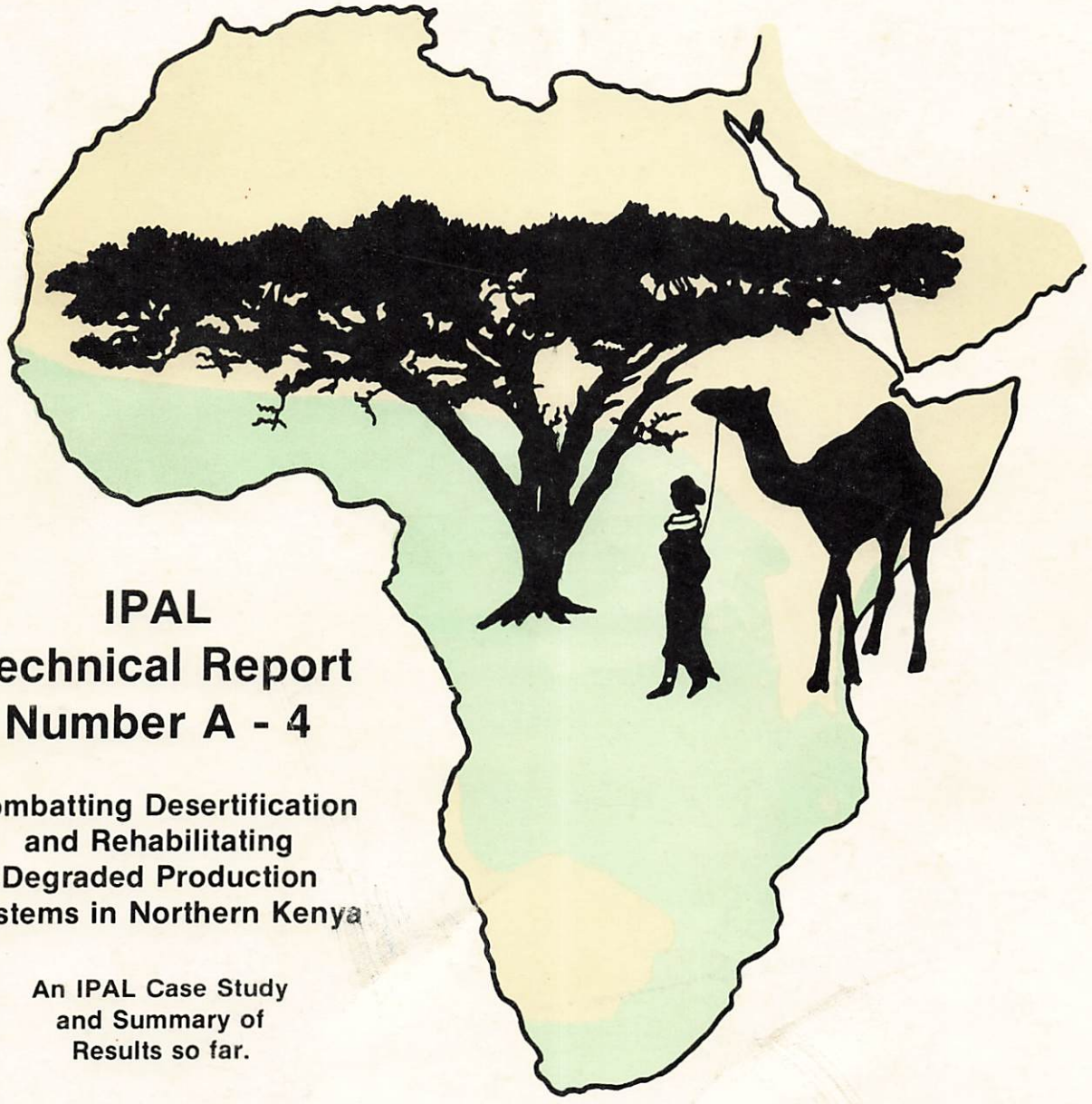
Federal Republic of Germany

Unesco Programme on Man and the Biosphere (MAB)

Republic of Kenya

Integrated Project in Arid Lands (IPAL)



IPAL Technical Report Number A - 4

Combatting Desertification and Rehabilitating Degraded Production Systems in Northern Kenya

An IPAL Case Study and Summary of Results so far.

MAN AND THE BIOSPHERE PROGRAMME

Project 3: Impact of Human Activities and Land Use Practices on Grazing Lands

IPAL Technical Report A-4

COMBATTING DESERTIFICATION AND REHABILITATING DEGRADED PRODUCTION SYSTEMS IN NORTHERN KENYA

by

Walter J. Lusigi (Unesco Integrated Project in Arid Lands,
Marsabit, Kenya)

September 1981

UNESCO-UNEP Integrated Project in Arid Lands

SUMMARY INTRODUCTION TO IPAL AND THE TECHNICAL REPORT SERIES

The Integrated project in Arid Lands (IPAL) was established by UNESCO with financial support from UNEP in 1976 with the aim of finding direct solutions to the most urgent environmental problems associated with desert encroachment and ecological degradation of arid lands. It forms part of the international UNESCO programme, Man and the Biosphere (MAB) which has links not only with UNEP's Desertification Unit but also with FAO, in response to the Plan of Action adopted by the 1977 United Nations Conference on Desertification. It is an example of the type of pilot activity that UNESCO and UNEP, together with other organizations and a number of governments, are trying to promote to provide the scientific basis for the rehabilitation and rational management of arid and semi-arid zone ecosystems, through integrated programmes of research (including survey, observation and experimentation), training and demonstration. Phase III of the project, 1980-1983, is supported by funds in trust to UNESCO provided by the Federal Republic of Germany.

During the first phases of IPAL, a co-ordination unit was established in Nairobi and the initial field work started in the arid zone of northern Kenya in a working area of 22,500 km^2 situated between Lake Turkana and Marsabit Mountain. The project now operates five field stations at Mount Kulal, Olturot, Kargi, Korr and Ngurunit, with the project headquarters in Marsabit which is the administrative centre of the District. Since its establishment the project has researched several aspects of experimental management of the region, concentrating upon 'human ecology' of the nomadic pastoralists in dynamic inter-relationship with the animals, plants and the other resources of a drought-prone, uncertain environment.

During the next three years (1980-1983), the investigations in progress will be extended and intensified to develop resource management plans or models for the area, taking into account the increasing human population, the trend towards sedentarization, the degradation of primary productivity, and the increasing incidence of soil erosion, all of which are factors resulting in the necessity for constant famine relief measures in this region. Results obtained in the project are the subject of a number of training workshops and seminars in which Kenyan and regional scientists from the Sudano-Sahelian region participate.

This report is one of a series published by IPAL describing technical findings of the Project and, where appropriate, giving management recommendations relating to the central problems of ecological degradation in the arid zone. The reports are divided into the following categories distinguished by the base colours of their covers:

A. general, introductory and historical: white

B. climate and hydrology: blue

C. geology, geomophorology and soils: brown

D. vegetation: green

E. livestock and other animal life: red

F. social and anthropological: yellow

Distribution: limited

MAB/CONF.81/2/2
Paris, 15 September 1981
Original: English

UNITED NATIONS
EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

PROGRAMME ON MAN AND THE BIOSPHERE (MAB)

UNESCO/ICSU CONFERENCE-EXHIBIT

ECOLOGY IN PRACTICE
Establishing a scientific basis for land management

Paris, 22-29 September 1981

Theme 2: Scientific basis for the management of grazing and marginal lands

PAPER 2/2

COMBATTING DESERTIFICATION AND REHABILITATING DEGRADED PRODUCTION SYSTEMS IN NORTHERN KENYA

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ABSTRACT

Three quarters of Kenya's land is arid and semi-arid, and supports over one quarter of its population including ten major ethnic groups who are solely nomadic pastoralists. Modern influences on these groups have resulted in the increase in both human and livestock populations and increased sedentarization. Resulting pressure has deteriorated the productivity of the land through over-grazing which, combined with effect of droughts, has led to the need for famine relief. In the last five years the Unesco Integrated Project on Arid Lands has been carrying out research on all components of this ecosystem - Human, Livestock, Vegetation, Geomorphology and Soil, Climate and Hydrology in order to study the processes leading to desertification and to find solutions for restoration of stability and improved productivity. Initial results indicate an urgent need to rehabilitate degraded lands and to improve productivity through reduction in live-stock numbers, redistribution of grazing pressure, water development and appropriate marketing infrastructure. Project results are being integrated into Education and Training.

KEYWORDS

Northern Kenya, desertification, rehabilitation, improved productivity, research, education and training.

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COMBATTING DESERTIFICATION AND REHABILITATING DEGRADED PRODUCTION SYSTEMS IN NORTHERN KENYA

Introduction

"No suitable management programme for a nation's natural resources - soils, waters, forests, rangelands and wildlife - can succeed without public support" (Gilbert, 1964). The philosophy embodied in this statement, which underlines much modern conservation activity, and which is reflected in UNESCO's "Man and the Biosphere" Programme, provides the background and some of the inspiration for this report.

Notwithstanding the relevance of the ecological approach to development planning, a common failing, even in ecologically orientated planners, is the scant attention they normally give to the so-called human factor. The existence of a human population presupposes a complex of ethnic, social and biological influences and interactions. If these are not understood and adequately accommodated in resource management plans, the consequences can be serious, even disastrous. We suggest that the failure of previous attempts to effect appropriate change in pastoral societies, which has been an important factor in the continuing deterioration of arid lands in Africa, has been due, at least partly, to an ignorance among planners of the biological and sociological bases of pastoralism. Little effort has been made to understand the values, the fears and the aspirations of the people we intend to help.

Although ecologists have long recognised the dominant role of man as a cause of change in the biosphere, in practice they have been reluctant to alter the conventional view that man is the last link in the ecological chain and should therefore be considered last. In this account of a study of an arid-zone ecosystem in northern Kenya, we intend to reverse the customary sequence, considering firstly the human populations, as the main focus of the study, and working outwards to consider the human environment. The ecosystem approach remains the guiding principle in the study.

Man can justifiably be regarded as the dominant biotic element in the grazing land ecosystems by virtue of his overwhelming impact upon them, exerted largely through his domestic animals. However, the human-orientated approach is adopted in this account mainly because it reflects the primary objective

of IPAL in seeking practical solutions to a critical human predicament. Expanding pastoral populations, responding to the impact of modern influences, occupy vulnerable habitats in which the production necessary for their support is being progressively reduced by over-exploitation.

The MAB Integrated Project in Arid Lands (IPAL), which has been working in Kenya for five years on a multi-disciplinary programme, has hitherto concentrated its studies mainly upon the interactions between pastoralism and the vegetation, in order to gain an understanding of the more immediate causes of desertification and to provide the information basis for recommendations on rational land use in the arid zone. The Project's objectives and results to date are described in a series of technical reports already published and in preparation (see reference list). In the course of the research, the complexity of the land-use and socio-economic problems underlying the more immediate causes of desertification have become evident.

The measurement and interpretation of most ecological parameters is relatively straightforward. They are generally amenable to systematic observation, analysis and integration and representation by quantitative models. The ecological constraints imposed upon the pastoral economy are broadly calculable in their effects. They include the arid and variable climate; impoverished and eroded soils; low and variable primary production and the limited tolerance to expoitation of arid zone vegetation; densities, distributions, and the consumption, production and offtake levels of livestock populations; and finally the most critical constraints - the sustainable carrying capacity of the grazing lands.

Similarly, the basic human biological requirements of food, fuel, shelter can be assessed. Human populations are censused and their structures and trends can be described. In the case of pastoralist societies, their fundamental resource requirements, met mainly by livestock production and woody vegetation, are calculable. Beyond these essentially measurable resources lies the relatively unquantifiable complex of human attitudes, characteristics and requirements which are not so amenable to inclusion in ecosystem models, but which are, nevertheless, essential considerations in the integrated planning of landuse programme. The Project's additional function of advising the Government of Kenya on the rational management of the arid grazing lands of Marsabit District necessitates an understanding of a wide range of local socio-economic conditions and trends as well as a knowledge of the ecological interactions of the pastoralists with their

environment.

The planned work programme of IPAL in its present (third) phase therefore includes a programme of research on human ecology in its broadest sense. In addition to augmenting the existing knowledge on the more purely ecological aspects of the human populations, it is intended to bring into focus the many socio-economic factors which have a bearing on the process of desertification in northern Kenya. To do this necessitates adopting a frank and uncompromising approach to several unpalatable truths and the discussion of matters which are normally avoided because they embarrass authority. Nevertheless, unless the realities of the socio-economic and the political background are squarely confronted, there appears to be little hope of implementing any land-use policies of significance in the battle against desertification.

The Special Nature of the Desertification Problem in Northern Kenya

Desertification has certain common characteristics wherever it occurs in the world. There is loss of vegetation cover followed by soil degradation through various forms of erosion and compaction. These in turn lead to greatly reduced productivity in the ecosystems concerned. In the case of grazing systems, there is decreased forage for livestock and a consequent reduction in animal products for the subsistence of the human population. Although desertification and its consequences can be attributed simply to the combined effects of climatic change and human impact, it is important to recognise that there are variations in the nature of the human influences from one region to another (as well as environmental differences) which make each local desertification problem unique. Northern Kenya is no exception to this rule.

Three quarters of Kenya's land surface is arid or semi-arid and, across this region several recent socio-economic factors contributing to the processes of desertification have been identified. Through the siting and re-alignment of political and administrative boundaries, the development of forest reserves and national parks, and the establishment of commercial ranches, and through the influence of missions and several other modern institutions, there has been restriction in the movement of nomadic people and a reduction in the area they formerly occupied.

Traditional antagonisms between tribes had caused the compression of some

tribal groups into a fraction of their former ranges until further encroachment was prevented some forty years ago. The antagonisms are still present and the lack of security against inter-tribal livestock raiding and banditry is a further cause of restriction in the movement of people and the occupation of grazing lands. Over 25 percent of the Project's study area is not used owing to fear of tribal raiding and the resulting additional pressure upon the more secure areas aggravates their over-exploitation.

Another distinctive feature of the Kenyan desertification problem is the special nature of the pastoral economy. Although the people inhabiting northern Kenya have many similarities to other pastoralists living in the Sahelian Zone, in Kenya, arid zone agriculture has never been practised and thus there is little of the close interaction and interdependence between agriculturalists and pastoralists which is an important feature of the Sahel.

The problem of accelerated human population growth in arid areas is perhaps not unique to Kenya but it is certainly one of the key factors in the desertification processes in the north of that country. Kenya's arid land human population has doubled in the last twenty five years and will, if present trends continue, double again in the next ten years. The human population pressure is further aggravated by pressure from Kenya's high potential areas where population has exceeded its carrying capacity and there is movement to the marginal lands. With the alarming increase in the human population there has come a corresponding increase in the numbers of domestic livestock.

A prominent factor in the deterioration of the arid lands of northern Kenya through overstocking, is the drive to satisfy normal ambition for wealth (over and above subsistence needs), combined with a certain helplessness or fatalism about the consequences. In earlier times, when human requirements demanded only a moderate and transitory exploitation of grazing land, it was possible for minor and localised damage to heal. More recently the pressing, and at times desperate, needs of an over-grown and frequently hungry human population have imposed intolerable pressures upon the arid lands which, with their delicate balances and fluctuations, are experiencing firstly the erosion of their productive levels and then the disintegration of their ecological structures.

As a result of the rising human populations there are increased demands upon the woody vegetation. In addition to the usual wood requirements for building and for fuel, the pastoralist people in northern Kenya use large quantities

in contructing night enclosures (bomas) to keep their animals together at night and to prevent depredations by carnivores. These bomas are built at permanent and temporary camps. In the latter situation they may be occupied for as short a time as a week before the livestock are moved to a new area and a new boma is constructed. In the semi-permanent settlements, an accumulation of ticks and other parasites, usually necessitates the burning of the boma periodically and the movement to a site that may be as little as one hundred meters away. It is this practice that appears to have the greatest impact upon the woodlands of northen Kenya and is one of the most serious causes of desert encroachment in the region. In addition to the changing constraints upon pastoralism noted earlier, e.g. reduced home ranges, another important trend of far-reaching consequences for land use is that of the increasing sedentarization of formerly nomadic people.

Centers of human and livestock concentration have arisen and recently have tended to expand rapidly, around a few springs and wells and especially around the boreholes which have been installed. While the presence of fresh water is the most important factor in such concentrations, several other incentives contribute to their expansion. Many of them have become the sites for shops, schools, medical centers and famine relief centers. However, of the greatest significance is the fact that these centers offer security from intertribal livestock raiding. Each of the concentration areas becomes a nucleus of denuded land which spreads in widening circles as the people are obliged to go farther for grazing and for the wood they need for fuel and for the fences for their livestock night exclosures. This accelerates the rate of localized desertification. As in many other arid regions of the world, the northern part of Kenya suffers from periodic droughts which have occurred frequently in recent historical times. Formerly these droughts were not as serious in their consequences as they are today since the populations in the arid regions were sparse. With the recent increases in population, droughts have become more serious, claiming the lives of large numbers of livestock and, where they shared the grazing lands, wildlife as well. After periods of drought the production systems do not recover fully. Some families lose the bulk of their herds, which may have been small in the first place, and many become destitute and reliant upon famine relief. The supply of famine relief food has become a permanent feature of the economy in Marsabit District. During serious droughts, such as that which occurred in north eastern Africa and the Sahel between 1968 and 1976, pastoralists become wholly dependent upon the few perennial water supplies and the destructive effects upon the vegetation of the consequent concentrations of people and livestock are most marked.

Although it is a normal traditional practice to disperse from such concentration areas when the rains come, there is an increased tendency for part of the population, especially women, children and the older men to remain behind, keeping with them the livestock they need for milk. The young men continue to take away into the surrounding country, the unproductive animals (known as the fora herds) males, castrates and barren females, following largely traditional nomadic practices.

The problem of desertification in Kenya is therefore serious and complex. It concerns the plight of people who are using the only traditional means they have known to cope with a vast problem that has been caused to a great extent by modern influences. As yet, although the problem of desertification in northern Kenya is recognized by the government and is expected to receive considerable attention in the course of development programmes in the coming years, a number of administrative and economic constraints have, until recently, militated against appropriate corrective measures. Among the most important have been the lack of funds available for the development of "Low potential" areas, the insufficiency of suitable educational facilities, the migration of educated people out of the more remote and inhospitable regions to the towns, the lack of attraction of such regions for high calibre civil and above all, the lack of information on human and other resources that is essential for the rational development of the region.

Since the lives of people are at stake, no efforts should be spared to develop the resources of the arid lands of northern Kenya for the well being of its people. However, development must take the form most suited to the sociological, economic and ecological circumtances to which the region is best adapted. In northern Kenya, owing to the arid and variable climate and the present culture, the greater part of the land must remain rangeland to be utilised through grazing and effective utilisation will depend upon maintaining considerable mobility in the livestock herds.

OBJECTIVES OF THE IPAL STUDY

The Integrated Project in Arid Lands (IPAL) was established in 1976 in recognition of the importance of the arid lands of Kenya both for the support of their indigenous people and in the economy of the country as a whole, and because these lands were gravely threatened by desertification through misuse. The Project was originally set up as a pilot operation to initiate investigations into the processes of environmental degradation in the arid and semi-arid region inhabited by pastoral nomads and the causes of these processes.

An important focus of the IPAL research has been to predict the ecological and socio-economic consequences for the pastoralists of continuing degradation.

In the light of its findings, IPAL is intended to contribute to the design of management activities directed towards achieving a sustained balance between production and consumption, taking into account the requirements of the growing and increasingly settled population. It is hoped where possible to demonstrate practical modifications and alternative to the traditional live-stock - based economy which could permit rehabilitation of already degraded lands. Equally important in this regard will be the use of project findings in education and training for dissemination of information on rational management.

Since most of the changes and processes being investigated continuous monitoring, one of the projects objectives is to provide the programme basis for the establishment of an institution in Marsabit District for continued research, monitoring and training relevant to the management of resources in the arid zone. The Project will develop and recommend the infrastructural basis for the required management.

THE STUDY AREA

The IPAL Study area (Figures 1 and 2), which covers approximately 22,500 sq.km. is sufficiently large and covers the major biotic communities found in the area where all processes being observed can be investigated. It lies between 1° 50' and 3° 30'N and 36° 10' and 38° 00'E. On the west it is bounded by Mt. Kulal, a major water catchment area, and to the east by Mt. Marsabit. The study area partly covers the homes of the Rendille, Gabra, Boran and Samburu who are the major nomadic tribes in this area. With varying degrees of facility within this area, the Project is able to study the problems of arid land deterioration and the combination of causative factors: climatic fluctuation, the activities and attributes of the pastoralist societies and of their cattle, camel sheep and goat herds, including such important aspects as human population increase and the practice and effects of boma construction.

