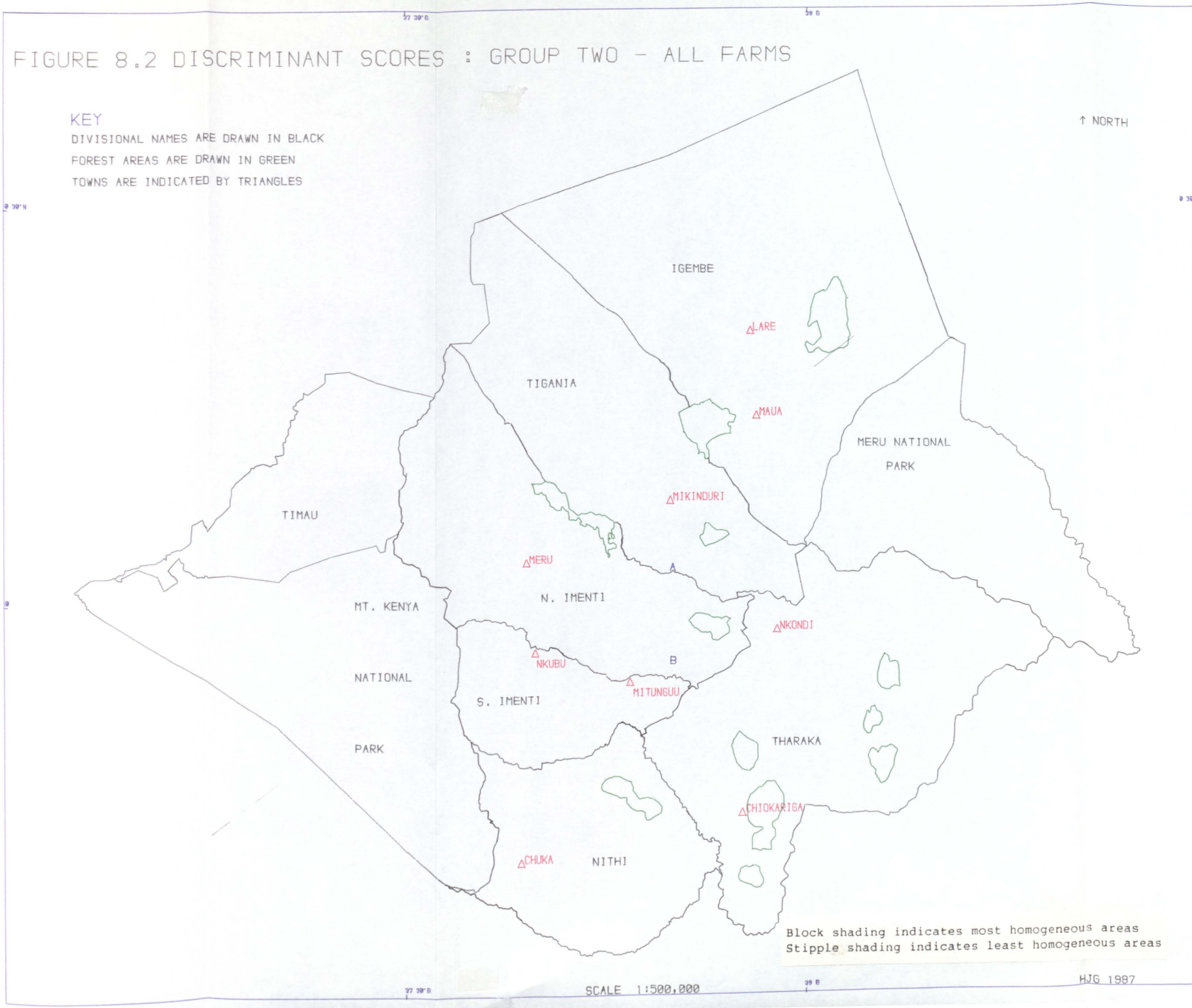
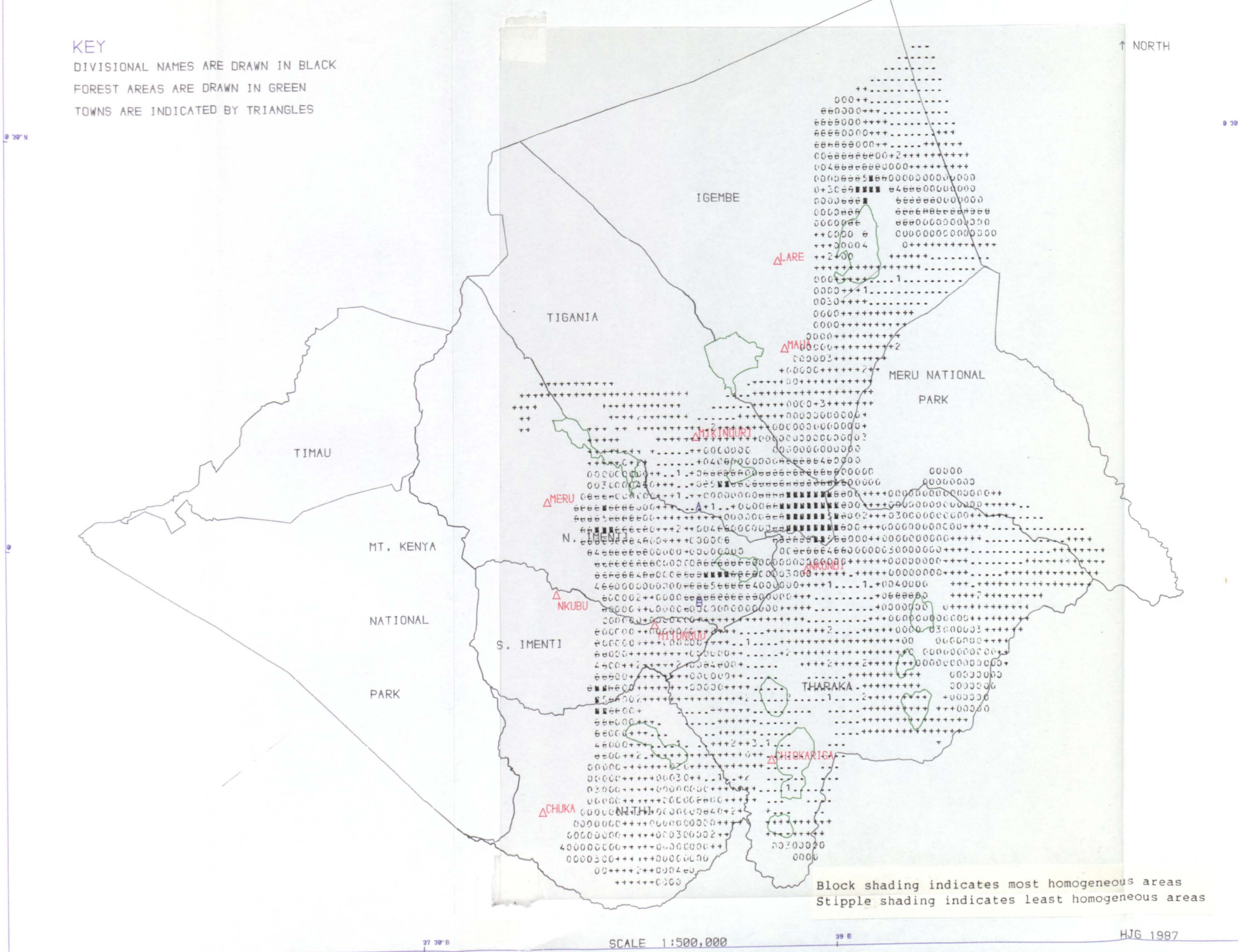


FIGURE 8.2 DISCRIMINANT SCORES : GROUP TWO - ALL FARMS



Two of the sample farm clusters within the marginal coffee-growing area (AEG one) are associated with this high income group as well as one sample cluster from the miraa-growing area in the north of the study region (AEG three). Perhaps more significant however are the two ground sample clusters from within the transitional farming zone which are included (indicated by A and B). Although in both of these areas some of the farmers are growing cash crops, food crops are important and many of the farmers sell these crops for cash (these two sample clusters were identified as being agriculturally homogeneous on the third component of the ground data set in Section 7.1.3 (Figure 7.6), but were not included in any of the AEGs as they did not correspond with any of the agriculturally conformant areas identified by the air data set).

Figure 8.3 shows the sample farm clusters which are most homogeneous - identified by the third discriminant function (Table 8.2). Unlike the farms in group two, livestock are not a significant source of income for the large majority of farmers in these areas (82% have no livestock income) although 93% do own some sheep, goats or cattle. Only 53% of farmers are growing any cash crops and only 12% (not shown in table) have any external income sources.

However, farmers in these areas quite clearly are better off than the majority of the livestock farmers identified by Figures 8.1 and 8.4. Significantly, all the farms in this group fall within the previously defined transitional farming zone. This suggests that even within this apparently rather heterogeneous zone individual farm data show there is some conformity in farming

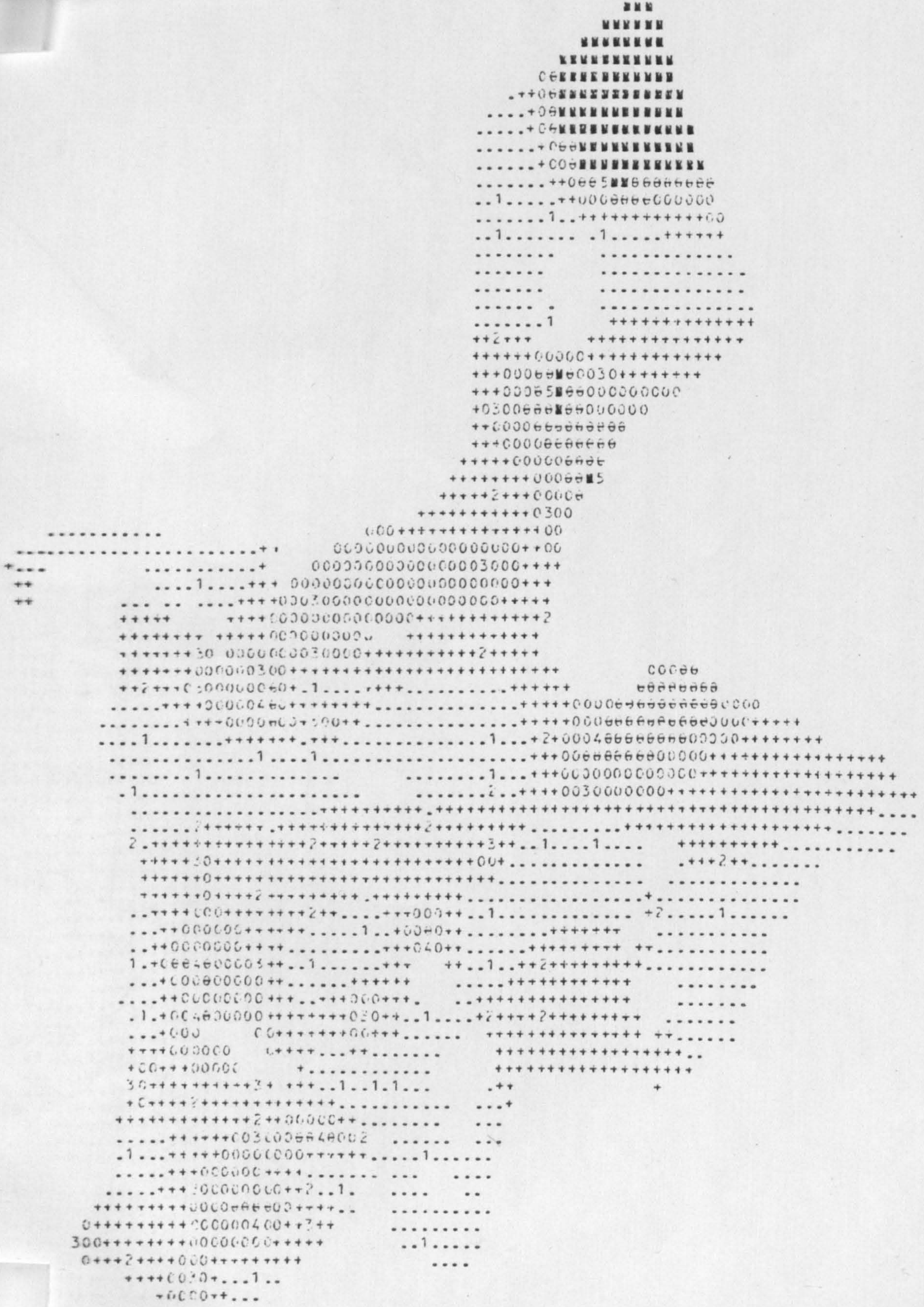


FIGURE 8.3 DISCRIMINANT SCORES: GROUP THREE - ALL FARMS

KEY

FOREST AREAS ARE DRAWN IN GREEN

DIVISIONAL NAMES ARE DRAWN IN BLACK

TOWNS ARE DRAWN IN RED

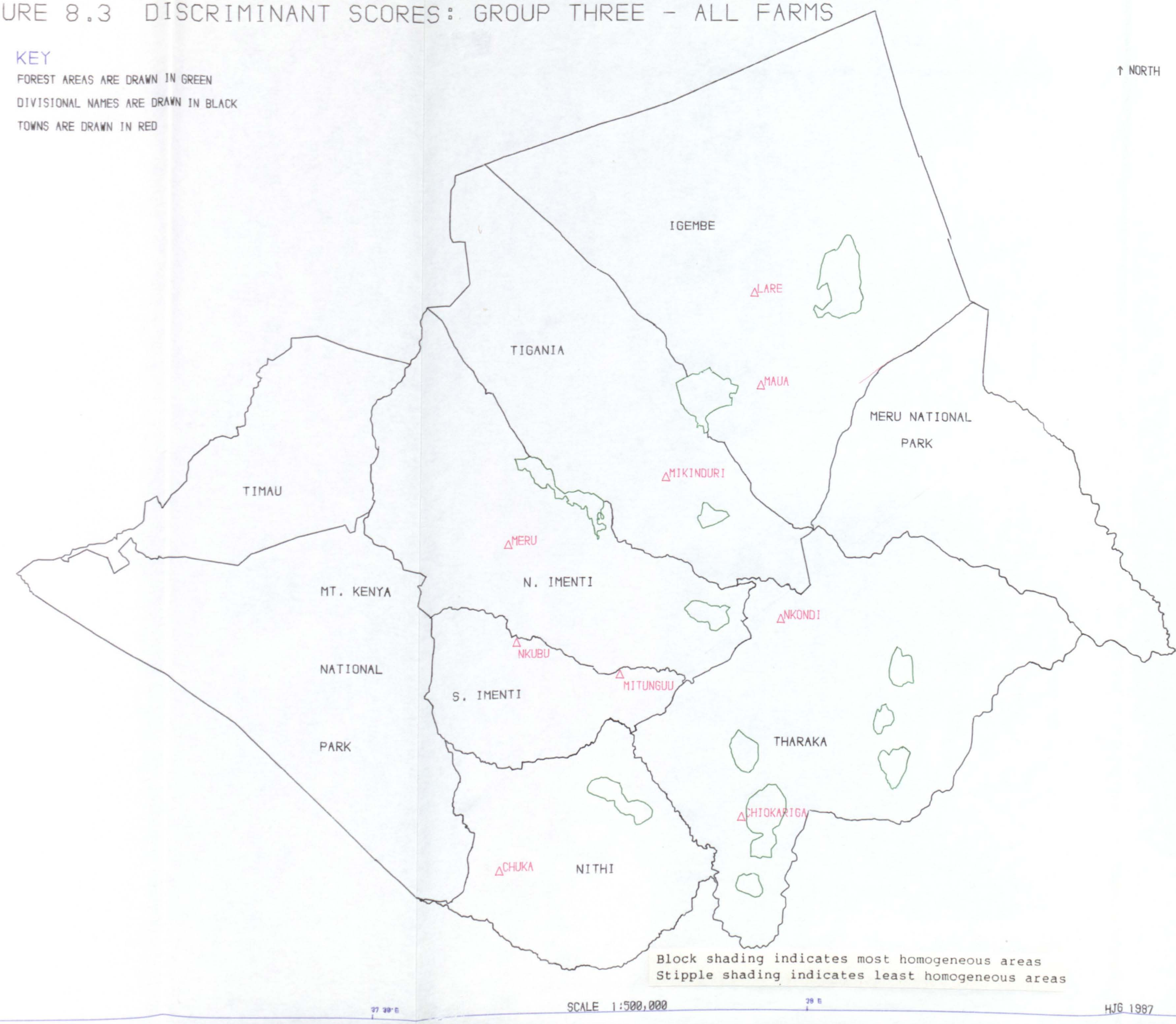


FIGURE 8.3 DISCRIMINANT SCORES: GROUP THREE - ALL FARMS

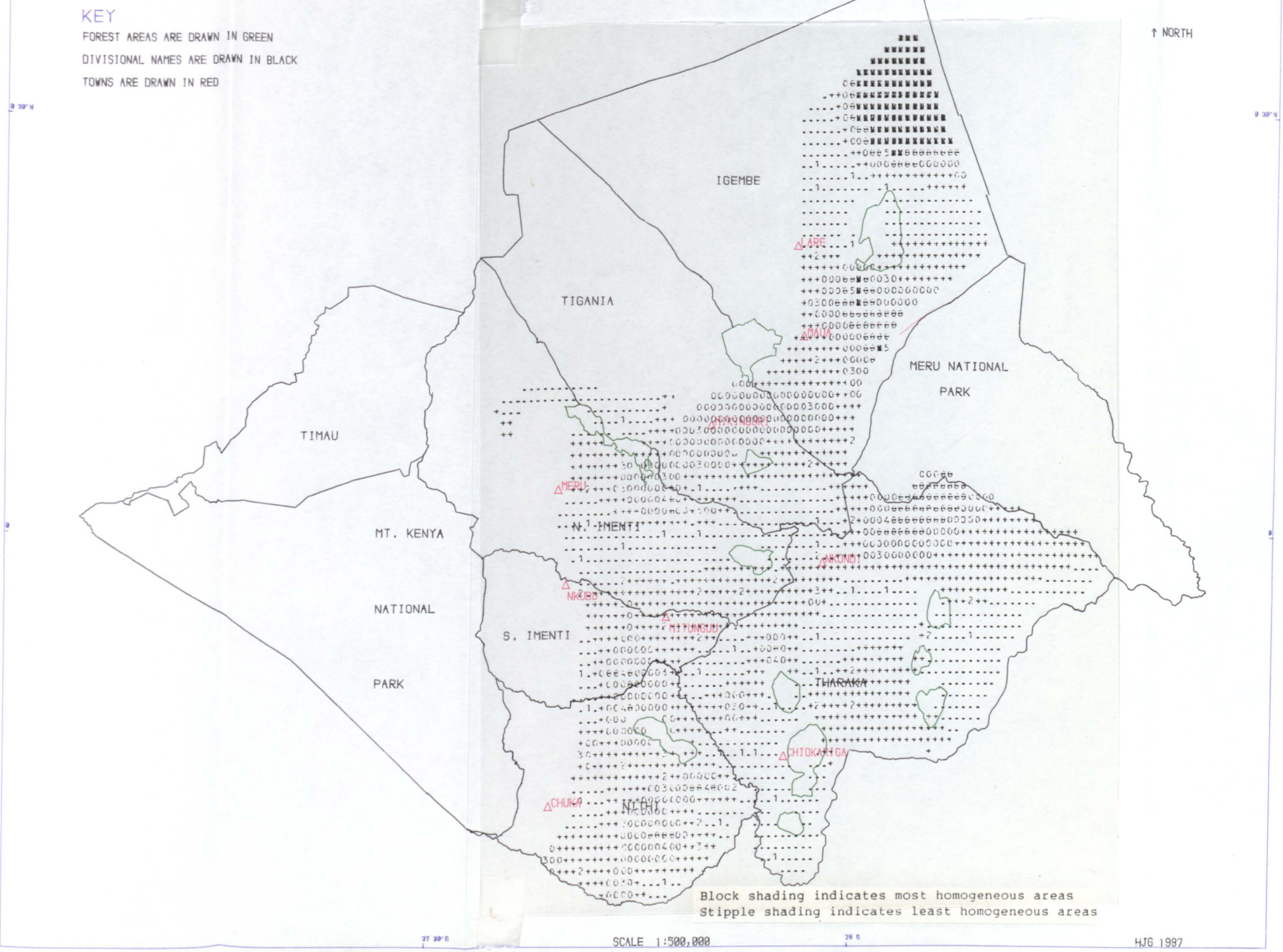


FIGURE 8.4 DISCRIMINANT SCORES : GROUP FOUR - ALL FARMS

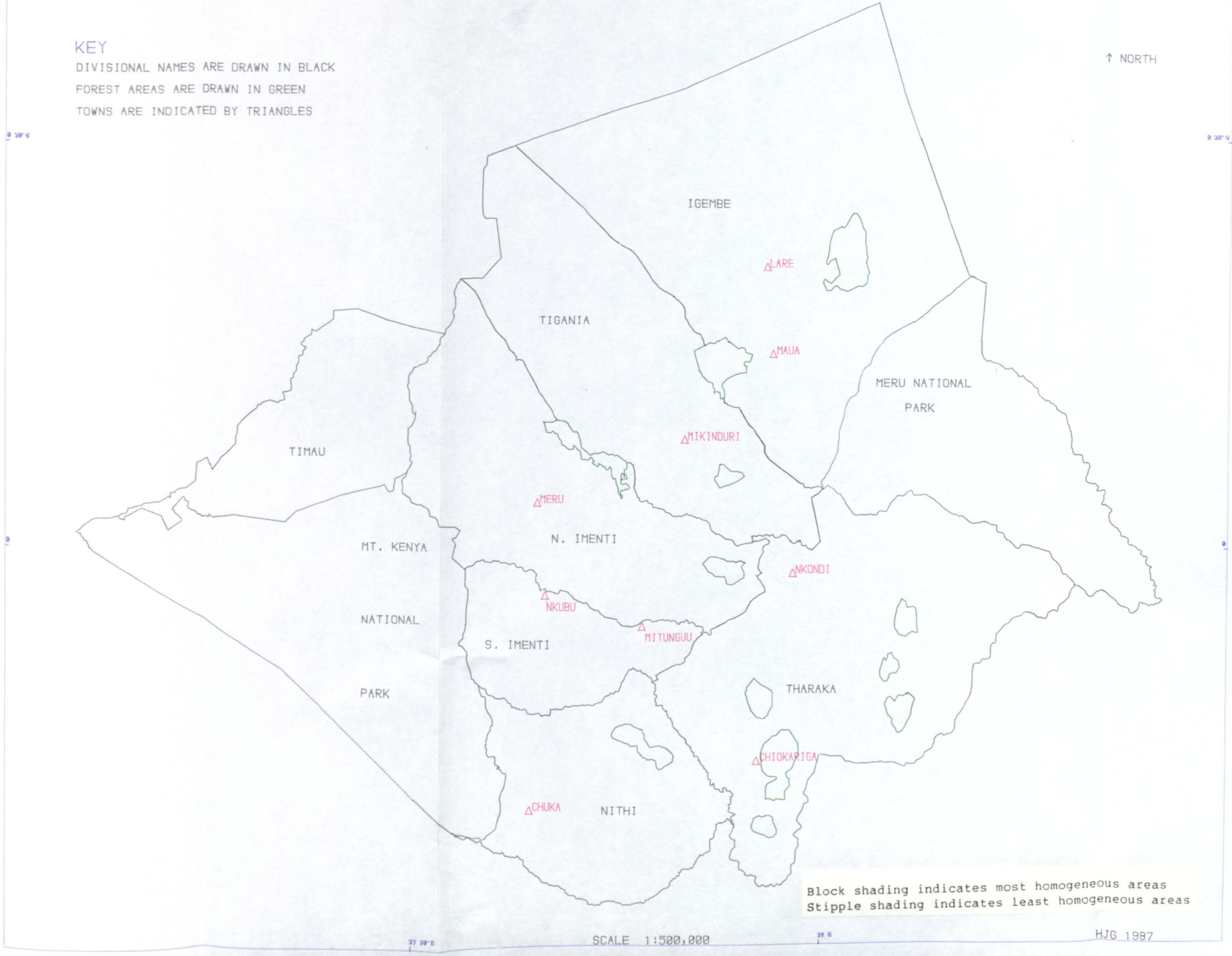
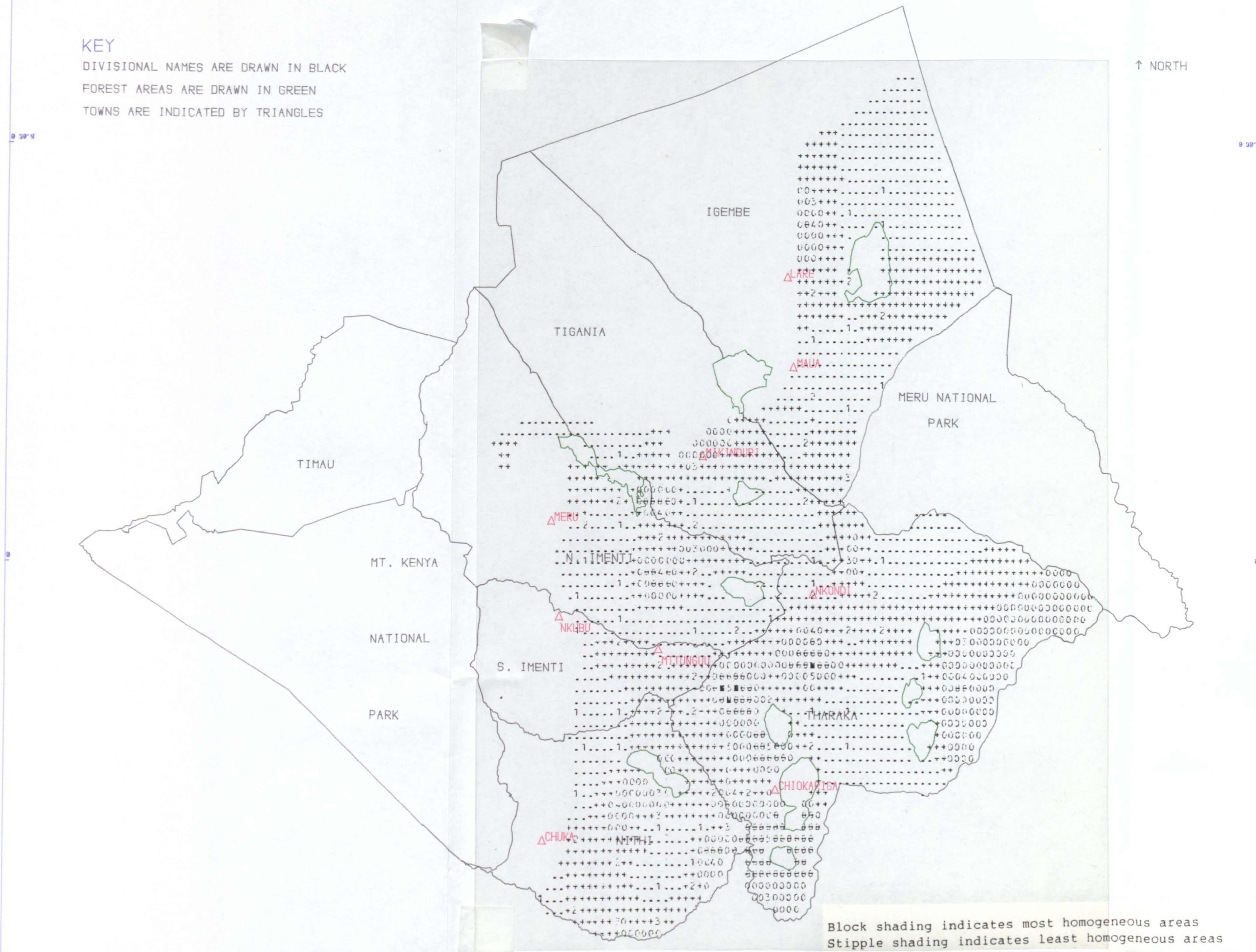


FIGURE 8.4 DISCRIMINANT SCORES : GROUP FOUR - ALL FARMS



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practices and relatively homogeneous farming areas can be distinguished. These were not identified using the spatial crop and land cover variables from the aerial survey.