The greater part of the study area consists of a large central plain at less than 700 m above sea level. The northern part of this plain is surrounded by volcanic mountain masses; the Huri Hills (1,301 m) to the north; Mt. Marsabit (1,836 m) to the east, and Mt. Kulal (2,295 m) to the west. In the south and south west, the area is bounded by the basement complex

Figure 1

Location of IPAL Study Area

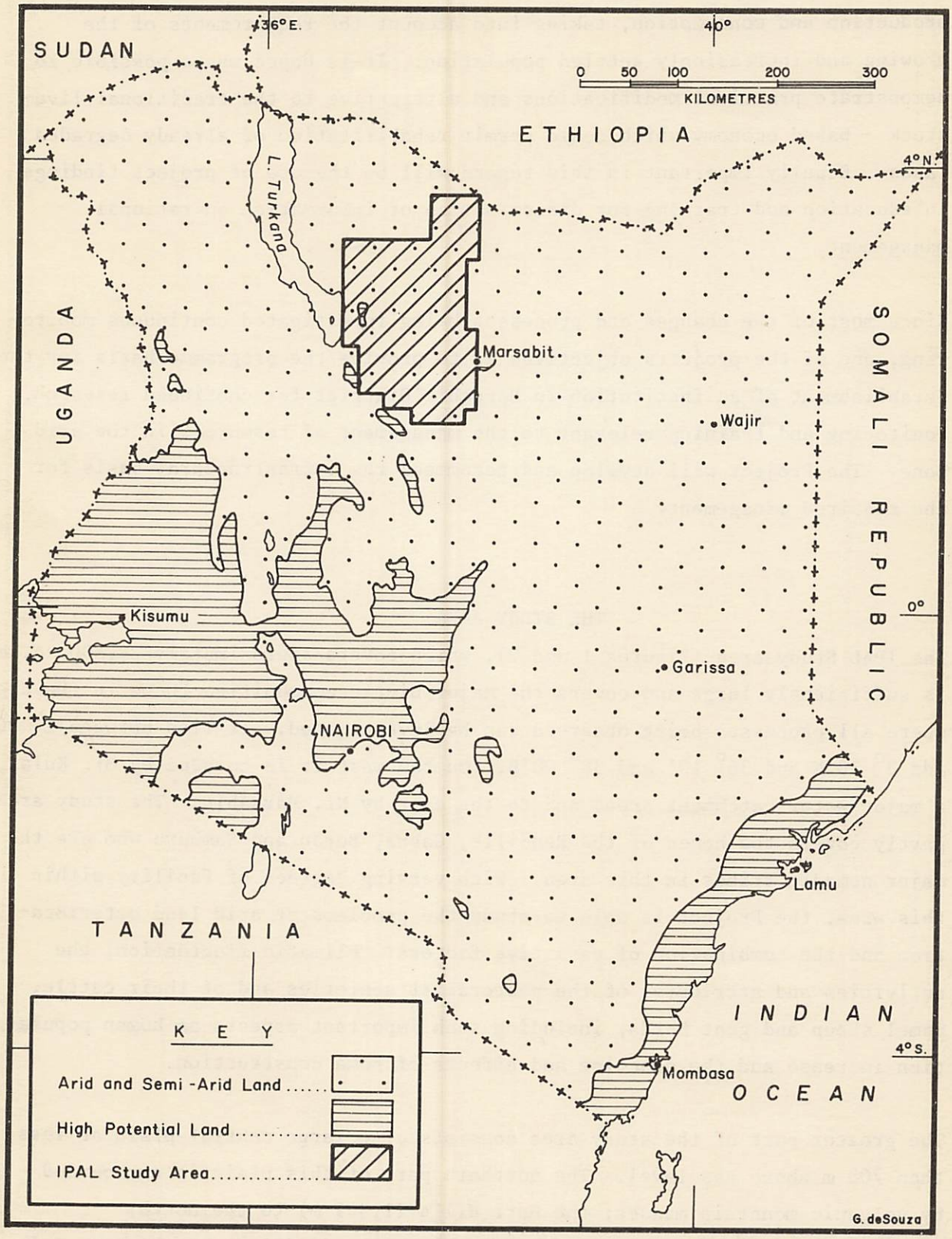
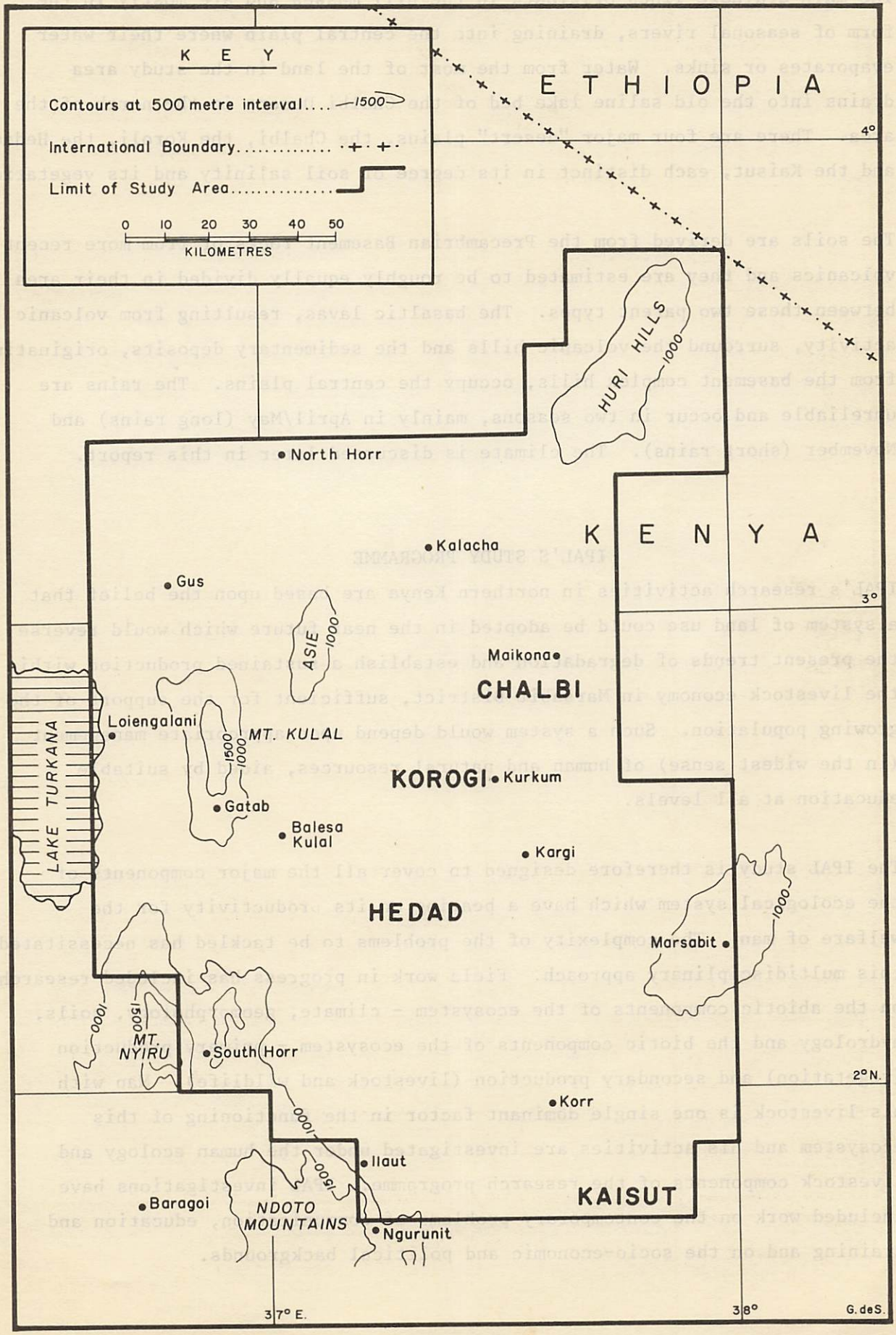


Figure 2

The Study Area



mountains, Mt. Nyiru (2,963 m), Oldoinyo Mara (2,224 m), the Ndoto Mts. (2,838 m) and Baio Mt. (1,885 m). To the west of Mt. Kulal lies Lake Turkana.

The main drainage lines originate in the hill masses and are mostly in the form of seasonal rivers, draining into the central plain where their water evaporates or sinks. Water from the most of the land in the study area drains into the old saline lake bed of the Chalbi Desert in the north of the area. There are four major "desert" plains, the Chalbi, the Koroli, the Hedad and the Kaisut, each distinct in its degree of soil salinity and its vegetation.

The soils are derived from the Precambrian Basement rocks or from more recent volcanics and they are estimated to be roughly equally divided in their area between these two parent types. The basaltic lavas, resulting from volcanic activity, surround the volcanic hills and the sedimentary deposits, originating from the basement complex hills, occupy the central plains. The rains are unreliable and occur in two seasons, mainly in April/May (long rains) and November (short rains). The climate is discussed later in this report.

IPAL'S STUDY PROGRAMME

IPAL's research activities in northern Kenya are based upon the belief that a system of land use could be adopted in the near future which would reverse the present trends of degradation and establish a sustained production within the livestock economy in Marsabit District, sufficient for the support of the growing population. Such a system would depend upon appropriate management (in the widest sense) of human and natural resources, aided by suitable education at all levels.

The IPAL study is therefore designed to cover all the major components of the ecological system which have a bearing on its productivity for the welfare of man. The complexity of the problems to be tackled has necessitated this multidisciplinary approach. Field work in progress has included research on the abiotic components of the ecosystem - climate, geomorphology, soils, hydrology and the biotic components of the ecosystem - primary production (vegetation) and secondary production (livestock and wildlife). Man with his livestock is one single dominant factor in the functioning of this ecosystem and his activities are investigated under the human ecology and livestock components of the research programme. IPAL investigations have included work on the contemporary problems of communication, education and training and on the socio-economic and political backgrounds.

It is now proposed to discuss in a little more detail work going on within each specific component to describe the preliminary technical findings of the Project within each component and, where appropriate, suggest in a preliminary way some management recommendations relating to the central problems of ecological degradation in the arid zone. It must be emphasized here that most of the studies being discussed are ongoing and in some of them, results are obtained slowly. However, because of the added responsibility of the Project to advise the Kenya Government on ongoing programmes of land management in the area, it is necessary to publish from time to time initial results which can be updated as new findings come in from ongoing studies. Where certain activities have not yet produced, or reported, results, these are described here in order to indicate their place in the whole integrated study programme being carried out by IPAL.

HUMAN ECOLOGY

Background

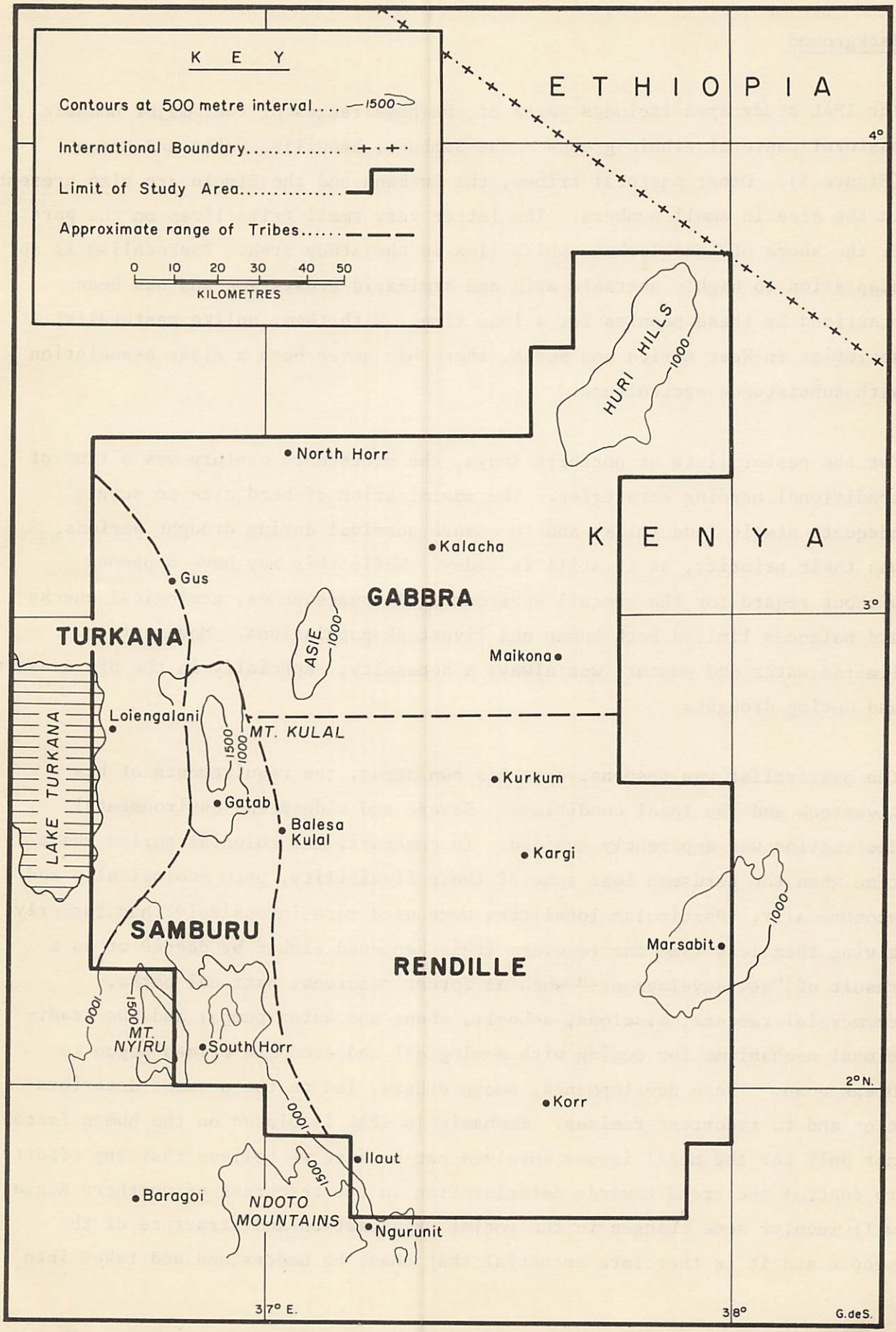
The IPAL study area includes parts of the home ranges of four major nomadic pastoral pastoral ethnic groups - the Samburu, Rendille, Gabra and Boran (Figure 3). Other pastoral tribes, the Turkana and the Elmolo are also present in the area in small numbers. The latter very small tribe lives on the part of the shore of Lake Turkana which lies in the study area. Pastoralism is an adaptation to highly unstable arid and semi-arid ecosystems and has been practised by these peoples for a long time. With them, unlike pastoralist societies in West Africa and Sudan, there has never been a close association with subsistence agriculture.

For the pastoralists of northern Kenya, the nineteenth century was a time of traditional herding strategies. The maximization of herd size to supply adequate staple food (milk) and to ensure survival during drought periods, was their priority, as it still is today. While this may have happened without regard for the overall environmental consequences, ecological checks and balances limited both human and livestock populations. Movement to limited water and pasture was always a necessity, especially in the dry seasons and during droughts.

The pastoralist was responsive to his own needs, the requirements of his livestock and the local conditions. Severe and widespread environmental destruction was apparently avoided. In contrast, the colonial period was a time when the herdsmen lost some of their flexibility, both ecologically and economically. Particular localities were used more intensively than formerly, giving them less time for recovery (this happened either by decree or as a result of "new developments" such as forest reserves, national parks, commercial ranches, missions, schools, shops and water pumps) and the traditional mechanisms for coping with ecological and economic crises began to break down. These developments, among others, led to the present deterioration and to recurrent famines. Emphasis in IPAL is placed on the human factor not only for the moral issues involved but because we believe that any efforts to control the trend towards deterioration in the resources of northern Kenya will involve some changes in the social organization and structure of the people and it is therefore essential that these be understood and taken into

Figure 3

People of the IPAL Study Area



account if any proposals for new approaches to resource management are to succeed.

The human ecology programme of IPAL seeks to ascertain the structure, social and economic organization and the dynamics of human populations within the study area and in the national context, in order to understand better the actual and potential land use problems in the study area itself and throughout northern Kenya. This programme also seeks to determine the distribution of the human populations within the area under investigation and, in co-operation with the other components of the study, relate these to essential resources - water, fodder, fuel, building material and livestock. Equally important in this regard is to ascertain the perceptions of the people concerned with regard to their needs, land use problems, natural environment and aspirations for the future. In conjuction with the synthesis of the results of the other IPAL component studies, land management guidelines will be prepared for improving the economic conditions of pastoralists and the long-term conservation of their pastoral habits. This will involve the study of the effects of sedentarization and other significant departures from traditional patterns of pastoral practice and will include an investigation into their present health status in the light of changing dietary habits. The human ecology studies will include historical enquiry, since without historical facts as a background for the present ecological setting, there is a risk of making serious mistakes in both research and management because the factors determining the prevailing situation are not understood.

The full human ecology study has just been launched and there will be a short period before we get detailed results from these studies. We have presented here some preliminary observations on the people of the study area. Since pastoralism, as a socio-economic mode, is common to all the pastoral peoples in the study area, we shall begin by considering its major premises and later see how the various ethnic groups in the study area have reacted to various changes and influences. The aim of IPAL must not be to change these peoples for the sake of change but rather to attempt to improve their pastoral economy for their own benefit.

Pastoralism

Within a broad belt beginning in the east from the Horn of Africa, covering both southern Ethiopia and northern Kenya, and continuing westward into the southern portion of the Sudan and eastern Uganda, the majority of societies have an emotional and economic commitment to herding. The socio-economic strategy of pastoralism relies on livestock to transform the energy stored in the grasses, herbage and shrubs of the local area into a form easily available to the local population, i.e. as milk, blood and meat products. Livestock, especially large stock such as cattle, camels and in some cases horses, is property which represents wealth, social status and by extension influence. The major focus of aspiration in this area is the acquisition of stock.

Livestock provides a basis for subsistence and is the essential factor in establishing and maintaining nearly all social relationships. It is essential to an understanding of pastoralism as practised in the Lake Turkana basin that these two aspects be distinguished. The loss of livestock must be seen as a social and an economic disaster. Notions of poverty relate not to the ability to survive physically, but to insufficient herds to live as a herdsman.

Stock breeding provides the pastoralist with staple food. Ideally he lives off the replenishable products of his herds rather than slaughtered beasts. Slaughtering for meat, unless for a special ritual occasion, generally occurs only when other forms of food are in short supply. Thus, it is in the dry season that small stock and cattle are regularly slaughtered and cattle bled. Ritual occasions, which invariably include the slaughtering of animals for meat-feasts, take place conspicuously more often in the dry season.

A side effect of ritual slaughter occurring most often in the dry season is to reduce the animal population when grazing and water are at a premium. Another device for the long-term conservation of herds is the exemption of female animals from slaughter, trade or exchange. Among camel herders as well, the ox-camel is the primary sacrificial beast.

In all these societies, social relationships and social values are focused on rights and obligations expressed in terms of cattle and/or camels to the virtual exclusion of small stock. Despite their important economic role, i.e., their hardiness in converting less edible vegetation into human food, small stock are seldom the subject of rivalry or dispute, and never the principal object of exchange in bridewealth negotiations. In the sphere of social relations their greatest use is in everyday expressions of friendship, exchanges which often serve to keep lines of communication open and active.

Stock serves a second crucial role as the means of maintaining and forming social linkage; 'pathways of stock exchange are usually analogous to pathways of social interactions'.

Every individual is the centre of a unique cluster of personal relationships entirely different from that of every other man. Birth establishes the agnatic members of his cluster, his marriage expands it to a particular group of affines and throughout his life the deliberate creation of bond friendships expands the network. Since all rights are reciprocal, an individual without stock becomes isolated from potential pathways of co-operation and insurance in times of hardship and must therefore survive outside the pastoral economy.

The elementary production unit, the family, is subject to an irregular food supply which corresponds to the unpredictable vegetation upon which its herds feed. The fact of the economic reverses which threaten the family's stability, and that of the society as a whole, results in the broad sharing of personnel and production property between domestic groups. Loans of labour in the form of unmarried sons to assist in herding, the dispersing of herds or certain beasts to other herdsmen to create viable herds or promote better management and the gift or loan of animals in times of need, be it economic or ritual, are all aspects of such sharing. Agnates are a source for such assistance.

Additional pathways of stock exchange and social relations centre around marriage. Bridewealth is paid by all pastoralists in varying, amounts of cattle or camels. Among the Samburu and Rendille the large stock received by the bride-givers number eight cattle and eight camels respectively. The transfer of bridewealth gives access to an entirely new range of individual within the wife's kinship group to whom the husband-herdsman can turn for

the sharing of herding labour, the loan of beasts to provide feasts or for ritual slaughter, and for sharing in times of famine, disease or other hard times. Polygamy is a preference among all pastoralists of the area although it is a practical proposition only among the cattle herders.

Bond friendships are exceptionally valuable for expanding an individual's lines of social and economic co-operation. They are deliberately selected to fill the gaps in a herdsman's range of relationships which are not filled through ties of kinship or marriage.

The gerontocratic authority of age-set systems covers the same region of east Africa in which the socio-economic strategy of pastoralism dominates. Named age-sets are corporate groups of men which are organized by generation or cycle and are initiated together. The corporate group having the grade of elder is the immediate source of political authority, and the age-set system is the main field in which it is exercised. The status of elder comprises the role of control in all significant family and settlement of affairs, e.g. the leading of ritual, the adjudicating of disputes, the negotiating of bridewealth, etc. The egalitarian nature of the societies puts each individual, in either the hub of his own unique social network or about the rim of many other net-works, in a position to manipulate as well as to be manipulated in socio-economic situations. The effect is that decision and direction come from the elders as a corporate group in the form of public consensus, and never as the directive of a simple individual.

The basic differences between the societies of the Lake Turkana basin are found in their individualized pattern of economic activity, dependent on the localized character of the environment they occupy and the different types of livestock they herd. Each society is capable of dealing with environmental fluctuations around the mean conditions under which it survives. It does so by adjusting its movement, shifting its emphasis to particular animal types and/or increasing the supplemental products of non-pastoral activities. Extreme events or ecological crises can be devastating. The intensity of the crises can be seen as the degree of deviation away from the mean conditions of survival. If the imbalance is too great to stabilize within the pastoralist framework, survival necessitates the adoption, either as an individual or within small groups, of another mode of economic existence with new mean conditions.

Within the environmental framework, prologed drought, the failure of seasonal vegetation, the presence of trypanosomiasis, anthrax, rinderpest, or other diseases of animals, smallpox, whooping cough or other disease of the human population, the hostility or neighbouring societies, etc., result in imbalances which must be stabilized. For example, under even 'normal' conditions herdsmen experience seasonal drought, i.e., dry seasons with limited pasturage. To adjust to this imbalance, herds are shifted to locations where adequate vegetation is available.

Should there not be sufficient rains to create a wet season, the result is the continuation of the dry season progression. The number of water points continues to diminish and the vegetation cover supports less and less livestock. The traditional adaptation for this kind of occurrence is to overstock when drought does not exist, thus ensuring that some animals survive from which whole herds can again be built. The concomitant effects of increased herds on existing pasturage lands are clear. Should stock growth continue unchecked, the need for increased grazing could lead to a number of stabilizing effects, including among others, long-distance moves to rarely used pasture or hostilities with neighbouring societies to gain use of new pastures (other dimensions of this type of problem might include concomitant human population growth, etc.). Either of these measures could result in herd losses, the former due to limited personal knowledge of the new area, the latter from reprisal raids.

The environmental effect is to allow the partial recovery of overutilized pasturage in preparation for renewed expansion following the return of normal conditions. Should the demand on the society's adaptive strategy prove too great to be met through adjustments within the pastoral strategy, fishing, hunting-gathering and agriculture may provide alternative adaptations for survival. This adjustment must however be viewed as a dynamic one, which allows a group to move from point to point along the continuum as conditions change.

Non-herding forms of subsistence practised in the region, cultivation and gathering, and to some extent hunting and fishing, are directly dependent on ecological conditions which occur seasonally. As a means of subsistence these alternative economic activities are limited for all but some small groups of people.

The limited technological level, coupled with unstable seasons which can vary drastically from year to year, make them generally unreliable as more than supplementary activities.

Agricultural products are the most significant dietary supplement of herdsmen. Some societies, such as the Boran, live in an area favourable to cultivation. More common is the trading of pastoral products, e.g. skins, fat, animals, for agricultural products as well as for craft requirements, e.g. pots, utensils, and spears.

Sporadic gathering is done even by the wealthiest herding families, especially the collection of fruits and berries by children and young girls who like their sweet taste. More substantial foods such as roots are usually only collected by herdsmen in times of hardship. Honey, which is eagerly sought after, is the virtual monopoly of the hunting-gathering groups and herdsmen must trade for it.

Wild animals exist in large numbers in certain localities and were probably more numerious in the past, yet little is known about the significance of hunting in the diet of the pastoralists. The products of wild animals, from ostrich feathers to giraffe-hide water containers, have served important functions throughout the region. It seems exceedingly likely that wild animals were hunted in times of prosperity as well as times of economic crises. Also fish, despite its professed avoidance and association with the poorest economic and social status, is caught and eaten as an alternative means of subsistence. In the Lake Turkana region communities of hunter-gatherers and fishermen have provided alternatives to pastoralism in times of extreme imbalance in the environment. The term 'ndorobo', applied to these communities, is here used as an economic mode and not as an ethnic referrent.

Human Populations and Activities in the IPAL Study Area

The human populations of the four ethnic groups found in the study area - Gabra, Boran, Samburu and Rendille have reacted in various ways to the influences and changes that have occurred to their environment. Some of these

reactions have been positive and some have been negative but common to all, there has been an reduction in their home ranges (Figure 3), their population has increased, their livestock populations have increased and they have had to make various adjustments in their way of life.

TABLE 1

Habitat and Livestock of tribes in IPAL study area
(Kruuk, 1980)

Tribe	Most common habitat in IPAL study area (Herlocker, 1979)	Livestock kept		
		Sheep and Goats	Cattle	Camels
Samburu	Mountainous woodland and bushland	++	++	-
Rendille	Bushland and dwarf-shrub; annual grassland	++	++	++
Gabra	Annual grassland dwarf-shrub barren land	++	+	++
Turkana	Annual grassland barren land, dwarf-shrubs	++	+	+

(++ = many, + = some, - = absent)

The Gabra

The Gabra are a Galla people speaking the same Eastern Cushitic language as the Boran and Sekuye. Although their present occupational area (Figure 4) varies in response to grazing, water and relations with surrounding people, they live generally around the Chalbi desert extending to Lake Turkana in the West, the Magedo escarpment in Ethiopia in the north and the Bula Dera plain to the east of the Marsabit - Moyale road.