In summary the groups identified using discriminant analysis have shown that at the individual farm level it is possible to distinguish areas of agricultural conformity which were not distinguishable using the aerial data. These distinctions are made largely on the basis of farm income level, involvement in the cash economy, cash cropping and livestock numbers. Discriminant analysis on the individual farm data has revealed some new, relatively homogeneous agricultural areas which are used to redefine the areas of agricultural homogeneity which have already been identified with the help of aerial photography. Using individual farm data homogeneous agricultural areas within the marginal coffee-growing area, livestock-rearing zone and Nkondi farmlands have been identified. The miraa-growing area to the north of the study region however has not been readily distinguished (although field experience shows this to be a distinctive farming area).

Areas of relative agricultural homogeneity (AEGs) are now examined using data on farmer mobility/residency to assess their stability. It is argued that areas that exhibit considerable farmer mobility are likely to be experiencing the greatest change in land use. Such change may lead to detrimental environmental consequences involving both soil and water losses. Areas of greatest change should therefore be the focus of development initiatives within the lower Meru region.

8.2 AGRO-ECONOMIC GROUPS AND FARMER MOBILITY

This section will examine AEGs and the transitional farming zone in respect of farmer mobility/residency. It will examine the hypothesis that the internal consistency of AEGs is affected by farmer mobility/residency. If there is a relation between farmer mobility and the internal structure of AEGs, results should show that for AEG one farmers are longest resident and least mobile, while for AEG four farmers are newest resident and most mobile. The transitional farming zone should reveal a less precise pattern of behaviour with some farmers being longer resident and less mobile than other newer arrivals.

It is suggested that where farmers are highly mobile or there are many new arrivals there is a greater likelihood of environmental degradation. Farmers will be less knowledgeable about their local environment, and hence farming practices/farming systems may incur considerable pressure on the natural resources of such areas. This may result in detrimental changes - deforestation, loss of ground cover, soil and water loss, etc.

Farmer mobility/residency is examined using nine variables, together these form what I call a mobility index. The variables included are: original home of the farmer, home of the farmer prior to present home site (where applicable), tenurial status of present farm, number of years of farming undertaken from present home site, length of farming on present farm, length to continue farming on present farm site, the number of farms owned, the location of the second and third farms (where applicable).

Each of these variables is examined separately for each AEG and for the transitional farming zone. Discussion is focussed on the implications of the findings with regard to the importance of mobility/residency in influencing the internal structure and therefore stability of each grouping. Finally, the overall findings are summarised in order to clarify the main trends which have been identified. Table 8.3 shows the number and percentage of farmers who have remained farming in their original home location since birth. A location is defined as an administrative area in the context of this study. It is the lowest administrative unit within the planning hierarchy in the Kenyan context.

TABLE 8.3

NUMBER AND PERCENTAGE OF FARMERS REMAINING IN ORIGINAL HOME LOCATION

ADMINISTRATIVE LOCATION	GROUPINGS (AEGs) 1	2	3	4	5*	ROW TOTAL
DIFFERENT LOCATION	6 8%	12 33.3%	12 22.6%	18 58%	65 23%	113 23.7%
SAME LOCATION	70 92%	24 66.6%	41 77.4%	13 42%	216 77%	364 76.3%
SIZE (N)	76	36	53	31	281	477

N = group size (number of farms).
5* signifies transitional farming zone.

Table 8.3 shows that there is generally a high degree of long-term residency within the groups. This is most marked in AEG one which represents the marginal coffee-growing zone to the west of the study region. 92% of farmers in this AEG have remained in the same administrative location since birth - a statistic which confirms that this area has been densely settled and intensively farmed for many years. There is no more room for pioneer settlement to occur.

The second point to note is the proportion of farmers who have moved from their original home location in AEG two. This AEG represents the dry livestock-rearing zone within Tharaka division. Typically, this area is characterised by a livestock and bush fallow system of agriculture which by its very nature includes some population movement. Although such population movement may be fairly localised, the figures above suggest that it transgresses locational boundaries.

Finally, AEG four which represents the Nkondi farming system and the more recently settled areas along the south-western perimeter of Meru park also contains a significant number of farmers who have moved from their original home locations to farm at new sites (58%). AEG four is found to have the most mobile farming population of all the AEGs, which implies that one reason for its greater heterogeneity is indeed due to causes related to farmer mobility.

It should be emphasised the above figures *do not* indicate how recent such population movements were. This aspect of farmer mobility is discussed below in relation to the number of years farmers have continued to cultivate on the same piece of land (Table 8.5) and, on how long they will continue to do so in the future (Table 8.6).

Table 8.4 shows the percentage and number of farmers who have moved more than once since leaving their original home. In other words this table shows the percentage of farmers who are more than just 'one time' movers.

TABLE 8.4

NUMBER AND PERCENTAGE OF FARMERS WHO HAVE MOVED MORE THAN ONCE

PREVIOUS HOME	GROUPINGS (AEGs) 1	2	3	4	5*	ROW TOTAL
DIFFERENT LOCATION	5 7%	11 31%	9 17%	17 57%	43 15%	85 17.9%
SAME LOCATION	71 93%	25 69%	44 83%	13 43%	236 85%	389 82.1%
SIZE (N)	76	36	53	30	279	474

N signifies group size (number of farms).
5* signifies transitional farming zone.

Table 8.4 shows that the large majority of farmers who have moved from their original homes have also *moved more than once*. In other words the same farmers are tending to move in any one AEG. This means for example that where 57% of farmers have moved in AEG four this is their second move from their place of birth. It is not clear whether the farmers who have moved more than once are selling their former farms and moving to farm on new land which they have purchased from the sale of their original land or, whether they are buying additional land to farm and moving homes in order to develop these new farms while maintaining their original farms. Evidence of multiple farm ownership (Table 8.8) suggests that the latter situation is more likely.

What the table does not show is whether both of these moves have been to different administrative locations. Table 8.9 shows that for the majority of farmers who own more than one farm all these farms are situated in the same location. If therefore farmers are moving homes to develop new farms while still maintaining their previous farm(s), then these moves are occurring within the same location. How frequent are these moves? The next two tables attempt to answer this question.

TABLE 8.5

LENGTH OF CULTIVATION OF FARM BY AGRO-ECONOMIC GROUPING (AEG)

AGRO-ECONOMIC GROUPING	LENGTH OF CULTIVATING FARM				N
	1	2	3	4	
AEG ONE	6 8%	7 9.3%	55 73.3%	7 9.3%	75
AEG TWO	30 85.7%	3 8.6%	1 2.8%	1 2.8	35
AEG THREE	4 8%	7 14%	36 72%	3 6%	50
AEG FOUR	8 27.6%	1 3.4%	18 62.1%	2 6.9%	29
5*	133 48.5%	40 14.6%	97 35.4%	4 1.5%	274

N signifies group size (number of farms).
5* signifies transitional farming zone.
1 = 5 years or less, 2 = 5 to 9 years, 3 = 10 years or more, 4 = don't know.

The above table clearly shows there is a difference in the recent mobility of farmers between AEG one and two, and is picking out the different characteristics of the two farming systems. AEG one represents a well established farming system in the densely settled west of the study region, while AEG two represents the livestock-rearing and short-term bush cultivation farming system in the east and south. Over 30% of farmers in AEG four have not been cultivating on their present farm for more than ten years, a statistic which appears to confirm fieldwork findings that there have been recent population movements into the previously uncultivated land south-west of Meru park (North Tharaka location).

In contrast only 17% of farmers in AEG one and 22% of farmers in AEG three were recent cultivators (i.e. had cultivated for less than ten years on their present farm sites). Within the transitional farming zone over 60% of farmers were recent cultivators. This statistic would seem to conflict with the earlier findings (Tables 8.3 and 8.4) for this zone which suggested that most farmers had remained in the location where they were born and had not therefore been particularly mobile. What these figures show therefore is that farmers in this zone are moving to cultivate different farms within the *same* administrative location (although perhaps across different sub-locations - each location is divided into a number of smaller units - these are called sub-locations). Farmer mobility in this area appears to be more localised, unlike farmers in AEG two.

TABLE 8.6

LENGTH TO CONTINUE CULTIVATING PRESENT FARM BY AGRO-ECONOMIC GROUPING (AEG)

AGRO-ECONOMIC GROUPS	LENGTH TO CONTINUE FARMING					N
	1	2	3	4	5	
AEG ONE	0 0	0 0	66 88%	0 0	9 12%	75
AEG TWO	12 33%	1 3%	7 19.4%	0 0	16 44.4%	36
AEG THREE	0 0	0 0	46 92%	0 0	4 8%	50
AEG FOUR	2 7%	0 0	23 79%	0 0	4 14%	29
5*	20 7%	0 0	180 66%	1 .4%	72 26.4%	273

N signifies group size (number of farms).
5* signifies transitional farming zone.
AEG signifies agro-economic grouping.
1 = less than five years, 2 = five to nine years,
3 = more than ten years, 4 = not continue, 5 = don't know.

Table 8.6 establishes that there is still considerable expected future mobility among farmers in AEG two, with 33% saying they will farm for less than five more years on the the land they presently cultivate. 44% also say they don't know how much longer they will continue to farm on the same land. These figures are correctly identifying the more mobile farmer population of the livestock-rearing and bush fallow cultivation farming system.

Although 79% of farmers in AEG four say they will continue to farm on their existing land for at least ten years (ten years of continuous farming is used to define a permanent farm unit in this study) 7% said they would farm for less than another five years, while 14% could not say how much longer they would be farming the same piece of land. These figures suggest that within AEG four there is still some farmer mobility (assuming that farmers in the "don't know" category (14%) are undecided about whether to move rather than this being an indication of their tenurial status). It also suggests that there is still land available for new cultivation, although access to this land may not be available to all newcomers if it is under clan ownership. However, judging from the high percentage of farmers who have moved in the past (Tables 8.3 and 8.4) farmer mobility in this AEG appears to be on the decline.

In the transitional farming zone 7% of farmers were going to continue farming for less than five years on their present farms while 26.4% said they didn't know how much longer they would continue to farm on these sites.

The significance of the "don't knows" is twofold: The first point relates to the land tenure system which operates in these areas. Where farmers are without title deeds and where there is no historical community/clan ownership, they will not be in a position to predict how long they may be allowed to continue farming in an area since they have no written claim on the land (see Table 8.7 below).

The second point concerns the mobility of the farm population. If farmers are recent arrivals in an area and do not know the local land capability, they may be unable/unwilling to state how long they will continue to farm a piece of land since they will not have had time to assess the fertility of this land. Either of these circumstances may influence the length of farmers' residency within AEGs which may in turn affect the agricultural homogeneity of the identified AEGs in the study region. AEGs with mobile populations will require a different form of development assistance from those with more stable human populations. Although less homogeneous farming areas may be more difficult to distinguish from the air, this does not mean that these areas should be excluded from development planning.

If farmers do not feel they 'own' the land they are farming, it is highly unlikely that they will invest in long-term agricultural developments, and this may lead to attitudes of short-term gain (where farmers are not title deed holders of the land they are farming) in lieu of longer term productivity incorporating soil and water conservation methods. Table 8.7 shows the tenurial status of farms within the study area. It suggests that most farmers are in fact title deed holders or *de facto* owners of the land which they are farming. This is significant since it implies that a considerable number of farmers in AEG two, four and in the transitional farming zone are still *thinking* about moving to farm new land in the future (Table 8.6) although they are already owners of at least one farm.

A considerable number of farmers (25%) in the transitional farming zone are cultivating farms on clan-owned land in contrast to farmers in the AEGs. As mentioned above these statistics may have important implications for long-term agricultural development in the area if these farmers decide to opt for short-term gains in lieu of longer term productivity. Interestingly there appear to be very few farms which are being rented or borrowed within the study region, which demonstrates that where farmers are cultivating more than one farm they are usually the owners of these farms (Table 8.8).

TABLE 8.7

FARM TENURESHIP STATUS BY AGRO-ECONOMIC GROUPING

AGRO-ECONOMIC GROUPING	TENURESHIP STATUS OF FARM				N
	1	2	3	4	
AEG ONE	70 90.9%	0 0	1 1.3%	6 7.8%	77
AEG TWO	34 94.4%	0 0	1 2.8%	1 2.8%	36
AEG THREE	48 92.3%	0 0	3 5.7%	1 1.9%	52
AEG FOUR	28 93.3%	0 0	2 6.6%	0 0	30
5*	200 70.4%	3 1.1%	8 2.9%	73 25.7%	284

N signifies group size (number of farms).
5* signifies transitional farming zone.
1 = owns the farm, 2 = rents the farm, 3 = borrows the farm, 4 = farm owned by clan.

Table 8.8 below shows the number of farms being cultivated by farmers in each of the AEGs and in the transitional farming zone. AEG three is clearly the most distinct with more than 50% of farmers cultivating three or more farms. However, AEG one also has a significant number of farmers with three or more farms (20%). In order to examine the possible implications of these findings with regard to farmer mobility within AEGs, it is necessary to identify the location of these farms, i.e. are these farms situated in the same location or are farmers purchasing land outside their local areas (location)?

If multiple farm ownership is occurring within the same location this is unlikely to have as much influence on the agricultural homogeneity of AEGs as when multiple ownership of farms occurs with these being widely separated from each other. It is assumed that a farmer will use similar practices and methods on all his/her farms. There is a greater likelihood therefore that these practices will differ from those of neighbouring farms when a farm is located at some distance from the owner's original home since the smallholder farm economy is complex with many different farming systems being operated in close proximity of each other. Such differences will contribute to the agricultural heterogeneity of an area.

TABLE 8.8

NUMBER OF FARMS CULTIVATED BY FARMER ACROSS AGRO-ECONOMIC GROUPING

AGRO-ECONOMIC GROUPING	NUMBER OF FARMS CULTIVATED					N
	1	2	3	4	> 5	
AEG ONE	31 40.3%	30 39%	13 16.9%	3 3.9%	0 0	77
AEG TWO	17 47.2%	15 41.7%	4 11.1%	0 0	0 0	36
AEG THREE	12 23.1%	11 21.2%	21 40.4%	4 7.7%	4 7.7%	52
AEG FOUR	18 58.1%	9 29%	2 6.5%	1 3.2%	1 3.2%	31
5*	145 50.9%	102 35.8%	26 9.1%	10 3.5%	2 .7%	285

N signifies group size (number of farms).
5* signifies transitional farming zone.

Table 8.9 compares the location of the farm household identified during the ground survey with the locations of the second and third farms held by these same farm families.

In general farmer mobility resulting from multiple farm ownership appears to be very localised. Over 80% of second farms are situated in the same location as the family home. Across all groups there is a small percentage of farmers (between 9% and 15%) who have farms outside their present home location, and these farmers appear therefore to be more mobile. A somewhat similar pattern emerges when we examine the location of third farms. Here however the samples represent very small absolute figures and therefore any interpretation should be undertaken with caution.

TABLE 8.9

LOCATION OF SECOND AND THIRD FARMS ACROSS AGRO-ECONOMIC GROUPINGS

AGRO-ECONOMIC GROUPING	LOCATION OF 2ND FARM			LOCATION OF 3RD FARM		
	SAME	DIFF	N	SAME	DIFF	N
AEG ONE	39 85%	7 15%	46	11 73%	4 27%	15
AEG TWO	16 89%	2 11%	18	3 75%	1 25%	4
AEG THREE	34 87%	5 13%	39	28 93%	2 7%	30
AEG FOUR	11 85%	2 15%	13	3 75%	1 25%	4
5*	124 91%	13 9%	137	35 90%	4 10%	39

N signifies group size (number of farms).
SAME signifies same location as present home location.
DIFF signifies different location from present home location.
5* signifies transitional farming zone.

A comparison of the figures for second and third farm locations suggests that within AEG one, third farms may be located a greater distance from the family home than second farms (27% compared to 15% of farms being located outside the present home location). The location of third farms at a greater distance from the family home than second farms is probably a result of there being very little land available in AEG one for extending the area under cultivation due to the density of human settlement. Land for new farms therefore has to be purchased in less intensively farmed areas.

AEG three remains the most distinctive grouping with 93% of third farms still located in the same locality. This confirms that AEG three represents a complex and intensively settled area, where farms are typically very small with each farm family owning many small land holdings which are generally located in close vicinity of each other. These findings suggest that farmer mobility may be most important in influencing the agricultural homogeneity of AEGs where farmers are shown to move between different locations in agricultural areas which are not characterised by bush fallowing practices (in AEG two human population movements are a characteristic of the bush fallow farming system).

In summary the following major differences have been identified: AEG one is generally the most stable with 92% of farmers remaining in their original home location. 73% of these have been cultivating the same land for ten or more years and 88% say they will continue to do so in the future. As with the three other AEGs over 90% say they own the land they presently occupy.

Although there is only a relatively low absolute number of farmers involved, 27% of those owning three farms have these in a different location to their home location. This suggests some of the farmers in this grouping are particularly mobile (and more prosperous?).

AEG two is the grouping most unlike AEG one. 33% of farmers have moved from their original home locations since birth and 31% have moved at least twice. 85% of farmers have been cultivating their present farms for less than five years and 33% say they will cultivate a new farm in the next five years (44% said they did not know how much longer they would continue to cultivate on the same farm). These figures suggest the area depicted by AEG two has a very mobile population, with both relocation of homes and farms being common place. This conforms to the farming system in Tharaka division, and is particularly true of the regions bordering the Tana river.

AEG three is most similar to AEG one. Although 22% of farmers have moved from their original home location since birth, 72% have been cultivating on their present farms for ten years or more and 92% say they will continue to do so in the future. The main difference between this AEG and the other three is in the number of farms owned by each farm family. 50% of farmers have three or more farms although 93% of these are in the same location as the family home.

AEG four has a similar structure to AEG two but is more stable with less inter-locational farmer movement. 58% of farmers are cultivating in different locations to their original home location and 57% have moved at least twice since birth. However, although 27% have been farming on their present site for less than five years, 79% say they will continue to farm on these sites in the future (14% were undecided). This AEG represents a recently mobile farm population, but whose future stability appears to be more certain with fewer farmers preparing to cultivate new farms than has been the case in the past.

The final grouping represents the transitional farming zone and is less distinctive. Although inter-locational farmer mobility has been limited, there does appear to be a considerable amount of intra-locational population movement occurring. 23% of farmers are cultivating in different locations to where they were born, although only 15% have moved more than once since birth. However, 48% have been farming on their present site for five years or less, and 26% say they don't know if they will move to cultivate new farms in the future (in contrast 66% say they will continue to cultivate their existing farms). Heterogeneity is shown in the tenureship of farms. 70% are 'owned' (either title deed or *de facto* ownership) by individual farmers while 25% are clan land under communal ownership.

The transitional farming zone has a very mobile farm population with over 60% of farmers having cultivated their farms for less than ten years. It is no coincidence that this zone was found to be the most heterogeneous in Chapter Seven. Clearly, when identifying target areas for agricultural research and development programmes it is important to ascertain the stability of the human population. If the rural population is highly mobile it may be necessary to establish policies to stabilise it where this mobility is occuring outside the traditional bush fallow farming systems, before attempting to initiate any long-term development objectives. In the case of bush fallow farming systems it will be important to develop programmes which do not conflict with such systems, but which aim to alleviate the increasing pressure resulting from a growing human population on these fragile environments.

This section has discussed the AEGs and the transitional farming zone using a number of different variables to examine the relationship between farmer mobility/residency and the internal structure of AEGs. The findings suggest that there is a relationship here, and it has been shown that where there is a more mobile farm population AEGs appear to be agriculturally less homogeneous. In these areas it is more difficult to distinguish between farming systems. It is suggested that differences in the internal consistency between AEGs may be caused by differences in inter-locational and intra-locational farmer mobility within the smallholder economy.

Agricultural planning must be based on an understanding of both farming systems (AEGs) and land capability (AEZs). Where farmers have been resident for many years and have a sound knowledge of their local environment, programmes should focus on improving the productivity of these farming systems. On the other hand, where farmers are recently settled, development assistance should give greater priority to assisting farmers to develop environmentally sound farming systems. In the next section farming systems (AEGs) are related to land capability (AEZs) to define recommendation domains. Recommendation domains are used for identifying priority areas for agricultural development.

8.3 THE DEFINITION OF RECOMMENDATION DOMAINS

Each AEG (Figures 8.5 to 8.8 show the redefined AEGs) was overlaid onto a map defining the major agro-ecological zones (AEZs) in the study region to distinguish recommendation domains - smallholder farming areas with similar natural resource endowments, access to markets and farming systems (Figure 8.9). Each of the recommendation domains was defined using AEGs, AEZs, soils, infrastructure and accessibility to market centres. Nine major recommendation domains were distinguished and the main characteristics of these are listed in Table 8.10 (the reader may like to refer to Map 1 for the location of place names mentioned in this section).

Domains one and three conform very closely to AEG one and three. Domain two is divided into two sub-domains since part of this area was originally included in the transitional farming zone. However, because of its geographic position within the livestock-rearing/bush fallow farming system it forms one major domain. Domain four is based on AEG four but is also sub-divided. It includes the Mitunguu (west), Makandune (central) and Nkondi (east) areas. These sub-domains are not considered in the analysis and discussion of recommendation domains in this chapter.

Domain one represents the marginal coffee-growing zone in the west of the study region. It conforms very closely to AEZ UM3 (Figure 8.9). The soils of this area are well drained, deep to extremely deep friable clays. In some places to the north these soils become gravelly. Fertility is moderate to high. The altitude ranges between approximately 1200-1560 metres. The area is close to the new Thuchi-Nkubu bitumen highway and the important

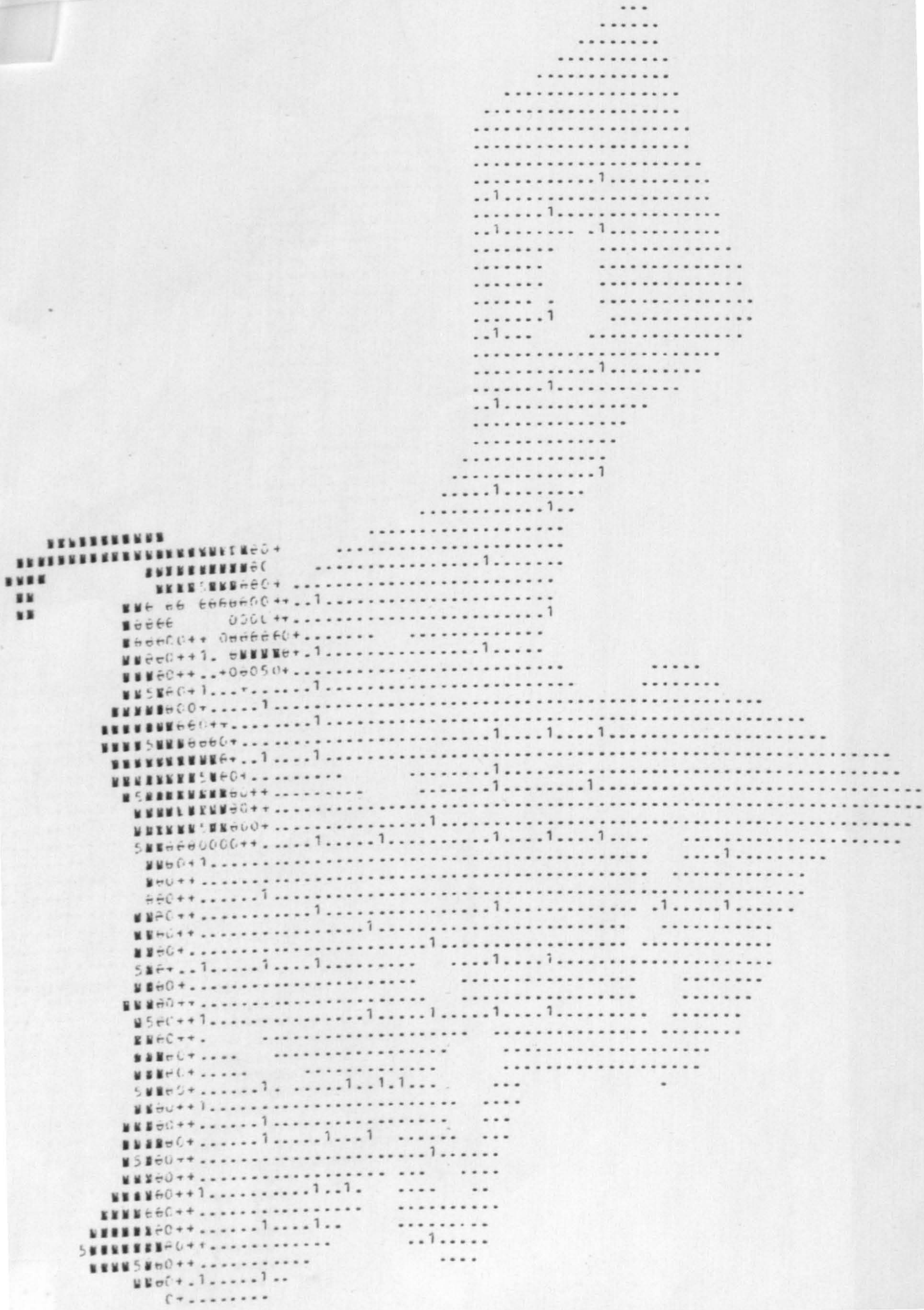


FIGURE 8.5 THE FIRST AGRO-ECONOMIC GROUPING

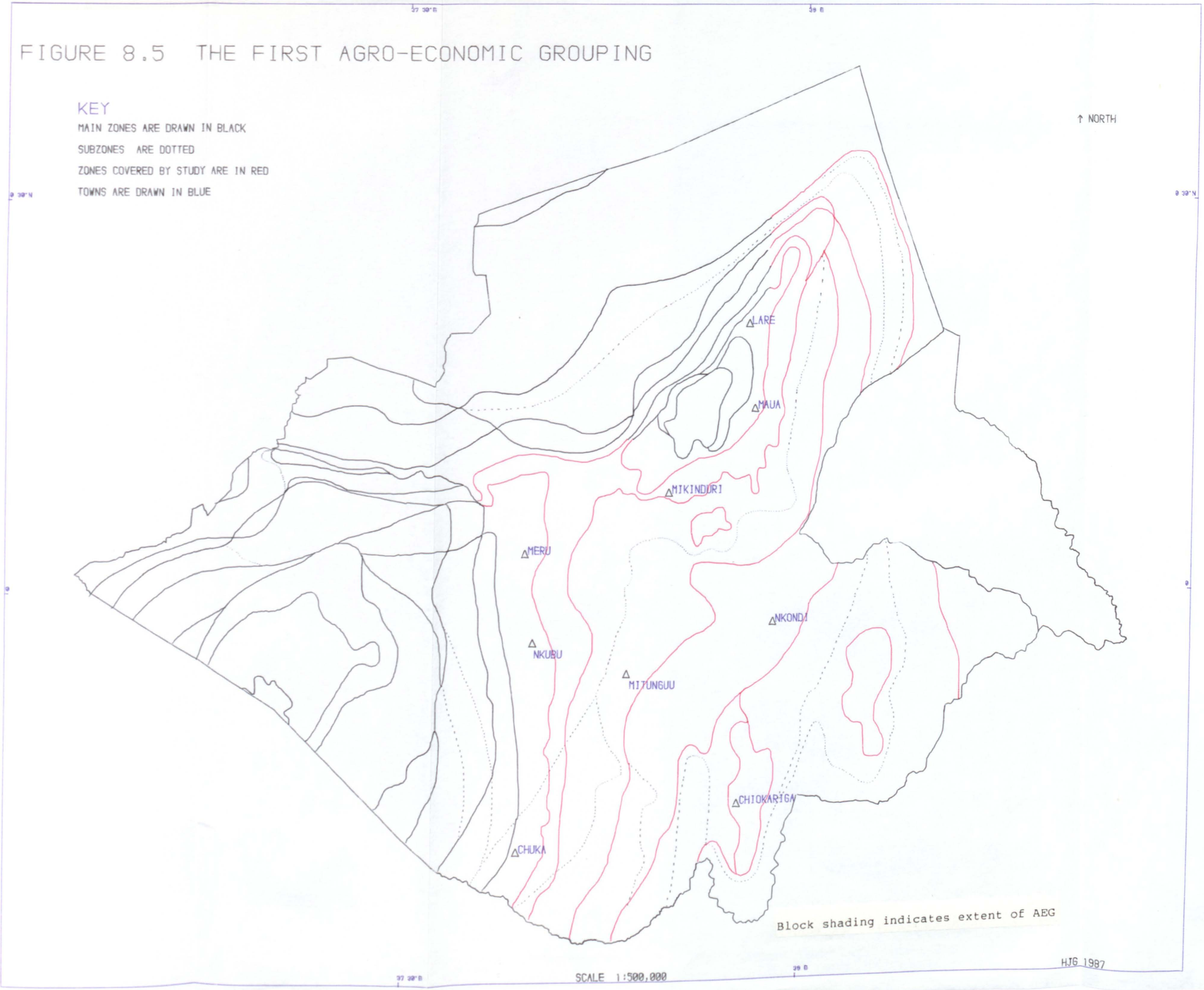


FIGURE 8.5 THE FIRST AGRO-ECONOMIC GROUPING

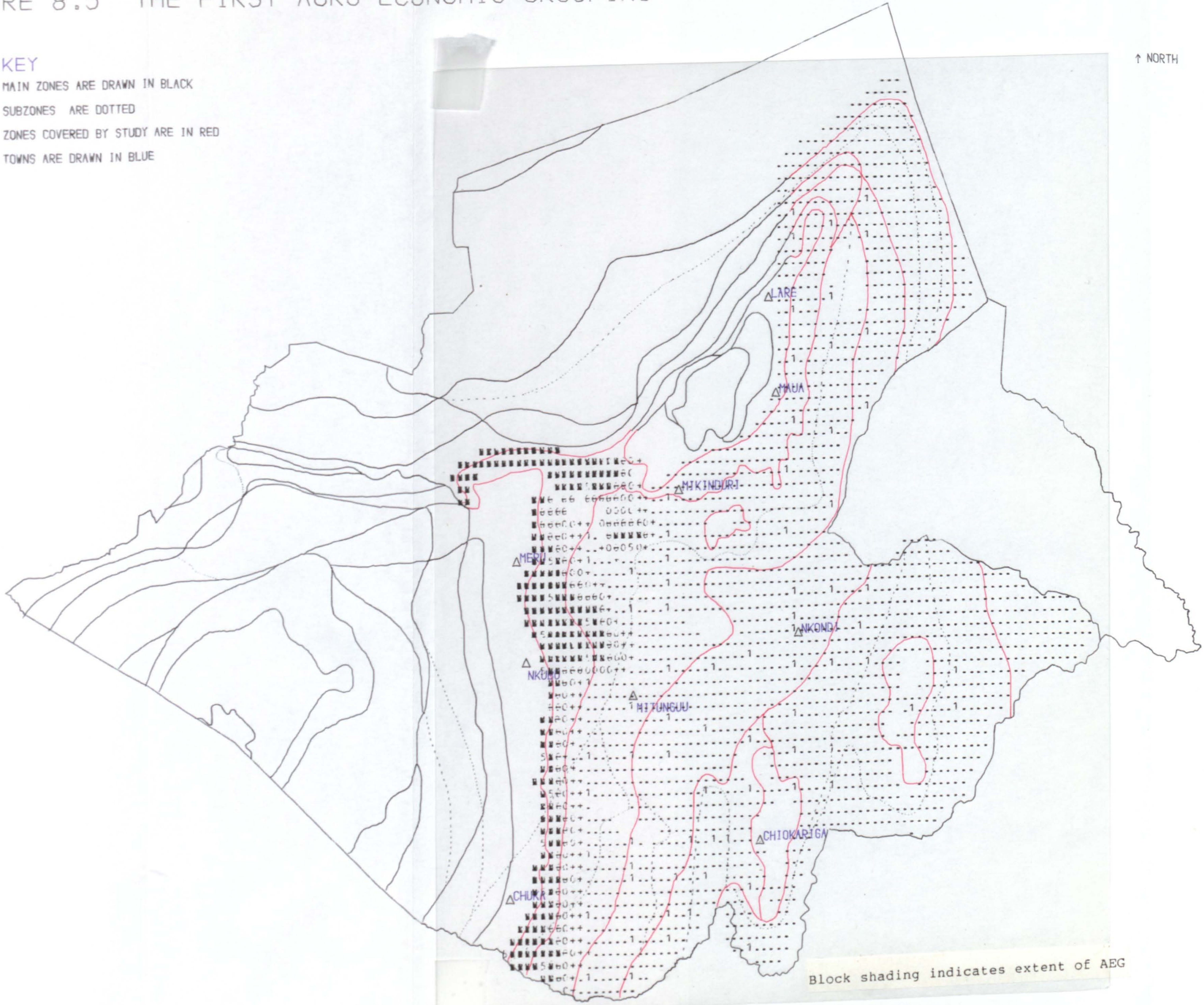
KEY

MAIN ZONES ARE DRAWN IN BLACK

SUBZONES ARE DOTTED

ZONES COVERED BY STUDY ARE IN RED

TOWNS ARE DRAWN IN BLUE



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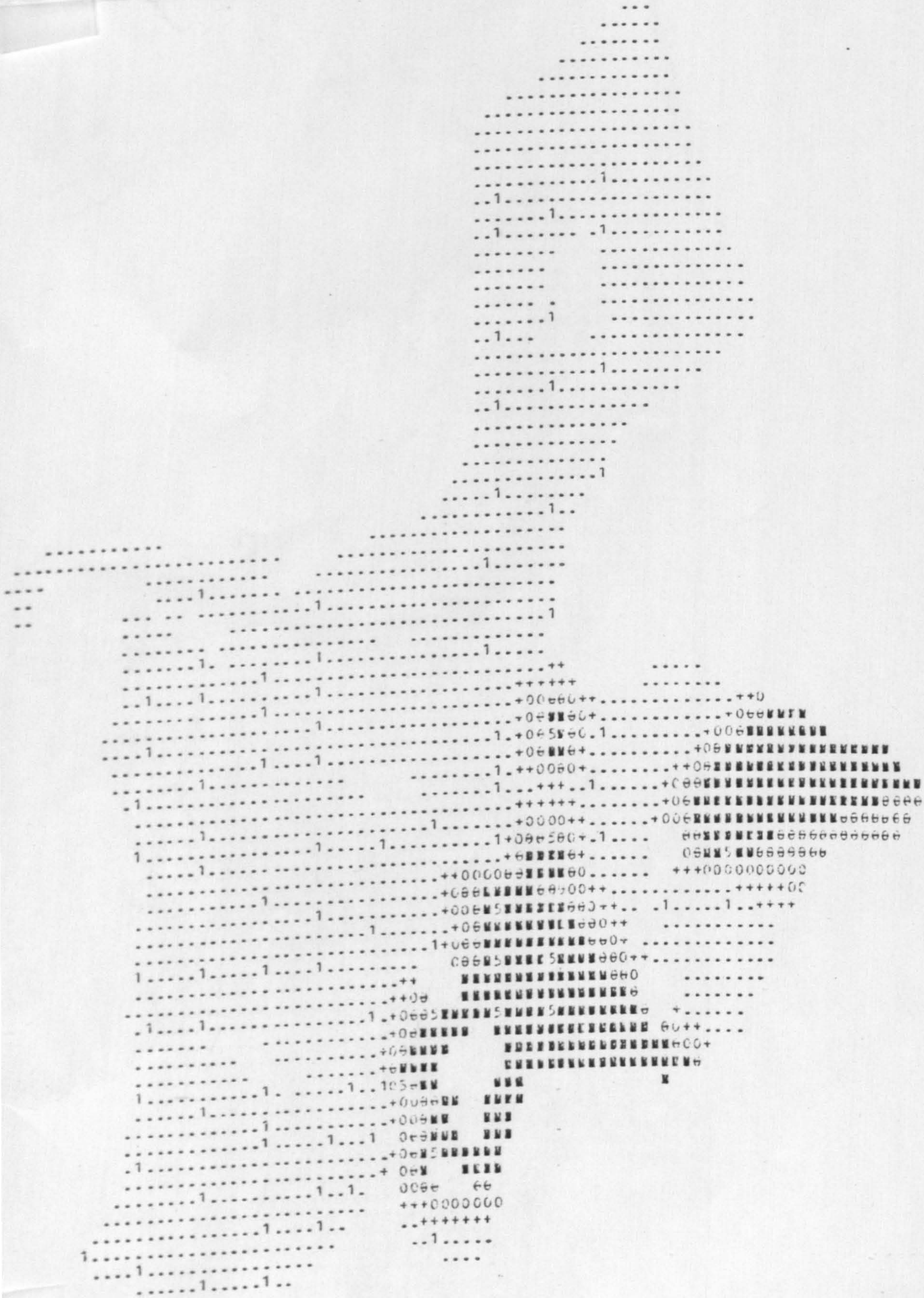


FIGURE 8.6 THE SECOND AGRO-ECONOMIC GROUPING

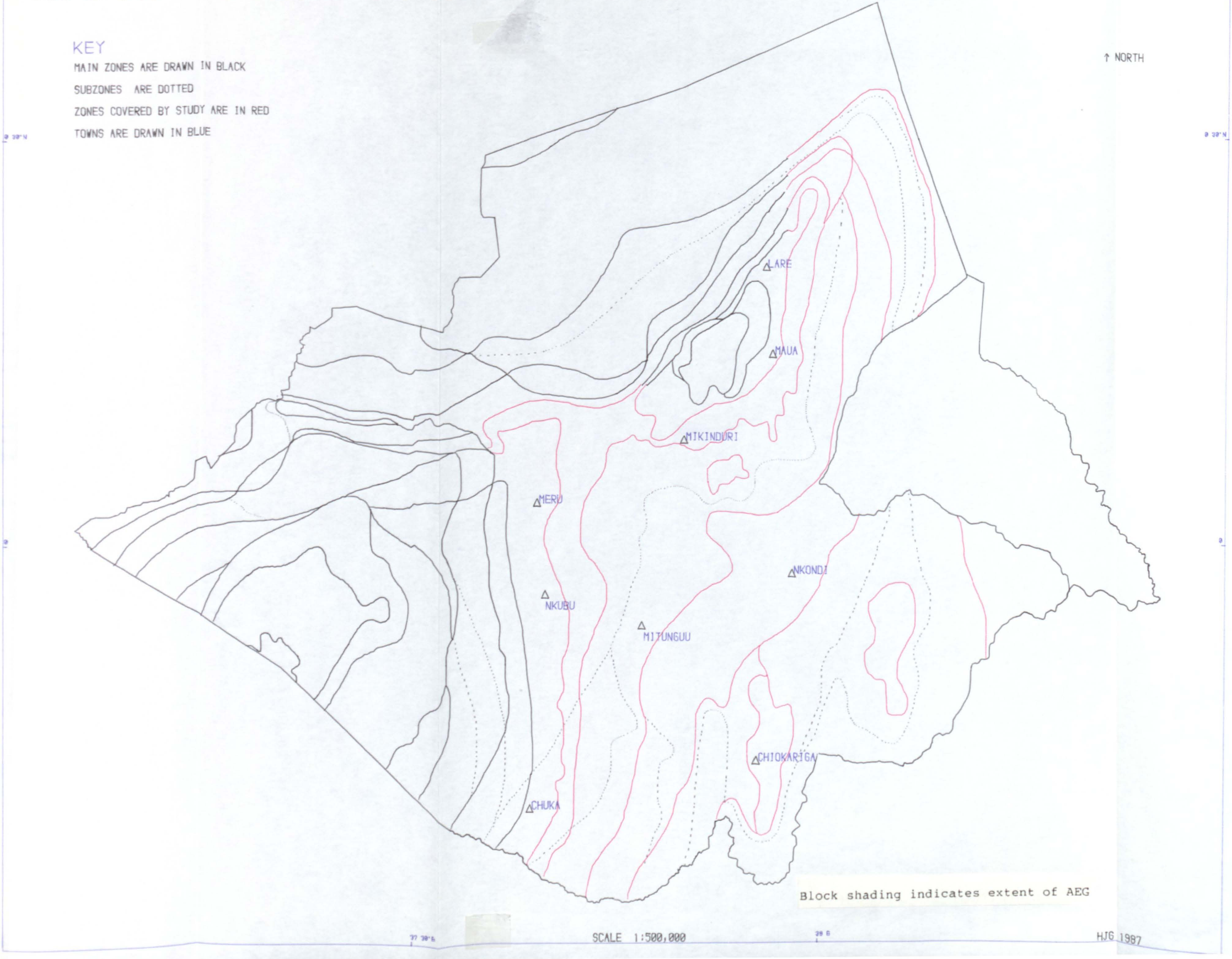
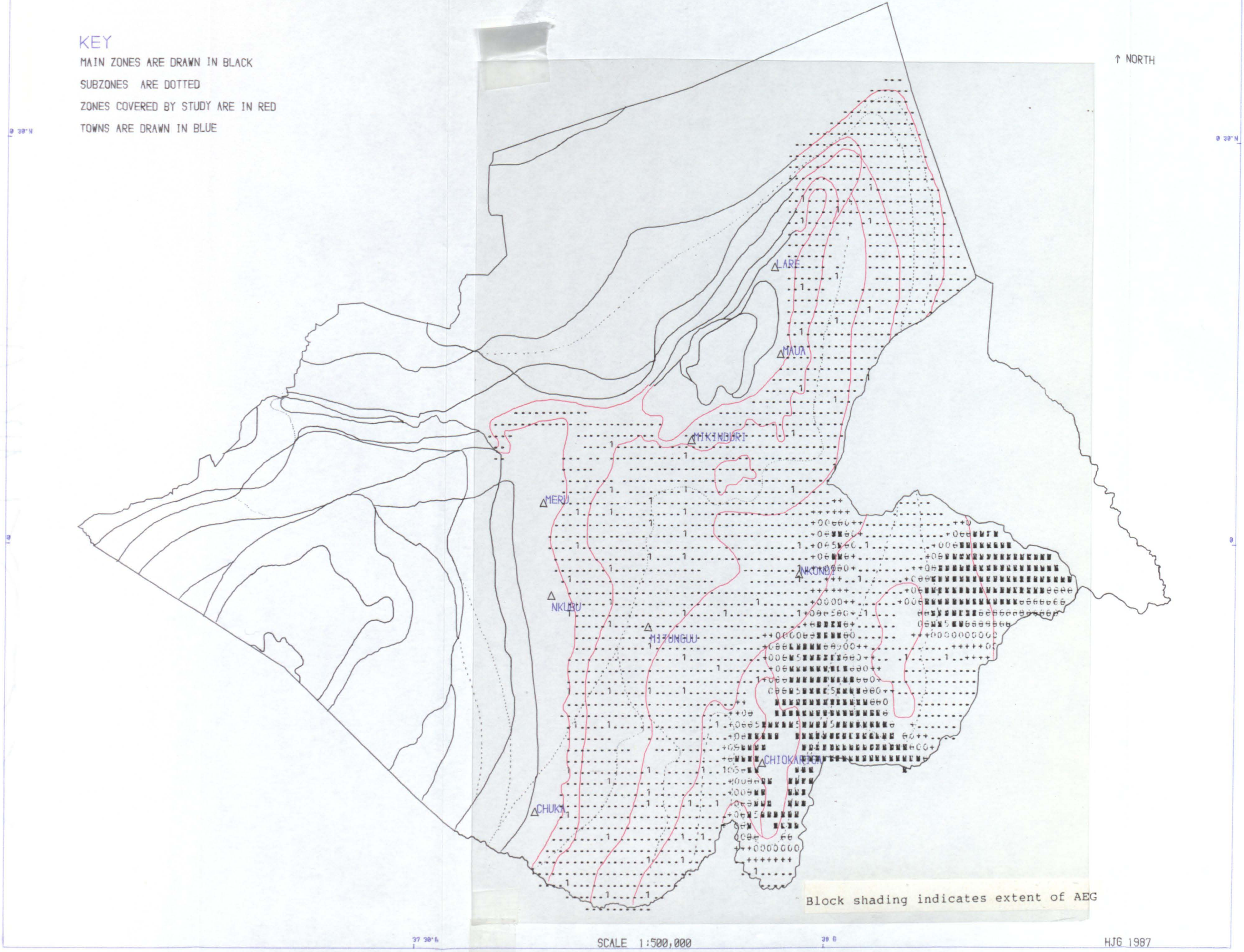


FIGURE 8.6 THE SECOND AGRO-ECONOMIC GROUPING



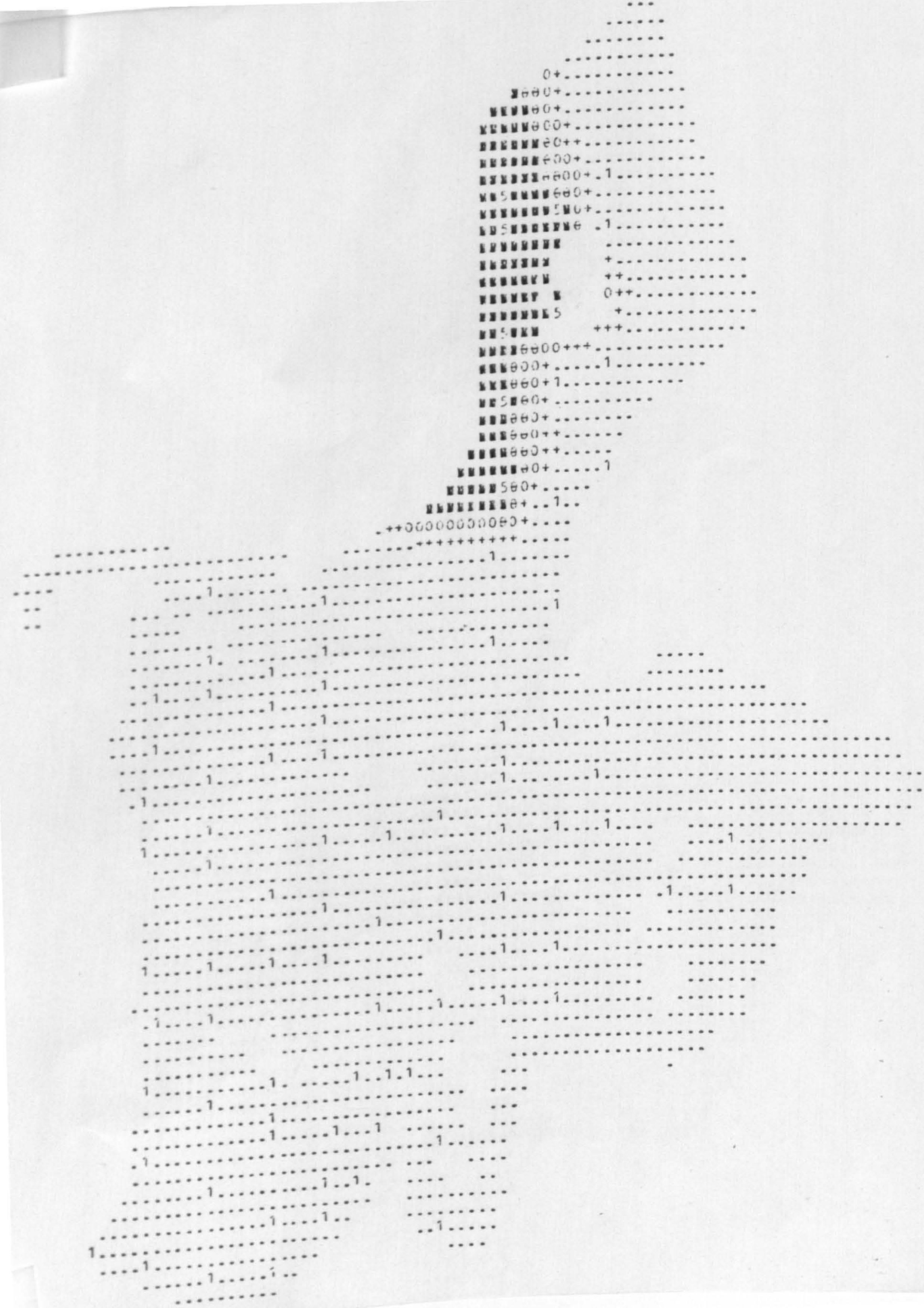


FIGURE 8.7 THE THIRD AGRO-ECONOMIC GROUPING

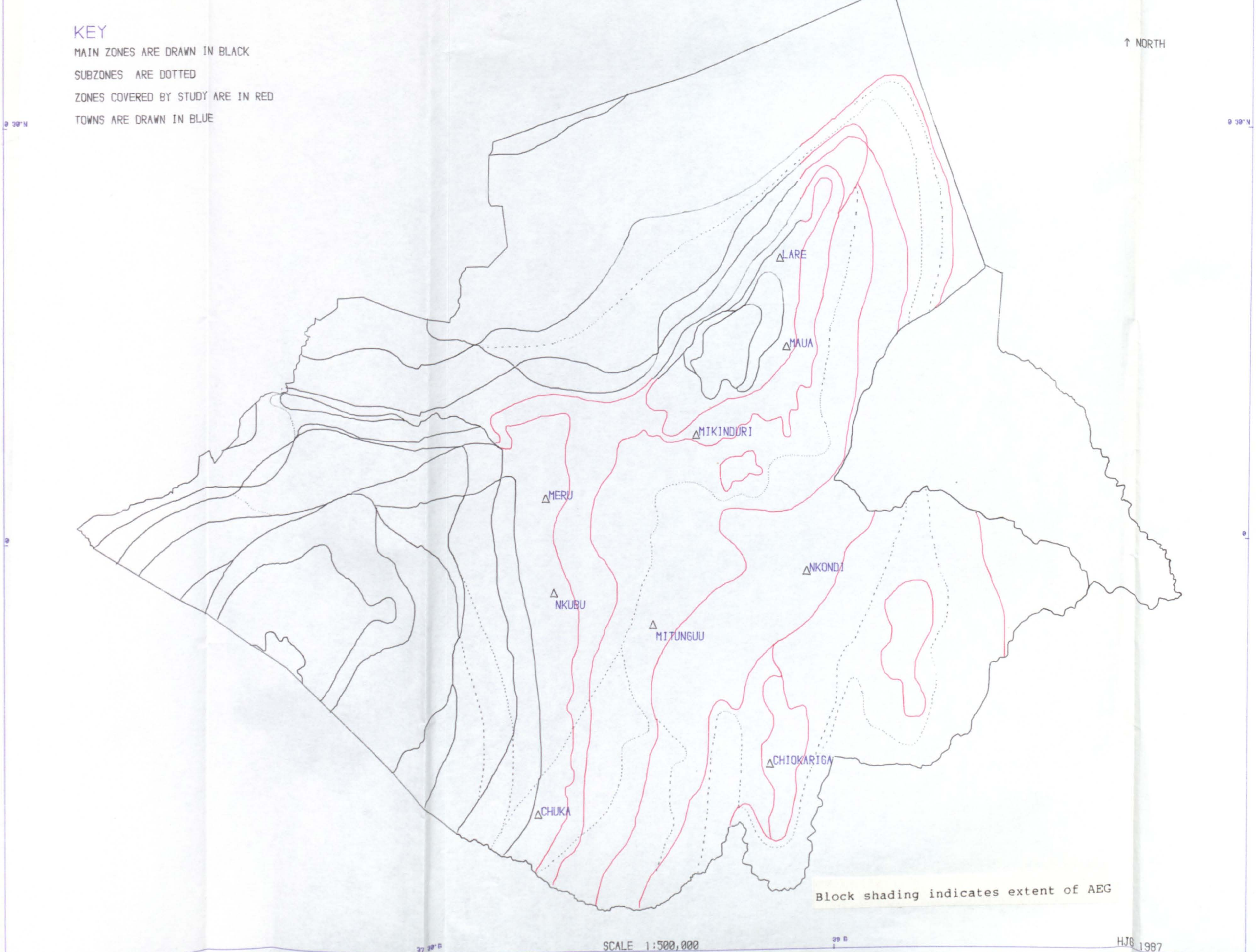
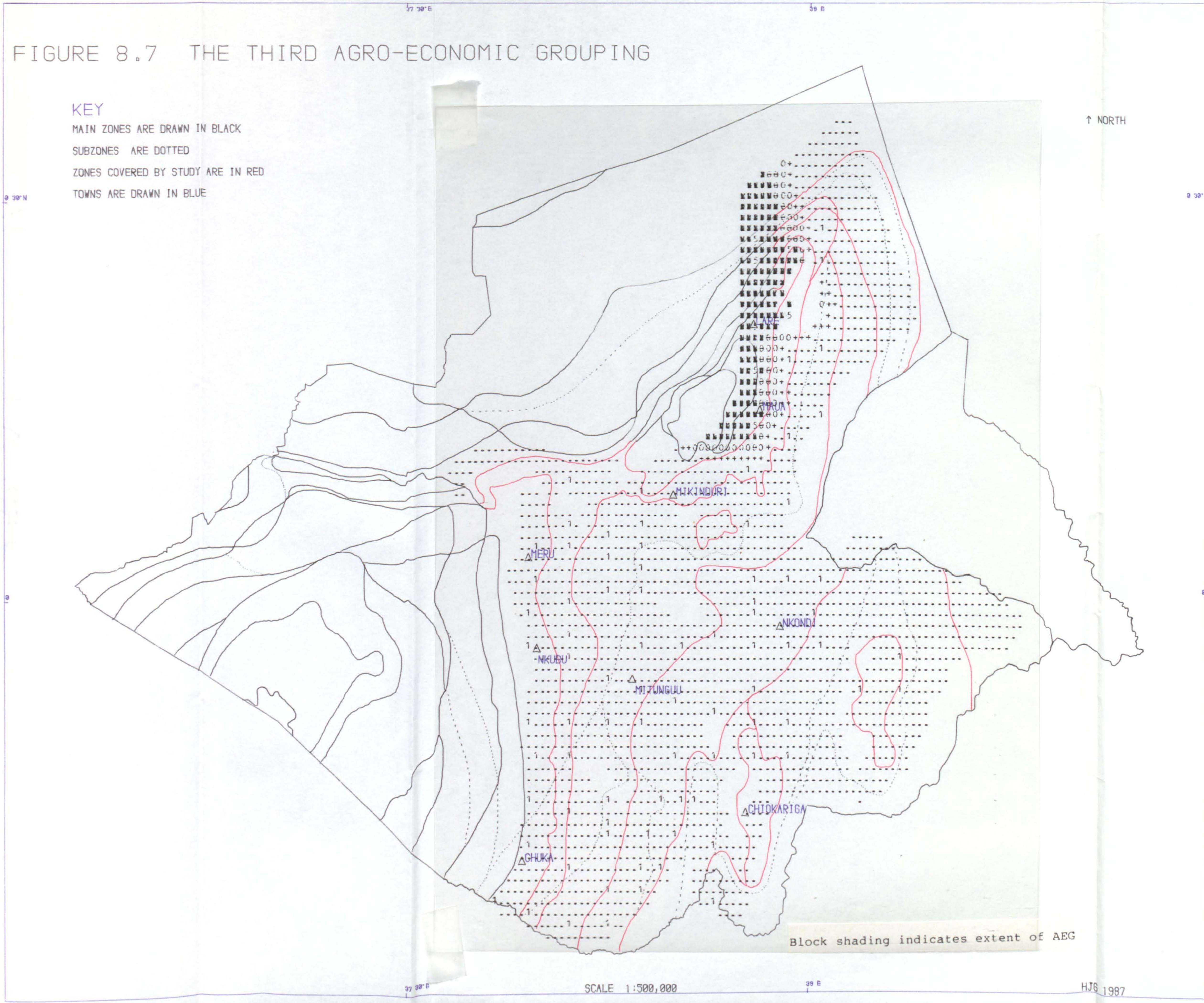