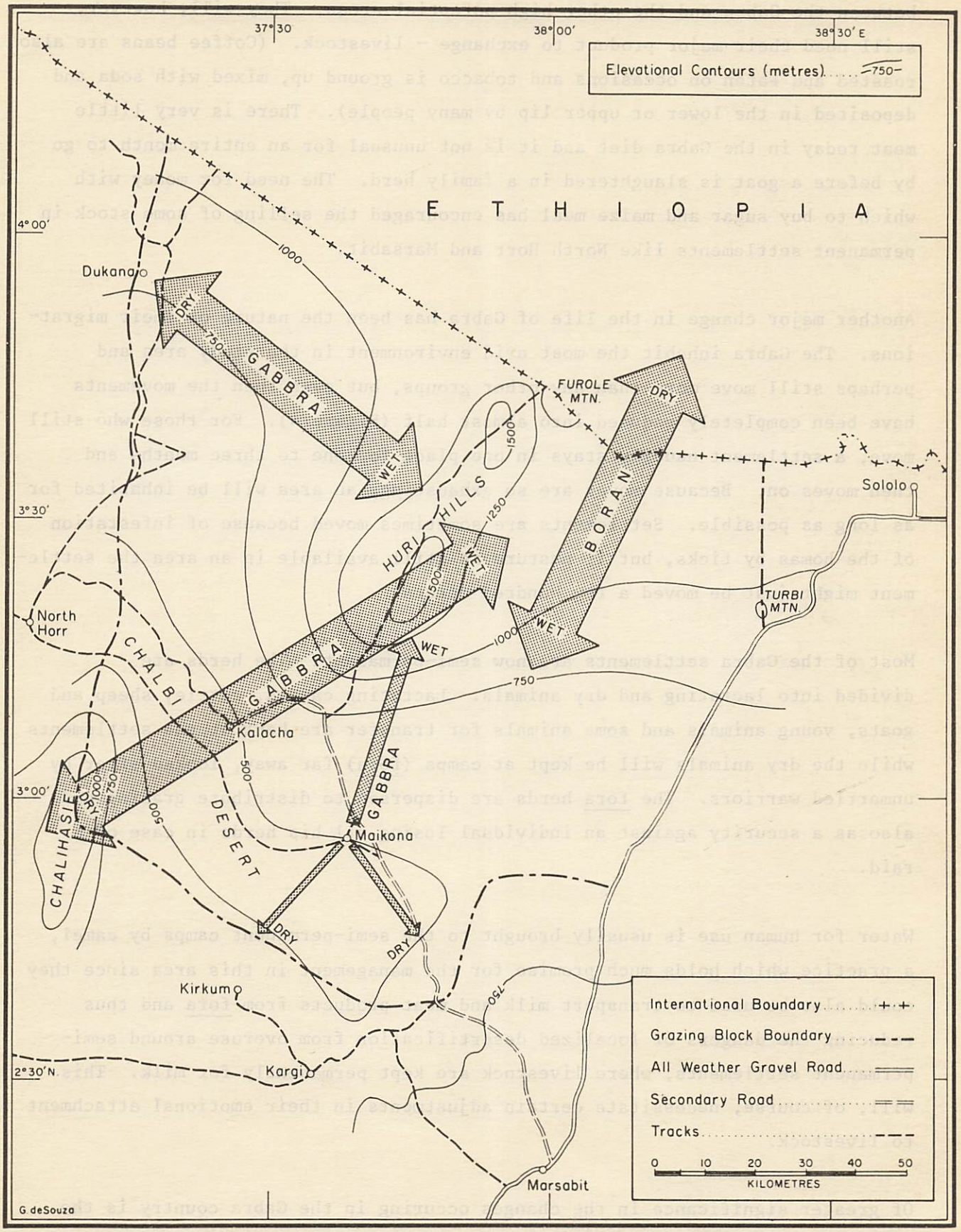
Although the Gabra had earlier migrated between Kenya and Ethiopia in search for pasture, the present Kenya Gabra population became resident at the beginning of the century when they came to Kenya as refugees fleeing from Menelik's army in Ethiopia which had intended to divide them among the soldiers as labourers. Resulting insecurity on the Ethiopian frontier led to their being moved South into the Huri Hills areas away from the border. In order to avoid tribal clashes between them and the Turkana to the East and Rendille to the South, who saw them as intruders, they were further confined by administrative boundaries. Today the Gabra administratively occupy about one quarter of their former range, with four administrative locations, and one chief. This confinement has had for reaching effects on how they use their territory. Most areas are having to be used for much longer than they should be.

Population. Like other communities in the area, the Gabra population since the turn of the century has shown marked fluctuations which has resulted from epidemics and droughts. Since 1949 largely because of the control of epidemics, better health facilities and famine relief, there has been a steady increase in population, now estimated at 15 - 20,000 compared to 5,000 in 1949. This population increase has been more than the traditional pastoral economy can support and it therefore necessitated major adjustments in their way of life. Even then, they have not been able to cope with their difficulties and famine relief that has become a way of life since 1969.

Present mode of pastoralism. A major departure from the subsistence pastoralism which was earlier practiced by the Gabra, has been the introduction of grain in their diet. From a pure dependence on milk, milk products and meat, maize meal and tea are a regular feature of their diet now. Although this is a change forced on to them by famine relief supplies of grain, it is probably a blessing because pure pastoralism could not support the population under the changed circumstances. This adjustment must be looked upon as a welcome

Figure 4

MIGRATION PATTERNS OF THE GABBRA



change since it opens up several possibilities for alternative resource management strategies that would encourage the flow of goods and services between the Gabra and the other high potential areas. They will, however, still need their major product to exchange - livestock. (Coffee beans are also roasted and eaten on occasions and tobacco is ground up, mixed with soda and deposited in the lower or upper lip by many people). There is very little meat today in the Gabra diet and it is not unusual for an entire month to go by before a goat is slaughtered in a family herd. The need for money with which to buy sugar and maize meal has encouraged the selling of some stock in permanent settlements like North Horr and Marsabit.

Another major change in the life of Gabra has been the nature of their migrations. The Gabra inhabit the most arid environment in the study area and perhaps still move more than any other groups, but even then the movements have been completely reduced into almost half (Figure 4). For those who still move, a settlement usually stays in one place for one to three months and then moves on. Because moves are so exhausting, an area will be inhabited for as long as possible. Settlements are sometimes moved because of infestation of the bomas by ticks, but if pasture is still available in an area the settlement might just be moved a few hundred meters.

Most of the Gabra settlements are now semi-permanent. The herds are divided into lactating and dry animals. Lactating camels, cattle, sheep and goats, young animals and some animals for transfer are kept at the settlements while the dry animals will be kept at camps (fora) far away, looked after by unmarried warriors. The fora herds are dispersed to distribute grazing and also as a security against an individual losing all his herds in case of a raid.

Water for human use is usually brought to the semi-permanent camps by camel, a practice which holds much promise for the management in this area since they could also be used to transport milk and meat products from fora and thus reducing the dangers of localized desertification from overuse around semi-permanent settlements, where livestock are kept permanently for milk. This will, of course, necessitate certain adjustments in their emotional attachment to livestock.

Of greater significance in the changes occuring in the Gabra country is the permanent settlements which have grown up in the area due to administration -

chiefs and Police centers, missions, schools and shopping centers. There are several such centre in Gabra country at north Horr, Kalacha, Maikona; Dukana and Illeret. Apart from people moving into these centres for security, they are concentrations of people who for the most part have lost their livestock and have to depend at these centres on famine relief.

Livestock. The Gabra are mainly camel keepers but have also cattle and small stock.

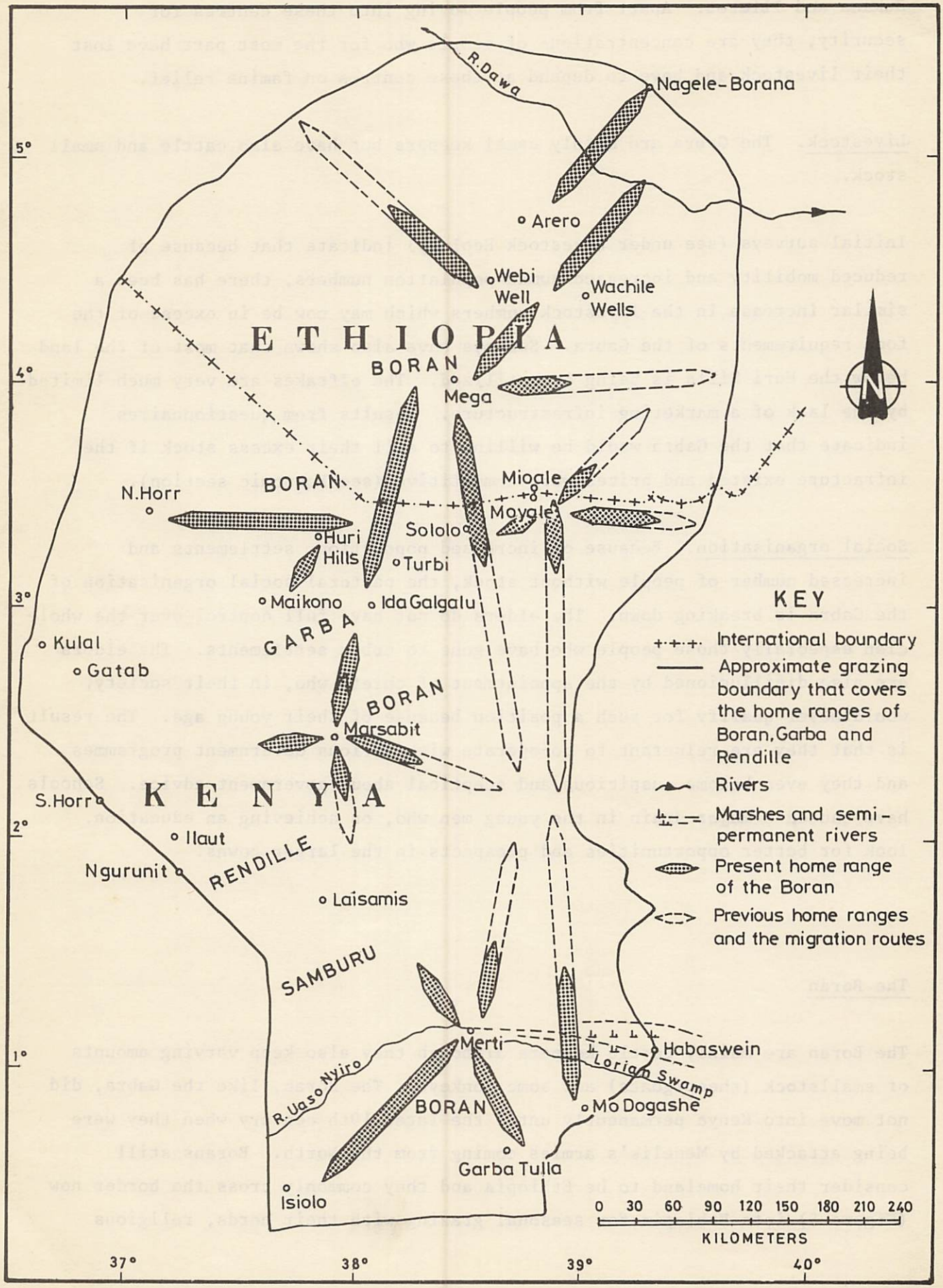
Initial surveys (see under Livestock Ecology) indicate that because of reduced mobility and increased human population numbers, there has been a similar increase in the livestock numbers which may now be in excess of the food requirements of the Gabra. Surveys have also shown that most of the land below the Huri Hills is being overutilized. The offtakes are very much limited by the lack of a marketing infrastructure. Results from questionnaires indicate that the Gabra would be willing to sell their excess stock if the infracture existed and prices were competitive (see Economic section).

Social organisation. Because of increased population, settlements and increased number of people without stock, the pastoral social organisation of the Gabra is breaking down. The elders do not have full control over the whole clan especially those people who have gone to urban settlements. The elders are also disillusioned by the appointment of chiefs who, in their society, would never qualify for such a position because of their young age. The result is that they are reluctant to co-operate with various Government programmes and they even become suspicious and sceptical about government advice. Schools have caused a major drain in the young men who, on achieving an education, look for better opportunities and prospects in the larger towns.

The Boran

The Boran are mainly cattle keepers although they also keep varying amounts of smallstock (sheep/goats) and some donkeys. The Boran, like the Gabra, did not move into Kenya permanently until the later 19th century when they were being attacked by Menelik's armies coming from the North. Borans still consider their homeland to be Ethiopia and they commonly cross the border now (Figure 5) into Ethiopia for seasonal grazing with their herds, religious

Figure 5 MIGRATION PATTERNS OF THE BORAN
PAST AND PRESENT



pilgrimages to sacred spots and for social visits to friends and relatives, but they are well established now in Kenya with a recognized core of territory of their own.

Earlier migrations of the Boran took them many kilometers south of Marsabit Mountain but after they sought permanent refuge in the present Kenya, they were settled around Marsabit Mountain and in the area between the Huri Hills and Sololo. Like the Gabra, during the years of Menelik's soldiers, they were relatively confined in their normal migrations which forced many of them to settle. They are now the only pastoral group in the study area which has been able to adopt agriculture on Marsabit Mountain and the Sololo area.

The rest of the Boran populations are semi-nomadic in that - except for a small group close to the Huri Hills, they do not move as whole families any more. As observed among the Gabra, they have resident groups while the warriors with the dry livestock wander in search of grazing. Being largely sedentary, especially on Marsabit Mountain, the Boran have successfully adopted other occupations like Business and Trading.

The Boran population in Marsabit District doubled in the last forty years from an estimated 1,500 in 1949 to an estimated 3,739 in 1960. The Boran now take a large proportion of grain in their diet - mainly maize meal - and they utilize sugar for tea and also consume various amounts of tobacco.

Like the other groups in the area, their land ownership system, except in agricultural areas on Marsabit Mountain and Sololo, is communal. The Boran being cattle keepers have occupied mainly high country which is better watered than the camel-keeping Gabra and Rendille but because of their increased settlement trends large tracts of their land around settlements is being overgrazed and eroded and famine relief is a permanent feature. They have perhaps the largest numbers of people wandering into the towns to seek alternative means of living due to the deterioration of their environment. Boran are subject to constant raids from Somalis in the east and large tracts of their land to the east of Soldo is unused.

Although the Boran seem to be the group showing the most notable departures from traditional pastoralism in the study area most of the changes were forced on them since, as refugees, they had few alternatives. A notable feature of their way of life however is the continued dependence on their cattle and

livestock both socially and economically. Their whole social system revolves around cattle and even the settled Boran in places like Marsabit usually keep large numbers of stock on the plains.

The Rendille

The Rendille utilize the largest part of the study area (Figure 3) and unlike the Boran, they are pure pastoralists dependent on the camel for their livelihood.

Like other groups in the study area the Rendille have been subject to various pressures on their territory. They were pushed southwards by the migrations of the Gabra and Boran, while Turkana expansion exerted pressure from the east and to the west were the Somalis and other Boran. The Masai, before the annexation of their territory, exerted pressure from the south. It is now estimated that the Rendille in total occupy only 8,000 sq. km. of a former home range of 57,6000 sq. km. (Schwartz, Dolan, 1981). Of their present range, over 40% is not utilized due to poor security and the fear of raids from neighbouring Turkana and Samburu.

From the 1979 census, the Rendille now number approximately 13,000 which means they have doubled in the last 40 years.

The Rendille have stuck to their normal pastoral practices although their flexibility and movement have been greatly reduced due to the shrinkage in their territory and establishment or rigid administrative boundaries. There are two major Rendille settlement centres in the study area - Korr and Kargi, which have come about as a result of the presence of permanent water. Although Rendille country is largely degraded due to overgrazing by livestock, these two settlements demonstrate some of the worst cases of localized desertification in the study area. Rendille country has never recovered completely from the effects of the 1969-73 drought as many of the people have been on famine relief since that time. This has been partly responsible for the present increase of grain in the Rendille diet - mainly maize meal. Sugar and tobacco are also being increasingly used as a component of the present diet. The emotional attachment of the Rendille to the camel makes it very difficult for them to sell and partly explains the present rate of overstocking. Other pressures are due to the increased population.

The traditional structure among the Rendille is still very rigid and the presently appointed young administrative chief wields little authority in terms of traditional practices. The society is still largely ruled by the decisions of the elders.

The Samburu

The Samburu like the Boran, are cattle keepers and occupy the mountain ranges in the south west part of the study area (Figure 3). Having bordered the Masai in the south in the past, most of Samburu country which was well watered was taken over for commercial ranching, forcing them into their wet season grazing area to the north permanently. They were subject to pressure from the Turkana in the east who pushed them into the mountains to the west of Turkana, while the migration of the Gabra and Boran southwards from Ethiopia took their northern territory. They now occupy only about one third of their former territory.

Samburu people now have their own district although the populations in Marsabit District (Figure 3) have shown considerable general increase. From an approximate number of 322 in 1927 they now are estimated at over 1,200 in Marsabit District. Samburu are still largely nomadic and the build up in both human and livestock numbers, coupled with the reduction in their home range, has led to some of the worst cases of soil erosion in their country. Large areas are devastated almost beyond any hope of recovery. Famine and famine relief have become almost permanent features in Samburu country. They now utilize increasing amounts of grain (maize meal) in their diet and, like their neighbours, they have also taken to tea with sugar and tobacco.

A Historical Perspective

As observed in the foregoing accounts, most of the far reaching influences of the life of the pastoral people in northern Kenya have not been resulted from weather fluctuations but rather from modern human external pressures and developments. These have included the restriction of land use due to imposed political boundaries and development policies. Better watered land, once part of seasonal pasturage, has been denied to pastoralists in order to increase agricultural

production for foreign exchange earnings and to feed increasing populations; and other land has been alienated for purposes of tourism, industry or urban expansion, thus restricting the pastoralists to marginal environments which are more susceptible to degradation.

From the earliest administrative records onwards it is clear that the colonial government made itself a major factor in the individual herdsman's decision-making process (at times actually taking the decision-making function from him) as to where he took his livestock so as to maximize the opportunity to secure the best pasturage and water.

Initially some decisions by herdsmen may have been attempts at avoiding the payment of "tribute/tax", as in the recorded observation in 1911 that not a single Rendille settlement remained in the neighbourhood of the Marsabit - Archer's post road. As the administration became more firmly established, however, its altitude of superiority characterized by its paternalistic outlook and its belief in "vigorous measures" to enforce the "correct way", resulted in restrictions in movements of herdsmen by delimiting "tribal grazing areas" and restricting movement for administrative, taxation, trade and protection purposes. These restriction among other things also restricted friendly exchanges between tribes. For example the Gabra assisted the Boran during drought, lending them animals and giving them food until they rebuilt their herds again.

When the concept of "overstocking" did appear, it was more a rationalization of seeking increased revenues than a manifestation of serious concern for the region's vegetation. It was the result of an individual's observation rather than an understanding of the minimum number of livestock a family or society required to exist in the worst environmental stress situations.

There was forced livestock sales and destocking which was greatly resisted by the people and reaffirmed their doubt in the concern of the colonial government for their welfare. In 1938 for example, plans were made for the destocking of excess Samburu livestock and meetings were held to explain the rules and procedures. From these it would appear that the administrators in Samburu at least were beginning to come to grips with the realization that force was

in itself a less than effective method of administration. The rules for the culling of Samburu stock were:-

(i) Stock of the most influential individual were to be culled first.
(ii) No small stock were to be culled unless the owner or family were present.
(iii) No bulls, expected to breed in 3-4 years were to be culled.
(iv) No members of the tribal police or Kenya police were to be used.
(v) All cattle not to be culled were to have a special brand.
(vi) Selection of the culls was to be done by an "expert" known to the Samburu eg. the District Office.
(vii) All cull selection was to be done first by the owner and more intensively by the officer if necessary.

Attempts to implement the destocking programme were however met by agitation among the Samburu. At a meeting on 1st January 1939 the government acceded to a number of Samburu demands, including one that stated no surplus bullocks other than the very oldest were to be culled until a census was completed. Having received one concession, however, the Samburu sought others and increased their opposition to the entire scheme. Their demands voiced at a meeting on 30th March included the following:-

(i) That the Samburu be allowed to graze cattle as and where they wish, not only on Samburu but also crown land north of Rumuruti.
(ii) The removal of the veterinary department from Samburu.
(iii) The abolition of the census and any idea of destocking.
(iv) The removal of all government appointed Chiefs.
(v) That the warrier age-grade be allowed to dress as warriers again and carry spears.

This specific example is quoted here to illustrate the importance of the human ecology approach adopted by IPAL since earlier attempts to bring about management controls largely failed through of lack of acceptance by the people. This in turn happened because the measures failed to take into account the people's interests, fears and needs. For example it can be seen that, where each family in a tribe is attempting to maintain a minimum herd for subsistence, there must be a critical level of human population beyond which continued reliance on

pastoralism must result in overstocking of the land and the ultimate destruction of the grazing resource. Once it is appreciated that it is this situation rather than perversity that is the cause of much of the overgrazing in Kenya today, it follows that the solution to the overgrazing problem must be sought not so much in enforced stock sales but rather in effective changes in the traditional system which will free the people from their dependence on milk. The basic principles for appropriate resource use like distribution of grazing, migrations, rational use of water, livestock sharing etc. already exist in the traditional system of pastoralism. The aim must not be therefore to change them but rather to improve on them to cope with the changed circumstances.

What does the future hold for the pastoralists of northern Kenya? There are two main considerations in the answer; one is environmental and the other is political. The first, as already observed, involves knowing whether pastoral systems are rational in terms of perpetuating the system, without turning northern Kenya into a semblance of the Sahara; the second concerns what decisions policy planners make for the socio-economic development of the region. If good decisions are made, the pastoralists will continue to enjoy their way of life while contributing to the national economy, and desertification can be halted or even reversed. If bad decisions or no-decisions are made, the pastoral way of life as it has been known through the centuries will be destroyed, possibly along with the land. It is of importance therefore to Kenya as a nation to decide well on the fate of its northern regions for the benefits of the people and land there, as well of the country as a whole. This can only be done by coming to understand the ecological and socio-economic functioning of the pastoral systems in the area. Livestock is the major link between man and his environment in this area and therefore becomes the next emphasis of the IPAL investigations.

LIVESTOCK ECOLOGY STUDIES

A few observations made in the Human Ecology Studies are worth reiterating here as they form the background against which the IPAL Livestock Studies should be viewed. However much we may regret the past and the changes which have been forced on the peoples of northern Kenya, life for them will never be quite the same again. According to the Organisation of African Unity charter, all territorial boundaries inherited from colonialism must be respected and within Kenya itself the administrative boundaries have been reaffirmed. When this is coupled with the population pressures from the outside there is little hope that the pastoral groups will ever regain their lost territories and hence they are forced to accept their present reduced grazing areas.

Secondly because of the limited land potential coupled with the firm livestock cultures of the people, northern Kenya will remain largely rangeland and a degree of mobility will continue to be a biological necessity for survival.

It is not IPAL's intention therefore to set the clock backwards but to assist in making the lives of the people of northern Kenya happy and meaningful under the changed circumstances. In their terms this means improved production of their land through their livestock. The major objective of IPAL's livestock studies therefore is the development of management strategies for the restoration of environmental stability. This specifically has involved the assessment of the current importance and potential economics of livestock production systems to the people; determination of livestock population parameters and their environmental impact with likely trends; development of livestock grazing and production strategies for controlled range use and long term sustained yield.

IPAL's Livestock Studies are concentrating on the four culturally and economically most important species to the people in the area - camels, cattle, sheep and goats.

Numbers, Densities and Distribution of Livestock and Wildlife

Accurate population estimates are an essential first step in calculating the biomass and productivity of large herbivores since factors affecting abundance cannot be evaluated unless population changes can be detected. Because of the

large size of the study area and the nature of the movement of livestock in the area, it was necessary to use the aerial survey technique developed by Norton Griffiths (1975) and now widely used in Africa (Watson, 1970; Western, 1976; KREMU, 1979).

Using a Cessna 185 as the observation platform the study area was systematically sampled at an intensity of 6% on a 10 x 10 Km. grid which is further subdivided into 5 x 5 Km. sub units. The area surveyed increased from a core of 14,000 Km^2.