FIGURE 8.7 THE THIRD AGRO-ECONOMIC GROUPING



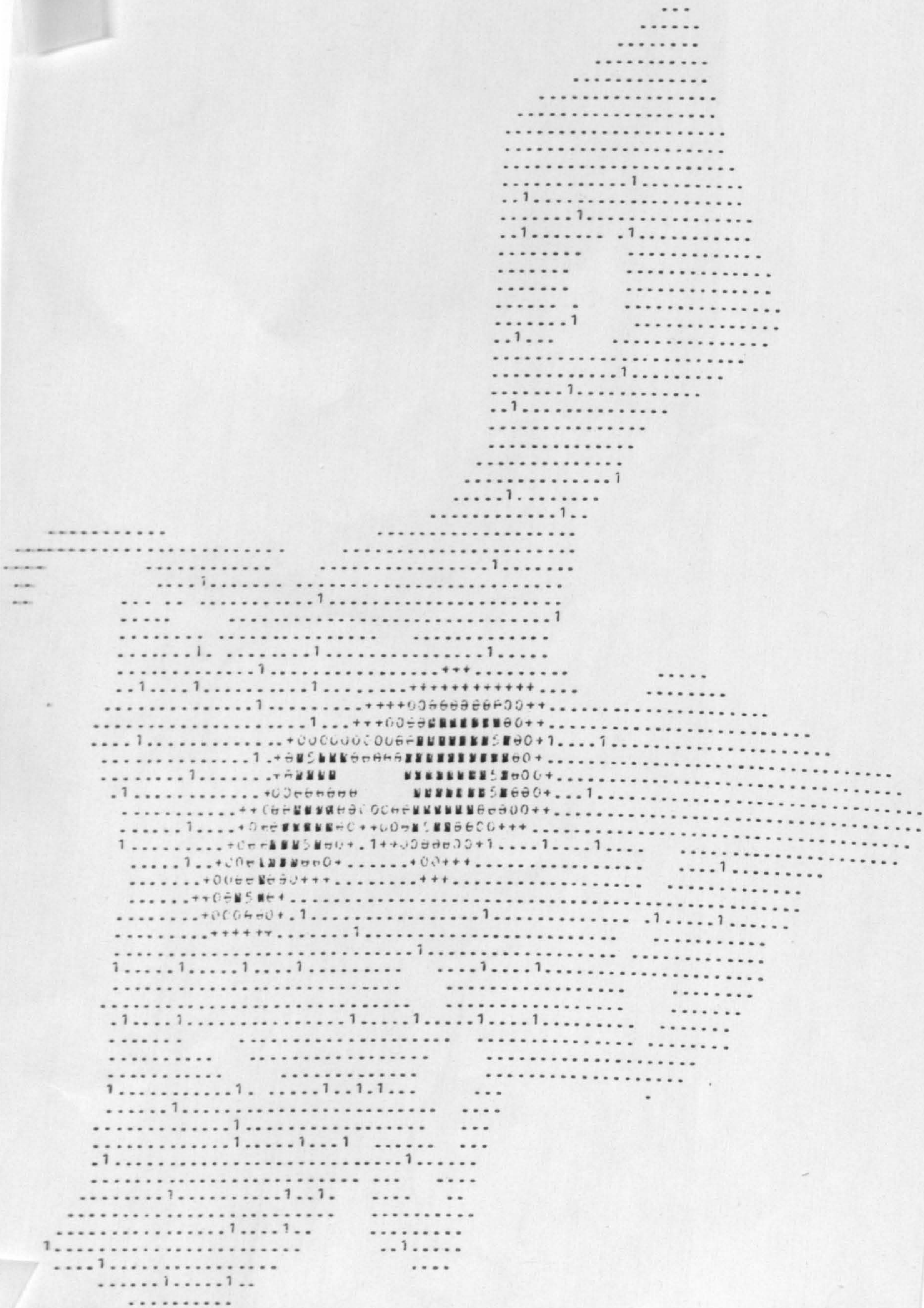


FIGURE 8.8 THE FOURTH AGRO-ECONOMIC GROUPING

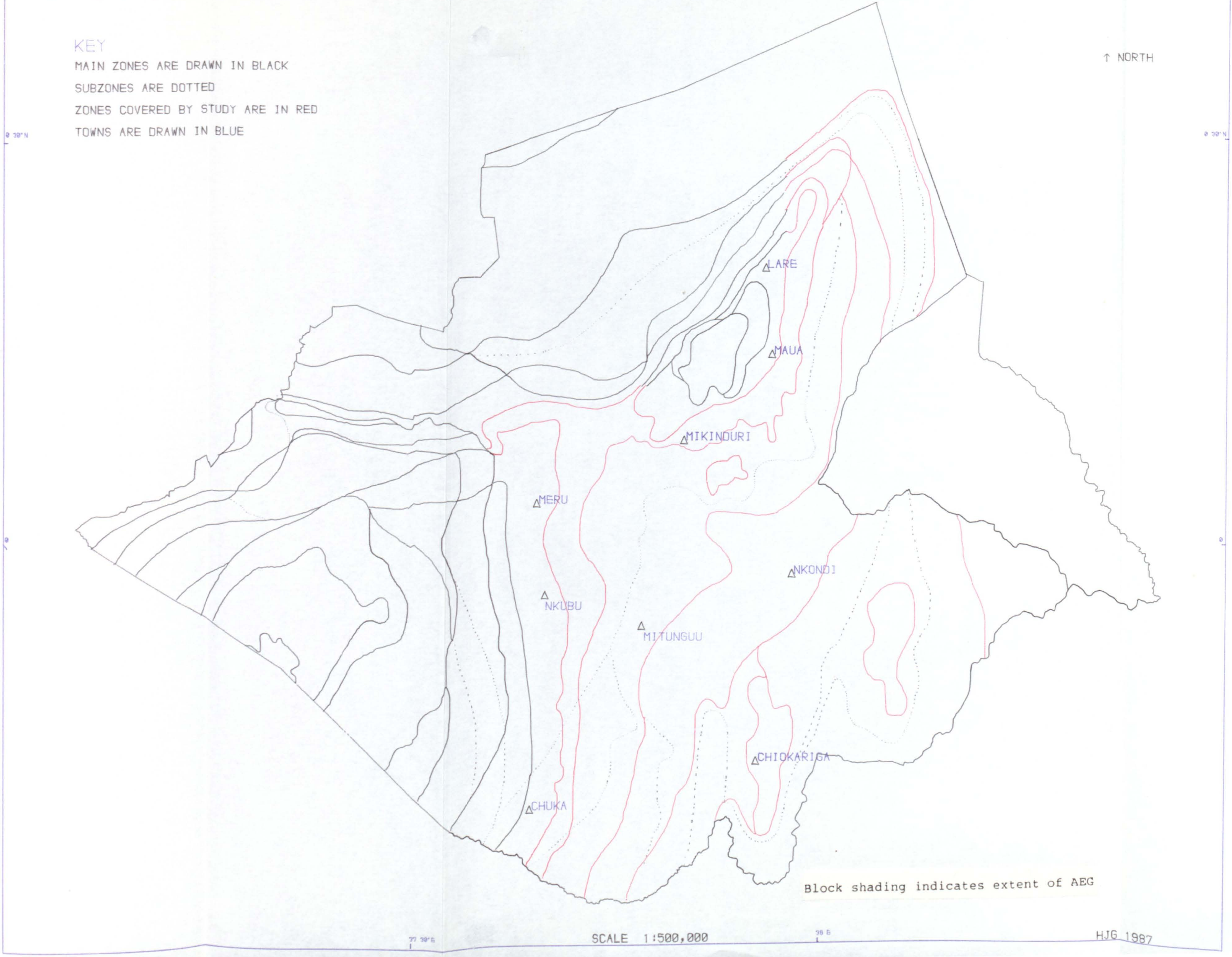
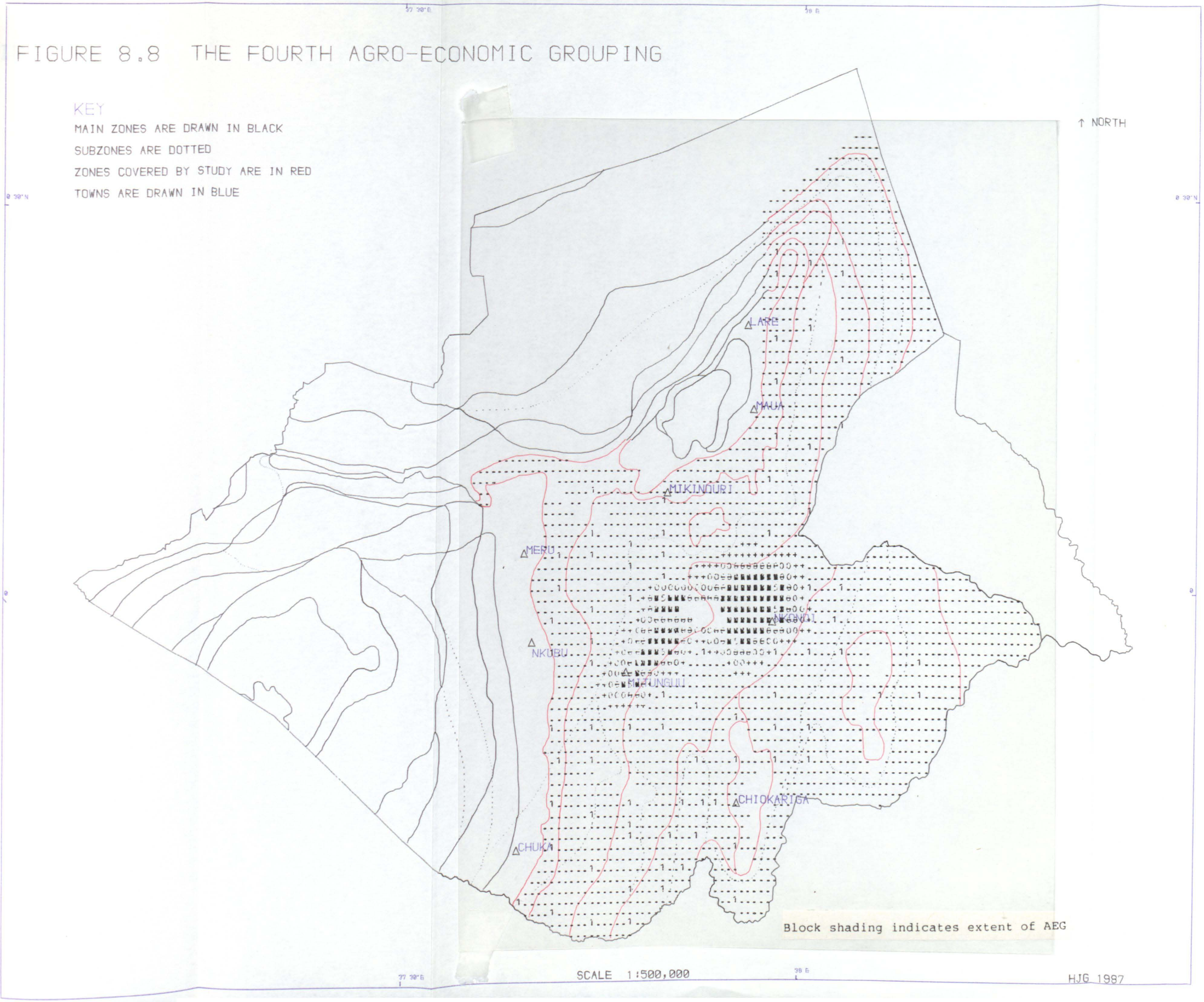


FIGURE 8.8 THE FOURTH AGRO-ECONOMIC GROUPING



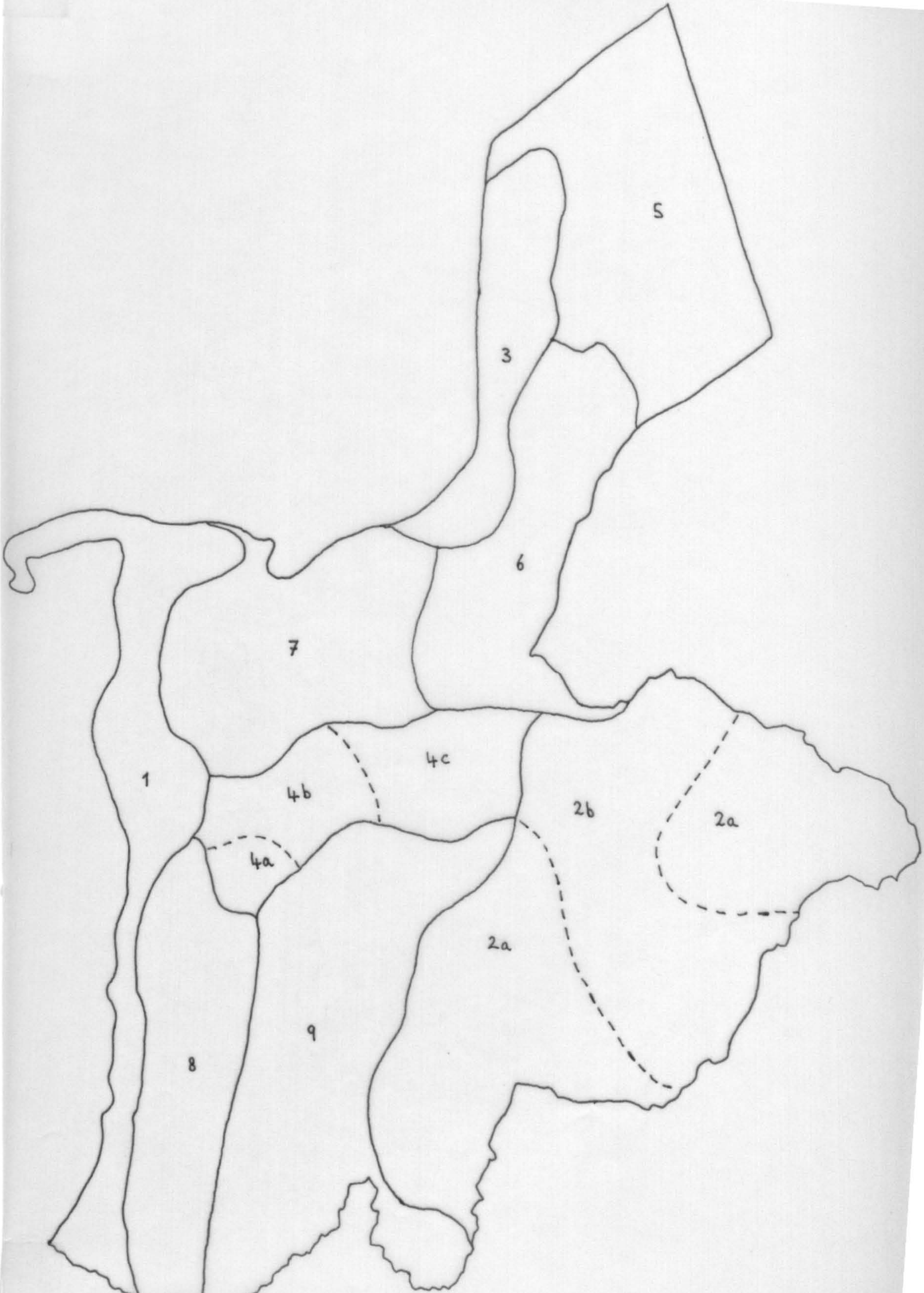

5
3
6
7
1
4c
4b
2b
2a
4a
2a
9
8

FIGURE 8.9 RECOMMENDATION DOMAINS IN LOWER MERU

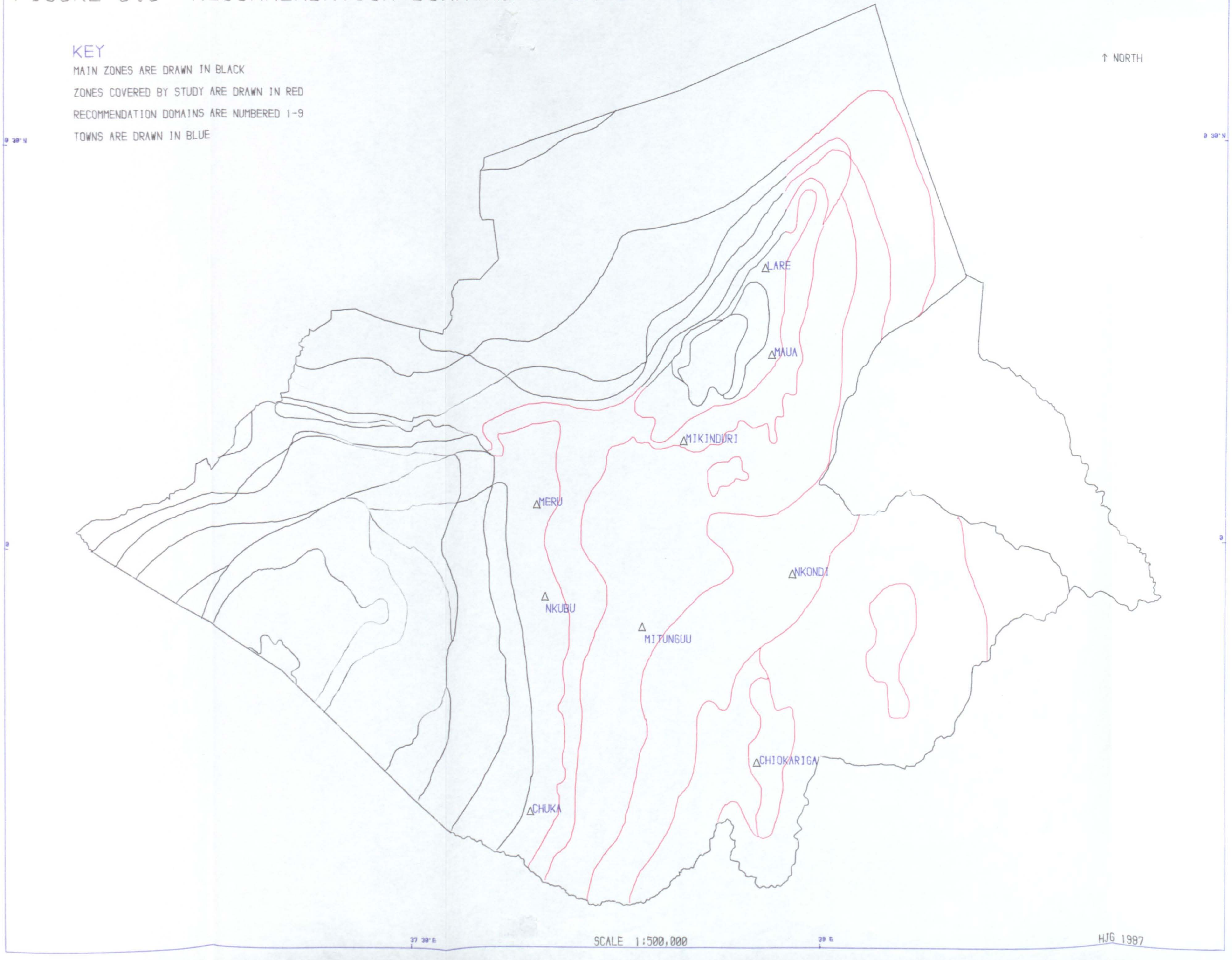


FIGURE 8.9 RECOMMENDATION DOMAINS IN LOWER MERU

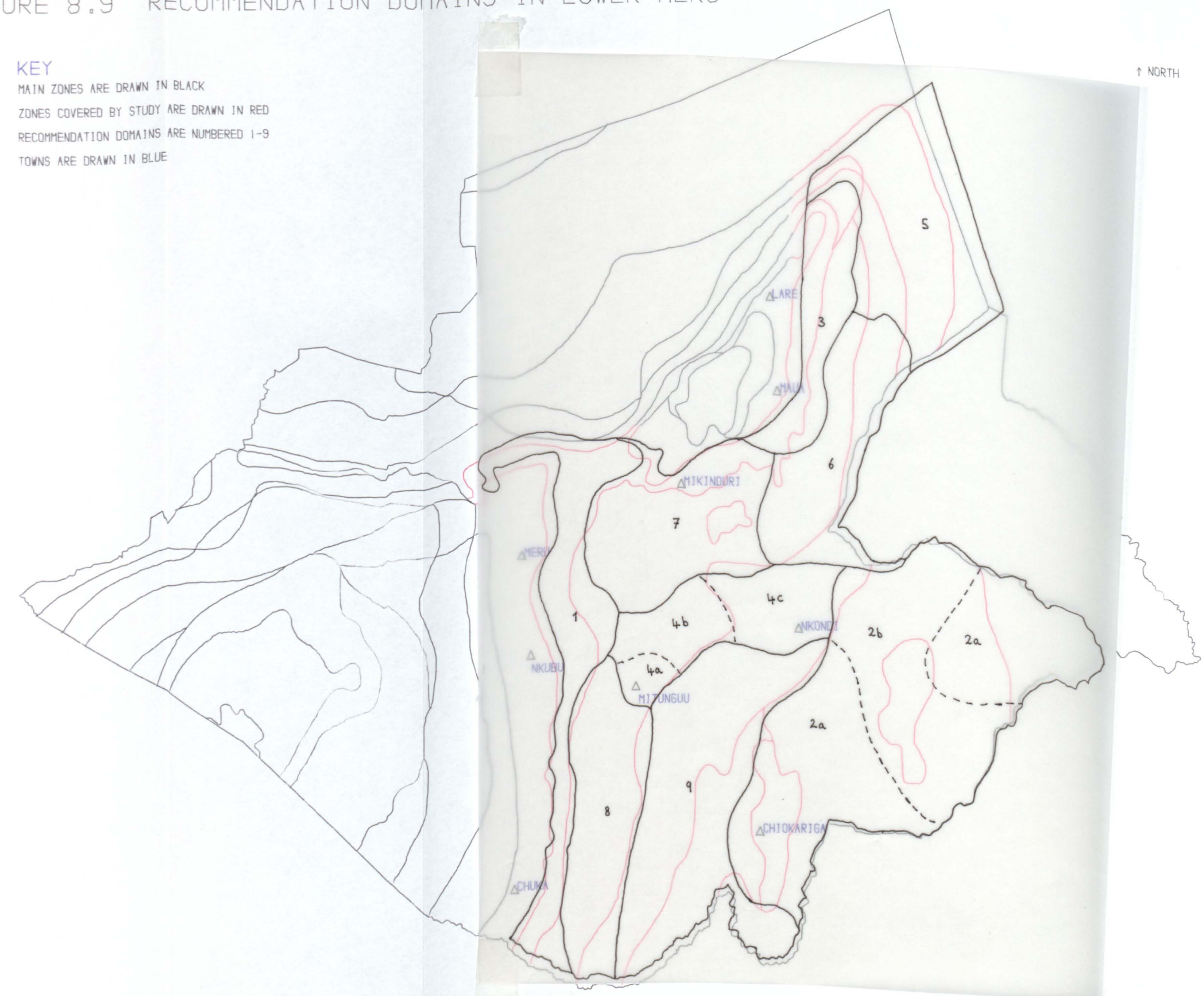
KEY

MAIN ZONES ARE DRAWN IN BLACK

ZONES COVERED BY STUDY ARE DRAWN IN RED

RECOMMENDATION DOMAINS ARE NUMBERED 1-9

TOWNS ARE DRAWN IN BLUE



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market towns of Meru, Nkubu and Chuka.

The second domain represents the livestock-rearing zone in the south-east. This zone conforms to the IL5 and IL6 agro-ecological zones although it also includes a small part of the LM5 zone in the south-west and LM4 zone in the north-east. The soils are well drained and range from deep to very deep sandy clay to clays, to shallow loamy sand to clay. Fertility of these soils is generally moderate to low. Altitude ranges from approximately 380-780 metres. Road communications in the area are poor although the building of a new bridge over the Tana river at Usueni in Tharaka may improve this situation in the near future. There are two main markets for farmers in the area - Marimanti and Gatunga. Previous analysis suggests that this domain should be divided into two sub-groups of farmers (Figure 8.2) and these are indicated by dotted lines within the domain (Figure 8.9).

The third domain represents the miraa-growing area to the north of the study region. The soils here are well drained and moderately deep. They are classed as clay loams to friable clays which are moderately to highly fertile. This domain conforms to the marginal coffee zone (UM3). Altitude ranges from approximately 1370-1700 metres. The area is served by the main Meru to Maua bitumen road but many of the smallholders in the north have poor links with the main market centres (Maua, Milu Tatu and Lare), and during the wet seasons transport becomes difficult.

Domain four represents the Nkondi and surrounding farmlands. Soils in this area are mixed and range in fertility from moderate to high in the Mitunguu area to moderate to low in the extreme east. The soils around Nkondi are generally more fertile and have a greater water retention capacity than those immediately to the south. The area falls within the LM3 and LM4 agro-ecological zones. Altitude ranges from approximately 700-1220 metres. There are a number of earth roads in the area but these are not all-weather roads and during the rainy seasons travel becomes difficult. The most important market centres are Nkondi and Mitunguu, both of which are likely to expand rapidly in the future. This domain should perhaps be sub-divided into three to distinguish between the Mitunguu (west), Makandune (central) and Nkondi (east) areas. The Mitunguu area includes some 400 hectares of irrigated farmland while at Nkondi farms are generally larger than in the other two areas. Makandune represents the least developed region of this domain. These areas are indicated by dotted lines within domain four (Figure 8.9).

The fifth domain represents the area in the extreme north of the study region. The soils of this area range from highly fertile clay loams with humic topsoils in the west (this soil represents only a minor area within the domain) to stony clay loams with rocky and bouldery surfaces of variable fertility in the north-east. The domain includes the marginal cotton-growing zone (LM4) a small part of the sunflower- and maize-growing zone (UM4) and the livestock/millet zone (LM5). The altitude of the area ranges from about 780 to 1400 metres. There are very few motorable roads in the domain and the area is predominantly used for livestock grazing. There are two livestock markets to the east and north of the domain (Kinna and Kula Mawe - both of which are in Isiolo district). The major limitation of the area is the lack of surface water.

Domain six represents the more recently settled land around the western fringes of Meru park. Soils here are generally well drained, moderately deep to very deep friable clays, although there are some areas in the central region of this domain which contain shallow to moderately deep friable gravelly clays. Soil fertility ranges from moderate to high in the west to low in the east and south. Parts of agro-ecological zones LM3 and LM4 are included in the domain, although the LM3 zone is restricted to the western side of the area. The road network is poor and in the wet seasons four-wheel drive vehicles are essential for travel. The nearest markets of any size include Maua and Uguti to the west. The altitude ranges from approximately 700-1280 metres.

Domain seven is contained largely within the main cotton-growing zone (LM3), although it also covers small parts of the marginal coffee zone (UM3) and the marginal cotton zone (LM4). The soils are mainly deep to extremely deep, friable to firm clays (gravelly in places). A small area in the east however contains shallow, friable, rocky or stony, sandy clay loams (Thuuri hill complex). Fertility of these soils is generally moderate to high but variable in the east. Although there are no bitumen roads in the area, it is well served by rural access roads. Altitude ranges from approximately 900-1400 metres. The two important market centres of Meru and Mikinduri serve farmers in the domain.

Domain eight is again contained mainly within the main cotton zone (LM3). Soils are well drained and generally deep to extremely deep, friable clays. There are however some very shallow to moderately deep, firm, stony and rocky clay loams around the hill complexes. These soils have a moderate to low fertility. Altitude ranges from about 790-1000 metres. Several market towns including Chogoria, Chuka and Ishiara serve farmers in this domain. A number of earth roads transect the area from east to west although some transport problems are experienced during the wet season.

The final domain includes parts of agro-ecological zones LM4 LM5 and IL5. Most of this domain is contained within the marginal cotton zone (LM4) however. Soils are generally well drained, moderately deep to very deep, friable sandy clays to clays. There are some soils which are shallow, stony, loamy sand to clay and these occur in the south-east of the domain. Altitude ranges from about 550-770 metres. The main Ishiara-Mitunguu road (earth) passes through the domain, yet the northern region is not served by this road and transport for farmers in this area is difficult. Marimanti, Mitunguu and Ishiara are the main market centres for farmers in the area.

The third research hypothesis suggests that farmers in the same agro-ecological zone act consistently and maintain similar farming systems. This hypothesis can be examined using the above mentioned domains as a basis for discussion since these domains have been derived on the basis of the relationship between AEGs and AEZs.

It is apparent that for domains one, two and three there is a considerable degree of consistency between AEGs and AEZs. AEGs one and three are largely confined to the marginal coffee zone (UM3) while AEG two includes the livestock and ranching zones (IL5 and IL6). AEG four, however, is divided between the main cotton (LM3) and marginal cotton (LM4) zones. Recent work by researchers at the Land Resources Development Centre (LRDC) has shown that around Nkondi, the main cotton zone (LM3) extends further south and east towards Meru Park than that designated by Jaetzold and Schmidt (1983). This suggests that even in this area (AEG four) farmers may be acting consistently within the same AEZ.

The main exceptions occur within the transitional farming zone. Here farming patterns are less distinctive with many farmers only recently settled, (Section 8.2) while there have also been considerable increases in cultivation indicating that farming systems may be undergoing change (Section 8.4). Farmers within this area are not acting consistently and to establish rural development programmes solely on the basis of AEZs will not account sufficiently for the wide diversity of farming practices presently in operation in this zone.

Table 8.10 summarises the main characteristics of the nine recommendation domains which have been identified. Mention has already been made of the differences between these domains with regard to soils, agro-ecological zones, altitude, road communications and market centres. The most distinctive farming characteristics of each domain are now discussed.

TABLE 8.10

SUMMARY STATISITICS FOR THE RECOMMENDATION DOMAINS

VARIABLE TYPE		RECOMMENDATION DOMAINS																	
		1		2		3		4		5		6		7		8		9	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
FARMERS GROWING CASH CROPS	COFFEE	63	84	0	0	12	13	0	0	0	0	0	0	8	16	5	16	0	0
	MIRAA	1	1	0	0	10	26	0	0	1	9	2	5	0	0	0	0	0	0
	COTTON	4	5	12	16	0	0	24	73	0	0	17	44	19	39	4	13	25	27
	N	75		75		39		33		11		39		49		31		94	
FARMERS GROWING FOOD CROPS	MAIZE	37	48	5	7	5	13	13	38	0	0	9	23	17	35	10	32	8	9
	BEANS	20	26	9	12	0	0	2	6	2	18	6	15	16	33	10	32	3	3
	MILLET	3	4	35	47	4	10	18	53	2	18	7	18	5	10	8	26	29	31
	SORGHUM	1	1	10	13	0	0	1	3	0	0	0	0	1	2	1	3	13	14
	N	77		75		39		34		11		39		49		31		94	
CROP INCOME	NIL	13	17	46	58	14	35	5	14	1	8	14	35	22	43	15	42	48	48
	<1000	14	18	17	21	4	10	7	19	1	8	7	17	8	16	9	25	22	22
	>1000	50	65	17	21	22	55	25	67	10	84	19	48	21	41	12	33	30	30
	N	77		80		40		37		12		40		51		36		100	
OFF-FARM INCOME	NIL	61	79	54	67	38	95	24	64	11	92	27	68	41	80	29	81	82	82
	<1000	3	4	15	19	2	5	5	14	0	0	7	17	4	8	4	11	9	9
	>1000	13	17	11	14	0	0	8	22	1	8	6	15	6	12	3	8	9	9
	N	77		80		40		37		12		40		51		36		100	
LIVESTOCK NUMBERS	<20	75	97	30	37	38	95	28	76	10	84	37	93	39	76	34	94	67	67
	20-50	2	3	31	39	2	5	7	19	1	8	3	7	12	24	0	0	20	20
	>50	0	0	19	24	0	0	2	5	1	8	0	0	0	0	2	6	13	13
	N	77		80		40		37		12		40		51		36		100	
LIVESTOCK INCOME	NIL	40	52	36	45	27	68	15	40	8	67	29	73	24	47	23	64	57	57
	<1000	16	21	20	25	8	20	14	38	1	8	5	13	9	18	10	28	20	20
	>1000	21	27	24	30	5	12	8	22	3	25	6	14	18	35	3	8	23	23
	N	77		80		40		37		12		40		51		36		100	
FARMS WITH NO CASH INCOME		9	12	18	23	11	28	4	11	2	17	7	18	12	23	9	25	30	30
	N	77		80		40		37		12		40		51		36		100	
LENGTH TO CONTINUE FARMING ON PRESENT SITE (YRS)	<10	0	0	23	31	0	0	2	6	0	0	2	5	0	0	0	0	8	8
	>10	66	88	14	19	37	95	29	83	9	90	36	92	50	96	20	59	57	58
	DK	9	12	38	50	2	5	4	11	1	10	1	3	2	4	14	41	33	34
	N	75		75		39		35		10		39		52		34		98	
LENGTH OF CULTIVATING ON PRESENT FARM (YRS)	<10	12	16	70	91	6	15	12	34	4	40	26	66	15	29	21	62	70	71
	>10	57	76	6	8	30	77	20	57	6	60	12	31	35	67	13	38	27	28
	DK	6	8	1	1	3	8	3	9	0	0	1	3	2	4	0	0	1	1
	N	75		77		39		35		10		39		52		34		98	
CROP PLANTING PRACTICES	ROW	219	48	100	50	28	22	141	88	3	13	59	39	197	79	63	39	132	47
	RANDOM	239	52	100	50	100	78	20	12	20	87	92	61	53	21	99	61	148	53
	N*	458		200		128		161		23		151		250		162		280	
YEARS OF CASH CROPPING	<10	18	23	78	98	19	48	24	65	5	42	30	75	23	45	25	69	89	89
	>10	59	77	2	2	21	52	13	35	7	58	10	25	28	55	11	31	11	11
	N	77		80		40		37		12		40		51		36		100	

n indicates farmers in a specified sub-category of a variable, % indicates percentage, N indicates the sample size for each variable, DK indicates farmer is uncertain, income is given in Kenyan shillings,
* indicates the number of plots and not the number of farms.

In domain one 84% of farmers grow coffee and 48% grow maize. Crop income levels are high with 65% of farmers earning more than 1000 shillings per annum (27% of all farmers also have livestock incomes of over 1000 shillings per annum). 76% of farmers have been farming for more than ten years on their present farms, and 88% say they will continue to do so in the future.

In domain two the most significant cash crop is cotton (16% of farmers grow this crop) while millet is the most important food crop with 47% of farmers growing the crop. Crop incomes are low (only 21% had incomes of more than 1000 shillings per annum) and income from the sale of livestock is more important with 30% of farmers earning more than 1000 shillings per annum. 24% of farmers have more than 50 head of livestock (sheep, goats and cattle). 91% of farmers have been cultivating their present farms for less than 10 years and only 19% say they will continue to farm on these sites for more than ten years. 98% of farmers say they have been growing cash crops for less than ten years.

31% of farmers in domain three grow coffee and 26% grow miraa indicating that this is the most important miraa-growing area in the study region. 55% of farmers have crop incomes of over 1000 shillings per annum. Livestock are not important and 95% of farmers have less than 20 head. 77% of farmers say they have been farming on their present farms for more than 10 years and 95% say they will continue to do so in the future. Crop planting practices in this domain are quite distinct with 78% of farmers planting crops using random methods. In contrast, in domain four 88% of farmers plant their crops in rows. 73% of farmers in this domain grow cotton with millet being the most important food crop

(53% of farmers grow the crop). 67% of farmers have incomes of more than 1000 shillings per annum. 65% of farmers have been growing cash crops for less than 10 years and 34% of farmers have been farming on their present farms for less than 10 years.

The summary statistics for domain five are based on a very small sample and interpretation of the data for this group of farmers should be undertaken with caution. Field experience suggests that a number of farmers in the extreme north-west of this domain realise considerable cash income from the sale of English potatoes and other food crops although this is not apparent from Table 8.10 above. Pastoralism is however the predominant land use. In domain six, 44% of farmers grow cotton and 23% grow maize. Livestock are not important to farmers as a source of income in this area and 93% of farmers own less than 20 head. This is a recently settled area with 66% of farmers saying they have been cultivating their present farms for less than 10 years although 92% say they will now farm permanently on this land.

Farmers in domain seven grow some coffee (16% of farmers) but the most important crops include cotton (39%) maize (35%) and beans (33%). 41% of farmers earn more than 1000 shillings per annum from the sale of their crops while 35% also earn a similar amount from livestock sales. Like farmers in domain four, crop planting practices are quite distinct with 79% of farmers planting in rows. In contrast 61% of farmers in domain eight use random planting methods. 69% of these farmers have been growing cash crops for less than 10 years and 62% have been cultivating on their present farms for less than 10 years. 41% say they do not know if they will continue to cultivate their existing farms in the future. The most important food crops are millet (26%), beans (32%) and maize (32%), with 13% of farmers also growing cotton and 16% coffee.

In domain nine cotton is the most important cash crop (27%), while millet is the most important food crop (31%). Like domain two this is the only other domain where a significant number of farmers are also growing sorghum. 13% of farmers have more than 50 head of livestock and 23% earn more than 1000 shillings from livestock sales per annum. 71% of farmers have been cultivating on their present farms for less than 10 years and 34% say they don't know it they will continue to do so in the future. 89% have been growing cash crops for less than 10 years.

In this section recommendation domains for agricultural research and development initiatives have been established. These cover the lower region of Meru district which has been the focus of the present study. Before being able to discuss the agricultural research and development priorities which arise from an analysis of these recommendation domains, it is necessary to examine the stability of these target areas over a period of time. Such an examination will help to identify domains which should become foci for development planners.

In the next section of this chapter recommendation domains are compared with areas of land use/cover change identified using Landsat MSS false colour composites and 1:50,000 stereo panchromatic aerial photography. It is suggested that where there have been marked cultivation changes the proposed recommendation domains are less stable and the farmer population is more mobile.

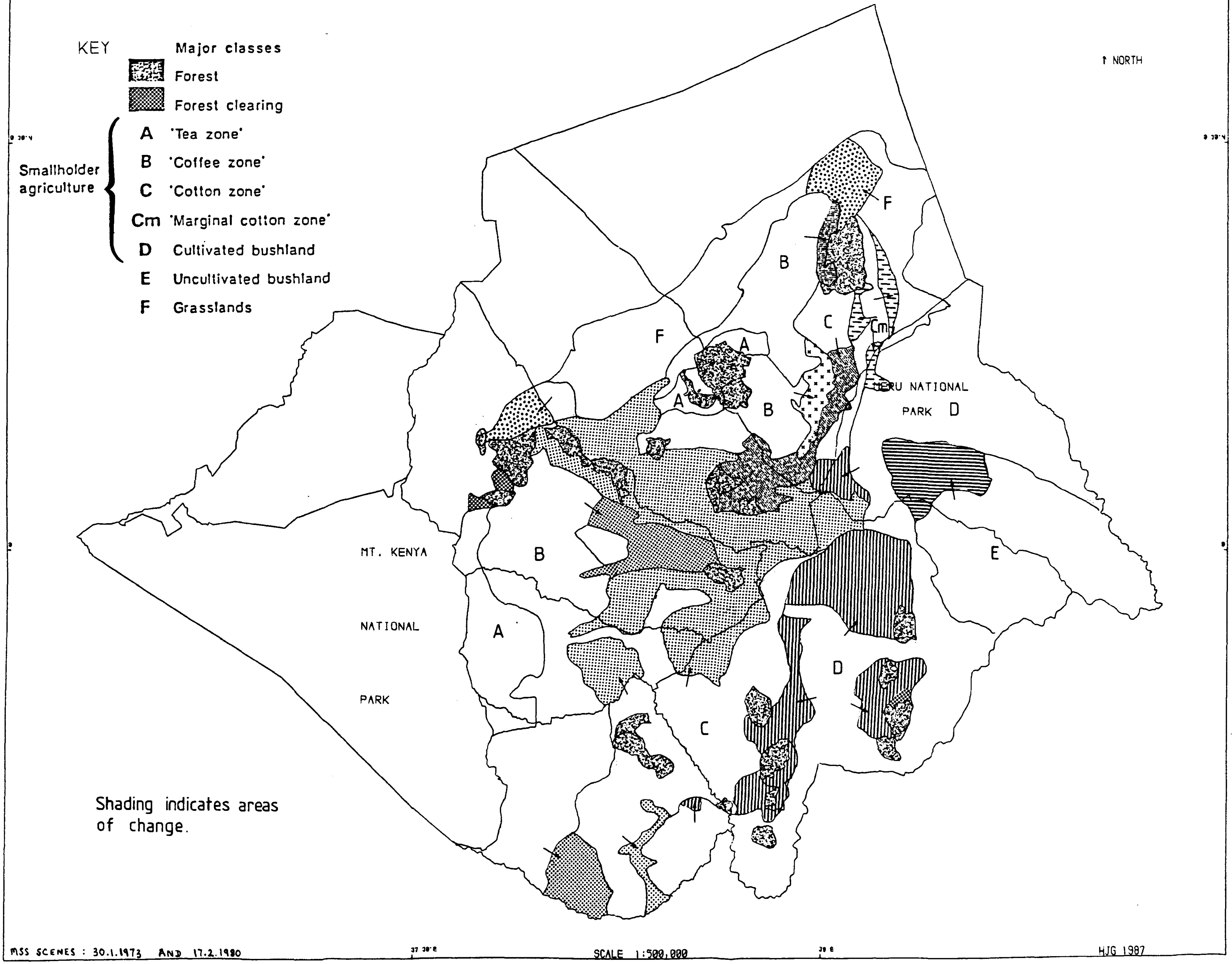
8.4 LAND USE/COVER CHANGES AND RECOMMENDATION DOMAINS

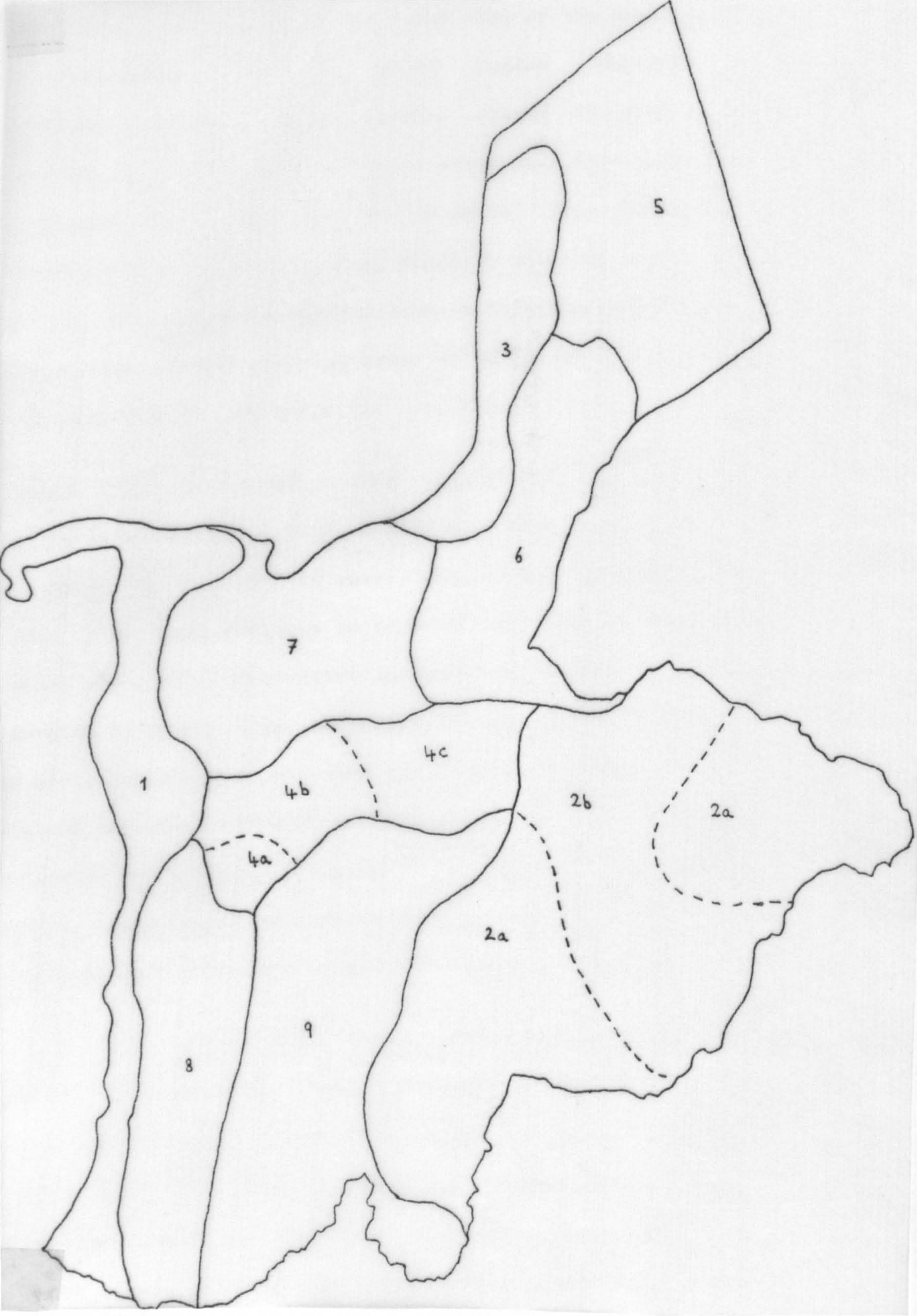
Figure 8.10 shows the areas of land use/cover change identified using Landsat MSS false colour composites for the period between two scenes from January 1973 and January 1980. Broad areas of difference were distinguished using the methods outlined in Chapter Four. The majority of these land use/cover changes were correctly shown to be occuring within the cotton (LM3) and marginal cotton (LM4) agro-ecological zones (arrows indicate the direction of change between zones).

Figure 8.11 shows a corresponding map for areas of cultivation change identified for the period between 1967 and 1980 using 1:50,000 panchromatic aerial photography. When these two maps were overlaid on to one another it became clear that the areas of change identified using Landsat MSS data were too broad to be of any use in helping to distinguish between different types of agricultural change within the study area, and it was therefore decided to concentrate on the 1:50,000 panchromatic photography. Figure 8.11 shows the relation between the recommendation domains and the areas of cultivation change identified using this photography.

It is clear from this figure that the majority of changes appear to have taken place within the transitional farming zone which was identified in Chapter Seven (Figure 7.10). The recommendation domains which appear to have experienced the most significant increases in cultivation during the period 1967-1980 include domains four, six, seven and nine. Note that over 30% of farmers in AEG four (Table 8.5) had been farming for less than ten years and over 60% of farmers in the transitional farming zone

FIGURE 8.10 AREAS OF LAND USE/COVER CHANGE : LANDSAT MSS DATA





5
3
6
7
4c
1
4b
2b
2a
4a
2a
9
8

FIGURE 8.11 CULTIVATION CHANGES IN LOWER MERU 1967-1980

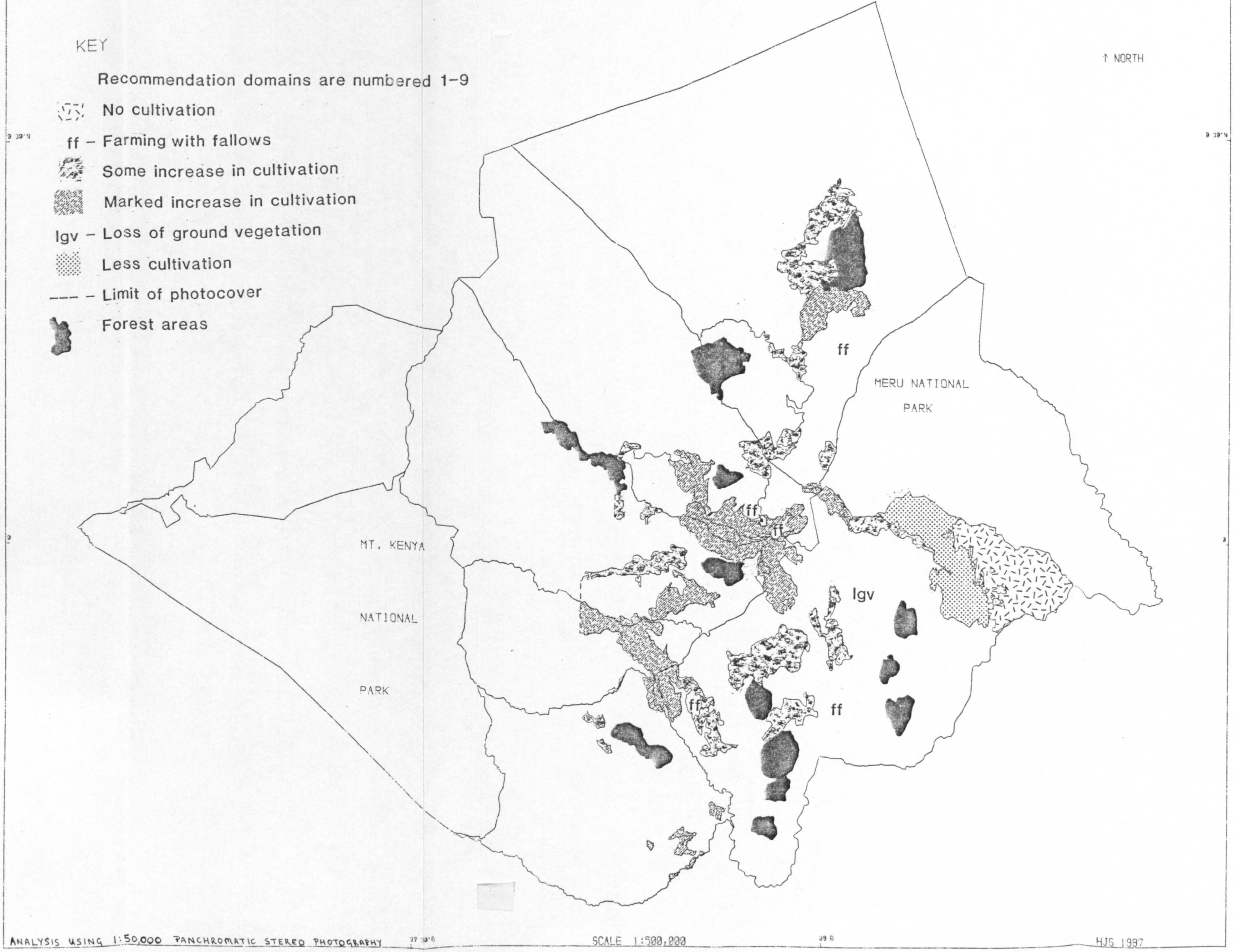
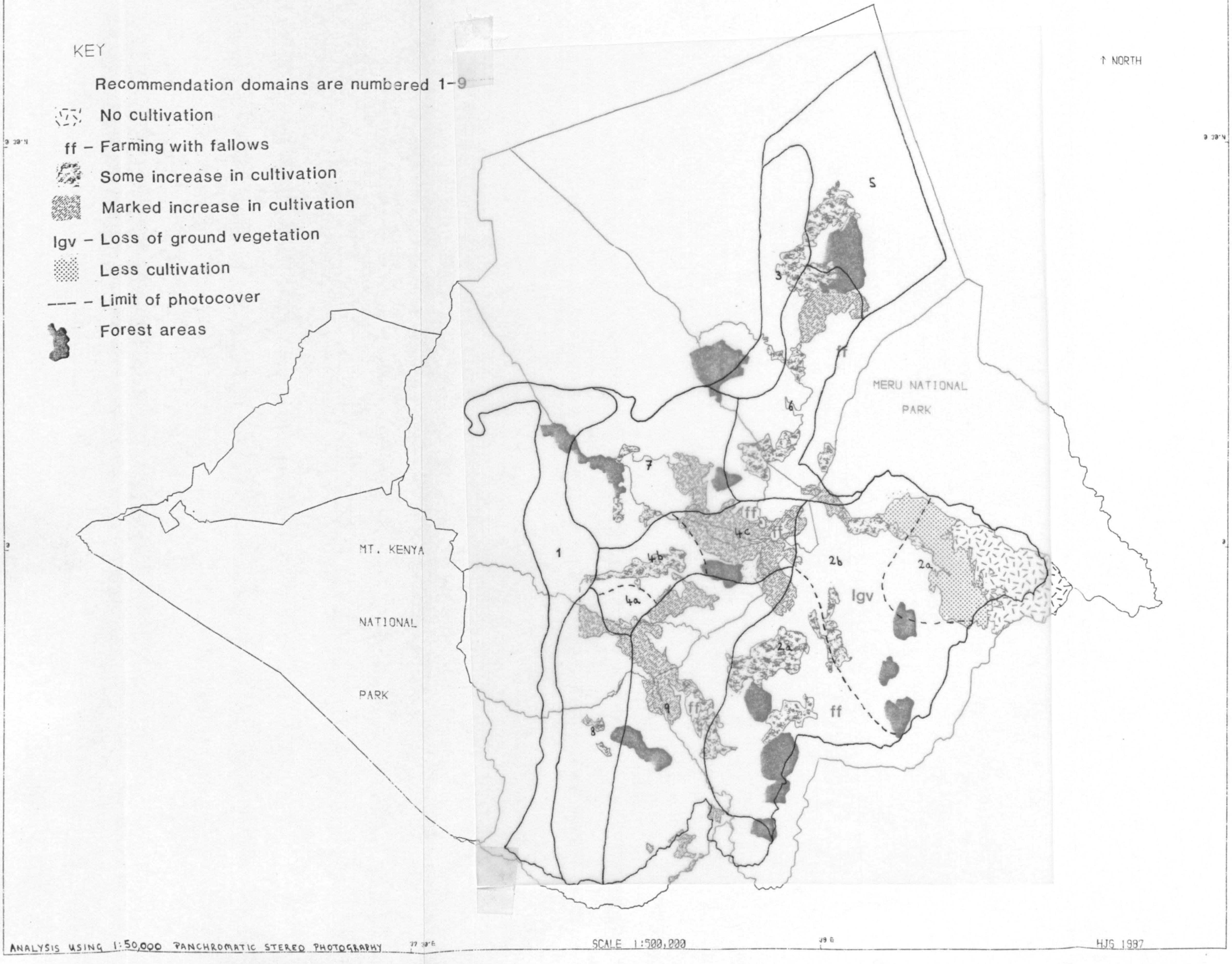


FIGURE 8.11 CULTIVATION CHANGES IN LOWER MERU 1967-1980



were similarly categorised. Table 8.10 confirms that farmers in domains four, six, and nine represent some of the most recently mobile populations in the study region outside the livestock-rearing/bush fallow farming system of domain two. However, only 29% of farmers in domain seven have been cultivating their present farms for less than 10 years. This suggests that the increased cultivation intensity which is observed within this domain may be due to a sub-division of holdings rather than an in-migration of farmers into the area, as is almost certainly the case in domains four, six and nine.

Domain eight is the only other region with a significant number of recently mobile farmers (62% have been farming on their present farms for less than 10 years, and 41% say they don't know how long they will continue to farm on their present holdings). One reason why little cultivation increase is shown within the area covered by domain eight (Figure 8.11) may be because the most recent air photo cover of the area was taken during 1980 - prior to most of the recent cultivation changes in the area. Since the ground survey was undertaken during 1985/6 and shows that recent cultivation (and human population movement) is occurring in this area there seems to be clear evidence to support this suggestion.

Analysis of 1:50,000 panchromatic photography has shown that cultivation changes have recently occurred in some of the recommendation domains. Areas of increased cultivation intensity have been mapped and compared with data on farmer mobility within specified recommendation domains. Clearly these cultivation changes may have affected both the farming systems and natural environments within these domains. In the final section of this chapter, foci for agricultural research and development are established by selecting five recommendation domains for special attention.

8.5 RECOMMENDATION DOMAINS AS FOCI FOR AGRICULTURAL RESEARCH AND DEVELOPMENT

Since 1981 Kenya has been been attempting to pursue a more intensive agricultural extension programme by adopting the World Bank Training and Visit (T and V) system. Agricultural extension is an essential link-pin between the small farmer and agricultural research and development regardless of whether rural development is examined from a 'top down' or 'bottom up' approach. In both scenarios communication between farmers and researchers is critical to successful development strategies.

In identifying foci for agricultural research and development in lower Meru it is important then that some examination of the extension service be undertaken so that where necessary within specific recommendation domains this service can be upgraded. After all, where significant cultivation changes have occured and where farmer populations are recently mobile both farming and environmental systems may be under strain. Under these circumstances the agricultural extension service will have a critical role to play to ensure the long-term prosperity of farmlands.

In the previous section four domains were identified to have experienced a marked increase in cultivation. A number of domains were also shown to have recently mobile farmer populations. In some cases domains were characterised by both these phenomena. In order to examine the existing role of the extension service in providing a link between smallholders and the agricultural research and development services, farmers where asked about their contact with extension service personnel. Table 8.11 shows the number of farmers who have been visited by extension personnel in each domain. From this table it is possible to evaluate the position of farmers in the least stable domains (four, six, seven, eight and nine) against farmers in the most stable domains (one and three) *vis-a-vis* the extension service.