Preliminary results. Although the detailed analysis of the results is still going on preliminary data from ten systematic reconnaissance flights (S.R.F.'s) covering the period July 1976 to August 1979 are discussed here.

On the basis of rainfall statistics obtained from between five and thirty gauges established in the study area, half of the surveys have been designated wet season and half dry season. The criterion for the former was an average of 50 mm or more of rain falling during the two month period prior to each survey. For each of the ten surveys twenty-two livestock, wildlife and settlement variables -

1. Total domestic stock density.
2. Domestic stock biomass.
3. Domestic stock (Tropical Livestock Units).
4. Total Wildlife Density.
5. Wildlife biomass.
6. Wildlife (Tropical Livestock Units)
7. Grazing Wildlife Density.
8. Browsing Wildlife Density.
9. Occupied Manyattas.
10. Abandoned Manyattas.
11. Sheep and goats.
12. Cattle.
13. Camels.
14. Donkeys.
15. Oryx.
16. Zebra.
17. Giraffe.
19. Gerenuk.
20. Ostrich.

21. Dik Dik.
22. Other Wildlife Species, were mapped by computer.

In addition six ephemeral environmental variables - Surface water, Green grass, Green riverine vegetation, Green woodland vegetation, Burnt vegetation, Rainfall and four fixed variables - Mean elevation, Distance from permanent water, primary vegetation types and mean annual rainfall have also been mapped. Altogether Rainfall prior to each survey has also been mapped using the polygon method. These have yielded about 300 distribution maps.

Numbers and densities. Mean estimated population for the greater study area (23,000 Km^2) and their sizes and proportions in terms of tropical livestock units are given in Table 2. In addition, results from each survey are presented as densities Km^2 in order to compare figures from the different sized areas.

There are almost 400,000 ungulates in the study area of which all but 3% are domestic livestock. Although most of the livestock are sheep and goats, when expressed in terms of Tropical Livestock Units, they contribute only 18% to the total while cattle comprise 40% and camels 36%.

Livestock were present at low densities during 1976 but increased in 1977 to more than three times their former densities ($P > 0.05$).

The drought which affected the Sahelo - Ethiopia zone of Africa in the first half of the last decade was broken in Marsabit District, Kenya in 1977. (Dalby, Church, Bezzaz, 1977, Edwards, Field & Hogg, 1979). During the drought it is apparent that from two thirds to three quarters of the domestic livestock vacated the area travelling to highland pastures approximately 80 Km to the south and a similar distance into Ethiopia. The marked increase in livestock numbers with the onset of the rains in 1977 corresponds with the return of the mobile 'fora' camps from these distant pastures as conditions improved.

Wildlife however, showed little response to the changing climatic conditions. In contrast to livestock they are relatively independent of water and hence of overgrazed areas. Because of the risk of theft and predation livestock owners pen their animals at night which puts them at a disadvantage compared with wildlife which can forage when it is cool at night and rest in the heat of the day.

TABLE 2

Estimated Livestock and Wildlife Densities Km^{-2} Total Populations and Livestock Units in the IPAL Study Area (23,000 Km^2)

Year	1976	1976	1977	1977	1977	1977	1977	1978	1979	1979	$\bar{x}$	Pop	T.L.U.	%
Month	July	Aug	Jan	Mar	June	Aug	Oct	Oct	Apr	Aug		Size		
Species														
Sheep and Goats	4.34	4.16	19.13	11.38	21.14	13.23	7.55	9.05	15.75	19.03	12.48	287040	26095	18.3
Cows	1.25	0.67	0.47	2.20	5.63	2.43	1.86	2.60	3.73	3.83	2.47	56810	56810	39.8
Camels	0.50	0.71	3.38	1.09	1.74	1.87	1.15	1.33	1.49	4.77	1.80	41400	51750	36.3
Donkeys	0.03	0.01	0.05	0.01	0.10	0.15	0.03	0.01	0.15	0.03	0.05	1150	1150	0.8
Oryx	0.20	0.06	0.11	0.03	0.04	0.08	0.05	0.01	0.07	0.10	0.08	1840	920	0.6
Zebra	0.06	0.04	0.12	0.05	0.04	0.09	0.03	0.06	0.05	0.06	0.06	1380	1380	1.0
Giraffe	0.05	0.05	0.07	0.11	0.09	0.12	0.06	0.05	0.06	0.05	0.07	1610	3220	2.3
Grant's Gazelle	0.30	0.19	0.21	0.10	0.16	0.22	0.19	0.11	0.26	0.21	0.20	4600	460	0.3
Gerenuk	0.05	0.10	0.00	0.08	0.03	0.04	0.03	0.00	0.02	0.03	0.05	1150	115	0.1
Ostrich	0.14	0.06	0.05	0.05	0.05	0.11	0.03	0.08	0.10	0.28	0.09	2070	690	0.5
Total												399050	142590	100.0

$\bar{x}$ = mean density T.L.U. = Tropical Livestock Units equivalent to one 250 Kg. cow.

Other T.L.U. equivalents as follows: Giraffe 0.5, Camel 0.8, Donkeys and Zebra 1, Grants gezelle and Gerenuk 10, Oryx 2, Sheep and Goats 11, Ostrich 3.

Distributions and stocking rates. Mean annual stocking rates in terms of Tropical Livestock Units Km^{-2} (a TLU = one cow equivalent weighing 250 Kg), have been plotted for each of the 100 Km^2 units in the study area. In the ten surveys no livestock were observed in 13% of the study area while a further 12% had less than one TLU Km^{-2}. This corresponded with either barren or insecure land.

Maps of wet and dry season ephemeral variables together with densities of livestock and households (manyattas) have been drawn using a computerized map plotter (Figures 6-13 inclusive). Overlap maps of livestock and households are also shown (Figure 14 & 15). With respect to the proportion of the study area occupied they show the following:-

	Wet Season	Dry Season
Smallstock	73%	50%
Camels	51%	39%
Cattle	46%	31%

Some explanation of these maps is relevant. The study area is an internal drainage system centred on the Chalbi desert. Transhumance is practiced by cattle pastoralists who concentrate on watersheds in dry seasons and disperse into sub desert areas after widespread rain. The exception which proves this rule is the Huri Hills in the north east of the study area where there is no permanent water. The pattern of transhumance in this area is the reverse of that found elsewhere. Pastoralists who own camels are less dependant on watersheds during dry seasons and practice a form of nomadism within the lowland areas.

Currently published data on potential carrying capacities of semi-arid and arid rangeland in Africa are limited to those of Le Houerou & Hoste (1977) and Pratt & Gwynne (1977) who refer to perennial or unspoiled natural grassland. Ongoing research at IPAL has reached the stage where first approximations have been made regarding the relationship between rainfall and primary productivity in the study area (Herlocker & Dolan, 1980). The synthesis of these data with information on livestock food requirements and their impact on the range will provide a more accurate estimate of true carrying capacities of the range than we have at present. Nevertheless it is of interest to map areas in which observed stocking rates are in excess of those rates recommended in the aforementioned literature. Results show that, the areas

Figure 6

Distribution of Manyattas, Camels and Cattle in relation to water

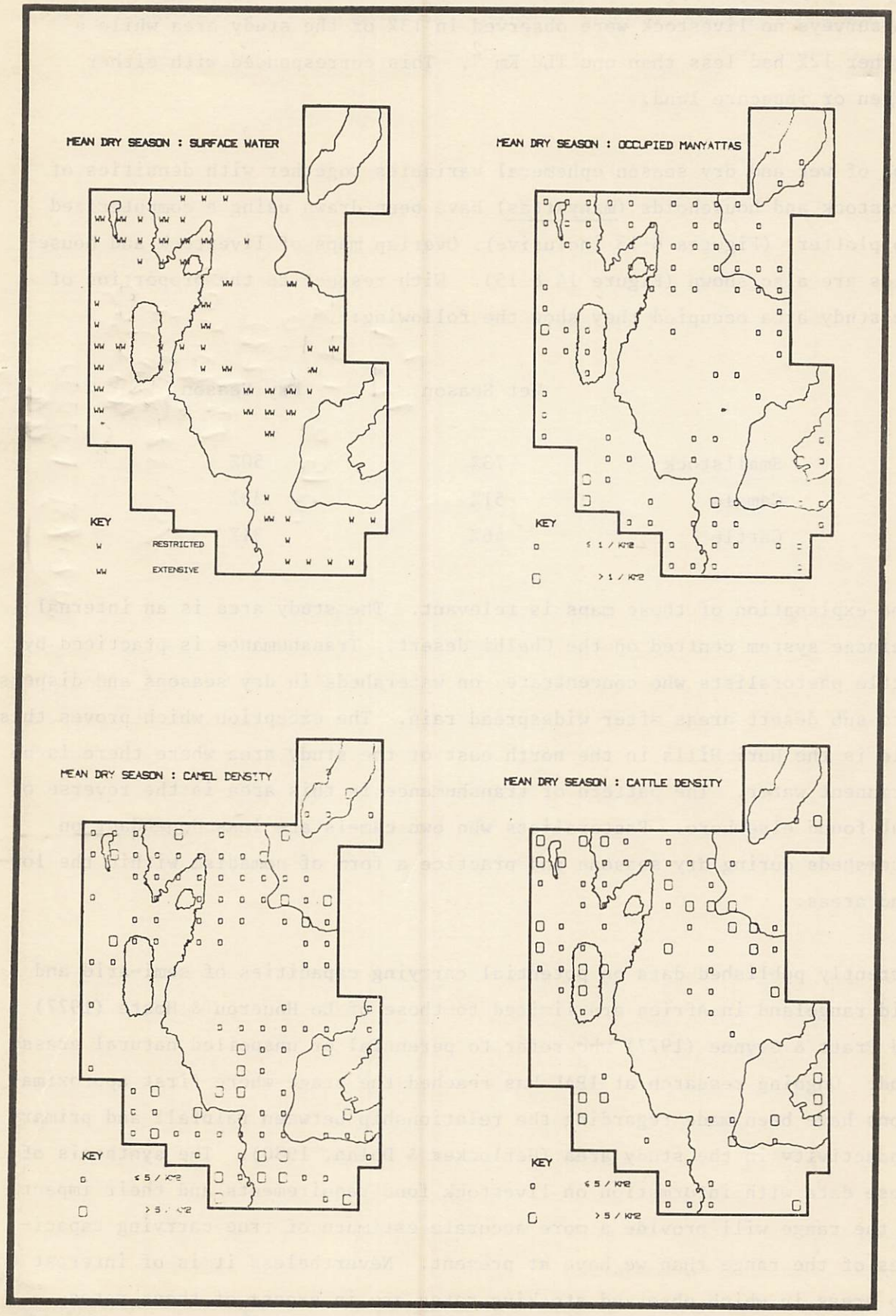


Figure 7

Distribution of Manyattas, Camels and Cattle in relation to green grass

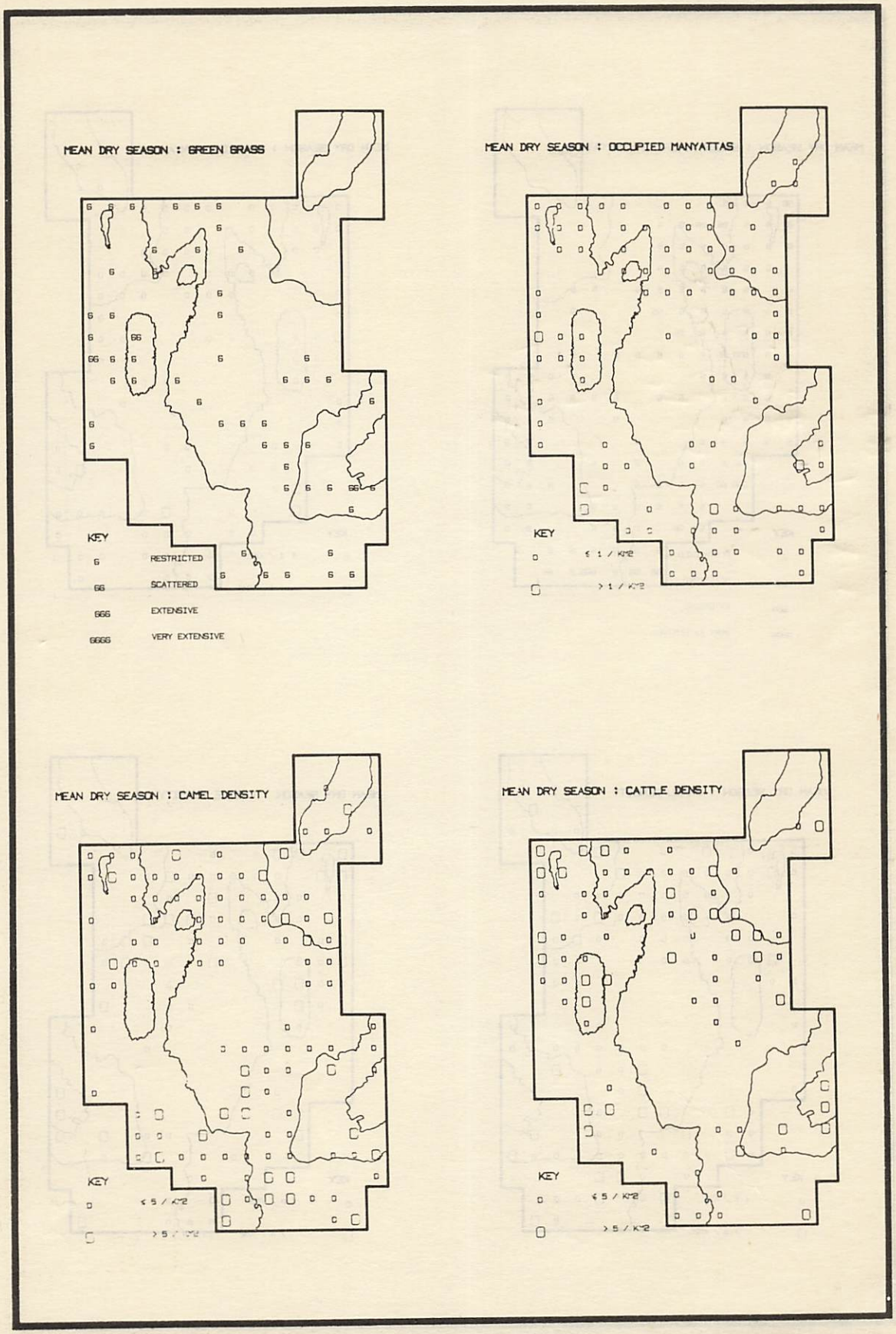


Figure 8

Distribution of Manyattas, Camels and Cattle in relation to green riverine vegetation

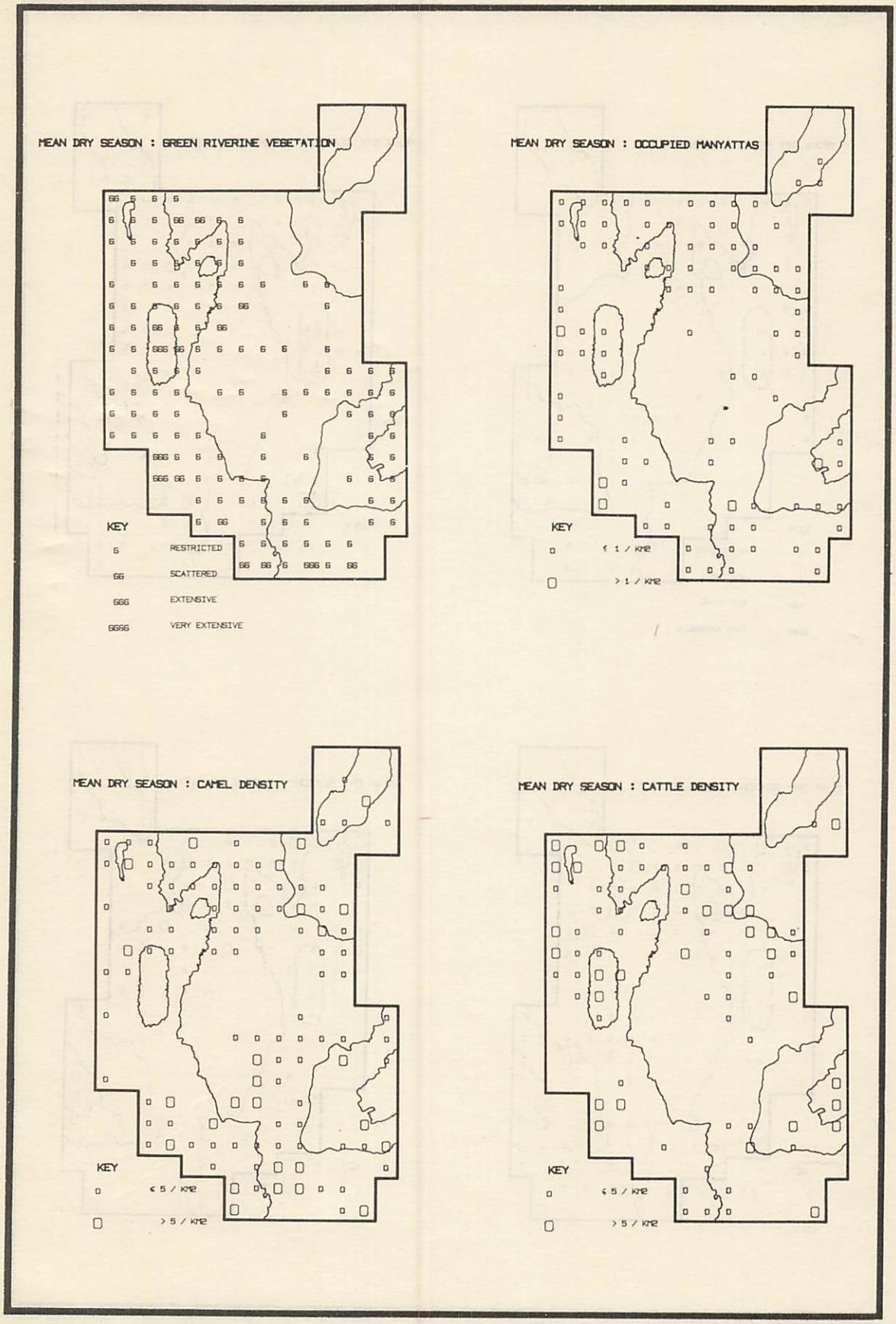


Figure 9

Distribution of Manyattas, Camels and Cattle in relation to green woodland vegetation