TABLE 8.11

FARMERS WITH SOME EXTENSION CONTACT

DOMAIN	LAST VISITED (months)			%A	%B	N
	<6	6-12	>12			
ONE	18	13	17	35	62	77
TWO	2	2	9	69	16	80
THREE	5	2	5	42	30	40
FOUR	6	2	9	53	46	37
FIVE	0	0	2	100	17	12
SIX	2	1	3	50	15	40
SEVEN	5	3	6	43	27	52
EIGHT	6	4	3	23	36	36
NINE	10	7	20	54	37	100

N indicates number of farmers in sample.
%A indicates the percentage of visits which occured over a year ago. %B indicates the total percentage of farmers visited in all categories.

It is clear from the above table that the number of farmers with recent extension contact is extremely limited even in the most stable domains. In this regard domain one has the highest number of recent contacts with 18 farmers (23%) reporting a visit in the last six months. Domain eight has the next most significant number (17%) followed by domain four (16%). It is significant that many of the reported visits occurred over a year ago indicating that the T and V extension system is not being effectively implemented in lower Meru. In fact field experience showed the only area where this system was being effectively operated was in the extreme west of domain four around Mitunguu.

Domains six and two show farmers with the lowest overall percentage of extension contact. Apart from domain eight the three other least stable domains (six, seven and nine) outside the livestock-rearing zone all have either, very low overall farmer/extension contact or, a high percentage of farmers with contact which is very infrequent. Indeed, this is the general picture that emerges from Table 8.11. Table 8.12 confirms that extension contact with smallholders in lower Meru is sporadic. Apart from the marginal coffee zone (domain one) and possibly the Mitunguu and Nkondi farmlands (domain four) farmers' contact with the extension services are negligible.

These statistics demonstrate that the extension services in the area need to be improved. If the trend in declining agricultural production within lower Meru (Table 2.3) is to be reversed a stronger extension and agronomic research component must be developed in the region. The necessary funding for this increased investment may have to come from both Government of Kenya and donor agency sources.

Although Table 8.12 indicates that within domains there appears to be considerable variation in the number of farmers in contact with the extension services, the total number of farmers reporting knowledge of other farmers' contact with such services is still very low. It should also be pointed out that these contacts are for *all* extension contact and therefore include both the government and private (e.g. EMI, tobacco and sunflower businesses) extension services.

TABLE 8.12

THE NUMBER OF FARMERS WHO KNOW OTHER FARMERS WITH EXTENSION CONTACT

DOMAIN	FARMERS KNOWN TO HAVE EXTENSION CONTACT					N
	TOTAL	MAXIMUM	MINIMUM	AVERAGE	TOTAL %	
ONE	41	30	1	9	53	77
TWO	16	6	1	3	20	80
THREE	14	5	1	2	35	40
FOUR	19	30	1	9	51	37
FIVE	2	2	1	1	17	12
SIX	6	30	2	8	15	40
SEVEN	12	60	1	15	23	52
EIGHT	10	10	3	7	28	36
NINE	35	21	1	8	35	100

N indicates number of farmers in sample.
% indicates the total percentage of farmers known to have contact. MAXIMUM indicates the maximum number of other farmers known by a farmer to have extension contact. MINIMUM indicates the minimum number of other farmers known by a farmer to have extension contact.

Bearing in mind the mobility of the farmers in domain two which is a characteristic of the farming system of this area, it is perhaps not surprising that these farmers have little contact with extension personnel. Equally clear however is the need for such contact if long-term agricultural research and development initiatives are to succeed in this domain (Tharaka). These statistics are particularly worrying bearing in mind that this domain is entirely within the programme area of the EMI.

Currently EMI supports a sheep and goat breeding project at Marimanti. This project needs to be upgraded to include an extension and agronomic research component. Since the farming system in the area includes both crop and livestock production, it is important that research is carried out into new range management systems and dryland food crop varieties.

Although domains one and four appear to have more acceptable levels of farmer/extension contact as reported by farmers in these areas, domains six, seven, and eight all have very low levels of contact and yet these have been identified as areas of recent farmer mobility and cultivation change. In domains three and nine farmers report of a slightly larger number of farmer/extension contacts, yet even in these domains only 35% of farmers knew of other farmers who had extension service contact.

In summary, despite the cultivation and human population changes which have been taking place in lower Meru there appears to be little farmer/extension contact. One is therefore left to assume that there are few effective links between smallholders and the agricultural research and development services operating in the area. It is critical therefore that better communication be developed between these two groups, especially in those areas which have experienced recent population movement and increases in cultivation. These changes are likely to detrimentally affect both the farming systems and natural environments within such areas.

8.6 SUMMARY

Remotely sensed data have been shown to be of value in facilitating the identification of recommendation domains. Cultivation changes within the study region have been mapped. Generally where marked increases in cultivation have occurred farmers have been more mobile. In some cases however increased cultivation may indicate that sub-division of farm holdings is occuring (domain seven).

Existing links between smallholders and the extension services (both public and private) in lower Meru are weak. It is concluded that there is therefore little effective communication between farmers and the agricultural research and development services within the region. More effective communication needs to be developed between farmers and those involved in agricultural development initiatives, especially in domains where pressure from recent cultivation and population increases seem certain to detrimentally affect both the local environment and farming systems. Unless greater effort is made by government and aid personnel in this area, it will not be possible to control the widening economic gap between farm household incomes in upper and lower Meru.

In the concluding chapter of this thesis the main findings and limitations of the study are reviewed. Recommendations are put forward which have direct relevance to both national and district level agricultural research and development initiatives.

CHAPTER NINE

CONCLUSIONS AND RECOMMENDATIONS

9.0 INTRODUCTION

This chapter is divided into four parts. The first section summarises the findings of the study in the light of the objectives and hypotheses presented in Chapter One. In the second section the main limitations of the research are described. In the third section the recommendations emanating from the study are discussed. Suggestions for further research are made in the final section.

9.1 RESEARCH FINDINGS

It was stated in Chapter One that 80% of the land area of Kenya is of marginal agricultural potential although this land area supports about a fifth of the country's population. In line with recent government policies which have aimed to involve both the districts (District Focus for Rural Development) and the poorer and more marginalised peoples of the arid and semi-arid regions (Arid and Semi-Arid Lands Development Programme) within the national rural development strategy, this study has focussed on land of medium to marginal agricultural potential within Meru district. Part of this region of Meru is also included under the British aid to Kenya, Embu-Meru-Isiolo soil and water conservation programme.

The reader is reminded that the main objective of the study was:

To test the utility of remote sensing techniques in identifying recommendation domains - relatively homogeneous agricultural areas - to act as foci for agricultural research and development initiatives within the study region.

In line with this above objective:

To establish the spatial distribution of agro-economic groupings (AEGs) within the study region.

To examine the internal consistency of AEGs in relation to farmer mobility/residency.

Three research hypotheses were also tested:

The homogeneity of AEGs is related to farmer mobility/residency. AEGs which are most homogeneous tend to include farmers who have been resident longer than farmers residing in AEGs which are more varied internally.

Areas of recent cultivation change are also the areas of greatest population movement.

Farmers within the same agro-ecological zone act consistently and maintain a similar farming system.

The methodology used to try to satisfy these objectives and to test the hypotheses outlined above has focussed on light aircraft remote sensing. In order to check the accuracy of the air survey data a detailed ground survey was also carried out. In Chapter Six several comparisons were undertaken using these two data sources to test the validity of using the aerial data to help identify AEGs. Four general findings resulted from this analysis:

The area planted under some crops may vary from one season to another (e.g. cotton) and therefore wherever possible such crops should not be used to differentiate between farms within the smallholder economy.

The resolution limitations of the January 1985 colour slide aerial photography prevented accurate identification of crop complexes on the ground. Since 51 of the 88 ground sample clusters were derived from this air survey crop complexes were not used to discriminate between AEGs (farming systems) in the region.

Spatial differences in the distributions of crops from one season to the next, although not marked, indicated the importance of avoiding reliance on single crop/land cover variables to define AEGs. Combinations of variables are considered to be both more reliable and more accurate at describing complex smallholder farming systems.

Crop cover percentage estimates for five of the major crops (coffee, cotton, miraa, maize, beans) in the area were shown to be comparable for both the air and ground data. Similar percentage estimates for one major crop (millet) were however shown to vary significantly between these two data sources, and were not therefore included among the variables used from the air survey to identify AEGs.

Using the five major crop variables identified above, together with a number of other variables selected from the air surveys and the ground survey, two separate principal component analyses were performed on the data. The new compound variables for each data set were regressed against each other and the resulting correlations used to identify areas of consistency between the two data sources. In Chapter Seven there were four main findings:

Four AEGs were identified corresponding to the four main farming systems in the region.

The ground survey data proved to be capable of distinguishing between areas on the basis of farm income levels indicating differences between farm clusters which were not identified from the air survey.

Some areas within the smallholder landscape appeared to be very heterogeneous and exhibit no consistent agricultural pattern (transitional farming zone).

Generally it was possible to distinguish between different AEGs (farming systems) using spatial variables generated from the air surveys although none of the identified AEGs were entirely homogeneous. Differences between AEGs were in some cases clarified by using data on crop planting practices collected during the ground survey.

In Chapter Eight the ground survey data, which included 482 separate farms, was used to assess the validity of the AEGs identified in Chapter Seven. Three of the AEGs were redefined as a result of this analysis. Farmer residency/mobility was examined for each of the AEGs and the transitional farming zone. Recommendation domains were defined and discussed in relation to cultivation changes which had been identified within the study region, using air photography for the period 1967-1980. It was shown that:

Individual farm data revealed certain areas of agricultural conformity which were not identifiable using the air survey data.

Generally, there appears to be an inverse relationship between the agricultural homogeneity of AEGs and the mobility of the farm population.

While the human population of the transitional farming zone might be expected to have the highest inter-locational mobility this does not appear to be the case. However, considerable intra-locational movement appears to be occurring within this zone.

Nine recommendation domains were defined within the study region. Four of these had experienced a marked increase in cultivation between 1967 and 1980.

While the four AEGs (farming systems) are largely consistent with agricultural potential as defined by agro-ecological zones (AEZs) this was not the case for farming systems within the transitional farming zone.

Existing links between smallholders and the extension services (both public and private) in lower Meru are weak. There is therefore little communication between farmers and the agricultural research and development services.

A number of recommendations are proposed based on these research findings and can be used to help strengthen national and local agricultural development initiatives within the country. Before discussing these however, it is necessary to mention the main limitations of the work presented here. Discussion of these limitations will provide a suitable background in which to situate the research recommendations.

9.2 RESEARCH LIMITATIONS

Due to financial limitations it was not possible to commission an air flight to cover the entire study region during 1986, and as a result the analysis presented in this study has had to rely, in part, on air photography from two previous air surveys undertaken by KREMU. Using the KREMU aerial colour slide photography it proved to be impossible accurately to identify crop complexes within the smallholder economy, and so crop complexes were not included as variables to help to identify AEGs. It is recognised that crop complexes cover a significant percentage of farmland within the agricultural sector and any future research should ensure therefore that variables describing this aspect of land use are included.

One of the major objectives of the study has been to assess the utility of aerial colour slide photography in identifying and defining recommendation domains by comparing aerial crop estimates with similar estimates obtained from a ground survey. This objective has been satisfied and it has been shown that the methodology used in this study is adequate for identifying AEGs. However, due to both the large amount of data involved, and the time needed to analyse all 433 aerial sample points, only 88 sample points were covered in the work presented here. Future research should concentrate on using the methodology developed in this study to use complete aerial sample cover of areas to define and establish the spatial distribution of recommendation domains.

Finally, although a number of recommendation domains in lower Meru have been identified for specific development attention, it has not been possible to present a detailed analysis of each individual domain. If these domains are to be used effectively for planning agricultural development in the district, it is essential that further analysis and monitoring of the changes taking place in these (particularly the transitional farming zone) is undertaken.

9.3 RESEARCH RECOMMENDATIONS

Five recommendations can be made based on the findings of this study. Two of these relate to planning at the national level and are considered first. The third and fourth recommendations relate to the rural district level. These are especially relevant to district agricultural planning given current Government of Kenya initiatives to decentralise decision-making and improve project implementation in the rural areas. Finally, suggestions are outlined for ways in which the findings of research carried out at district level can be made more readily available to practitioners working in the field.

RECOMMENDATION ONE

This study has shown that by using spatial crop and land cover data obtained from light aircraft remote sensing it is possible to distinguish between different farming systems within the smallholder agricultural environment and to define areas of relatively homogeneous agriculture - AEGs. The ability to distinguish AEGs quickly and efficiently, using the techniques examined, provide direction for improving the field methodology of FSR in the Kenyan context. At the same time these methods should also be applicable to other countries in the region. It is suggested that FSR teams should make greater use of light aircraft remote sensing in order to:

1) Improve on the timeliness of the research findings resulting from FSR.

2) Help strengthen the position of FSR in the current national agricultural development strategy within Kenya.

As outlined in Chapter Three, the most time-consuming aspect of FSR occurs in the identification and definition of recommendation domains. The importance of reducing the initial time spent on identifying areas for research and development initiatives within the FSR approach is simply that more time then becomes available for on-farm research and experimentation. Innovations can be tested and tried on farmers' fields at the appropriate stages in the crop/farming cycle, and there is thus a greater likelihood of generating results and improving the innovation adoption rate among farmers. With greater farmer participation project implementation and completion rates should improve. In the context of Meru district this will help to reverse the presently widening gap in living standards between people in upper and lower Meru (Chapter Two).

Collinson (1986b) argues that the institutionalisation of FSR in Kenya has been very dependent on individual personalities, and has suggested that lack of progress in the formal recognition of FSR within the national agricultural research and extension services (NARES) in the country has been linked to changes in the top personnel. In 1984 however, a new director of research was appointed and this appointment has heralded a new interest in FSR, with eight FSR regional research teams currently being established under a restructuring of the research services through the Kenya Agricultural Research Institute (KARI) legislation of 1979. By 1988 Kenya may have an institutional capacity in FSR if this restructuring goes ahead as planned (Ibid., 1986). Given the renewed interest in FSR, its practitioners should seriously consider the benefits of using light aircraft remote sensing to reduce the initial time-lag between identifying recommendation domains and undertaking on-farm experimentation (Chapter Three).

In demonstrating the feasibility of using light aircraft remote sensing techniques to stratify complex agricultural landscapes into 'relatively homogeneous' farming areas which can be used as target areas for agricultural research and extension, both the practice of FSR and its position within the NARES in Kenya will be enhanced. In this regard a second recommendation is established.

RECOMMENDATION TWO

It is suggested that there should be much greater interaction between the Kenya Rangeland Ecological Monitoring Unit (KREMU) and the Ministries of Agriculture and Livestock Development (MOALD) and specifically between KREMU and KARI. KREMU has been involved in providing up-to-date data on population estimates and the spatial distributions of livestock and wildlife since the mid 1970's. More recently KREMU has moved into the arena of agricultural land use planning, conducting light aircraft surveys in the high agricultural potential districts within the country to provide district development committees with current land use/cover information to assist in district planning.

As mentioned in Chapter Three, a bill was passed in parliament as early as 1979 to set up a new parastatal body (KARI) to carry out all crop, animal and forestry research. Although this institute has not yet taken up the full role intended for it, it is important that both KARI and KREMU should work closer together. KREMU already has the expertise and equipment necessary to undertake aerial surveys to stratify smallholder agricultural areas into target regions - recommendation domains - for agricultural and development initiatives which could be undertaken by FSR research teams within KARI. Given these existing institutional structures FSR could become much more prominent in the national agricultural strategy if efforts were made to establish links between these organizations.

By promoting closer cooperation at National level there is a greater likelihood that the fundamental participatory characteristics of FSR (which is one of the keys to the success of the approach) will become more widely recognised and valued. Closer institutional links between KREMU and MOALD make economic sense, given recent government budgetary and financial rationalisation programmes which are affecting all ministries (for example, parastatals in the agricultural and livestock sectors, Kamau and Nzube, 1986).

Recommendations three and four are more district specific. Recommendation three suggests that agricultural planning undertaken purely on the basis of agro-ecological stratification will be less successful than planning which is based on an understanding of current farming practices (farming systems) *and* natural land potential. It suggests that recommendation domains are therefore a more valid agricultural classification for district planning.

RECOMMENDATION THREE

Chapter Eight showed that while some of the AEGs were largely consistent with the main agro-ecological zones (for example, Figure 8.5 and Figure 8.7) farming patterns do not conform with agricultural potential for all zones. Recommendation domains are based on AEGs and agricultural potential zones (AEZs). AEGs represent generalised farming systems and four of the recommendation domains were based on these. For the transitional farming zone where farming systems were not clearly defined in the analysis, recommendation domains were defined on the basis of both AEZs and an analysis of the ground survey data.

Development must start from an understanding of what the farmer is doing and why s/he is doing this. Without this basic understanding, unrealistic assumptions are made which effectively eliminate farmers from the development process. To rely on agricultural potential (AEZs) as a framework for agricultural planning at district level is to ignore what small farmers are actually doing. In attempting to induce more participation from rural people in development initiatives at district level, it is not adequate to carry out such initiatives solely on the basis of the agricultural potential of an area. District agricultural planning should start from an understanding of existing farming patterns, and research and development initiatives should be based on relating these to land capability (AEZs). Recommendation domains provide a suitable framework for planning under this approach.

There are two implications for the district agricultural services here. Firstly, because existing extension and training services are organized on the district administrative structure (divisions, locations and sub-locations), staff will need to be redeployed. This will be necessary since recommendation domains do not (unless fortuitously) coincide with these administrative boundaries. Extension personnel (especially the lower cadres - technical assistants and junior technical assistants) should be stationed so that they can assist farmers within a given domain most effectively. In other words research and extension should be directed to the farmers within a particular domain. The farming problems of such domains should be dealt with separately from other areas (unless of course it can be shown that these problems occur over a wider range).

Secondly, extension training will need to be more specific, to meet the particular needs of the farmers within a given domain. Field extension personnel should be entirely familiar with the farming system(s) of the domain in which they are stationed.

The costs of this staff redeployment and training need not necessarily be any greater than those incurred by the present extension service - the objective being to use the existing resources within the district more efficiently. However, for a selected number of the domains in lower Meru greater investment and manpower is required if development is to be sustainable. These domains are identified below and a number of recommendations are proposed.

RECOMMENDATION FOUR

Five recommendation domains are identified for priority agricultural research and development attention in lower Meru. These are domains two, six, seven, eight and nine. These domains have been selected for specific rural development attention primarily on evidence of farmer residency/mobility obtained from the ground survey, and increases in cultivation identified from analysis of 1:50,000 stereo panchromatic air photography. Four of these fall within the transitional farming zone and are undergoing marked cultivation and population changes. Greater development investment and increased manpower are needed in these areas if they are to be developed on an ecologically sound basis. Without such assistance the differences in prosperity between the relatively rich, west and north, and the poor, south and east will become further exaggerated.

Recommendation domain two shows farmers are highly mobile with 91% having cultivated their present farms for less than ten years and 31% saying that they will move to cultivate new farms within the next ten years (Table 8.10). Population movement is a characteristic of the the farming system of this area with shifting cultivation being practiced.

This domain falls within the ASAL region and EMI programme area. It is selected for special development attention for three reasons. First, it is the poorest area within Meru, yet as Table 8.11 shows, the farmers in this domain have one of the lowest rates of contact with the extension services. Only 16% of farmers have any extension contact, and 69% of these farmers had been contacted over a year ago. Secondly, there is an urgent need to reconsider the range management of the area. Parts of this region have experienced fundamental changes in vegetation cover. During the field survey many of the farmers in the domain commented on the loss of ground cover and the increase in woody vegetation - a change in the last twenty years. Finally, yet equally important, are current government initiatives to register and adjudicate the land in lower Meru. All of these factors influence the farming system in the region, and demonstrate the need for new land management initiatives.

In the area immediately to the west and north of domain two (AEZs LM3 and LM4 - represented by recommendation domains six, eight and nine) increased cultivation and recent farm population movements show that more people are attempting to farm in this environment. Most of this area is outside the ASAL region and represents a region of slightly greater agricultural potential than domain two. However, where farmers are new arrivals in an area they will have to learn about the local natural environment and they may well use methods and practices brought from other regions which are not suited to this environment. In these domains farmers will have to learn new soil and water conservation methods and develop ecologically sound farming systems. This is particularly important where these farmers are considering settling on this land permanently. 92% of farmers in domain six for example consider the land they are presently cultivating to be their permanent farm holding (Table 8.10).

Four of the domains identified for new development initiatives fall within the transitional farming zone which is characterised by a heterogeneous farming environment (Chapter Seven). Where the agricultural environment is complex with many different farming practices occuring within a relatively small area, extra research and extension resources will be needed in order to reach a majority of the farmers. Many different farming systems may be present and if farmers in each of these systems are to benefit from new rural development programmes, then each system must be understood and enough field personnel stationed in the area to link agricultural research with the needs of farmers in each system. More funds are needed for agricultural research and extension in domains two, six, eight and nine.

In view of the characteristics mentioned above, three recommendations are made. All of these are interrelated. The first concerns improvements in dryland agronomic research. The second focusses on upgrading the extension service of the region, and the third deals with range management.

A number of roads and bridges will need to be upgraded or repaired in domains six and eight before these recommendations can be practically initiated in these regions. For example, bridges over the Thangatha on the Kunati/Irereni road and over the Akothima river north of Nkondi need rebuilding or repair, while the Itugururu road linking to the Ishiara/Mitunguu road needs upgrading. Also, a bridge over the Mutonga river by Tharaka Girls' School needs to be built to provide a link between the Magutuni road and the Ishiara/Mitunguu road.

The first recommendation is that dryland farming/agronomic research at Marimanti be upgraded and improved. The research undertaken at Marimanti could be linked to KARI and the national FSR programme (when this becomes operational). Two resident agronomists should be based at the site. One of these could include an expatriate employed under the EMI programme and financed by the ODA. The functions of these agronomists would be:

1) To undertake on-farm research in domains two, six, eight and nine (transitional farming zone).

2) To research into intercropping methods which will improve the productive capacity of farms, and ensure ecologically sound farming practices are maintained in these domains.

3) To work in conjunction with personnel from the sheep and goat breeding project at Marimanti to develop an integrated farming system in cooperation with the farmers of Tharaka. This should take into account; a) the poverty of natural resources in the region and, b) the implications of recent vegetation changes for cattle/livestock farmers.

4) To support the extension services in the region by communicating on-farm research findings to the relevant technical field officers and thus assist extension personnel in providing relevant farming information to farmers.

The second recommendation is that; the existing extension service within lower Meru should be improved. In order to minimise the cost involved in improving this service it is suggested that the Marimanti sheep and goat project should be used as a training and extension centre for this purpose. The functions of this centre would be:

1) To provide training for regional field extension staff.

2) To organize open days for farmers to visit on-farm research sites and to discuss farming problems.

3) To work closely with the agronomic and range management teams in establishing a thorough understanding of the farming systems in lower Meru and the most pressing problems facing farmers.

The third recommendation proposes that there should be a range management team attached to the sheep and goat project. The functions of this team would be:

1) To research into new management systems for the rangelands of lower Meru.

2) To work together with the team of agronomists to develop an integrated farming system based on the improved use of bush fallows and small scale irrigation along selected river sites in Tharaka.

3) In conjunction with extension personnel, ensure that there is greater contact between the Marimanti sheep and goat project and livestock farmers in lower Meru.

These new initiatives should be seen as part of a long-term strategy and therefore funding should be made available for an initial period of at least ten years. The benefits resulting from these proposals must therefore be measured over a similar time period. Donor agency monies should be used to fund some of the initial costs of the proposals outlined above. In this regard since EMI is already operating in part of the lower Meru area (ASAL region) it is proposed that the EMI programme area be expanded to include the transitional farming zone (LM3). Funding could then be made available from the ODA under an existing aid programme. This would minimise any delays in making such development plans operational.

Using figures derived from the 1984 district agricultural officer's report and broken down according to the categories; transport, personnel, accommodation, farm inputs, training, purchase of equipment for the station, maintenance and miscellaneous, it is estimated that the above proposals are likely to require *at least* a doubling of the investment currently available for the Marimanti sheep and goat project.

Although it is difficult to estimate all the benefits which are likely to result from these proposals, it is clear that within the transitional farming zone there is still considerable unrealised agricultural potential. Once this is developed, the transitional farming zone could well become the most important food growing region within Meru district, especially since more and more of the high potential land is being used to produce cash crops.

The above estimate assumes that by more than doubling the numbers of agricultural research and development personnel working at Marimanti (to include; 2 agronomists, 2 range managers, 9 junior technical assistants together with other supporting personnel) the costs of accommodating, providing transport and other equipment for the smooth running of the programme will require an additional investment equivalent to the existing annual operating costs of the site.

Finally, domain seven, although showing a more stable population (67% have been cultivating their present farms for more than ten years - Table 8.10), has experienced a marked increase in cultivation in several areas (Figure 8.11). Such cultivation changes suggest that a sub-division of land holdings may be occurring. With increasing pressure from a fast expanding population, the sub-division of holdings may be a short-term and short-lasting solution to the land problem, enabling farmers to give their offspring access to a means of production. However, sub-division of holdings increases the likelihood of exhausting the fertility of the land as farmers attempt to intensify production without adequate capital to purchase farm inputs such as improved seeds and fertilizers.

Although most farmers in domain seven appear to be long-term residents and as a result will certainly be experts of their local agricultural environment, increasing cultivation is leading to a need to develop new methods of farming which will ensure the long-term fertility of these farmlands. Many farmers may not be in a position to adopt such methods given the small size of their farm holdings and the lack of adequate capital.

Areas which are undergoing most rapid sub-division within this domain should become the focus of attention for new agricultural initiatives. One of these initiatives must be to enforce a minimum size of land holding (capable of sustaining the subsistence requirements of a farm family) below which it would become illegal to subdivide (as proposed in Sessional Paper No 1, 1986). This is essential to ensure that future agricultural developments in the domain remain ecologically sound.

RECOMMENDATION FIVE

Meru district is perhaps fortunate in that a considerable amount of research related to rural development has been carried out since the early 1980's within the district. However, it appears that few of the research findings from these studies are either; 1) available or, 2) used and adopted by practitioners in the field.

In order to rectify this situation it is proposed that all rural based research in Kenya should be:

1) Registered at district level with a district information and documentation officer.

2) Copies of all working papers be made available to the district information centre.

3) A copy of the final report and findings be filed in the district information centre.

The benefits of a more structured approach to research within the districts would make; 1) research more relevant to local needs, 2) more accessible to practitioners in the field, 3) support efforts to decentralise decision making away from Nairobi by developing resources within the districts and, 4) help to generate an environment in which greater participation from rural people is possible.

In the final section of this chapter directions for further research are suggested which build on the findings presented in this study.

9.4 FUTURE RESEARCH DIRECTION

It has been suggested that five recommendation domains should become the focus for new agricultural research and development initiatives within the lower Meru region. More work needs to be done however to understand the processes operating in each of these areas. In recommendation domain seven, for example, land records should be examined to ascertain the rate of the sub-division of farm holdings. The type of households involved, age of the family members, educational level, socio-economic background, ethnic group, off-farm income sources, and the reasons for the sub-division should all be examined so that effective strategies can be developed to combat any detrimental effects resulting from the division of landholdings (e.g. soil degradation and ecological damage).

It is recommended that future work undertaken by Nottingham and Nairobi universities should focus on the five domains identified for special development attention in this dissertation.

In focussing on these areas there should be two main objectives. First, to promote more balanced rural development between upper and lower Meru. Second, to improve food production within the district and particularly in the lower and traditionally poorer reaches of Meru.

APPENDIX 1A
LAND USE SURVEY QUESTIONNAIRE 1985/6

FARMER NAME:
SEX:
AGE: < 30, 30-50, > 50
AGRO-ECOLOGICAL ZONE:

A: LOCATIONAL/GEOGRAPHIC INFORMATION

1.0 Location name:
1.1 Sublocation name:
1.2 Number of farms:
1.3 If more than one farm, location of other farms:
1.4 Sublocation of these farms:

B: FARM INFORMATION

2.0 Size of farm holding:
2.1 Size of cultivated area:
2.2 If other farms, size of these:
2.3 Size of cultivated area on other farms:
2.4 Number of farm buildings: House: modern/traditional
Granary: modern/traditional
Kitchen: modern/traditional
Other:
2.5 Have you recently purchased any land: yes/no
2.6 If yes, where is this land (location):
2.7 What was the cost of this land:
2.8 Do you rent any land: yes/no
2.9 If yes, a) What is the cost of this:
b) Where is this (location):
2.10 How did you acquire the land you currently farm:
Clan land   Purchased land   Inherited land
2.11 If farmer doesn't own the land, who owns this land:
2.12 Where does this person live (location):
2.13 What is the source of your farm labour:

Own family   Hired labour   Oxen   Tractor

C: CROP HUSBANDRY

3.0 What area do you have under cash crops:
3.1 What area do you have under food crops:

Intercropped: Pure stands:

3.2 What area do you have under food/cash crops:
3.3* What are the most important crops on the farm:
Maize (Mpembe) Millet (Mwere) Cowpea (Nthoruko)
Green Gram (Ndengu) Sorghum (Munya) Cotton (Mpamba)
Pigeon Pea (Ncugu) Sunflower (Mpembe cia Nguku)
Castor oil (Mbariki) Other:

LAND USE SURVEY QUESTIONNAIRE 1985/6

3.4 How long have you been growing these crops:

Food crops: Cash crops:

3.5 Why do you plant these crops:

3.6* What yields do you get from these crops (per season):

	1st season	2nd season
Maize..		
Millet..		
Cowpea..		
Green Gram..		
Sorghum..		
Cotton..		
Pigeon Pea..		
Sunflower..		
Etc..		

3.7* What crops do you intercrop:
e.g. Maize/beans, Millet/sorghum, etc.

3.8 Do you grow any forage crops:

3.9 If yes, What species:

3.10 Do you have any fields fallow:

3.11 Do you graze these fallows:

3.12 What area do you have under fallows:

3.13+How old are these fallows:

3.14+Have you practised fallowing in the past:

3.15+For what length of time did you leave these fields fallow:

3.16+What has made you change this fallow length (if answer to 3.13 different from 3.15):

3.17 Do you plant any trees on your farm:

3.18 If yes, what types of trees (local names):

3.19 What will you/do you use these for:

3.20 Do you practice any crop rotations:

1st season	2nd season	3rd season	4th season

3.21 Do you think you cultivate more or less than in the previous two years:

3.22 What is the reason for this:

3.23 Do you buy any food for your family at any time during the year:

3.24 What type of food is this:

3.25 Do you ever borrow any food from relatives:
Neighbours: Traders: Others:

3.26 When was this:

3.27 Where do these people live:

3.28 Have you ever lent any food to relatives:
neighbours:

3.29 When was this:

3.30 Where do these people live:

3.31 Have you ever received any food from the goverment:
3.32 What sort of food was this:
3.33 Where do you market your crops (name of market):
3.34 What do you think your income is from your crops/year:

D: LIVESTOCK

4.0 What animals do you keep on your farm:
Sheep Goats Local Cattle Grade Cattle
Chickens Other
4.1 What is the composition of the herd:

	Sheep	Goats	L Cattle	G Cattle	Chickens
Adult male........					
Adult female........					
Immature male........					
Immature female........					
Castrated male........					
Young........					

4.2 What changes have there been in the herd this year:

	Sheep	Goats	L Cattle	G Cattle	Chickens
Births:........					
Deaths:........					

4.3 Do you own your own grazing land:
4.4 Do you rent any grazing land:
4.5 If renting grazing land, how much does this cost/season:
4.6 Do you let other farmers' livestock onto your land:
4.7 Do you use any communal grazing land:
4.8 Do you practice tethered grazing:
4.9 Do you practice zero grazing:
4.10 Do you have any improved grazing:
4.11 Are there any areas where you are not allowed to graze your livestock:
4.12 Where is this:
4.13 Why is this:
4.14 How often do you water your animals:
4.15 How far is this from your farm:
4.16 What type of water source is this:
4.17 Do you move your herd at different times of the year:

LAND USE SURVEY QUESTIONNAIRE 1985/6

4.18 If yes, how far is this from your farm:
Place no 1:
Place no 2:
Place no 3:
4.19 Why do you move your herd here:
4.20 Do you think there is enough feed/grazing for expanding your herd:
4.21 If yes, where is this:
4.22 Do you feed your animals any crop residues:
4.23 If yes, what type of residue:
4.24 What types of wild plants do you feed your animals:
4.25 Why do you keep livestock:
4.26 How many sheep ( ) goats ( ) local cattle ( ) grade cattle ( ) chickens ( ) have you sold this year:
4.27 What do you think your income is from your animals/year:

E: GENERAL FARMING

5.0 Have you ever taken any steps to protect your farm from soil erosion:
5.1 Type of action: Terracing Mulching Trash lines Ditches Other
5.2 Do you have any contact with the agricultural extension service:
5.3 If yes, what sort of contact is this:
5.4 When was this:
5.5 Do you know of other farmers who have had contact with the agricultural extension service:
Number:
5.6 In years of drought which of your crops do best:
5.7 Would you prefer to grow any different crops:
5.8 If yes, what types:
5.9 Do you experience any problems with wild animals:
Type:

F: FAMILY INFORMATION

6.0 How many family members are living here:
6.1 How many of these are farmers:
Children under 12:
6.2 What occupations do the others have:
6.3 How much do they earn from these occupations:
6.4 Where are these family members living:
Sublocation: Location:
6.5 Are there any family members living here who earn cash from other activities apart from the sale of crops/livestock:
6.6 If yes, what do they do: Honey/wax Charcoal Casual labour Regular work Basket making Other

APPENDIX 1A (../5)
LAND USE SURVEY QUESTIONNAIRE 1985/6

6.7 What is the value of these/year:
6.8 If you earn cash from honey or wax, how many hives does the family have:
6.9 Where does the family originally come from:
Sublocation: Location:
6.10 How long ago did you move here: <5 years
5-10 years >10 years
6.11 Where were you before this:
Sublocation: Location: Date:

G: FUTURE OUTLOOK

7.0 Do you think you will change your farming system in the future:
7.1 How will you change it:

7.2 Since you have been in this area what changes have you noticed in the vegetation:
Trees More/less/same
Bushes More/less/same
Shrubs More/less/same
Grasses More/less/same
Soil erosion More/less/same
7.3 Are there any particular plants that have increased or decreased:
7.4 What are the most common plants in the area:
7.5 What are you major worries for the future:
7.6 What can you do to overcome these:
7.7 How can the government help you overcome these problems:

ASANTE SANA /NIBWEGA MONO

* Varied according to agro-ecological zone.
+ In some cases more explicit questions were asked on the length of fallows although it was often difficult to collect accurate information because of land tenureship. On clan land farmers would often not return to cultivate previous fallows.
Questions 3.25 to 3.32 were restricted to the livestock-rearing zone.

APPENDIX 1B : FARM SURVEY 1985/6 - CROP RECORD

Farmer number:
Date:
Grid Reference:

	1984		1985		
Farm Number	1st Season	2nd Season	1st Season	2nd Season	Date First Cult
Plot Number 1					
Plot Number 2					
Plot Number 3					
Plot Number 4					
Plot Number 5					
Plot Number 6					
Plot Number 7					
Plot Number 8					
Plot Number 9					
Plot Number 10					
Plot Number 11					
Plot Number 12					

Crop Planting Codes:

1. Single crop, rows.
2. Single crop, random.
3. Mixed crop, alternate.
4. Mixed crop, random.
5. Mixed crop, inter-row.
6. Mixed stand, alternate.
7. Mixed stand, random.
8. Single plus mixed stand, alternate.
9. Single plus mixed stand, random.
10. Single plus mixed stand, inter-row.
11. Mixed crop, one row, one random.
12. Mixed stand, rows.
13. Mixed crop, cross-rows.
14. Mixed crop, rows.
15. Not planted.

APPENDIX 2
PROGRAMME FOR TI 66 FOR ESTIMATING CROP AREAS (FAO, 1982)

DISPLAY			DISPLAY			DISPLAY		
LINE	CODE	KEY	LINE	CODE	KEY	LINE	CODE	KEY
000	76	*LBL	045	07	7	090	43	RCL
001	15	E	046	55	÷	091	02	2
002	47	*CMs	047	02	2	092	95	=
003	58	*Fix	048	95	=	093	91	R/S
004	02	2	049	85	+			
005	25	CLR	050	53	(			
006	91	R/S	051	43	RCL			
007	44	SUM	052	04	4			
008	02	2	053	65	X			
009	32	x⇆t	054	43	RCL			
010	37	*P→R	055	05	5			
011	44	SUM	056	75	-			
012	03	3	057	43	RCL			
013	32	x⇆t	058	03	3			
014	44	SUM	059	65	X			
015	04	4	060	43	RCL			
016	65	X	061	06	6			
017	43	RCL	062	54	)			
018	03	3	063	55	÷			
019	44	SUM	064	43	RCL			
020	05	5	065	01	1			
021	95	=	066	95	=			
022	94	+/-	067	55	÷			
023	44	SUM	068	01	1			
024	07	7	069	00	0			
025	32	x⇆t	070	00	0			
026	65	X	071	00	0			
027	43	RCL	072	00	0			
028	04	4	073	95	=			
029	44	SUM	074	91	R/S			
030	06	6	075	76	*LBL			
031	95	=	076	13	C			
032	44	SUM	077	43	RCL			
033	07	07	078	03	3			
034	01	1	079	32	x⇆t			
035	44	SUM	080	43	RCL			
036	01	1	081	04	4			
037	43	RCL	082	22	INV			
038	01	1	083	37	*P→R			
039	61	GTO	084	32	x⇆t			
040	00	0	085	65	X			
041	06	06	086	01	1			
042	76	*LBL	087	00	0			
043	11	A	088	00	0			
044	43	RCL	089	55	÷			

* Indicates Inv function key.

APPENDIX 3A

LAND USE / COVER CATEGORIES IDENTIFIED ON THE JANUARY 1985 AIR SURVEY

CODE	LAND COVER / USE	CODE	LAND COVER / USE
1	Maize pure	44	Water body
2	Maize intercrop	45	Footpath/livestock path
3	Coffee pure		
4	Coffee intercrop	46	Farm track
5	Bananas pure	47	Road
6	Bananas intercrop	48	Hedgerow
7	Beans pure	49	School field
8	Beans intercrop	50	School
9	Pigeon pea	51	Thatched house
10	Green gram	52	Iron-roofed house
11	Sunflower	53	Duka/shop
12	Black beans	54	Factory
13	Sweet potato	55	Latrine
14	Oranges	56	Rock outcrop
15	Sorghum	57	Shadow/unclassified
16	Millet pure	58	Woodland
17	Millet intercrop	59	Sugar cane
18	Cassava	60	Eroded field under cultivation
19	Cotton pure		
20	Cotton intercrop	61	Miraa
21	Tobacco pure		
22	Tobacco intercrop		
23	English potatoes		
24	Napier grass		
25	Rough grazing		
26	Improved grazing		
27	Forest		
28	Trees/woodlots		
29	Swamp/marsh		
30	Riverine bush		
31	Bushcover with erosion		
32	Bushcover with severe erosion		
33	Unspecified bushcover		
34	Acacia bushcover		
35	Commiphora bushcover		
36	Seasonal river		
37	Perennial river		
38	Harvested field		
39	Ploughed field		
40	Eroded fallow		
41	Fallow land		
42	Bare soil		
43	Land under clearing		

APPENDIX 3B

LAND USE / COVER CATEGORIES IDENTIFIED ON THE MAY 1985 AIR SURVEY

CODE	LAND COVER / USE	CODE	LAND COVER / USE
1	Maize pure	42	Cassava intercrop
2	Maize intercrop	43	Cotton pure
3	Maize/Sorghum	44	Cotton intercrop
4	Maize/Sorghum/	45	Tobacco pure
	Pigeon pea	46	Tobacco intercrop
5	Maize/Beans	47	English potato
6	Maize/Cowpea	48	Napier grass
7	Beans/Maize/Sorgh	49	Rough grazing
8	Coffee pure	50	Improved grazing
9	Coffee intercrop	51	Forest
10	Coffee/Bananas	53	Woodland
11	Bananas pure	54	Woodlots/Trees
12	Bananas intercrop	55	Swamp/Marsh
13	Beans pure	56	Riverine bush
14	Beans intercrop	57	Bushcover with
15	Beans/Bananas		erosion
16	Pigeon pea pure	58	Bushcover with severe
17	Pigeon pea		erosion
	intercrop	59	Acacia bushcover
19	Pigeon pea/Beans	60	Commiphora bushcover
20	Pigeon pea/Maize	61	Acacia/Commiphora
21	Pigeon pea/		bushcover
	Sorghum	62	Seasonal river
22	Green gram	63	Perennial river
23	Green gram	64	Harvested field
	intercrop	65	Ploughed field
24	Cowpea pure	66	Fallow field
25	Cowpea intercrop	67	Eroded fallow
26	Sunflower pure	68	Bare soil
27	Sunflower	69	Land under clearing
	intercrop	70	Water body
28	Black beans pure	71	Footpath/livestock
29	Black beans		path
	intercrop	72	Farm track
30	Sweet potato	73	Road
31	Sorghum pure	74	Hedgerow
32	Sorghum intercrop	75	School
33	Sorghum/Millet	76	School field
34	Sorghum/Beans	77	Thatched house
35	Orange pure	78	Iron-roofed house
36	Orange intercrop	79	Duka/shop
37	Macadamia	80	Factory
	intercrop	81	Latrine
38	Castor oil	82	Rock outcrop
	intercrop	83	Shadow/unclassified
39	Millet pure	84	Sugar cane
40	Millet intercrop	85	Eroded field under
41	Millet/Sorghum		cultivation

APPENDIX 1C

LAND USE / COVER CATEGORIES IDENTIFIED ON THE JANUARY 1986 AIR SURVEY

CODE	LAND COVER / USE	CODE	LAND COVER / USE
1	Maize pure	43	Swamp/Marsh
2	Maize intercrop	44	Riverine bush
3	Maize/Beans	45	Bushcover with erosion
4	Maize/Beans/ Sorghum	46	Bushcover with severe erosion
5	Coffee pure		
6	Coffee intercrop	47	Bushcover unspecified
7	Coffee/Banana	48	Acacia bushcover
8	Banana pure	49	Commiphora bushcover
9	Banana intercrop	50	Acacia/Commiphora bushcover
10	Beans pure		
11	Beans intercrop	51	Seasonal river
12	Pigeon pea pure	52	Perennial river
13	Pigeon pea/Bean	53	Harvested field
14	Green gram pure	54	Ploughed field
15	Green gram intercrop	55	Fallow
		56	Eroded fallow
16	Cowpea pure	57	Bare soil
17	Cowpea intercrop	58	Land under clearing
18	Sunflower pure	59	Water body
19	Sunflower intercrop	60	Footpath/Livestock path
20	Black beans pure	61	Farm track
21	Black beans intercrop	62	Road
		63	Hedgerow
22	Sweet potato	64	School
23	Sorghum pure	65	School field
24	Sorghum intercrop	66	Thatched house
25	Orange pure	67	Iron-roofed house
26	Orange intercrop	68	Duka/Shop
27	Macadamia intercrop	69	Factory
		70	Latrine
28	Castor Oil intercrop	71	Rock outcrop
		72	Shadow/Unclassified
29	Millet pure	73	Sugar Cane
30	Millet intercrop	74	Eroded field under cultivation
31	Cassava intercrop		
32	Cotton pure	75	Cabbages
33	Cotton intercrop	76	Tea
34	Tobacco pure	77	Miraa/Beans
35	Tobacco intercrop	78	Miraa/Banana/Maize
36	English potato	79	Miraa/Banana
37	Napier grass	80	Miraa/Maize
38	Rough grazing	81	Miraa/Coffee
39	Improved grazing	82	Miraa pure
40	Forest	83	Miraa/Beans/Maize
41	Woodland	84	Maize/Sorghum
42	Woodlots/Trees	85	Maize/Cowpea

APPENDIX 3C (../2)

LAND USE / COVER CATEGORIES IDENTIFIED ON THE JANUARY 1986 AIR SURVEY

CODE	LAND COVER / USE	CODE	LAND COVER / USE
86	Maize/Sorghum/ Pigeon pea		
87	Maize/Banana		
88	Maize/Black beans		
89	Coffee/Maize		
90	Coffee/Macadamia		
91	Coffee/Beans		
92	Beans/Banana		
93	Pigeon pea intercrop		
94	Pigeon pea/Maize		
95	Pigeon pea/ Sorghum		
96	Sunflower/Black beans		
97	Sunflower/Beans/ Maize		
99	Sunflower/Beans		
100	Sorghum/Millet		
101	Sorghum/Beans		
102	Cassava pure		
103	Cassava/Beans		

APPENDIX 4

LAND USE/COVER PERCENTAGE ESTIMATES

RESULTS OF ZAKARY TEST FOR MARGINAL COFFEE ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
1	Maize pure and intercrop	22.10	7.10
2	Coffee pure and intercrop	18.40	23.30
3	Bananas pure and intercrop	9.20	7.00
4	Beans pure and intercrop	6.22	3.70
5	Pigeon pea	0.06	1.20
6	Green gram	0.00	0.00
7	Sunflower	0.00	0.00
8	Black beans	0.00	0.00
9	Sweet potato	0.00	0.00
10	Oranges	0.00	0.00
11	Sorghum	0.00	0.60
12	Millet pure and intercrop	0.24	0.06
13	Cassava	0.00	0.00
14	Cotton pure and intercrop	0.00	0.00
15	Tobacco pure and intercrop	0.00	0.00
16	English potatoes	0.00	0.00
17	Napier grass	3.10	1.00
18	Rough grazing	2.20	13.30
19	Improved grazing	1.50	0.06
20	Forest	5.80	6.80
21	Trees/woodlots	5.30	5.50
22	Swamp/marsh	3.40	4.30
23	Bush cover	7.00	12.52
24	Seasonal river	0.00	0.06
25	Perennial river	0.12	0.12
26	Harvested field	2.80	0.67
27	Ploughed field	0.00	0.00
28	Fallow	4.50	6.06
29	Bare soil	2.00	0.60
30	Land under clearing	0.00	0.00
31	Water body	0.00	0.06
32	Footpath/ livestock path	0.80	0.90
33	Farm track	1.00	0.80
34	Road	0.80	1.00
35	Hedgerow	1.50	1.90

APPENDIX 4 (../2)

LAND USE/COVER PERCENTAGE ESTIMATES

RESULTS OF ZAKARY TEST FOR MARGINAL COFFEE ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
36	School field	0.24	0.30
37	School	0.00	0.00
38	Thatched house	0.12	0.20
39	Iron-roofed house	0.90	0.60
40	Duka/shop	0.00	0.06
41	Factory	0.20	0.20
42	Latrine	0.00	0.06
43	Rock outcrop	0.00	0.06
44	Unclassified	0.30	0.20

LAND USE/COVER PERCENTAGE ESTIMATES

RESULTS OF ZAKARY TEST FOR COTTON ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
1	Maize pure and intercrop	8.70	1.40
2	Coffee pure and intercrop	0.12	0.00
3	Bananas pure and intercrop	1.01	1.87
4	Beans pure and intercrop	1.24	2.10
5	Pigeon pea	0.30	4.70
6	Green gram	0.00	0.00
7	Sunflower	0.37	0.00
8	Black beans	0.00	0.00
9	Sweet potato	0.06	0.00
10	Oranges	0.00	0.36
11	Sorghum	1.90	2.60
12	Millet pure and intercrop	5.70	1.90
13	Cassava	0.00	0.00
14	Cotton pure and intercrop	8.00	7.30
15	Tobacco pure and intercrop	0.49	0.00

APPENDIX 4 (../3)
LAND USE/COVER PERCENTAGE ESTIMATES
RESULTS OF ZAKARY TEST FOR COTTON ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
16	English potatoes	0.00	0.00
17	Napier grass	0.24	0.24
18	Rough grazing	15.80	21.10
19	Improved grazing	0.43	0.12
20	Forest	14.30	14.30
21	Trees/woodlots	1.80	0.73
22	Swamp/marsh	0.73	0.43
23	Bush cover	19.95	29.91
24	Seasonal river	0.00	0.00
25	Perennial river	0.12	0.30
26	Harvested field	2.90	1.70
27	Ploughed field	0.00	0.00
28	Fallow	12.50	4.80
29	Bare soil	0.37	0.06
30	Land under clearing	0.24	0.06
31	Water body	0.00	0.00
32	Footpath/ livestock path	0.55	0.61
33	Farm track	0.80	0.18
34	Road	0.00	0.00
35	Hedgerow	0.80	2.40
36	School field	0.30	0.24
37	School	0.12	0.06
38	Thatched house	0.37	0.20
39	Iron-roofed house	0.30	0.24
40	Duka/shop	0.00	0.00
41	Factory	0.00	0.00
42	Latrine	0.06	0.00
43	Rock outcrop	0.00	0.12
44	Unclassified	0.37	0.20

APPENDIX 4 (../4)
LAND USE/COVER PERCENTAGE ESTIMATES
RESULTS OF ZAKARY TEST FOR MARGINAL COTTON ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
1	Maize pure and intercrop	1.02	0.00
2	Coffee pure and intercrop	0.00	0.00
3	Bananas pure and intercrop	0.18	0.00
4	Beans pure and intercrop	0.73	0.18
5	Pigeon pea	0.12	0.00
6	Green gram	0.00	0.00
7	Sunflower	1.00	0.00
8	Black beans	0.00	0.00
9	Sweet potato	0.00	0.00
10	Oranges	0.00	0.00
11	Sorghum	0.00	0.00
12	Millet pure and intercrop	8.60	1.00
13	Cassava	0.00	0.00
14	Cotton pure and intercrop	5.44	11.60
15	Tobacco pure and intercrop	0.00	0.00
16	English potatoes	0.00	0.00
17	Napier grass	0.00	0.00
18	Rough grazing	20.40	30.80
19	Improved grazing	0.00	0.00
20	Forest	0.00	0.00
21	Trees/woodlots	0.55	0.12
22	Swamp/marsh	0.00	0.00
23	Bush cover	42.70	46.90
24	Seasonal river	0.06	0.06
25	Perennial river	0.00	0.00
26	Harvested field	4.90	1.60
27	Ploughed field	0.00	0.06
28	Fallow	9.47	5.20
29	Bare soil	0.24	0.00
30	Land under clearing	0.18	0.00
31	Water body	0.00	0.00
32	Footpath/ livestock path	0.50	0.37
33	Farm track	0.18	0.00
34	Road	0.06	0.06
35	Hedgerow	1.20	1.10

APPENDIX 4 (../5)

LAND USE/COVER PERCENTAGE ESTIMATES
RESULTS OF ZAKARY TEST FOR MARGINAL COTTON ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
36	School field	0.06	0.12
37	School	0.00	0.00
38	Thatched house	0.06	0.12
39	Iron-roofed house	0.00	0.00
40	Duka/shop	0.00	0.00
41	Factory	0.00	0.00
42	Latrine	0.00	0.00
43	Rock outcrop	0.43	0.50
44	Unclassified	0.24	0.00

LAND USE/COVER PERCENTAGE ESTIMATES
RESULTS OF ZAKARY TEST FOR LIVESTOCK ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
1	Maize pure and intercrop	0.00	0.00
2	Coffee pure and intercrop	0.00	0.00
3	Bananas pure and intercrop	0.00	0.00
4	Beans pure and intercrop	0.00	0.00
5	Pigeon pea	0.00	0.00
6	Green gram	0.00	0.00
7	Sunflower	0.00	0.00
8	Black beans	0.00	0.00
9	Sweet potato	0.00	0.00
10	Oranges	0.00	0.00
11	Sorghum	0.00	0.00
12	Millet pure and intercrop	4.06	0.00
13	Cassava	0.00	0.00
14	Cotton pure and intercrop	4.30	0.67
15	Tobacco pure and intercrop	0.00	0.00

APPENDIX 4 (.../6)
LAND USE/COVER PERCENTAGE ESTIMATES
RESULTS OF ZAKARY TEST FOR LIVESTOCK ZONE

CODE NUMBER	LAND USE/COVER TYPE	TEST ONE ESTIMATES	TEST TWO ESTIMATES
16	English potatoes	0.00	0.00
17	Napier grass	0.00	0.00
18	Rough grazing	21.10	27.20
19	Improved grazing	0.00	0.00
20	Forest	0.00	0.00
21	Trees/woodlots	0.00	0.00
22	Swamp/marsh	0.00	0.00
23	Bush cover	54.90	64.62
24	Seasonal river	0.67	0.37
25	Perennial river	0.00	0.30
26	Harvested field	0.00	0.30
27	Ploughed field	0.00	0.00
28	Fallow	15.30	3.70
29	Bare soil	0.12	0.24
30	Land under clearing	0.18	0.12
31	Water body	0.00	0.00
32	Footpath/ livestock path	0.80	0.67
33	Farm track	0.00	0.00
34	Road	0.00	0.00
35	Hedgerow	0.55	0.30
36	School field	0.00	0.00
37	School	0.00	0.00
38	Thatched house	0.06	0.00
39	Iron-roofed house	0.00	0.00
40	Duka/shop	0.00	0.00
41	Factory	0.00	0.00
42	Latrine	0.00	0.00
43	Rock outcrop	1.00	1.00
44	Unclassified	0.00	0.00

APPENDIX 5
FARM MEASUREMENTS: CULTIVATED AREA (HA)

GRID REF	FARM NO	AREA	GRID REF	FARM NO	AREA
35449900	351	0.50	37989828	75	1.09
35459628	374	1.23	37989828	76	0.89
35469950	251	0.40	37989828	77	1.11
35479758	341	1.26	38009550	101	1.58
35500050	249	1.93	38009550	100	1.57
36009525	310	1.29	38009749	137	0.64
36009606	326	0.52	38009749	139	0.79
36009910	184	0.90	38009749	135	1.38
36009892	209	1.25	38019925	39	1.40
36000052	203	1.27	38019925	41	1.81
36000132	215	1.96	38019925	42	1.14
36010035	222	1.06	38019925	43	2.38
36499650	276	0.36	38450145	470	1.27
36509700	268	0.31	38480081	463	0.67
36509978	142	1.02	38500000	47	4.64
36509800	330	1.09	38509853	132	0.71
36510067	221	0.87	38509853	133	0.84
36539669	383	0.33	38509853	134	0.62
36559862	357	3.12	38500209	394	0.37
36959600	283	0.47	38500450	426	0.22
37000008	233	3.75	38500480	438	0.51
37000040	236	2.45	38519950	32	0.88
37000070	170	0.57	38519950	33	0.45
37000120	175	1.65	38529802	116	1.12
37009802	114	3.58	38529802	117	0.39
37009850	162	0.76	38529802	119	1.18
37259600	298	1.64	38559755	67	1.32
37259700	93	0.45	38559755	68	0.91
37259700	94	0.76	38559900	129	1.01
37459650	288	0.34	38559900	126	2.15
37479750	106	0.40	39000000	51	1.66
37479750	110	1.16	39000000	52	0.85
37479825	102	1.32	39000203	453	0.58
37479825	103	2.77	39000450	446	0.39
37509690	90	0.54	39009900	80	0.21
37509690	91	1.16	39009900	78	2.02
37509690	88	0.73	39029750	12	0.70
37559900	120	1.69	39029750	13	0.31
37559900	122	0.93	39029750	10	0.47
37559900	123	1.34	39029750	11	2.99
37759700	83	0.75	39039798	3	0.67
37759700	84	0.87	39039798	4	0.99
37759700	85	0.96	39039798	5	4.32
37979625	55	0.65	39039798	2	0.27
37979625	58	0.54	39039798	1	1.38
37979625	59	0.68	39359950	27	0.65

APPENDIX 5 (../2)
FARM MEASUREMENTS: CULTIVATED AREA (HA)

GRID REF	FARM NO	AREA	GRID REF	FARM NO	AREA
39359950	28	0.83	39500231	421	0.70
39459900	29	2.06	39500316	405	0.85
39459900	6	1.09	39500493	428	0.57
39459900	7	0.87	40019850	60	1.06
39459900	9	0.62	40529848	14	3.03
39509998	19	1.65	40529848	15	0.39
39509998	21	1.25	40529848	17	1.18
39509998	22	0.95	40529885	54	2.14
39509998	23	1.47			

APPENDIX 6

FARM MEASUREMENTS AND FARMER ESTIMATES OF CULTIVATED AREA (HA)

FARM	MEASUREMENT	ESTIMATE	FARM	MEASUREMENT	ESTIMATE
54	2.14	2.23	14	3.03	3.64
60	1.06	1.21	23	1.47	1.21
22	0.95	0.81	21	1.25	1.62
19	1.65	1.21	28	0.83	1.21
4	0.99	0.40	3	0.67	1.62
2	0.27	0.40	1	1.38	1.01
13	0.31	0.81	12	0.70	0.40
10	0.47	0.61	78	2.02	2.02
52	0.85	0.81	51	1.66	2.43
9	0.62	1.01	7	0.87	0.80
6	1.09	1.00	129	1.01	0.81
126	2.15	1.42	117	0.39	0.91
134	0.62	0.50	47	4.64	2.42
43	2.38	2.63	42	1.14	2.02
41	1.81	1.82	39	1.40	2.02
100	1.57	1.21	77	1.11	1.0
76	0.89	1.21	58	0.54	0.81
85	0.96	1.01	84	0.87	1.62
123	1.34	1.21	122	0.93	1.01
120	1.69	2.43	91	1.16	1.21
90	0.54	0.61	88	0.73	1.21
288	0.34	0.61	270	1.22	1.62
175	1.65	1.61	170	0.57	1.21
233	3.75	2.40	283	0.47	0.62
357	3.12	3.64	221	0.87	1.01
142	1.02	1.21	268	0.31	0.81
222	1.06	1.62	184	0.90	1.00
209	1.25	1.94	326	0.52	0.81
310	1.29	2.02	203	1.27	1.21
249	1.93	1.62	341	1.26	2.02
251	0.40	0.40	374	1.23	1.41
351	0.50	0.80			

Farm indicates the number of the farm.