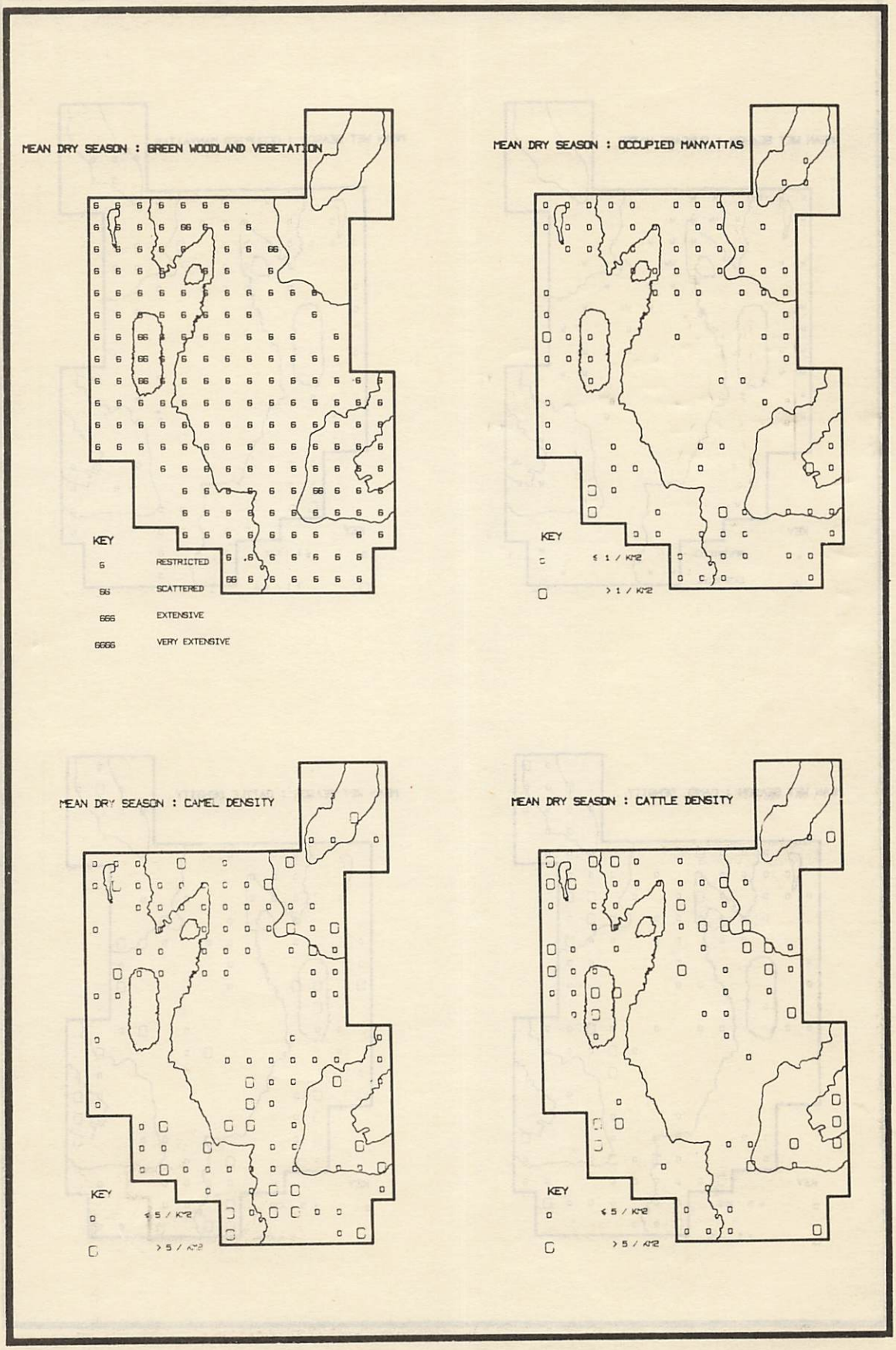


Figure 10

Distribution of Manyattas, Camels and Cattle in relation to water

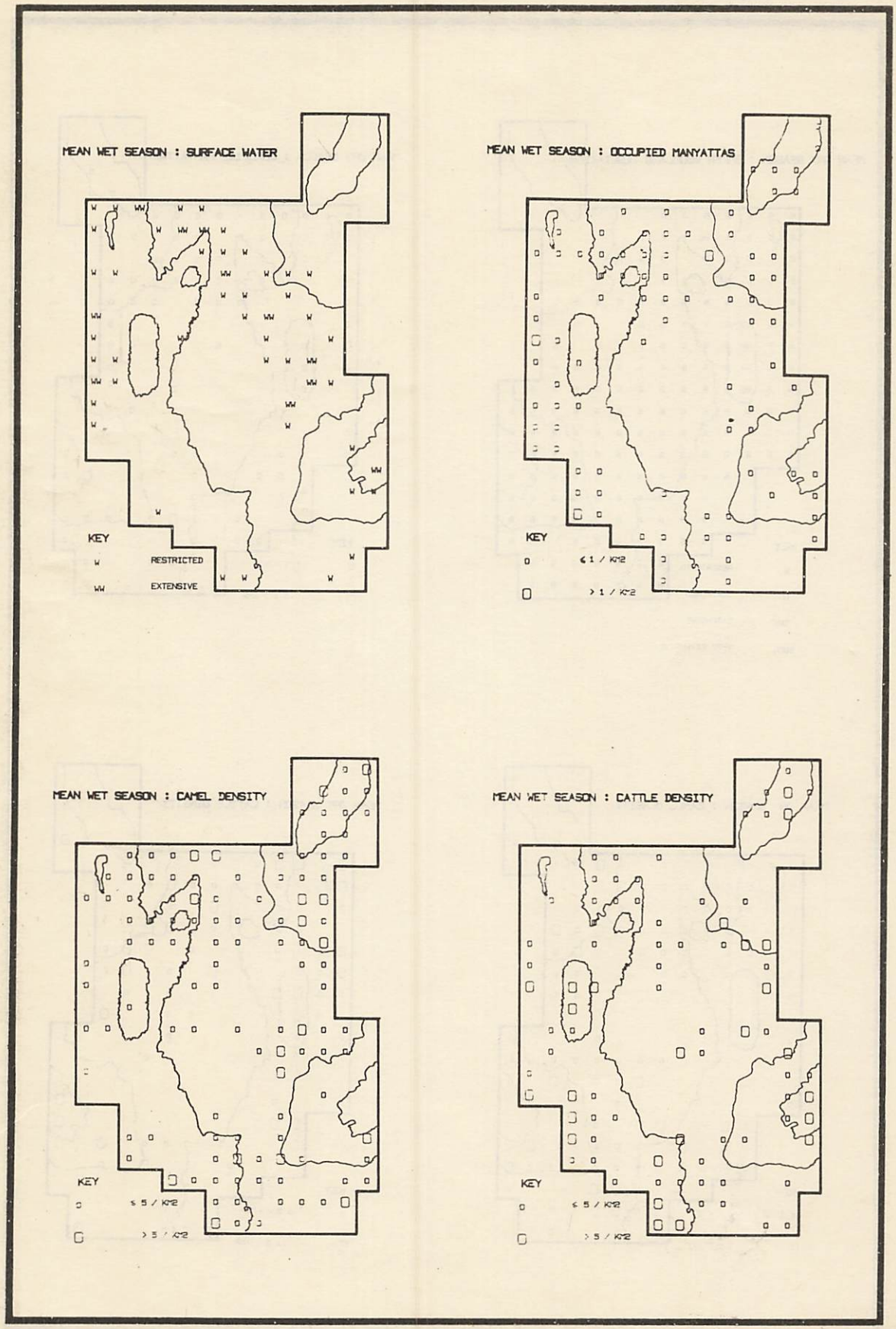


Figure 11

Distribution of Manyattas, Camels and Cattle in relation to green grass

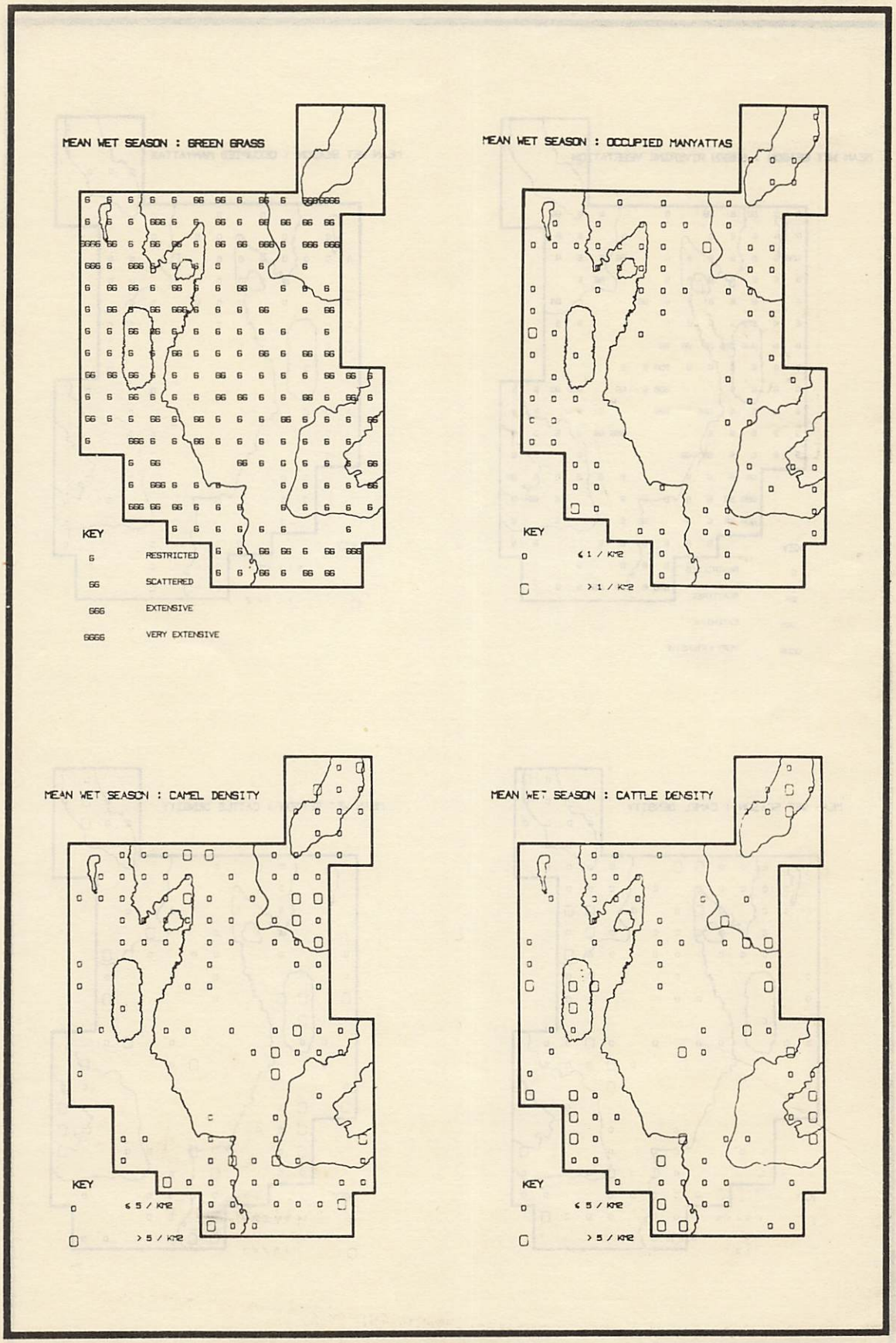


Figure 12

Distribution of Manyattas, Camels and Cattle in relation to green riverine vegetation

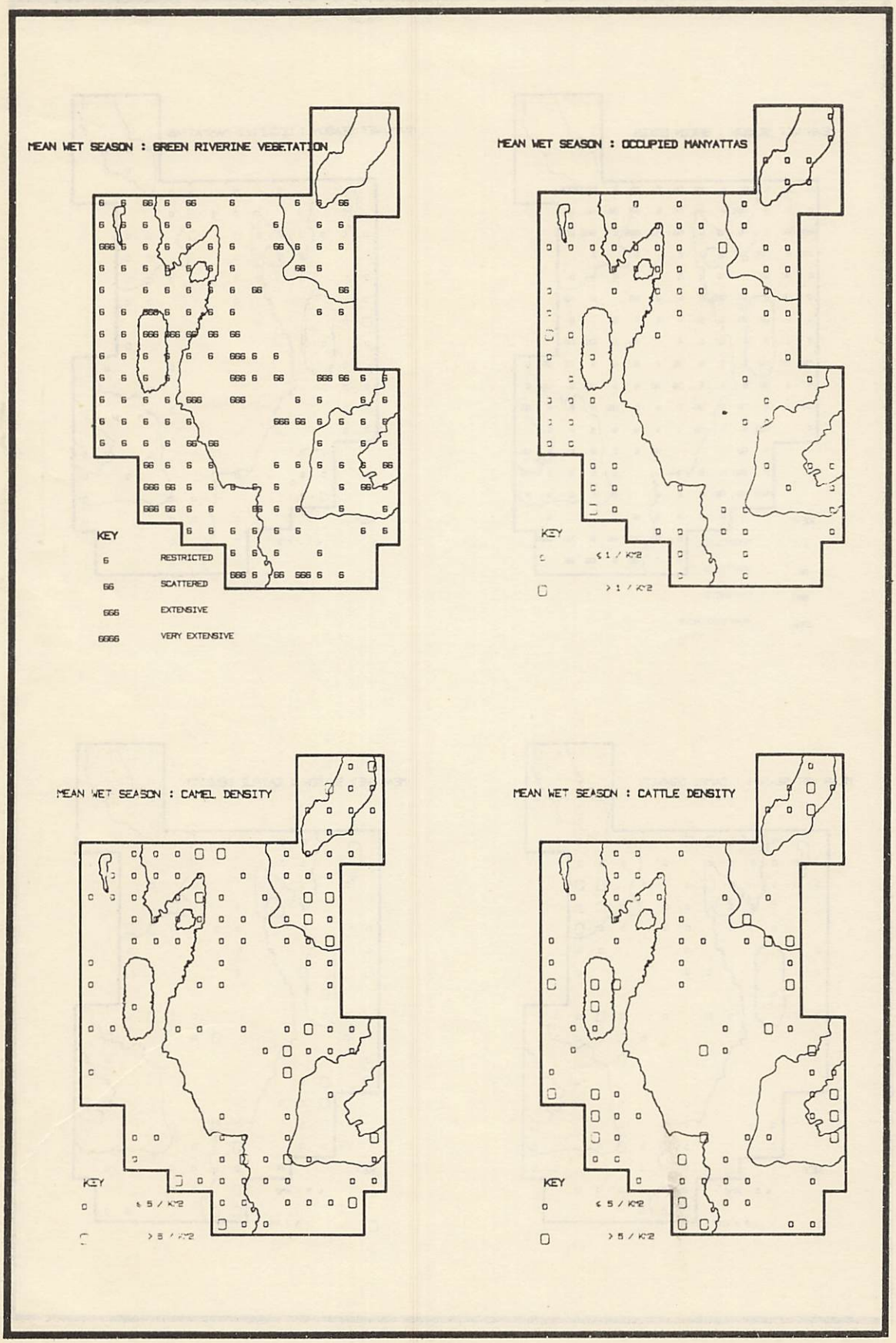


Figure 13

Distribution of Manyattas, Camels and Cattle in relation to green woodland vegetation

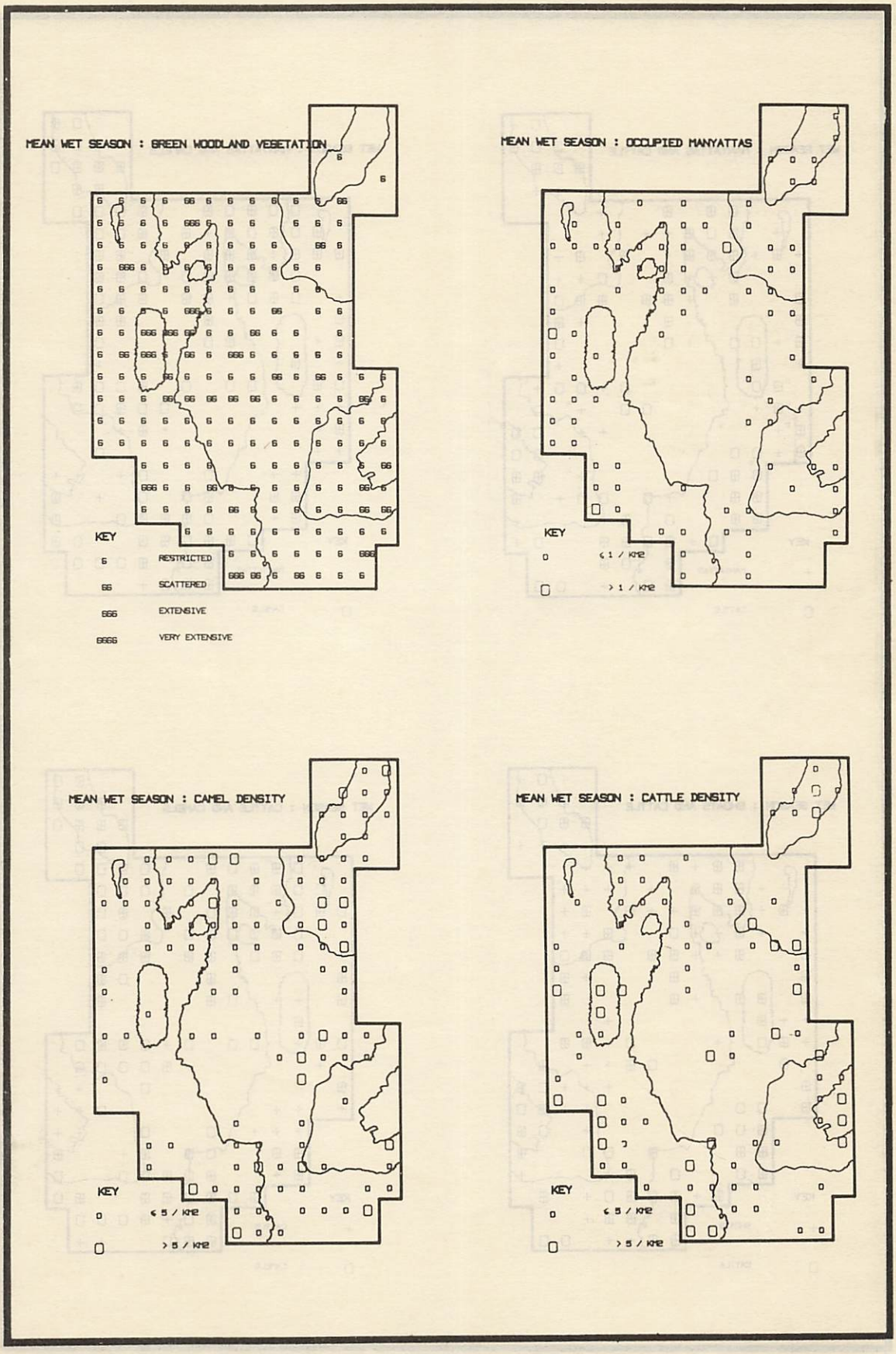


Figure 14

Overlap between Manyattas, Cattle and Shoats

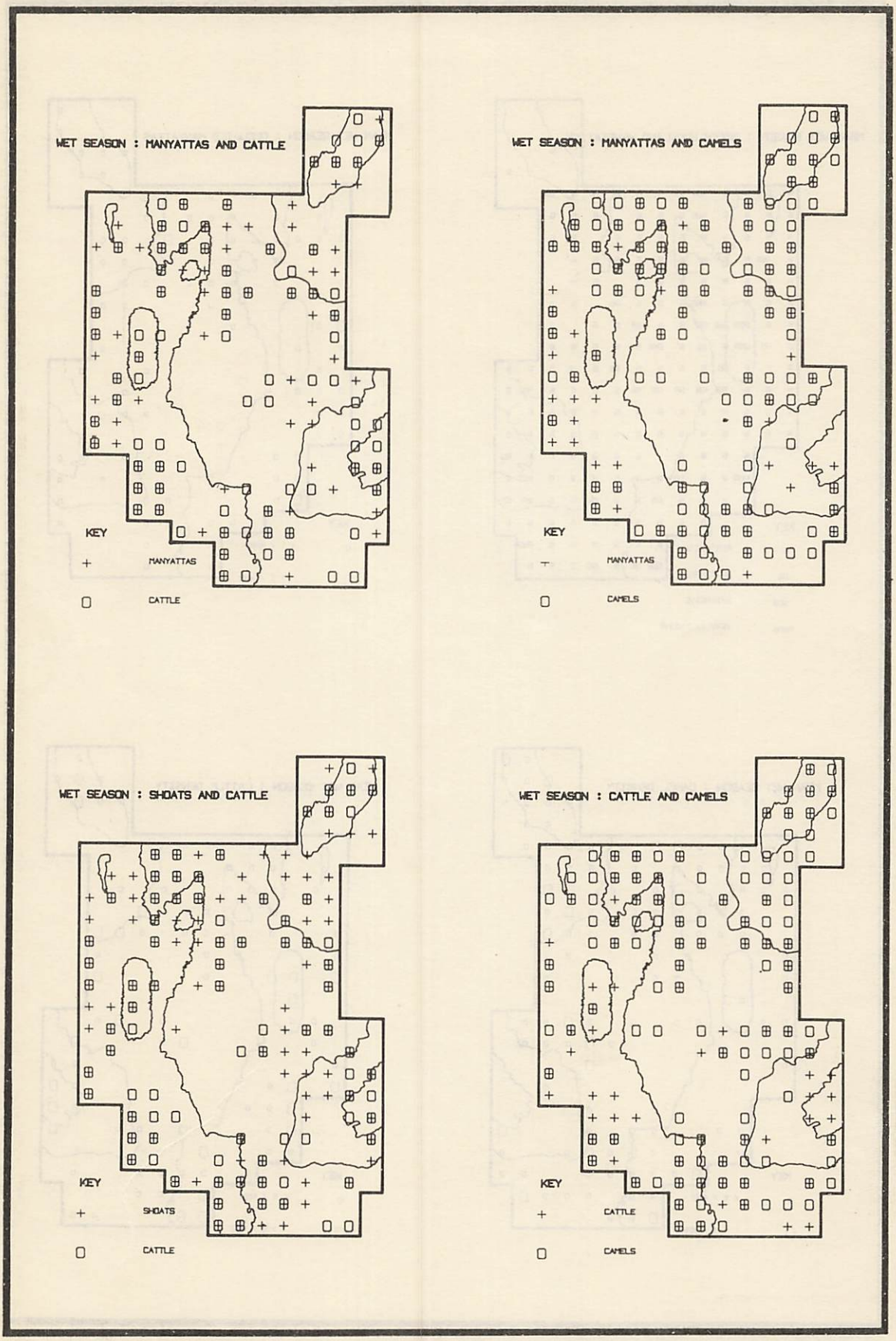
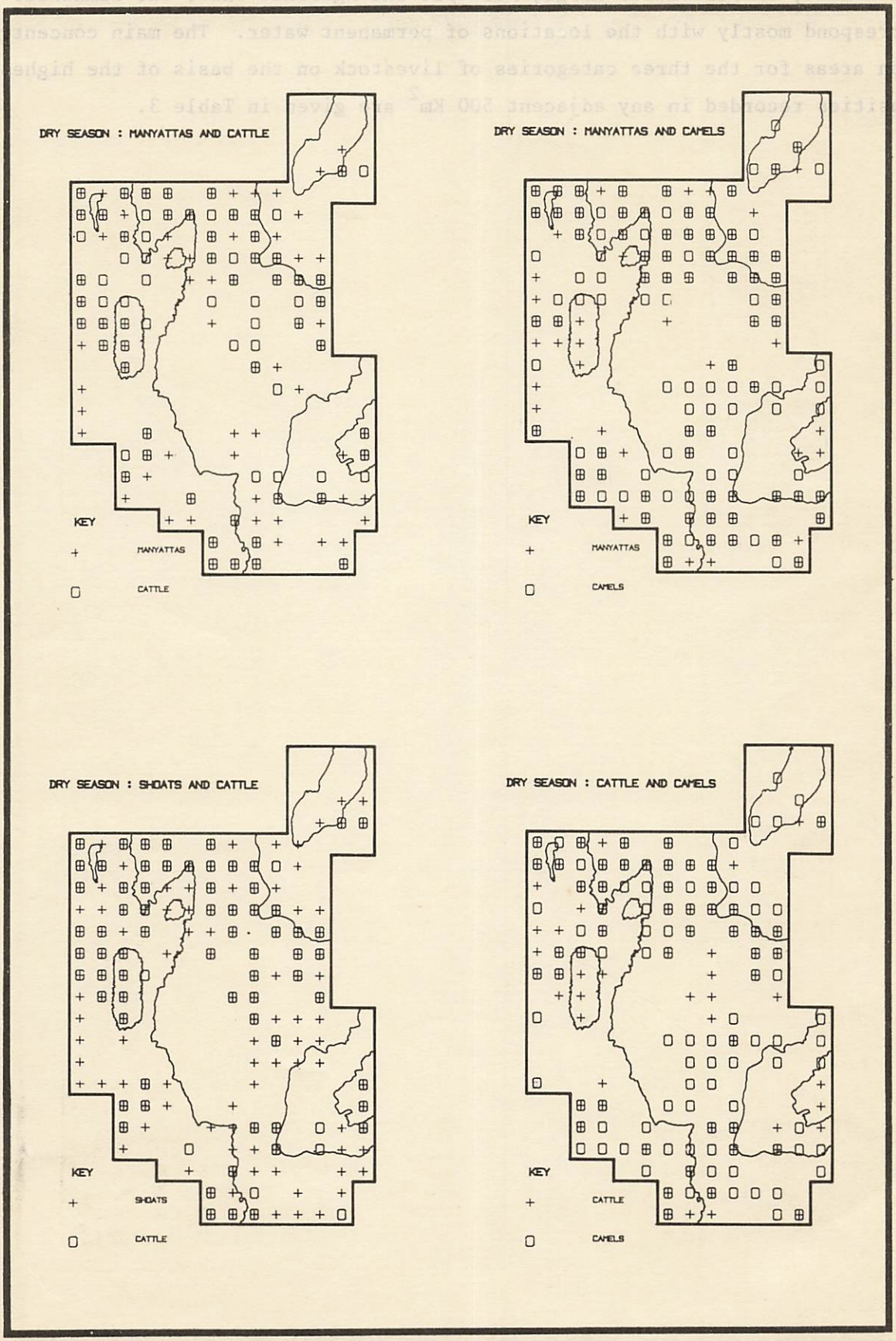


Figure 15

Overlap between Manyattas, Cattle and Shoats



of excessive stocking comprise from 16 - 21% of the study area (Field, 1981) (Figure 16). About one third of these occur in areas of permanent settlement, in particular Kargi, Marsabit and Ngurunit while the remainder correspond mostly with the locations of permanent water. The main concentration areas for the three categories of livestock on the basis of the highest densities recorded in any adjacent 500 Km^2 are given in Table 3.