APPENDIX 7A

FARMDAT COMPUTER DATA FILE

COL	VARIABLE DESCRIPTION	NUMERIC INT	CODE CAT
1-3	Farm number		x
4	Record number		x
5-6	Agro-ecological zone		x
7-8	Administrative location		x
9-10	Administrative sub-location		x
11-18	Grid coordinate reference		x
19	Number of farms	x	
20-23	Size of cultivated area	x	
24-27	Area under cash crops	x	
28-31	Area under food crop complexes	x	
32-35	Area under pure food crops	x	
36-39	Area under cash/food crops	x	
40-49	Important farm crops (codes)		x
50-51	No of years growing cash crops	x	
52-53	No of years growing food crops	x	
54	Forage crops (y/n)		x
55	Fallow fields (y/n)		x
56	Graze fallows (y/n)		x
57-58	Area under fallows	x	
59-60	Fallow length (yrs)	x	
61	Type of crops sold		x
62	Fallows in past (y/n)		x
63-65	Length of past fallows (yrs)	x	
66	Plant trees (y/n)		x
67	Trees for timber		x
68	Trees for food/fruit		x
69	Trees for charcoal		x
70	Trees for sale (fruit/timber)		x
71	Trees for fencing		x
72	Trees for fuel		x
73	Other uses		x
74	Crop rotations (y/n)		x
75	Increased/decreased farm size		x
76-80	Crop income	x	

COL signifies column number of variable in data set. INT signifies integer variable, CAT signifies category variable.

APPENDIX 7A (../2)

FARMDAT COMPUTER DATA FILE

COL	VARIABLE DESCRIPTION	NUMERIC INT	CODE CAT
1-3	Farm number		x
4	Record number		x
5	Grows different crops (y/n)		x
6-11	Crop types (coded)		x
12-13	Location of original home		x
14	Length of farming at present site (coded)		x
15	Tenureship of farm (coded)		x
16-17	Place of residence before present site		x
18	Change farming system (y/n)		x
19	Type of change (coded)		x
20	Changes in tree cover (coded)		x
21	Changes in bush cover (coded)		x
22	Changes in grass cover (coded)		x
23	Changes in soil erosion (coded)		x
24-28	Animals kept (coded)		x
29-38	Sheep (adult, immature, young)	x	
39-48	Goats (adult, immature, young)	x	
49-58	Grade cattle (adult, immature, young)	x	
59-68	Local cattle (adult, immature, young)	x	
69-78	Chickens (adult, immature, young)	x	
79-80	Sub-location of where animals kept		x

COL signifies column number of variable in data set.
INT signifies integer variable, CAT signifies category variable.

APPENDIX 7A (../3)

FARMDAT COMPUTER DATA FILE

COL	VARIABLE DESCRIPTION	NUMERIC INT	CODE CAT
1-3	Farm number		x
4	Record number		x
5	Farmer owns grazing (y/n)		x
6	Farmer rents grazing (y/n)		x
7	Farmer uses communal grazing		x
8	Farmer accepts others' grazing on land		x
9	Farmer owns improved grazing		x
10	Farmer practices zero grazing		x
11	Farmer practices tethered grazing		x
12	Farmer moves herd (y/n)		x
13	Reason for moving - water		x
14	- grazing		x
15	Farmer lends grazing		x
16	Crop residues fed to livestock		x
17-22	Types of crops (coded)		x
23-27	Income from livestock	x	
28-31	Farm measurements - total area	x	
32-35	- area under cash crops	x	
36-39	- area under cash/food crops	x	
40-43	- area under food crops	x	
44-47	- area under intercropped food crops	x	
48-51	- area of compound	x	
52	External sources of income		x
53-57	External income	x	
58-59	Location of second farm		x
60-61	Sublocation of second farm		x
62-67	Crop codes on second farm		x
68-70	Crop complexes (coded)		x
71-72	Length of cultivation	x	
73-74	Length to continue cultivating	x	
75-76	Location of third farm		x
77-78	Sublocation of third farm		x

COL signifies column number of variable in data set. INT signifies integer variable, CAT signifies category variable.

APPENDIX 7A (../4)

FARMDAT COMPUTER DATA FILE

COL	VARIABLE DESCRIPTION	NUMERIC INT	CODE CAT
1-3	Farm number		x
4	Record number		x
5-10	Crop codes on third farm		x
11-13	Complex crops on third farm (coded)		x
14-15	Length of cultivating	x	
16-17	Length to continue farming	x	

APPENDIX 7B

CROPTAB COMPUTER DATA FILE

COL	VARIABLE DESCRIPTION (FARM RECORD)	NUMERIC INT	CODE CAT
1-3	Farm number		x
4-5	Number of plots	x	
6	Record number		x
7-8	Agro-ecological zone		x
9-10	Administrative location		x
11-12	Administrative sublocation		x
13-20	Grid reference		x
21-22	Length of cultivation	x	
23-24	Length to continue cultivation	x	
25	Season number		x
	(PLOT RECORD)		
1-3	Farm number		x
4-5	Plot number		x
6	Record type		x
7	Season number		x
8-9	Crop code (pure crops)		x
10-12	Crop code (complexes)		x
13-14	Planting code		x
15	Number in complex	x	

COL signifies column number of variable in data set. INT signifies integer variable, CAT signifies category variable.

APPENDIX 8
CROP/LAND COVER TYPES RECORDED DURING FIELD SURVEY (COMPUTERISED ON CROPTAB FILE)

COMMON NAME	SCIENTIFIC NAME	CODE
Coffee	Coffea arabica	1
Tea	Camellia sinensis	2
Maize	Zea mays	3
Bullrush millet	Pennisetum typhoides	4
Sorghum	Sorghum bicolor	5
Finger millet	Eleusine coracana	6
Sunflower	Helianthus annuus	7
Cotton	Gossypium herbaceum	8
Common beans	Phaseolus vulgaris	9
Black beans	Dolichos lablab	10
Bananas	Musa cultivars	11
Tobacco	Nicotiana tabacum	12
Kimeru tobacco	Nicotiana spp	13
Soya bean	Glycine max	14
Green gram	Phaseolus aureus	15
Chick pea	Cicer arietinum	16
Pigeon pea	Cajanus cajan	17
Cowpea	Vigna sinensis	18
Castor	Ricinus communis	19
Orange	Citrus sinensis	20
Mango	Mangifera indica	21
Pineapple	Ananas comosus	22
Miraa (Khat)	Catha edulis	23
Cassava	Manihot esculenta	24
Sweet potato	Ipomoea batatas	25
English potato	Solanum tuberosum	26
Napier grass	Pennisetum purpureum	27
Fallow/grazing		28
Not cultivated		29
Trees (planted)		30
Sugar cane	Saccharum cultivars	31
Tomato	Lycopersicon esculentum	32
Onion	Allium cepa	33
Bottle gourd	Lagenaria siceraria	34
Pumpkin	Cucurbita moschata	35
Egg plant	Solanum melongena	36
Macadamia nut	Macadamia ternifolia	37
Arrowroot	Maranta arundinacea	38
Sukuma wiki	Brassica spp	39
Cabbage	Brassica spp	40
Yam	Dioscorea spp	41
Rice	Oryza sativa	42
Groundnuts	Arachis hypogaea	43
Carrots	Daucus carota	44
Guava	Psidium guajava	45
Avocado	Persea americana	46
Pyrethrum	Chrysanthemum cinerariaefolium	47
Cashew nut	Anacardium occidentale	48

APPENDIX 9

PERCENTAGE OF AREA UNDER COMPLEXES IN LOWER MERU

GRID REF	% CULTIVATION	GRID REF	% CULTIVATION
35009556	44.0	37559900	30.8
35449900	56.9	37759700	64.6
35459545	41.0	37979625	38.9
35459628	36.3	37989823	37.8
35459695	55.8	38009550	53.0
35459804	33.0	38009749	53.0
35469950	22.7	38019925	36.7
35479758	45.4	38450145	53.0
35480002	44.1	38480081	53.0
35500050	46.3	38500000	26.4
35989750	76.4	38500209	42.9
36000052	75.0	38500351	65.2
36000083	36.1	38500450	21.0
36000132	63.6	38500480	28.4
36009525	25.7	38509853	40.3
36009606	77.5	38519950	11.8
36009892	61.5	38529970	7.2
36009921	71.5	38559755	53.0
36009970	64.0	38559900	33.3
36019673	39.1	39459900	55.5
36500029	69.3	39000000	62.5
36509521	75.7	39000105	25.4
36509574	64.5	39000203	43.2
36509700	59.0	39000308	69.5
36509800	22.0	39000370	77.0
36509978	79.4	39000452	24.2
36510067	33.2	39009900	54.5
36539669	56.0	39029750	54.4
36559862	24.2	39039798	74.1
36959600	60.0	39359950	38.9
37000008	96.2	39500231	27.6
37000040	19.7	39500316	70.7
37000070	37.1	39500440	56.3
37000120	73.9	39500493	55.0
37009802	17.2	39509998	43.0
37009850	46.2	40019850	39.4
37009910	80.0	40529848	8.6
37009990	69.9	40529885	60.2
37029575	63.7	35989802	57.2
37059650	69.1	36499650	64.2
37259600	59.6	38500296	48.1
37259700	28.4	38529802	55.2
37459650	54.0		
37479750	53.7		
37479828	27.5		
37509690	70.3		

APPENDIX 10

CROP COMPLEXES IDENTIFIED DURING FIELD SURVEY

CODE	COMPLEX TYPE	CODE	COMPLEX TYPE
001	MIL/SOR	047	BAN/CAS
002	MZ/GGR	048	OR/B
003	SOR/CP	049	CP/BB
004	MIL/CP	050	BB/PP
005	MIL/MZ	051	BB/BAN
006	COT/GGR	052	BAN/B
007	SOR/GGR	053	COF/B
008	COT/MZ	054	SUN/GND
009	MZ/SOR	055	BB/B
010	MZ/B	056	COF/MZ
011	COT/MIL	057	SOR/PP
012	COT/B	058	OR/MAN
013	MZ/PP	059	SUN/BB
014	MZ/CP	060	EPOT/OR
015	MZ/SUN	061	MIR/B
016	COT/CP	062	MIR/MZ
017	COT/SOR	063	MIR/OR
018	SUN/GGR	064	MZ/FM
019	GGR/CP	065	SCAN/ARR
020	SUN/MIL	066	SPOT/MZ
021	SUN/COT	067	NAP/SOR
022	GGR/PP	068	CP/B
023	SUN/CP	069	CAS/B
024	SUN/B	070	OR/COT
025	MIL/PP	071	FM/PP
026	COT/PP	072	SCAN/BAN
027	MZ/BB	073	YG/MZ
028	MZ/TOB	074	COIL/MIL
029	COF/PP	075	TOB/BAN
030	SUN/B	076	SPOT/CAS
031	SUN/NAP	077	EPOT/MZ
032	SUN/CAS	078	MAN/B
033	TOB/B	079	MAN/MZ
034	SUN/TOB	080	OR/BB
035	B/PP	081	OR/GND
036	MZ/BAN	082	OR/NAP
037	SUN/PP	083	OR/SUN
038	CP/PP	084	BAN/SPOT
039	MZ/CAS	085	TOB/COF
040	EPOT/CAS	086	TOB/SOR
041	COF/BB	087	TOB/PP
042	COF/YG	088	SUN/SOR
043	COT/BB	089	CAS/PP
044	BAN/NAP	090	COF/CAS
045	FM/CP	091	TOB/FM
046	OR/MZ	092	FM/MIL

Abbreviations are explained at end of Appendix.

APPENDIX 10 (../2)

CROP COMPLEXES IDENTIFIED DURING FIELD SURVEY

CODE	COMPLEX TYPE	CODE	COMPLEX TYPE
093	YAM/B	139	PAP/MZ/B
094	MIR/EPOT	140	COF/MZ/BAN
095	CAB/MZ	141	SUN/CP/SOR
096	MAC/BAN	142	MZ/GG/COT
097	ARR/BAN	143	COIL/COT/SOR
098	EPOT/PP	144	COIL/GG/SOR
099	YG/PP	145	COT/GG/SOR
100	MIR/MIL	146	COT/CP/SOR
101	MIR/CP	147	MIL/PP/GG
102	FM/MIR	148	SPOT/PUM/GOR
103	MIR/SOR	149	CP/GG/SOR
104	CAS/MIR	150	BAN/CP/PP
105	EPOT/BAN	151	COF/CAS/NAP
106	ON/BAN	152	EPOT/CAS/CP
107	YAM/OR	153	TOB/NAP/MZ
108	MAC/COF	154	CAS/COT/MZ
109	MIR/SPOT	155	COT/MZ/CP
110	YAM/EPOT	156	MZ/MIL/SOR
111	EPOT/COF	157	SPOT/TOB/MZ
112	MIR/SCAN/BAN	158	COT/SOR/PP
113	BAN/ARR/YAM	159	CP/GG/PP
114	BAN/ARR/B	160	CAS/MZ/SOR
115	CAS/SPOT/B	161	CAS/BAN/B
116	CAS/SWIK/B	162	CAS/MZ/BAN
117	SPOT/MZ/B	163	SPOT/CAS/MZ
118	MIR/BAN/NAP	164	TOB/COF/BAN
119	EPOT/MZ/B	165	SCAN/BAN/SPOT
120	EPOT/MIL/B	166	YAM/BAN/B
121	BB/B/MZ	167	TOB/MZ/SOR
122	MIR/BAN/MZ	168	GG/SUN/SOR
123	BB/B/EPOT	169	YG/CP/PP
124	BAN/MIL/B	170	SUN/MIL/SOR
125	MIR/B/CAS	171	COT/SUN/GG
126	MIR/MZ/CAS	172	CAS/MIL/SOR
127	MIR/MIL/CAS	173	TOB/MZ/PP
128	MIR/B/EPOT	174	BB/MZ/CP
129	MIR/MZ/MIL	175	PAW/COF/B
130	MIR/MZ/FM	176	SUN/COT/MIL
131	EPOT/SOR/B	177	MZ/SUN/CP
132	CAS/FM/MIL	178	MIL/SOR/B
133	MIR/COT/PP	179	BAN/MZ/CP
134	BAN/YAM/COF	180	YAM/BAN/MZ
135	MAC/BAN/YAM	181	YAM/BAN/MIL
136	MIR/SCAN/COF	182	SUN/MZ/B
137	MAC/COF/BAN	183	TOB/OR/BAN
138	COF/MZ/SUN	184	OR/BAN/CP

Abbreviations are explained at end of Appendix.

APPENDIX 10 (../3)

CROP COMPLEXES IDENTIFIED DURING FIELD SURVEY

CODE	COMPLEX TYPE	CODE	COMPLEX TYPE
185	MR/MZ/B	231	MIL/SOR/CP
186	COF/SUN/B	232	SOR/GG/B
187	BB/MZ/SUN	233	MIL/SOR/CP/GG
188	TOB/MZ/B	234	COT/MZ/GG/PP
189	SCAN/BAN/MZ	235	COIL/MZ/GG/PP
190	MZ/B/CP	236	MIR/B/SUN/MZ
191	FMIL/MZ/SOR	237	MZ/SUN/B/PP
192	SOR/B/PP	238	MZ/SUN/GG/PP
193	BB/MZ/PP	239	MZ/SUN/CP/PP
194	BB/SOR/PP	240	COT/SUN/MZ/PP
195	COT/B/PP	241	MZ/B/CP/SOR
196	OR/MZ/B	242	MZ/SUN/B/SOR
197	BB/CP/PP	243	CAS/MZ/B/SOR
198	SUN/B/PP	244	MZ/SUN/SOR/PP
199	SUN/MIL/PP	245	MZ/PP/SOR/B
200	MZ/MIL/PP	246	BAN/YAM/MZ/B
201	COT/SUN/PP	247	BB/MZ/SUN/PP
202	MZ/SUN/PP	248	BAN/CAS/MZ/SOR
203	BB/SUN/PP	249	SPOT/BAN/MZ/B
204	BB/MZ/SOR	250	BAN/MZ/SUN/PP
205	MZ/B/SOR	251	BAN/MZ/SOR/B
206	CAS/MZ/B	252	COF/MZ/SUN/B
207	COF/MZ/B	253	OR/BAN/FMIL/MZ
208	BAN/MZ/B	254	OR/FMIL/MZ/SOR
209	CP/SOR/PP	255	COT/SUN/B/PP
210	MZ/GG/PP	256	COT/MZ/B/PP
211	MZ/MIL/PP	257	COT/MZ/SUN/B
212	NAP/SUN/PP	258	COT/MZ/PP/SOR
213	MZ/B/PP	259	MZ/B/CP/PP
214	TOB/CAS/MZ	260	CAS/FMIL/MZ/PP
215	COT/B/MZ	261	MZ/SOR/PP/CP
216	COT/MZ/PP	262	MIL/MZ/GG/CP
217	MZ/SUN/MIL	263	MIL/MZ/GG/PP
218	COT/MZ/MIL	264	SPOT/SUN/MIL/PP
219	SUN/SOR/PP	265	CAS/SUN/MIL/PP
220	MIL/SOR/PP	266	MZ/GG/SUN/SOR
221	MZ/CP/PP	267	PAW/COF/MZ/BB
222	COT/GG/PP	268	TOB/MZ/SOR/PP
223	COT/MZ/SUN	269	TOB/SOR/GG/PP
224	COT/GG/B	270	MIL/MZ/SOR/PP
225	COIL/GG/PP	271	MIL/SOR/CP/PP
226	MZ/GG/MIL	272	MIL/SUN/CP/GG
227	MZ/B/MIL	273	SPOT/CAS/MZ/CP
228	COT/GG/CP	274	SPOT/MZ/B/MIL
229	MIL/PP/CP	275	NAP/BAN/MZ/B
230	SOR/MZ/CP	276	ARR/BAN/YAM/NAP

Abbreviations are explained at end of Appendix.

APPENDIX 10 (../4)

CROP COMPLEXES IDENTIFIED DURING FIELD SURVEY

CODE	COMPLEX TYPE	CODE	COMPLEX TYPE
277	SCAN/BAN/SPOT/CAS	323	BAN/YAM/NAP/MZ/B
278	SCAN/BAN/MZ/B	324	BAN/MZ/B/SOR/SUN
279	CAS/MZ/B/PP	325	MZ/MIL/SOR/CP/GG
280	COT/MZ/GG/CP	326	MZ/MIL/CP/GG/PP
281	MZ/MIL/SOR/CP	327	SCAN/MZ/CP/SOR/MIL
282	TOB/MZ/SOR/B	328	SPOT/BAN/EPOT/CAS/MZ
283	BAN/CAS/MZ/B	329	SCAN/BAN/SPOT/MZ/B
284	NAP/MZ/B/PP	330	PUM/GOR/MIL/SOR/PP
285	SOR/B/GG/CP	331	COT/MIL/MZ/PP/SOR
286	MIL/SOR/GG/PP	332	CAS/BAN/PP/GG/SUN
287	COT/MIL/SOR/GG	333	TOB/MZ/CAS/PP/SOR
288	MZ/MIL/SOR/GG	334	CAS/BAN/MZ/MIL/PP
289	COT/CP/MIL/SOR	335	COT/MZ/MIL/SOR/SUN
290	COT/MZ/SOR/CP	336	MZ/MIL/SOR/GG/PP
291	COT/SOR/GG/CP	337	COT/MZ/B/SUN/PP
292	ARR/BAN/YAM/CAS	338	COF/MZ/B/SUN/PP
293	PAP/SUN/MZ/B	339	CAS/MZ/B/SOR/PP
294	SWIK/EGG/BAN/SCAN	340	BB/SUN/MZ/CP/PP
295	MIR/SCAN/BAN/NAP	341	MZ/SUN/PP/SOR/B
296	SPOT/MIR/BAN/MZ	342	MIL/SUN/PP/MZ/CP
297	COT/MIR/PP/MZ	343	COT/MZ/SUN/GG/PP
298	MIR/FMIL/EPOT/B	344	MZ/SUN/PP/SOR/CP/BB
299	MIR/CAS/MZ/B	345	BAN/MZ/B/SUN/BB/PP
300	COF/BAN/CAS/YAM	346	CAS/MZ/B/SOR/SUN/PP
301	MIR/BAN/NAP/MZ	347	BAN/SPOT/MZ/SUN/BB/CP
302	MIR/EPOT/BAN/NAP	348	MZ/SOR/SUN/PP/B/CP
303	BB/CAS/MZ/B	349	TOB/MZ/CAS/SOR/B/PP
304	BB/MZ/B/SOR	350	ON/BAN/CAS/YAM/SPOT/
305	MIR/MZ/B/PP		MZ
306	TOM/FMIL/GOR/MZ/SOR	351	COT/CP/GG/MIL/SOR/MZ
307	MZ/BB/PP/CP/B	352	COT/MZ/GG/PP/SUN/CP
308	CAS/MZ/B/MIL/PP	353	MIR/COF/SCAN/CAB/B/MZ
309	YAM/MZ/B/MIL/PP	354	ARR/MIR/CAB/BAN/YAM/
310	SPOT/BB/B/MZ/MIL		MZ
311	MIR/YAM/BAN/BB/B	355	MIR/YAM/BAN/EPOT/MZ/B
312	EPOT/MIR/YAM/BB/B	356	COF/EPOT/YAM/BAN/MZ/B
313	CAS/BAN/MZ/BB/B	357	MIR/SPOT/MZ/B/BB/PP
314	COF/CAB/CAS/BAN/MZ	358	MIR/EPOT/MZ/B/SOR/CP
315	SPOT/BAN/CAB/MIR/MZ	359	YAM/BAN/EPOT/MIR/BB/B
316	NAP/BAN/MZ/SUN/PP		MZ
317	COT/MIL/SOR/GG/CP	360	MIR/SPOT/CAS/BAN/ARR/
318	COT/CP/GG/PP/SOR		YAM/MZ
319	MZ/CP/MIL/SOR/PP	361	CAB/BAN/ARR/CAS/YAM/
320	MZ/CP/GG/B/PP		SCAN/NAP
321	COT/MZ/CP/SOR/PP	362	YAM/SCAN/ARR/CAB/BAN/
322	NAP/BAN/CAS/MZ/B		MZ/B/CAS

Abbreviations are explained at end of Appendix.

APPENDIX 10 (../5)

CROP COMPLEXES IDENTIFIED DURING FIELD SURVEY

CODE	COMPLEX TYPE	CODE	COMPLEX TYPE
363	MZ/SOR/MIL/GG/CP/PP	409	MZ/B/SOR/COF
364	YG/PP/SUN/COT	410	NAP/BB/PP
365	COF/PAW	411	COT/SUN/B
366	TOB/SPOT	412	BAN/MIL
367	GG/CP/SUN	413	COT/MZ/B/PP/SOR/CP
368	MIL/GG	414	BAN/MZ/SOR
369	MIL/SUN/GG	415	SPOT/BB/PP
370	MIL/GG/CP	416	SPOT/B/PP
371	MZ/SUN/GG	417	SOR/MIL/MZ/B/PP
372	MIL/GOR/SOR/PP	418	COT/MIL/PP
373	MZ/GG/CP	419	COT/MIL/PP
374	MZ/PP/SOR	420	BAN/ARR/YAM/GUA
375	MIR/MZ/B/BAN	421	YAM/MZ
376	MIR/BAN/CAS	422	COT/GG/MIL
377	COF/NAP/APP	423	MZ/NAP
378	COF/MIR/EPOT	424	MZ/B/NAP
379	COF/ARR	425	COF/NAP
380	MIR/MZ/B/EPOT	426	YAM/MZ/B
381	MIR/BAN	427	COT/SOR/MIL
382	MIR/YAM/MZ/B/BAN	428	MIL/SOR/GG
383	BB/SOR/MIL/B/EPOT	429	COT/MIL/CP
384	MZ/SOR/MIL/B/EPOT	430	COT/MZ/SOR
385	MIL/B	431	TOB/MIL
386	YAM/BAN	432	TOB/NAP
387	EPOT/MZ/B/BAN/CAS	433	CAS/MZ/CP
388	MIR/BAN/YAM/MZ	434	MZ/B/SOR/CP/CAS
389	MIR/MZ/B/EPOT/BAN	435	MZ/CAS/EPOT/BAN
390	MIR/COF	436	MIL/SUN/CP
391	MIR/NAP/B		
392	COF/BAN		
393	CAS/PP/B/MIR		
394	B/CAS/PP		
395	MIR/FMIL/B		
396	MZ/B/BAN/CAS/PP		
397	COF/MZ/B/BAN		
398	MIL/SOR/MZ/B/SPOT		
399	MIR/B/BB/PP/GG		
400	MZ/B/SOR/CP/PP		
401	MZ/B/SPOT/EPOT		
402	SUN/MZ/BB/PP		
403	MIL/PP/SOR/CAS		
404	SPOT/B		
405	COT/MZ/SUN/GG/PP/B		
406	SUN/CP/PP		
407	COT/SUN/MIL/PP		
408	MZ/B/GND		

Abbreviations are explained at end of Appendix.

APPENDIX 10 (../6)

EXPLANATION OF CROP ABBREVIATIONS

CODE	CROP DESCRIPTION	CODE	CROP DESCRIPTION
COF	COFFEE	TEA	TEA
MZ	MAIZE	MIL	BULLRUSH MILLET
SOR	SORGHUM	FMIL	FINGER MILLET
SUN	SUNFLOWER	COT	COTTON
B	BEANS	BB	BLACK BEANS
BAN	BANANAS	TOB	TOBACCO
GG	GREEN GRAM	YG	CHICK PEA
PP	PIGEON PEA	CP	COWPEA
COIL	CASTOR	OR	ORANGE
MAN	MANGO	PAP	PINEAPPLE
MIR	MIRAA	CAS	CASSAVA
SPOT	SWEET POTATO	EPOT	ENGLISH POTATO
NAP	NAPIER	SCAN	SUGAR CANE
TOM	TOMATO	ON	ONION
GOR	GOURD	PUM	PUMPKIN
EGG	EGG PLANT	MAC	MACADAMIA
ARR	ARROWROOT	SWIK	SUKUMA WIKI
CAB	CABBAGE	YAM	YAM
RIC	RICE	GND	GROUNDNUTS
CAR	CARROTS	GUA	GUAVA
AVO	AVOCADO	CASH	CASHEW
PAW	PAWPAW		

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