Figure 16

Areas where stocking rates exceed potential carrying capacity (CC)
(CC) after Pratt and Gwynne (1977) excess in TLU km^{-2} yr^{-1} = 20.9%)

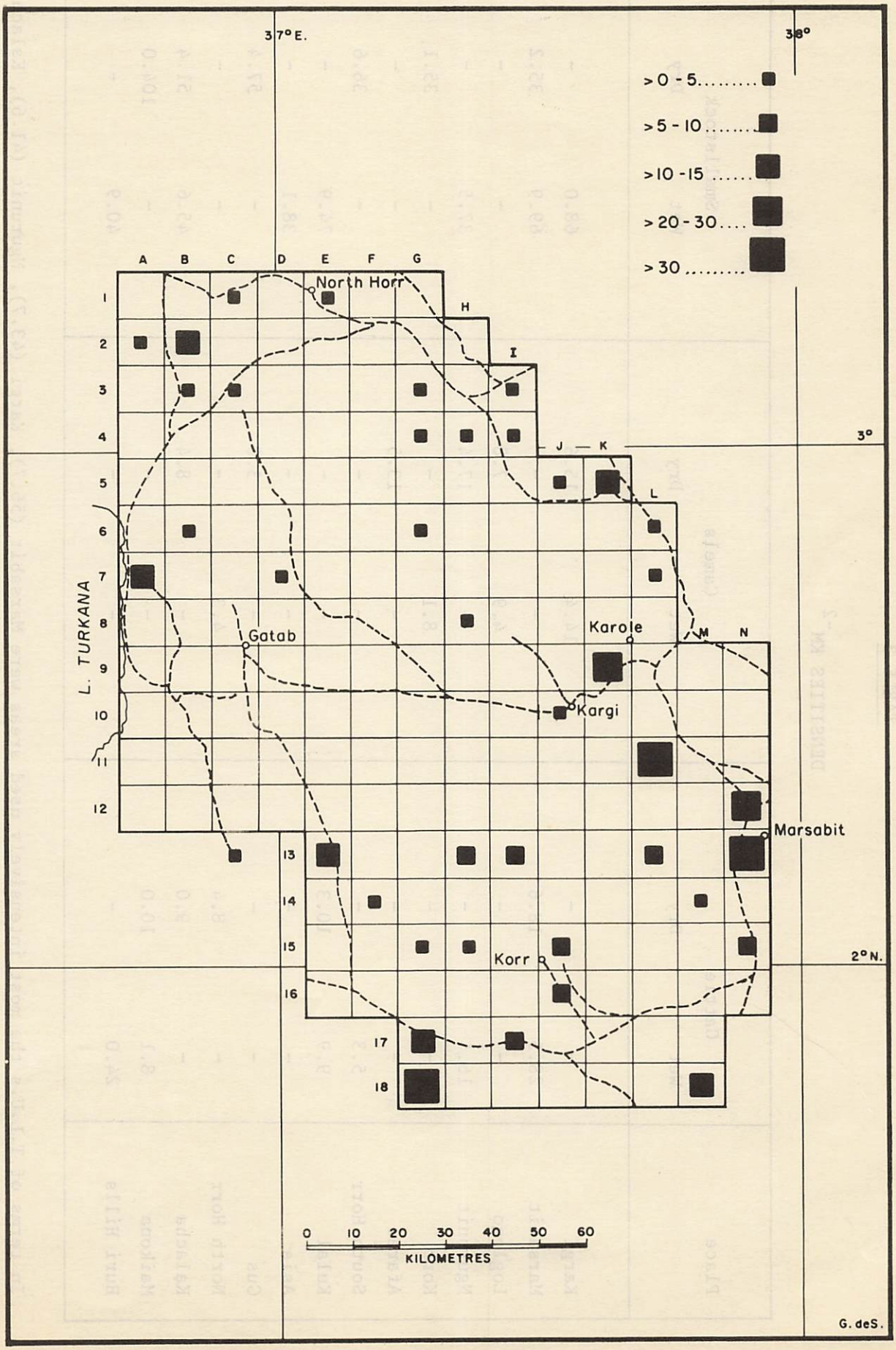


TABLE 3

DENSITIES KM^{-2}

Place	Cattle		Camels		Smallstock	
	Wet	Dry	Wet	Dry	Wet	Dry
Kargi	-	-	14.4	15.6	68.0	-
Marsabit	28.5	18.6	-	-	69.9	35.2
Loglogo	-	-	4.9	7.8	-	-
Ngurunit	16.4	-	-	17.4	37.5	-
Korr	-	-	8.1	-	-	35.1
Afarei	-	-	-	13.5	-	-
South Horr	5.3	-	-	-	-	36.6
Kulal	9.9	10.3	-	-	74.9	-
Asie	-	-	-	-	38.1	-
Gus	-	-	-	5.0	-	57.4
North Horr	-	8.4	4.3	-	-	-
Kalacha	-	9.0	-	8.4	45.6	51.4
Maikona	8.1	10.0	-	-	-	104.0
Huri Hills	24.0	-	-	-	40.9	-

In terms of T.L.U.s the most intensively used areas were Marsabit (56.7), Kargi (43.7), Ngurunit (41.6), Kalacha (28.3), Huri Hills (27.7), Maikona (27.6), and Kulal (27.0).

Statistical analysis of distribution data. A vast quantity of data have been generated from the analysis of variance of the distribution of manyattas, livestock and wildlife in relation to various environmental variables.

In this preliminary presentation it is not possible to do full justice to these data but rather to present some selected examples from the first five aerial surveys. The initial step in the analysis is to carry out two-way analyses of variance between animals (columns) and stratifications (rows). The areas are stratified in order to enhance homogeneity and reduce the sampling variance. Stratification also permits proportional or optimal allocation of sampling effort to strata. The following stratifications have been used in the analysis of IPAL census data.

(a) Mean annual rainfall bands:
  (i) 150 - 200 mm.
  (ii) 200 - 250 mm.
  (iii) 250 - 300 mm.
  (iv) 300 - 400 mm.
  (v) > 400 mm.

(b) Dominant vegetation type in each 10 x 10 Km grid cell.
  (i) Forest.
  (ii) Evergreen semi-deciduous bushland.
  (iii) Bushland.
  (iv) Shrubland.
  (v) Dwarf Shrubland.
  (vi) Annual Grassland.
  (vii) Perennial Grassland.
  (viii) Barren land.

(c) Mean elevation in each 10 x 10 Km grid cell.
  (i) < 328 m.
  (ii) 328 - 656 m.
  (iii) 656 - 984 m.
  (iv) 984 - 1312 m.
  (v) >1312 m.

(d) Distance to permanent water from the centre of each grid cell.

(i) < 5 Km.

(ii) 5 - 10 Km.

(iii) 10 - 20 Km.

(iv) 20 - 30 Km.

(v) >30 Km.

variance ratios (F) are obtained for strata, animals and interactions. Thus where the F - ratio for strata is significant it shows that the strata are influencing the distribution of animals. In almost all cases the F - ratios for animals are significant since after all, the animals are themselves different from one another. This indicates that the animals are different from one another with respect to the strata. Where the interaction F - ratio is significant it tells us that the animals are responding very differently to vegetation strata.

The variance component for each F - ratio indicates the proportion of the distribution of all the animals taken together which is explained by the stratification.

The total sums of squares have then been decomposed for each individual animal to show their F - ratios and variance components with respect to strata.

A useful indication is given by the variance component (which indicates the proportion of the animals' distribution that can be explained by the stratification). Thus any animal with a variance component > 10% is particularly interesting.

A complete tabulation is available for each animal in relation to each stratum. It gives the area of the stratum, the number of units in the stratum, the number sampled, the density and standard error, the population estimate, variance and confidence limits all of which are summarized for the study area as the stratum total.

The null hypothesis of these analyses is that animals are distributed randomly with respect to the strata and that accordingly their densities within each should be the same and should be equal to the grand mean.

This null hypothesis is tested by investigating individual stratum densities and using the least significant difference test between any two means or between a mean and the grand mean.

In the following table (Table 4) we have selected examples from the first five flights where among strata variance components for individual animals are >10% and list animal densities in those strata which are selected and the strata population totals for those strata carrying the most animals as a percentage of the total for the study area.

Initial observations. It is clear from the table that during the drought conditions of 1976 the people preferred to herd their cattle in the evergreen semi-deciduous bushland although a greater proportion of the cattle population occurred in annual grassland or bushland. Stock biomass and TLU's were influenced here by cattle. For both smallstock (shoats) and cattle the herdsmen showed a strong preference for areas of >400 mm annual rainfall and on one occasion no less than 87% of cattle occurred in the stratum. A similar situation applied early in the rains of 1977 (Flight 03). Giraffe selected for high rainfall areas while ostrich selected for drier areas. Cattle were kept in forest areas although nearly half the population were found in bushland.

In the drier conditions of March 1977 cattle were again mainly found in the evergreen and semi-deciduous shrubland although half the population occurred in annual grassland. Giraffe showed a strong preference for bushland. Again herdsmen put their domestic stock in areas above 1312 m elevation although half the population were found above > 656 m elevation.

By June 1977 shoats were found mainly in the forest although 65% of the population occurred in annual grasslands. Cattle also were largely found in evergreen and semi-deciduous bushland and elevations over 1312 m. They had a strong influence on total domestic stock, stock biomass and TLU's. Grants' gazelle here showed preference for perennial grassland.

25% of the study area is little used due to insecurity and lack of water. These areas which are in good or fair condition perhaps hold the key to a possible solution in combating desertification in this area in the short term. As rehabilitation efforts will require some areas to be rested for extended periods of time, development of water and improvement of security in these areas will need a high priority. This will have to be done within the frame-

TABLE 4

A summary of the results of analyses of variance for five flights, between animals and fixed environmental variables

Flight Number	Species	F Ratio	Among strata Variance Component	Substratum	Density	Proportion of population Total
01						
July 1979	Cattle	7.55	33%	Evergreen S.D. bushland	22.22	36%
Dry	Cattle	7.55	33%	Annual grassland	1.54	48%
	Stock biomass	5.76	26%	Evergreen S.D. bushland	58.51	20%
	Stock biomass	5.76	26%	Annual grassland	7.06	45%
	Stock T.L.U.'s	5.98	27%	Evergreen S.D. bushland	23.24	21%
	Stock T.L.U.'s	5.98	27%	Annual grassland	2.70	46%
	Dik Dik	5.37	14%	>30 km from water	0.12	84%
02						
August 1976	Shoats	3.31	11%	>400 mm annual rain	26.79	43%
Dry	Cattle	6.57	23%	>400 mm annual rain	8.82	87%
	All Domestic Stock	4.22	15%	>400 mm annual rain	36.0	43%
	Cattle	3.48	16%	Evergreen S.D. bushland	7.77	18%
	Cattle	3.48	16%	Bushland	6.43	69%
	Other species of wildlife	5.28	24%	Bushland	0.25	72%

Continued.....

03						
Jan. 1977 Wet	Shoats	3.71	13%	>400 mm annual rain	38.28	43%
	Cattle	4.73	17%	>400 mm annual rain	5.32	95%
	All Domestic Stock	4.16	15%	>400 mm annual rain	108.03	40%
	All Domestic Stock	4.16	15%	200 - 250 mm rain	13.40	43%
	Giraffe	3.37	12%	>400 mm rain	0.27	34%
	Giraffe	3.37	12%	200 - 250 mm rain	0.06	60%
	Ostrich	4.10	15%	150 - 200 mm rain	0.16	48%
	Ostrich	4.10	15%	200 - 250 mm rain	0.03	46%
	Domestic Stock Biomass	4.89	18%	>400 mm rain	52.36	27%
	Domestic Stock Biomass	4.89	18%	200 - 250 mm rain	15.13	67%
	Stock T.L.U.'s	5.04	18%	>400 mm rain	13.71	27%
	Stock T.L.U.'s	5.04	18%	200 - 350 mm rain	5.45	66%
	Cattle	5.40	25%	Forest	11.33	26%
	Cattle	5.40	25%	Shrubland	0.32	46%
04						
March 1977 Dry	Domestic Stock Biomass	4.49	16%	>400 mm rain	46.22	24%
	Domestic Stock Biomass	4.49	16%	200 - 250 mm rain	10.38	55%
	Stock T.L.U.'s	4.39	16%	>400 mm rain	17.35	24%
	Stock T.L.U.'s	4.39	16%	200 - 250 mm rain	3.87	54%
	Cattle	3.75	17%	Evergreen S.D. shrubland	27.78	19%
	Cattle	3.75	17%	Annual grassland	3.16	50%
	Giraffe	2.65	11%	Bushland	0.57	39%
	Domestic Stock	2.84	12%	Evergreen S.D. shrubland	63444	9%
	Biomass	2.84	12%	Annual grassland	12033	35%
	Stock T.L.U.'s	2.94	13%	Evergreen S.D. shrubland	27.78	9%
	Stock T.L.U.'s	2.94	13%	Annual grassland	4.67	36%
	Domestic Stock	3.67	12%	>1312 mm	58155	12%
	Biomass	3.67	12%	< 656 mm	13683	52%
	Stock T.L.U.'s	3.62	12%	>1312 mm	22.32	13%
	Stock T.L.U.'s	3.62	12%	< 656 mm	5.10	51%

Continued.....

05

June 1977 Wet	Wildlife browser	3.10	10%	300 - 400 mm rain	0.36	26%
	Density	3.10	10%	200 - 250 mm rain	0.25	60%
	Shoats	3.40	15%	Forest	231.67	12%
	Shoats	3.40	15%	Annual grassland	31.18	65%
	Cattle	3.13	14%	Evergreen bushland	83.33	13%
	Cattle	3.13	14%	Bushland	23.74	84%
	Total domestic	3.16	14%	Forest	273.33	10%
	Stock	3.16	14%	Annual grassland	35.85	52%
	Grant Gazelle	3.54	16%	Perennial grassland	1.36	23%
	Grant Gazelle	3.54	16%	Annual grassland	0.15	35%
	Cattle	8.99	30%	>1312 m	76.67	37%
	Cattle	8.99	30%	<1312 m	18.24	38%
	Total Domestic	3.13	10%	>1312 m	156.83	17%
	Stock	3.13	10%	< 656 m	24.41	40%
	Domestic Stock	5.50	19%	>1312 m	21225	23%
	Biomass	5.50	19%	< 984 m	1328	32%
	Stock T.L.U.'s	5.88	20%	>1312 m	84.15	24%
	Stock T.L.U.'s	5.88	20%	< 984 m	7.13	31%

work of a well organized management plan.

Nutrition

Studies on the nutrition of camels, smallstock and cattle have involved the following methods.

(i) Observations on food habits and water requirements of experimental herds and some traditional herds.
(ii) Analyses of the chemical nature of the diet including moisture content.
(iii) Intake studies.
(iv) Impact studies.
(v) The relationship between diet and herd production.

Food habits. Much of the work carried out from July 1976 to December 1977 has been presented in IPAL Technical Reports E1a and b, E2, E3, and A3. Methods employed have also been described in these reports.

Observations were made in four to six plant communities depending on the livestock species and with the exception of cattle (which were only observed in one wet season) at different seasons of the year. Results are summarized as follows:-

TABLE 5

Percentage composition of the diet

	Trees & shrubs	Dwarf shrubs	Herbs	Grasses	Number of Observations
Camels	30	48	11	11	> 10,000
Cows	0	2	11	87	Not recorded
Goats	30	23	22	25	> 2,500
Sheep	9	24	30	37	> 2,500

A considerable amount of seasonal variation was observed in food habits of camels and smallstock. Smallstock surprisingly appeared to eat more browse in wet seasons rather than dry seasons.

There were also compositional differences in the diet of animals observed feeding in different plant communities. These appeared to result from differences in the composition of available food and also, at least in the case of camels, in preferences shown by the browsing animal.

When available the most important plant species in the diet of both camels and smallstock appeared to be Indigofera spinosa. Halophytic shrubs were important to camels in the vicinity of the Chalbi desert and annual grasses were eaten as standing hay when green food was unavailable.

Chemical nature of diet. Since January 1979, 20 monthly sets of feeding observations have been carried out on the IPAL camel herd and smallstock flock. These comprise about 5,000 observations on each species. Animals have been herded in four different plant communities.

The availability of the main plant components and key forage species has been recorded on a routine basis by the IPAL Range Ecologist and his assistants.

During each set of observations, samples of six to eight key forage species were selectively clipped and sent for chemical analyses.

Results of 80% of these analyses (115 samples) are now available. They are in terms of % crude protein, energy, gas production and in vitro organic matter digestibility.

There was considerable variation in crude protein (CP) content of samples (range 3.97 - 24.36% dry matter. In general the protein content of grasses, in particular perennials in dry seasons, was lower than of other plant categories. Mean % CP fell from a maximum of 16.5% in the early growing season to a minimum of 7.3% in the late dry season of 1979.

Dietary crude protein (DCP) has been calculated for sheep and goats by summing the crude protein content of the components of the diet (Figure 17). During 1979 this ranged from a maximum of 14.6% for goats in the growing season to a minimum of 6.3% at the end of the dry season. Maxima for sheep were 12.6 -

13.1% and the minimum was similar to that of goats. The maxima were lower in sheep because of the greater proportion of grasses of low protein content in their diet. Dietary crude protein only fell below the stated minimum requirements for ruminants (7%) on one occasion. In the following month the ripening of Acacia tortilis pods enabled a marked but temporary increase in dietary crude protein which tided the animals over the drought.

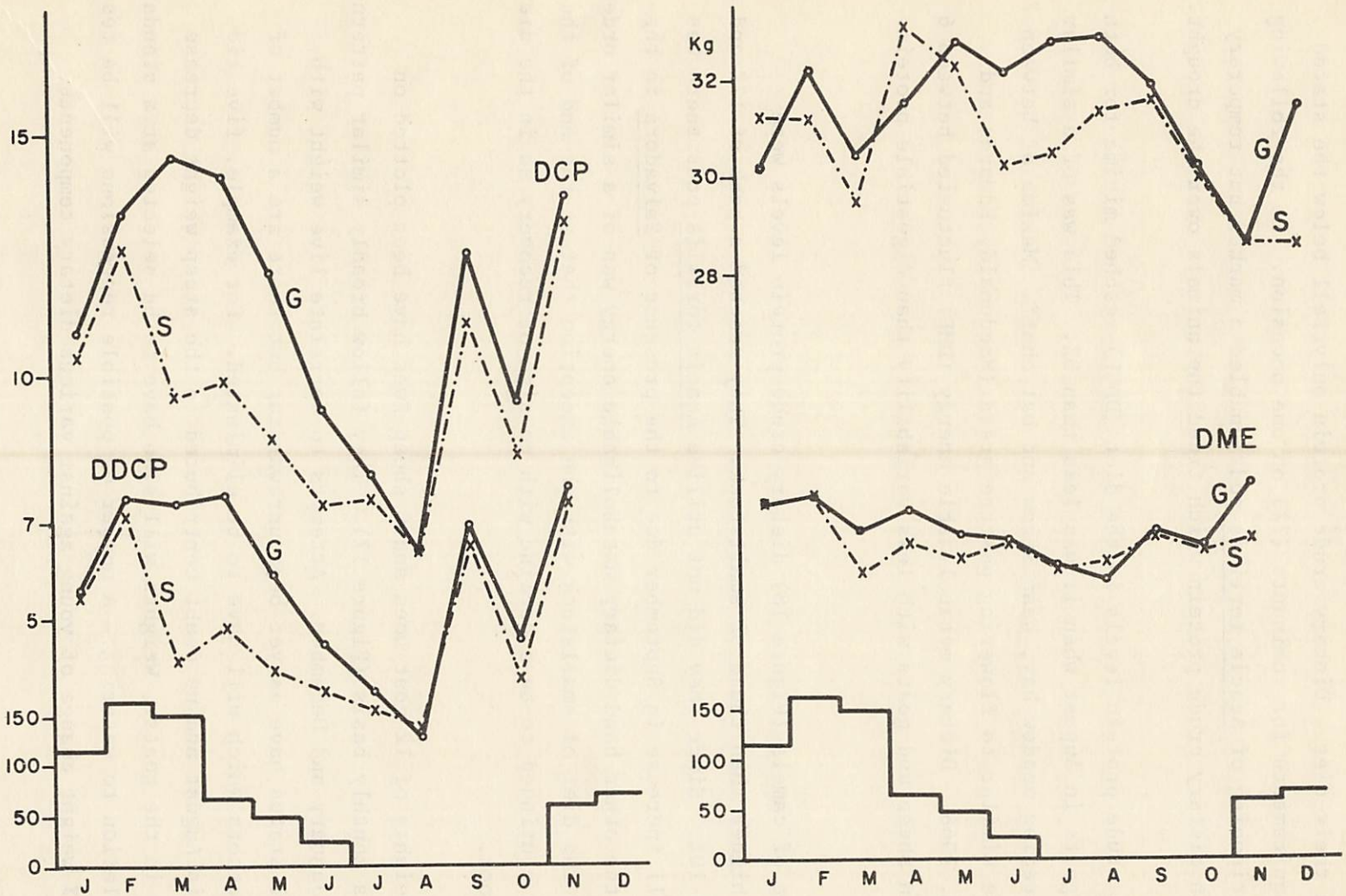
Digestible crude protein levels in the diet (DDCP) reached minima for both sheep and goats in August when it was less than 3%. This was of a similar order to seeding meadow hay, bean straw and oat chaff. Maxima of between 7 and 8% were similar to flowering pasture grass (Macdonald, Edwards and Greenhalgh, 1966. Dietary metabolizable energy (DME) fluctuated between 6 and 7.5% in sheep and goats with less variability than digestible protein levels.

In the case of camels (Figure 18) dietary crude protein levels were generally higher than those of smallstock. They reached a peak of 17% and a minimum of 10%. Since they did not utilize Acacia tortilis pods there was only a small increase in September due to the presence of Salvadora in the diet. On the other hand dietary metabolizable energy was of a similar order to that of the diet of smallstock with the exception that at the end of the year there continued to be a decline with no sign of recovery as in the diet of smallstock.

The mean weights of 12 goat Does and 9 sheep Ewes have been plotted on graphs on a monthly basis (Figure 17). They follow broadly similar patterns except in January and December. Attempts to correlate live weight with nutritional status have as yet been unrewarding but there are a number of variable factors which will have to be eliminated. For example, five kids were born in August and no doubt contributed to the steep weight decrease thereafter in the goats. Weights will also have to be selected at a standard time in relation to watering. A number of possible regressions will be tested including % weight change of young against various dietary components.

Weights of camels have been plotted (Figure 18) but are incomplete as the platform scale could not always accompany the herd to remote places. More recently a relationship has been established between the sum of three body measurements and liveweight and has been used during 1980. However the weights

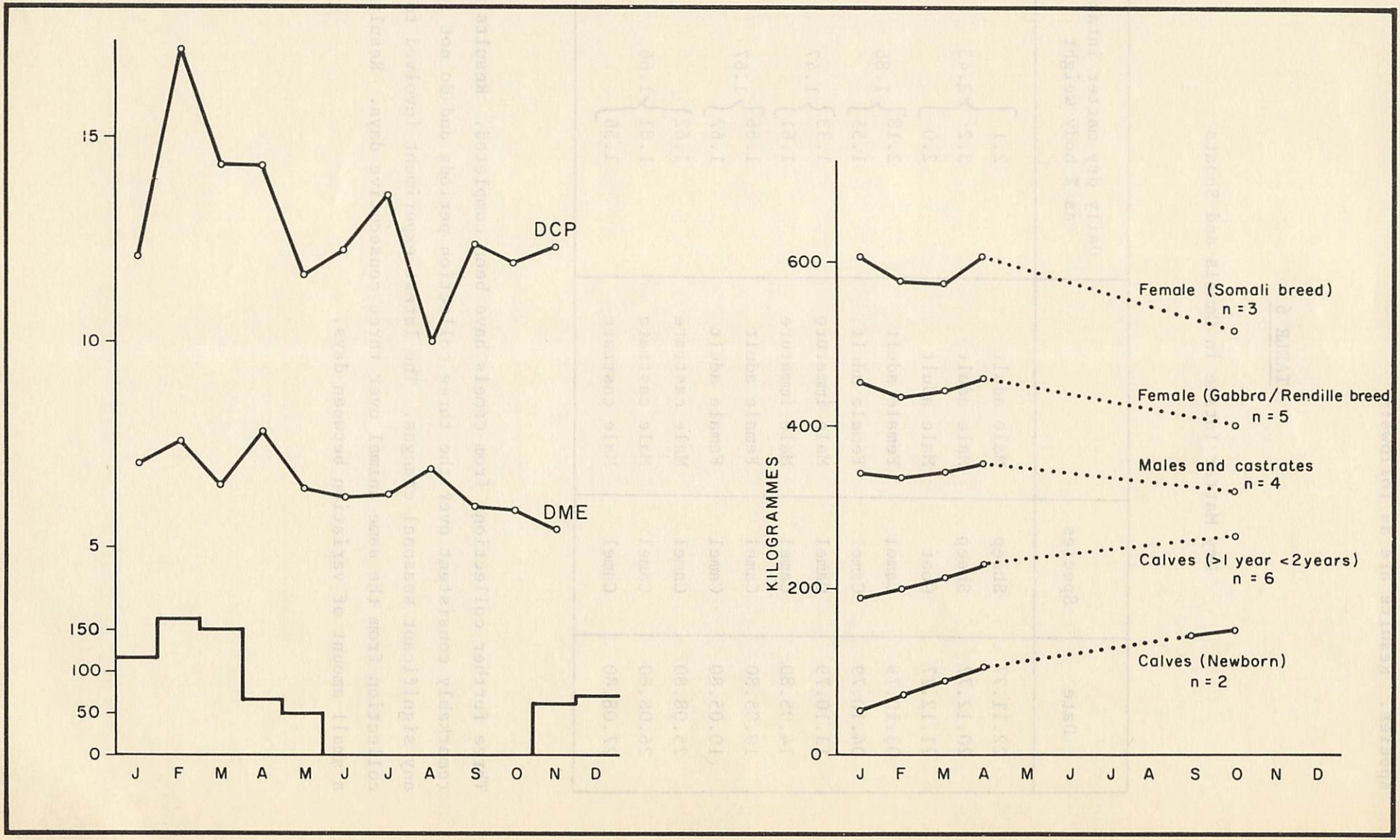
Figure 17



Seasonal variations in dietary crude protein (DCP), metabolizable energy (DME) and liveweight in sheep (S) and goats (G). Histograms show two monthly running totals of rainfall.

Figure 18

Seasonal variations in dietary crude protein (DCP), metabolizable energy (DME) and liveweight (Kg) in camels. Rainfall histograms are two monthly running totals.



Intake. A small number of intake trials have been carried out on all three species. Results are as follows:-

TABLE 6

Dry Matter Intake in Camels and Shoats

Date	Species		Daily dry matter intake as % body weight	
22.11.77	Sheep	Male adult	2.1	
20.12.77	Sheep	Male adult	3.2	2.43
21.12.77	Goat	Male adult	2.0	
03.10.79	Camel	Female adult	2.18	
04.10.79	Camel	Female adult	1.55	1.86
13.10.79	Camel	Male immature	1.33	
14.05.80	Camel	Male immature	1.61	1.47
19.05.80	Camel	Female adult	1.66	
10.05.80	Camel	Female adult	1.67	1.67
25.08.80	Camel	Male castrate	1.62	
26.08.80	Camel	Male castrate	1.81	1.66
27.08.80	Camel	Male castrate	1.56	

Three further collections from camels have been completed. Results are remarkably consistent over the three collection periods and do not indicate any significant seasonal changes. The latest experiment involved total faecal collection from the same animal over three consecutive days. Results indicate a small amount of variation between days.

Impact studies. Results of the impact studies carried out at a paddock complex at the Balesa Station have been inconclusive and will not be mentioned in detail here.

Offtake of Indigofera spinosa by smallstock in Trial I was as follows:-

	Offtake in Kg/ha	Expected intake Kg/ha
Heavily stocked	97.5	29.6
Medium stocked	11.9	13.7
Lightly stocked	3.9	3.7

Expected intake was calculated from the known stocking rates. Differences between observed and expected may be due to trampling, offtake by insects or sampling error. In a subsequent impact trial trampling by smallstock at high stocking rates was clearly evident and substantially more than that observed by camels at a similar stocking rate. However, it was not possible to demonstrate this using the plant sampling techniques available. It is, nevertheless, likely that trampling, in particular by smallstock and cattle, may contribute significantly to environmental impact and plant loss and this is a factor which should not be ignored in future studies.

Water. The consumption of water by the individual IPAL camels has been recorded over a period of about 30 months and that of the flocks of sheep and goats for about 20 months. There are also eight months of data on the moisture content of key forage plants used by these animals.

The pattern of increasing water consumption with drought is illustrated in six camels as follows:-

	April	May	June	July	1978
Ml kg^{-1} d^{-1}	3.37	21.70	25.06	25.24	
Number of times watered	1	5	5	5	

Water consumption of lactating female camels was 38% higher than that of males and castrates (females 28.6 ± 1.9 ml kg^{-1} d^{-1}; males 20.7 ± 2.0 ml kg^{-1} d^{-1} during June 1978). Camels used for riding purposes including 50% trotting, consumed 0.8-1.0ml kg^{-1} km^{-1}. Their consumption was 55-95% higher than similar camels not being ridden.

The moisture content of the diet has been calculated for seven months during 1980. This shows that for each 9.1 kg dry matter ingested daily by an average camel the following amounts of water would also be consumed.

	March	April	May	June	July	Aug.	Sept.
Daily intake in litres	6.25	17.37	16.09	5.66	5.52	3.31	21.52
Rainfall in mm	0	45	50	0	0	0	0

The increase in water intake in September in the absence of a corresponding increase in rainfall is due to a switch in food habits in the late dry season to evergreen trees and shrubs, namely Salvadora persica and Salsola dendroides.

Production

The following aspects of production have been measured in the Project herd of camels and flocks of sheep and goats.

1. Growth
   Weight at birth, liveweight.
2. Milk
   Volume, chemical composition (camels only), duration of lactation, age at weaning.
3. Reproduction and fertility
   Age at first kidding/lambing, abortions, births including twinning, calving interval, mating.
4. Mortality,
   Diseases, causes of death, deaths and longevity.

Supplementary data have been collected from camels, smallstock and cattle owned by indigenous people as follows:-

(i) Growth. Weight of 300 camel calves and two smallstock flocks.

(ii) Mortality by questionnaires and collection and ageing of about 150 camel skulls. Data from two smallstock flocks over two years.

(iii) Milk production from two smallstock flocks, one with no veterinary input, the other with antibiotics only.

Results are presented in IPAL Technical Reports E1a, E1b, E2, A3, E3. They are summarized as follows:-

Growth rates.

Weights at birth were as follows in Kg:

	Sheep	n	Goats	n	Camels	n
Males	2.26	17	2.07	22	28 ± 3.0	3
Females	2.11	13	2.01	27	34.8 ± 1.4	4

Growth of kids and lambs up to 5 months of age and born during the rains ranged from 75-107 gm d^{-1} while those born during dry seasons ranged from 44-92 gm d^{-1}. Growth of lambs was faster than kids. In dry seasons there was greater competition between humans and kids for milk.

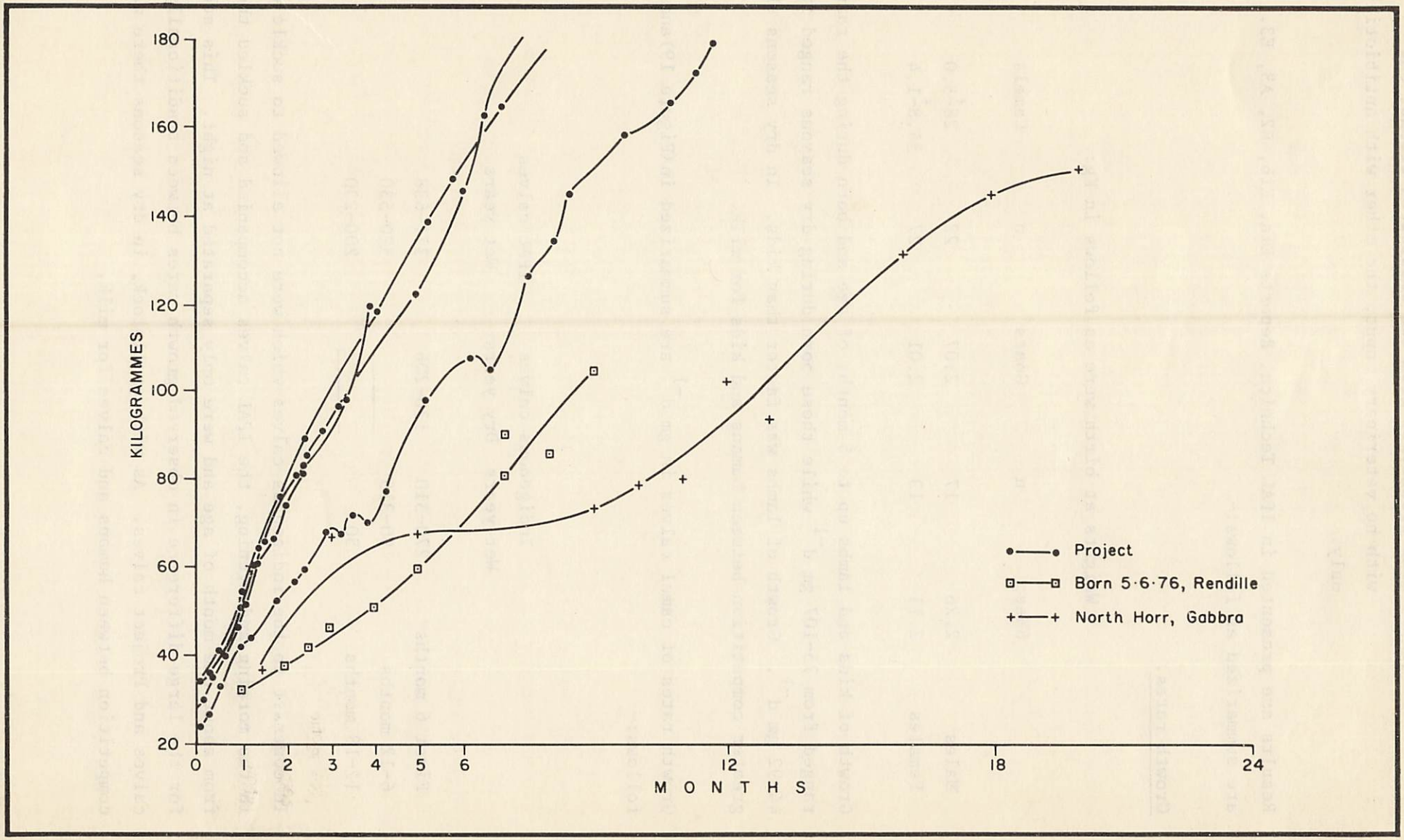
Growth rates of camel calves in gm d^{-1} are summarized in (Figure 19) and as follows:-

	Indigenous calves		IPAL calves
	Wet years	Dry years	Wet years
First 6 months	270-310	170-206	371-638
6-12 months	90-315	_____	520-530
12-18 months	50	_____	200-230

In contrast to the indigenous calves which were not allowed to suckle except in the morning and evening, the IPAL calves accompanied and suckled their dams from about one month of age and were only separated at night. This accounts for the large difference in observed growth rates between traditionally managed calves and Project calves. As with smallstock, in dry seasons there was greater competition between humans and calves for milk.

Figure 19

Camel growth



Milk production. It has been estimated from data from the IPAL flock that annual milk production by Galla goats, assuming 1.5 lactations, is 88 litres and half of this would be available for human consumption. Sheep produce about 59 litres, but only a quarter is available for human consumption because the lamb usually stays with the ewe at night.

In another study on Small East African goats there is no evidence that the length of lactation is a serious constraint, although clearly the total yields are low (Table 7). The other remarkable point is the considerable increase in yield that regular drenching of internal parasites produces - of the order of 35%.

TABLE 7

Lactation Performance

Lactation parameter	Group	
	Undrenched	Drenched
Number of lactations	30	10
Yield (litres)	16.3 ± 10.85	22.0 ± 11.12
Length (days)	175.0 ± 59.8	215.0 ± 64.0

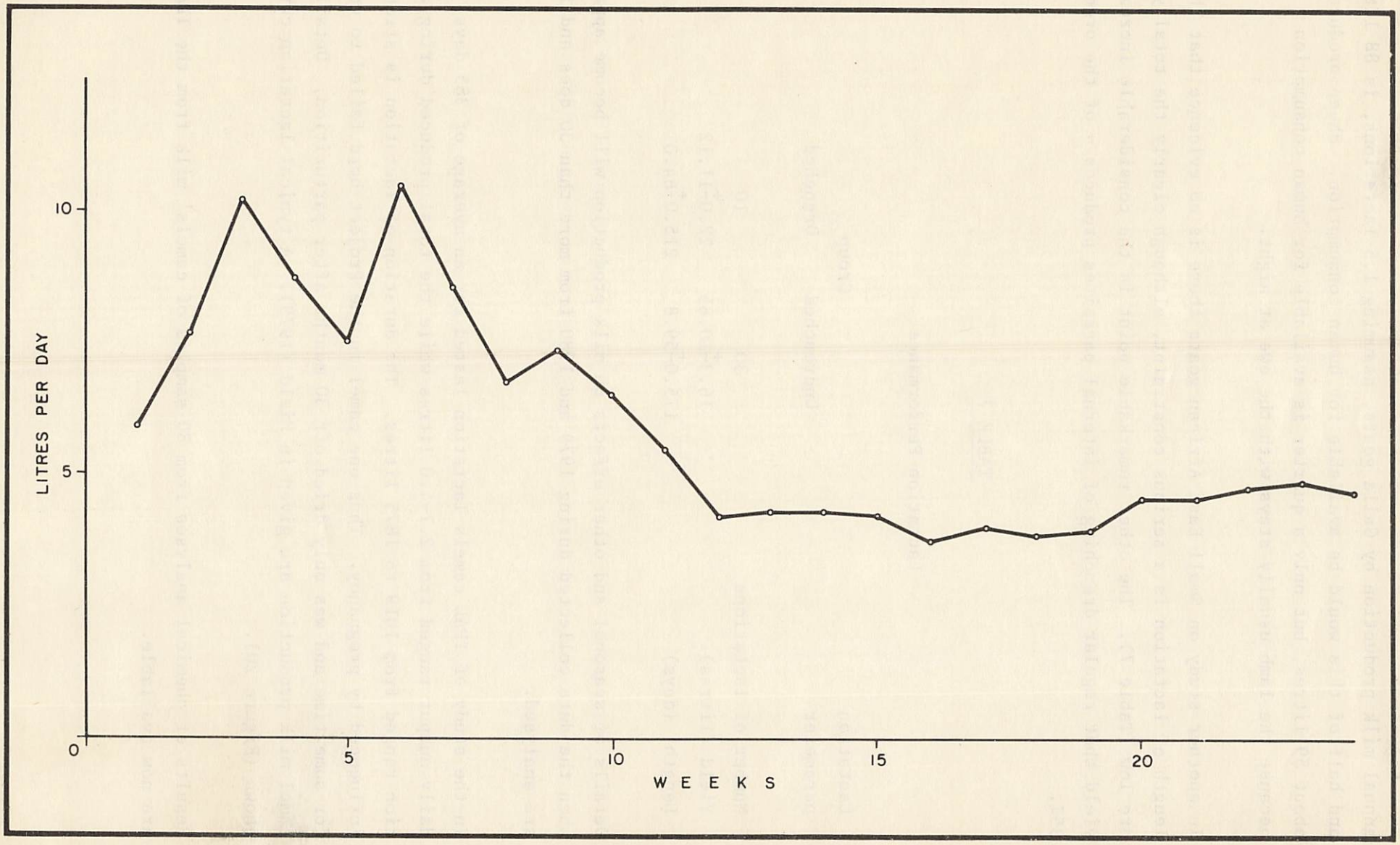
Details of seasonal and other effects on milk production will become apparent when the data collected during 1979 and 1980 from more than 30 does and 15 ewes are analysed.

In the study of IPAL camels lactation lasted for an average of 385 days, daily output ranged from 2.7-4.0 litres while the total produced during a lactation ranged from 1019 to 1875 litres. The duration of lactation is strongly influenced by pregnancy. Thus one camel in the Project herd failed to conceive for some time and was only dried off 30 months after parturition. Details of camel milk production are given in Field (1979). A typical lactation curve is shown (Figure 20).

Results of chemical analyses from 80 samples of camels' milk from the IPAL herd are now available.

Figure 20

Camel No. 5. Milk yield



Fat content of milk shows considerable individual variation and can be as high as 7.5%. In those animals in which there are results from eight monthly collections, mean fat content ranges from 2.11% to 2.73%. There appears to be a decrease in fat content with duration of lactation. These results are 6-23% lower than those quoted in the literature (Dahl and Hjort, 1976).

Reproduction and fertility. In another set of studies of a Project herd the changes in herd size during the 12 month period show that despite an above average proportion of breeding females at the start, the herd decreased in size by 11%, despite only 4 animals having been cropped. The cropping level represents a turnover of 4% which is extremely low for small ruminants.

During the year 32 live births and 11 abortions were recorded (this latter figure is undoubtedly less than the actual level). These indicate a mean maximum conception rate of approximately 83% (rather low), and an abortion rate of over 26% of all pregnancies, which is extremely high.

Analysis of the proportion of services to abortions plus live births confirms this serious picture. For that part of the 12 month period that this was possible the ratio of services per recorded conception was 4.7:1.

A likely major cause of this low fertility is infection with Brucella melitensis. Serum samples were collected from the whole herd on four occasions and examined for Brucella melitensis antibodies. The results (Table 8) show that a significant number of positives are present throughout the year, with a very marked peak following the pulse of births and abortions during April to June.

TABLE 8

The Incidence of Brucella antibodies

Date	Proportion of total sampled		Total
	Positive	Doubtful	Number
	%	%	
23.1.79	6	7	84
28.7.79	29	43	70
10.12.79	13	19	79
2.3.80	23	4	82

Disease - A Constraint to Livestock Production

A simplistic remedy to desert encroachment in northern Kenya would be to reduce livestock numbers by increasing offtake. However, it has been maintained that pastoralists have little or no marketable surplus and that they require all their stock for food, transport and social purposes. If this is so then to avoid undue shortage and suffering an increase in productivity should coincide with any reduction in numbers. This is the philosophy behind a series of experiments conducted by IPAL on constraints to production of smallstock, camels and cattle.

The major constraints to production are nutrition and disease. The former is related to problems of localized overstocking in particular in the vicinity of water and settlements. There is little hope in improving this situation in the short term except perhaps where insecurity precludes the use of part of the grazing range. Improved security and the wider distribution of water will buy time but serve only as temporary gain in the absence of some alleviation of the constraints to offtake. Supplementation of the diet of breeding stock during periods of nutritional shortage in barely feasible because of spiralling transport costs. Similar provisions would apply here with regard to offtake.

Diseases whether acute or chronic may also depress livestock production, but in general those of economic significance are less important in arid than in humid areas. This is because the causal agents or vectors are less active during times of drought.

Transport costs of drugs are not high and their administration may be relatively simple e.g. vaccines are often required on an annual basis.

It was therefore decided that IPAL should investigate the importance of diseases as constraints to production of livestock in the study area. Disease experiments however cannot stand alone in the absence of parallel studies on constraints to offtake. We are therefore placing considerable importance on an economic study of livestock marketing which is running concurrently with the disease studies which themselves include a cost benefit analysis in their design (Njiru, 1980).

A pre-treatment period of six to eighteen months has been spent in the identification and monitoring of the main diseases affecting the species under study. For this purpose a representative sample (>100) of indigenous animals of each species was chosen and monitored at approximately monthly intervals.

The sample animals were then divided into treatment and control groups. On the basis of the findings in the pre-treatment period groups were then given a maximum veterinary input to minimize disease constraints to production. The controls received no veterinary input with the exception of mandatory vaccination for Rinderpest and bovine pleuropneumonia in cattle.

Tick burdens.

a) Camels.

Mean monthly tick counts in two herds fell between the following limits. (Wilson and others, 1981).

Herd 1	Balesa	10 ± 3	to	121 ± 8	)	1979
Herd 2	Ngurunit	41 ± 4	to	100 ± 6	)	1980

The effect of twice monthly acaricide treatment with Bacdip^{R} has been as follows (Rutagwenda, 1981).

1981	April	May	May	June	June	July
Control	68.8	43.5	43.8	67.2	64.0	66.8
Treatment	68.9	76.7	19.4	11.3	25.2	31.8

Treatment began

b) Cattle.

Mean monthly tick burdens ranged from 3 to 36 in lowland areas and 178 to 354 for animals in highland areas.

c) Goats.

Tick burdens in goats were not important.

Tick species composition. In lowland areas various species of the genus Hyalomma were important in camels and cattle. Some of these may be the cause of tick toxicosis in camel calves.

In highland areas Rhipicephalus pulchellus and Amblyomma gemma were important in both camels and cattle. The tick vector of East Coast Fever, R. appendiculatus was not recorded.

Helminthiasis. The incidence of strongyle eggs (mean number per gram Faeces) and the effect of drenching with Panacur^{R} is illustrated in the following table.

TABLE 9

Mean Number of Strongyle Egg per Gram of Feaces

Date	Goats		Date	Camels		Cattle	
	Control	Treated 2% Panacur		Control Panacur	Treated 10% Panacur	Control	Treated 10% Panacur
1.79	1027±1317	-	2.81	-	156	245	-
7.79	380±372	419±219	3.81	126	15	114	-
12.79	857±676	38±80	4.81	127	4	91	-
2.80	500±468	259±578	5.81	265	97	85	-
3.80	1373±1421	27±103	6.81	507	25	120	58
			7.81	429	0	-	-

Data Source: Goats (Carles, 1980; Camels (Rutagwenda, 1981);
Cattle (Field, unpublished)

Pack cell volume. (P.C.V.) The mean PC.V. of undrenched and drenched goat, cattle and camel blood was as follows:

TABLE 10

Mean P.C.V. of Drenched and Undrenched Goats, Cattle and Camels

Date	Goats			Camels		Cattle	
	Control	Treated	Date	Control	Treated	Control	Range
12.79	$24^{+}_{-}4$	$27^{+}_{-}4$	9.80	-	-	33	26-43
2.80	$27^{+}_{-}3$	$29^{+}_{-}3$	5.81	$22^{+}_{-}3$	$22^{+}_{-}4$	29	14-37
3.80	$27^{+}_{-}4$	$28^{+}_{-}3$	7.81	$24^{+}_{-}4$	$26^{+}_{-}5$	-	-

Data Source: Goats (Carles, 1980); Camels (Rutagwenda, 1981); Cattle (Field, unpublished)

Blood protoplasms and trypanosomes. The point prevalence percentage of blood protoplasm and trypanosomes in the different species are indicated in the following table after Carles (1980), Wilson and others (1981) and Field (unpublished data).

TABLE 11

Point Prevalance Percentage of Blood Protoplasm and Trypanosomes

	Marginal bodies	Babesia	Trypanosomes	Trypanosome antibodies
Goats	1.3 - 7.1	0	0	-
Camels Herd 1	-	-	71.4	95.2
Camels Herd 2	-	-	9.7	79.4
Cattle	-	-	0	1.0 - 9.5

Methods involved blood smears for goats; mouse inoculations and antigen tests for Camels and Cattle.

Other infectious diseases. The following table summarizes the point prevalence percentages of our diseases based on antibody studies or clinical tests.

TABLE 12

Point Prevalence Percentages of Four Diseases
Based on Antibody Studies

	Goats	Camels		Cattle
		Herd 1	Herd 2	
Brucellosis	6-29	10-38	15-37	3-8
Camel Pox	-	0	3	-
Foot and Mouth	-	0	70	-
Tuberculosis	-	-	-	8

Data Source: Goats (Carles, 1980); Camels (Rutagwenda, 1981); Cattle (Field, unpublished)

Post mortem analysis. The proportions of positively diagnosed causes of mortality are shown in the following table.

TABLE 13

Positively Diagnosed Causes of Mortality

	Goats %	Camels %	Cattle %
Number examined	40	13	29
Cause of death			
Pneumonia	38	15	24+
Undernutrition	0	0	28
Acute trypanosomiasis	0	15	0
Ephermeral fever	0	15	0
Calf enteritis	0	8	3
Tape worm larvae/cysts	10	8	0
Tick toxicosis	0	8	0
Miscellaneous	8	0	10
Predation	13	15	3
Not diagnosed	32	15	31

+ Although pneumonia was the proximal cause, undernutrition was considered to be the ultimate cause of death in cattle.

Flock/herd dynamics. The following table gives the gross dynamics of the goat flock and camel and cattle herds under investigation together with the time periods to which these figure relate.

TABLE 14

	GOATS					CAMELS					CATTLE				
	NUMBER	ADDITIONS		LOSSES		NUMBER	NUMBER	ADDITIONS		LOSSES		NUMBER	NUMBER	ADDITIONS		LOSSES		NUMBER
	PRESENT 10.3.79	BIRTHS	BOUGHT	DISEASE	PRED ATOR	SLAUGHTER	PRESENT 9.3.80	PRESENT 1.4.77	BIRTHS	LOANS	DISEASE	PRED ATOR	SLAUGHTER	PRESENT 1.4.81	PRESENT 27.8.81	BIRTHS	BOUGHT	DISEASE	PRED ATOR	SLAUGHTER	PRESENT 26.6.81
Breeding females	56	-	2	8	3	-	47	5	-	3	-	-	-	8	60		-	12	-	-	48
Breeding males	2	-	-	-	-	-	2	1	-	-	-	-	-	1	4	-	-	1	-	-	3
Mature castrates	16	-	-	11	-	4	13	3	-	-	-	-	1	2	20	-	11	1	-	19	11
Immatures	17	32	-	16	2	-	18	0	8	6	3	-	-	11	21	19	-	12	-	-	28
Total	91	32	-	35	5	4	80	9	8	9	3	-	1	22	105	19	11	26	-	19	90
Mean annual growth							-12%							36%							-19%
Net offtake *							2%							-22%			11%				
Annual growth rate less net offtake							-10%							14%							

* Net offtake = Slaughtered animals less purchases or loans.

Data source = Goats (Carles, 1980); Camels and Cattle (Field, unpublished)

The data summarized above albeit from ongoing experiments, serve to illustrate some important points.

Growth rates of the herds are poor despite some veterinary input. Disease is clearly important in goats and camels while under-nutrition is a major factor in cattle losses.

Helminthiasis may contribute in varying degrees to chronic lowering of production in goats and camels while it does not seem to be a serious problem in cattle. Likewise, ticks are an added burden to camels but not to goats and only appear to affect cattle pastured in highland areas.

The effect of reducing worm and tick burdens in goats and camels is illustrated by the increase in blood pack cell volume. Agents causing anaemia are apparently less important in cattle.

Other diseases of potential importance are brucellosis and pneumonias in goats and brucellosis, trypanosomiasis and pox in camels. Under-nutrition appears to predispose cattle to pneumonia.

Drugs are available for the prevention or cure of all the above diseases with the exception of camel pox. However, they are relatively expensive, for example a single dose of Panacur^{R} costs US$ 1.50 per cow while Naganol^{R} trypanocide costs US$3.00 per camel. The only exception to this is acaricide which costs approximately US$0.03 per beast.

In the long term sound ecological range management coupled with animal husbandry might prove cheaper. For example improved security against predation and theft could permit grazing at night. In the arid zone this would confer considerable advantages upon domestic stock. Among immediate benefits would be to reduce the risk of reinfection by parasites in night enclosures. Indirect benefits include less destruction of trees for enclosures, increased shade and time spent resting in shade with better water conservation, less dependence on water and reduced time spent searching for food in overgrazed areas around permanent water holes. Wildlife enjoy such conditions and are generally healthier than domestic stock. However, when given access to night grazing the latter perform equally well. Conversely attempts to domesticate wildlife which have involved restricting grazing to diurnal period (Lewis, 1977) have faced similar problems as are being faced by pastoral nomads and their livestock today.

Human Requirements From Livestock

Estimates have been made of Rendille requirements for meat and milk based on the literature, IPAL data on productivity and sixty five questionnaires at households which own camels. Since human protein requirements are fulfilled by less than half (44%) the volume of milk required to provide calorific requirements it follows that milk is a relatively poor source of energy. Preliminary estimates indicate that five lactating camels are required to supply a Rendille household with protein needs and eleven with energy needs. However, an average household owns over 100 head of smallstock and it is likely that limits of survival are reached at about four camels and 120 head of smallstock. While the exact composition of the owners livestock is important it may vary and still supply the required amount of food.

Additional animals are needed for transport and to fulfil social obligations e.g. eight camels are required for a bride price. Any males in excess of these requirements may be sold and/or slaughtered. When converted into cash they may be used to purchase grain which will then supplement milk as an additional source of energy; this is commonly the case with smallstock but less often so with camels, possibly because of the lack of market outlets. Furthermore Rendille have a system of loaning female camels on request to poor people. This has the effect of balancing the extremes between rich and poor. It does not however, apply to male camels or to smallstock which are thus free for trade.

The further analysis of data arising from these past studies will help to elucidate this complex balance between man, his livestock and the environment.

VEGETATION STUDIES

The Basic Resource of the Pastoralists and the Problem of its Excessive Exploitation

The Project's first approach to the investigation of desertification in northern Kenya was to initiate a quantitative ecological study of the interations and relationships between the livestock populations and the vegetation. It was envisaged that at least part of the solution to the most obvious problem, that over-grazing, would depend upon a firm factual basis relating to primary production and animal fodder requirements in the region.

The programme of research on vegetation has maintained its main objectives; in the short term, to identify and describe the processes contributing to desertification in the region and to determine the nature, the rates and the causes of the changes taking place in the vegetation. In the long term, the main objective is to provide, for the Government of Kenya, recommendations on the management of the rangelands (within the context of a more comprehensive programme of land and social reform), which will ensure the maximum sustainable productivity of the region, based upon the rational and controlled use of the vegetation and appropriate rehabilitation measures. The urgency for such recommendations is evident from the rapid deterioration of the vegetation in the inhabited areas with the consequent reduction in livestock productivity, combined with the increasing food requirements of the growing human population. The increase in animal numbers necessary for the support of the pastoralists, together with the continuing reduction in nomadic movement and the trend towards settlement have resulted in the gross overstocking of the country within foraging range of the villages. The programme of research on vegetation was designed to answer the following fundamental questions:

- What major plant communities occur in the region and what are their botanical and physiognomic characteristics?
- What are their distributions and their relationships to altitude, topography, soils, climate and human and animal influences?
- What are the characteristic biomass densities of the two main layers (herb/dwarf shrub and tree) in each major community in relation to mean rainfall, drainage and soil conditions, and to human and animal influences?

- What are the annual primary production levels in each major plant community (in the herb and tree layers) in relation to recent rainfall under different conditions of soil, drainage and use?

The answers to these questions will constitute the base-line information on the vegetation of region upon which future ecological monitoring will depend. A further series of questions has to be posed, the answers to which relate more directly to the management of the vegetation resources:

- What proportion of the annual primary production is available to livestock and what proportion is consumed?
- What proportion of the biomass and annual production of wood is used by the pastoralists for building, fencing and fuel, and what are their annual requirements?
- What is the spatial distribution of utilisation of the vegetation?
- What are the tolerance levels of species and communities to exploitation?
- What are the rates of change in plant biomass and productivity in the different areas in the region in response to human and animal impact?

Several of these questions, together with the final one which concerns the estimation of carrying capacities and other aspects of management, must be answered in collaboration with the livestock ecologists. In this account of the vegetation research completed and in progress in the IPAL study area, published work is summarized and recent and current research is described more fully.

Vegetation description and mapping. The classification, description and mapping of the vegetation of the IPAL study area in south western Marsabit District, was undertaken in the first three years of the Project's operation and published as a technical report (Herlocker, 1979). This basic document is providing a framework for a large proportion of the systematic survey of plant and animal biomass and production, human and animal occupance and the computer analysis of such data. The map is shown as Figure 21 Appendix I. This report lists, describes and maps the nine primary (physiognomic) vegetation types in the region, giving their absolute and relative areas and the criteria for their classification, in terms of life form, height, percentage canopy cover and vertical stratification. Further description is given of the thirty four secondary (physiognomic) types and the seventy three tertiary (botanical community) types into which the author has sub-divided the vegetation, in each case describing the environmental conditions and relationships of the communities concerned and of their dominant species. Seventeen of most important communities (tertiary types) are illustrated

by photographs, ranging from the evergreen forest on Mt. Kulal, through the semi-arid Acacia tortilis woodlands and the arid Acacia reficiens shrublands and Indigofera spinosa dwarf shrublands to the sparse annual grasses (mainly Aristida mutabilis)of the lava deserts. In most cases the distribution of the communities which the author has distinguished can be accounted for on basis of climatic (including atitudinal), and edaphic or drainage criteria. A small number of exceptions to this general rule are of particular interest since they are the communities which appear to have been modified by their histories of land use and which are likely to be in a state of change now. These include the Juniperus procera wooded grasslands and the evergreen to semi-deciduous bushland grassland mosaic of the mountain slopes, which have been derived from the lower levels of the highland forests through frequent grass - burning by the pastoralists. The implications of this progressive reduction in the forest cover are discussed in the following section. The perennial grasslands of the Huri Hills and the northern slopes of Mt. Kulal are maintained by periodic burning and Herlocker comments on the uncertainty of the earlier condition of the former area, while suggesting that latter shows definite evidence of being derived from evergreen forest and semi-deciduous bushland (as a successional stage) by burning. The most interesting and problematical vegetation boundary is that between the very extensive shrublands and dwarf shrublands of the Hedad region. To a great extent this boundary is arbitrarily placed on the map since the change from the former type to the latter is a relatively gradual transition in which trees become less dense and dwarf shrubs become somewhat more numerous, with the plant species concerned being represented in both types with few exceptions. It is difficult to discern any environmental cause for this situation in the Hedad since it cuts across climatic and soil continua and it appears likely to be related to human and livestock occupance. The shrublands of the Hedad appear to occupy the region furthest from permanent water and they correspond closely to the areas of least occupance as determined by the systematic aerial surveys. The distinction between the Hedad shrublands and dwarf shrublands is referred to again in the context of the varying levels of wood biomass and productivity across the region.

The montane forests. The forests of the IPAL study area occupy only 0.5 percent of the region but their importance in the economy and ecology of Marsabit District is clearly very much greater than this small area would suggest. In particular, it is evident that many of the sparse surface springs in the District have their catchments on the mountains. The evidence of progressive destruction of the montane vegetation suggested that there was an urgent need to document

the status of the montane forests, to describe their role in the economy of the region and to make recommendations on their future management.

For these purposes a consultancy was undertaken by a specialist in forest ecology and a comprehensive report has been published in the IPAL technical report series (Synnott, 1979). This report provides an account of the six montane and sub-montane areas which are situated around the perimeter of the IPAL study area, giving their total and demarkated areas, describing their botanical compositions and their histories of protection and conservation and the vicissitudes of fire and other human influences, particularly those of livestock browsing and grazing. The author described how, in the past, the forests have maintained a dynamic equilibrium with the effects of climate, fire and livestock and suggested, "It seems likely that if the human and livestock populations of past generations and the old land use practices continued to prevail with all their periodic fluctuations (induced by war, disease, famine and social practices) the forests would continue to maintain themselves, with no iminent danger of disappearance, affected largely by occasional local catastrophes and climatic fluctuations." The author contrasted this situation with the present one in which a number of modern developments had greatly increased the hazards affecting the forests and demonstrating the urgent necessity for positive conservation measures to ensure their survival. His recommendations included legislation to create forest reserves on Mt. Kulal and the upper levels of Oldoinyo Mara (the main forested areas still unprotected legally at the time the report was written), regulation of fuel wood collection, controlled grazing, the piping of water away from forest springs, and tree planting in suitable localities. He also recommended the continued monitoring of forest areas through the use of new aerial photography for comparison with the old series and through double-edge enhanced imagery based on LANDSAT photographs, preferably for two different periods or seasons (e.g. during the long drought of 1968-76 and following a recent wet season).
It is of considerable significance that since Synnott's report was published, a legally established forest reserve has been declared by the Government of Kenya on Mt. Kulal, for which the boundaries are now being demarkated.

Tree planting and forestry programmes. In accordance with the Project's aim of seeking direct remedies for desert encroachment, considerable attention was given during the first three years of work to tree planting. It was envisaged that, despite the known difficulties of planting trees in the arid zone, particularly in the absence of water for irrigation, trial planting of drought adapted species might have limited success, at least in settlements. The Project staff were aware that tree planting on an operational scale was not feasible and was outside their

terms of reference, but understood that the establishment of experimental nurseries and trial plots should be attempted. Considerable justification for such an attempt lay in the fact that the Kenya Forestry Department was not at the time engaged in arid zone forestry trials. Although the Project Evaluation Mission in 1980 decided that IPAL should discontinue its tree planting experiments owing to the need to concentrate its research and to make more effective use of its limited funds and staff the results achieved prior to this decision are considered sufficiently positive to report.

The tree planting programme started in 1976 with the establishment of nurseries at Gatab (in the sub-humid zone on Mt. Kulal) and at Balessa Kulal in the arid zone. At the same time the Project agreed to cooperate with the Catholic Mission at North Horr and the Africa Inland Mission at Kalacha where other tree nurseries had already been started. The results of the planting out from these nurseries have been described in a recent comprehensive report by Herlocker and colleagues (1981) in which tree planting trials in the IPAL study area are compared with others in the Baringo area of central Kenya. The report describes seed sources, nursery practices, germination trials, planting sites and methods, maintenance and watering. Relative success with certain species (and of failure with others) is analysed, the best "performers" in the arid sites being Prosopis chilensis, Parkinsonia aculeata and Azidarachta indica. In late 1978 and early 1979 a three month consultancy was undertaken on the needs and prospects for tree planting in Marsabit District. The results are contained in an IPAL technical report (Synnott, 1979). The author discussed the processes of desertification through the destruction of the indigenous vegetation, drawing attention to the salient fact that it is in the vicinity of permanent settlements, most of which are of recent development, that nearly all serious destruction of trees and shrubs is taking place. The author discussed the use of wood for fuel and livestock fencing materials, giving estimates of the pastoralists' requirements. This subject is discussed below in connection with wood production and utilisation. The author assessed the results of tree planting already accomplished in the District, pointing out that the degree of success achieved by the Missions demonstrated that any household or institution with access to water, and with control over its own compound, can quite easily grow a wide range of tree and shrubs to provide at least some of its own day-to-day needs for fuel and building poles; for fruits and some edible leaves; for some of its fence construction; and for shade from the sun, shelter from the wind and protection from dust.

Such examples showed that other institutions such as schools, medical centres, and police posts often had enough ground for hundreds of trees, including boundary hedges and large shade trees. Even the smallest household in a crowded village can maintain one or two trees or shrubs as had been shown in the village of North Horr. The author gave lists of suitable situations for tree planting and listed the benefits to be obtained. He discussed the possibilities of planting trees and shrubs for rangeland improvement, suggesting the use of Prosopis, Atriplex, Acacia, Opuntia and Haloxylon spp. on the basis of experience with these species in Tunisia and Chile where large yields of fodder have supported high sheep densities in almost rainless areas and with shallow brackish water-table. Nevertheless, as he pointed out, at present in a region of unrestricted grazing, it is not feasible for any private livestock owner or for Government to plant significant areas of rangeland shrubs. With the introduction of grazing control it may be possible to establish shrubs by planting or seeding if parts of the rangeland can be closed to grazing for one to two years. Although there is almost no experience of rangeland improvement in tropical Africa, the success achieved locally in north Africa through planting, suggests that field trials with a few shrub species would be worthwhile. For this and other purposes Synnott recommends species likely to be successful, procedures for carrying out trials, follow-up extension work, surveys of wood requirements, the testing of live fences, and a survey for the potential of a gum arabic industry based upon the indigenous tree Acacia senegal. He provides a guide to tree planting with information on site selection and tolerances and the principle uses of recommended species. With particular reference to the IPAL study area he discusses site types and briefly assesses the performance of tree and shrubs already planted.

Although, through the lack of resources, it has not been possible for IPAL to follow up this very comprehensive set of recommendations, it is hoped that future research and development activities in the region will benefit from them. The foregoing study is complemented by a published report by Herlocker (1979b) on the procedures for implementing forestry programmes for local community development in Marsabit District in Kenya. The author proposed a cooperative programme supported jointly by the Government of Kenya, several Catholic and Protestant Missions, the National Christian Council of Kenya and IPAL with the aim of providing employment for the residents of settlements; providing wood for fuel and building materials; establishing tree crops usable as cash crops for subsistence and re-establishing a vegetative cover for denuded areas. The proposal was likely

to receive enthusiastic support within the District. In general, Herlocker suggested strategies suitable for the local conditions but pointed out the prior necessity for ensuring adequate water supplies for the irrigation of nurseries. There are small number of suitable sites with limited water supplies which could be used for forestry trials in Marsabit District.

With regard to the utilisation of the indigenous trees, the author further proposed the managed exploitation of the Acacia tortilis woodlands and the Acacia tortilis woodlands and the Acacia reficiens shrublands for the production of high quality charcoal. However, he stressed the need for adequate control of such a scheme to ensure that offtake would not exceed production and stressed that the responsibility for such control would rest with the Government or the Marsabit District Council. Further possibilities for the economic exploitation of the natural vegetation, indicated by Herlocker, include the harvesting of gum arabic from the Acacia senegal woodlands and the collection of Aloe species, both of which are marketable commodities. As with the production of charcoal, such harvesting should be regulated by Government and, if trial collections proved successful, there is the possibility of planting both species to improve production. One area in particular in Marsabit District, the Huri Hills, offers possibilities for reafforestation and the author suggested that species trials should be carried out. Oral tradition indicates that the Huri Hills once supported forest, (now confined to the deeper east-facing canyons). This recommendation has been followed up with the experimental planting of several useful tree species by the Africa Inland Mission. Heavy mists occur for several months of the year and its seems possible that the re-establishment of trees may set in train an improvement of the water catchment through condensation from the cloud and a increase in the flow of the springs. This proposal for forestry on the Huri Hills now forms part of more comprehensive guidelines management for that area which have been prepared jointly by IPAL and the Africa Inland Mission (Herlocker and colleagues, 1981). Since these guidelines are subject to discussion and confirmation, they have not been published yet and they will not be discussed in this report.

Primary Production in the Herb Layer and its Relationship to Rainfall

Following the mapping and description of the vegetation of the IPAL study area, the second priority in the programme of vegetation studies was the measurement of primary production in the herb layer. This study has been undertaken by

Herlocker and is the subject of a report (Herlocker and Dolan, 1981) in which the second author has provided the statistical analysis of the results. The importance of obtaining production values for the herb layer (and the dwarf-shrub layer which is included for the purposes of this report) lies in its significance as a determinant for livestock carrying capacity and localised stocking rates. Whereas the general composition of the vegetation reflects the environmental condition of the site in question, which includes the level of mean annual rainfall, the production in the herb layer within any ecoclimatic zone in which water is limiting closely reflects the actual recent rainfall. Primary production will therefore be expected to fluctuate as much from year to year as the highly variable rainfall does. The implications of this variability for carrying capacity and other management issues are discussed elsewhere in this report.

The first vegetation communities selected for the measurement of primary production were the annual grassland, the dwarf shrublands and the perennial grasslands. The first two vegetation types are the most extensive within the study area together comprising 60 percent of the total area. The perennial grasslands are the most important cattle habitat. The annual grasslands and the dwarf-shrublands are important sheep and goat range and dwarf shrubs are an essential part of the diet of camels. The technique for sampling net standing crop of herbaceous (and small dwarf-shrub) vegetation is well known and easy to execute and can be used without the need for prior experiment, testing and calibration (Brown, 1954; Mannetje, 1978).

Methods and results. Primary production was sampled by clipping plants within 0.5 m^2 quadrat frames at the peak of the growing season in order to obtain net standing crops. New growth (leaves and new twigs) were separated from old growth of dwarf-shrubs (Gimmingham and Miller, 1968). Nine fenced enclosure sites were sampled twice a year during 1976 and 1979 following the end of the rains, which have a bimodal pattern in northern Kenya (Edwards and colleagues, 1979). Four arid zone (annual grassland and dwarf-shrubland) and five semi-arid (perennial grassland) sites were sampled. Clipped vegetation was divided and placed in paper bags in the field on the basis of species, standing dead, herbaceous litter and this season's growth. Samples were air dried for one month, weighed and sub-sampled for oven drying. Rainfall was measured by raingauges in the enclosures or within 3 km of them. Different aspects of (a) annual rainfall and (b) seasonal rainfall were used to predict primary production in annual and perennial grasslands respectively. The data were analysed using the stepwise multiple regression analysis (XDS 3) available on the Nairobi University Computer.

Of the four different aspects of annual rainfall included in the analysis, it was found that total annual rainfall and rainfall of more than 10 mm per month were highly correlated with each other and accounted for the variation observed in primary production in both annual and perennial grasslands. Of the other two aspects of annual rainfall in the analysis, (number of months with less than 10 mm per month and the longest consecutive period in months with over 10 mm rainfall) it was found that both accounted for very little of the variation observed in primary production. Total annual rainfall was tested as a predictor for primary production and shown to be highly correlated with production in perennial grasslands and low correlation with production in annual grasslands. Figures (22 and 23) show the rainfall primary production relationship in both annual and perennial grasslands observed in the IPAL study area over a range of 150 to 1200 mm annual rainfall and a range of 300 to 17,500 kg ha^{-1} yr^{-2} oven dry weight primary production. In relation to seasonal rainfall, annual grassland production was not shown to be significantly correlated with any measurements. Perennial grassland production was significantly correlated with (a) rainfall since the last dry period, (b) total rainy season rainfall, and (c) quarterly rainfall. The single best predictor of primary production in the perennial grassland is

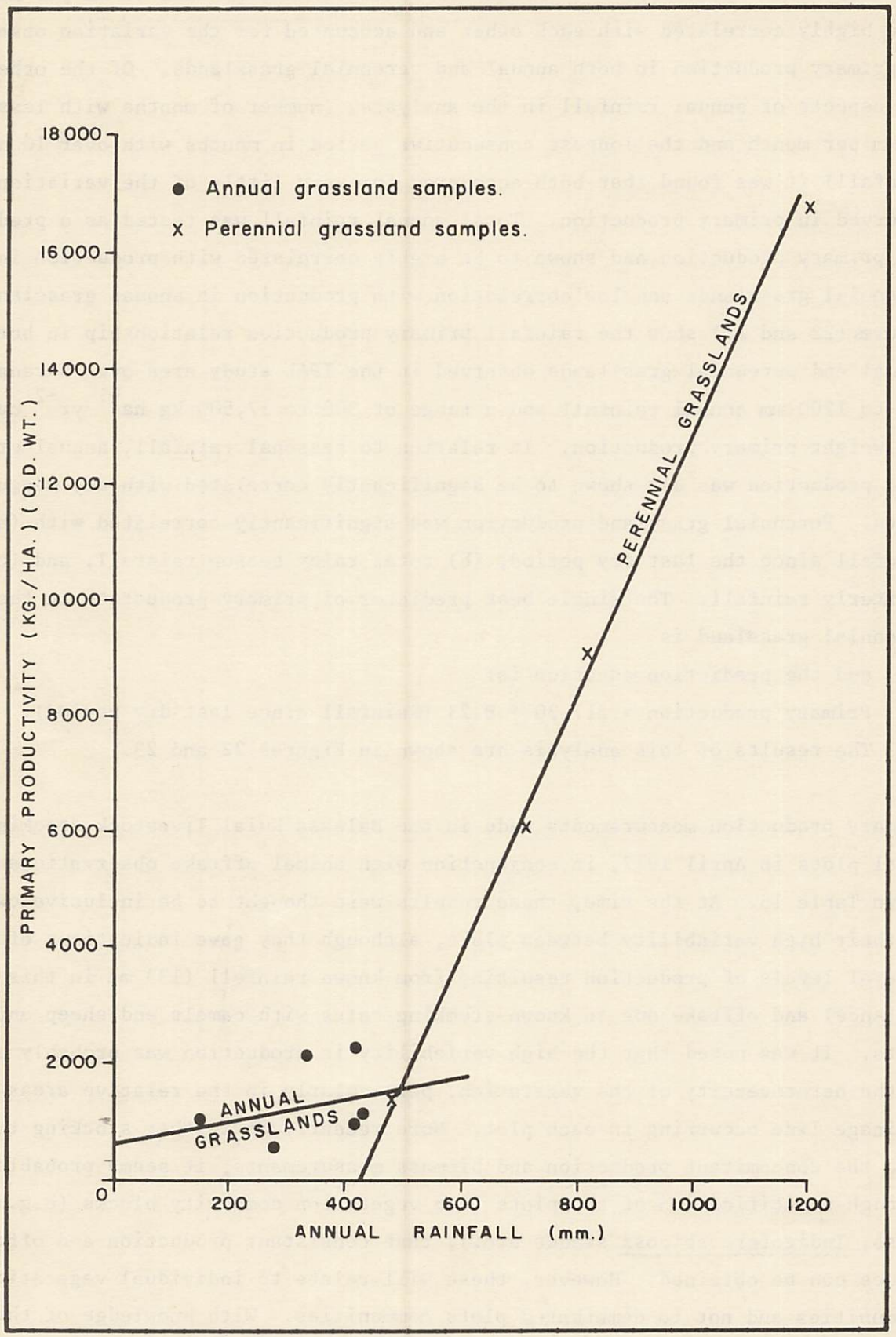
(a) and the prediction equation is:

Primary production = 217.30 + 8.23 (Rainfall since last dry period).

The results of this analysis are shown in Figures 22 and 23.

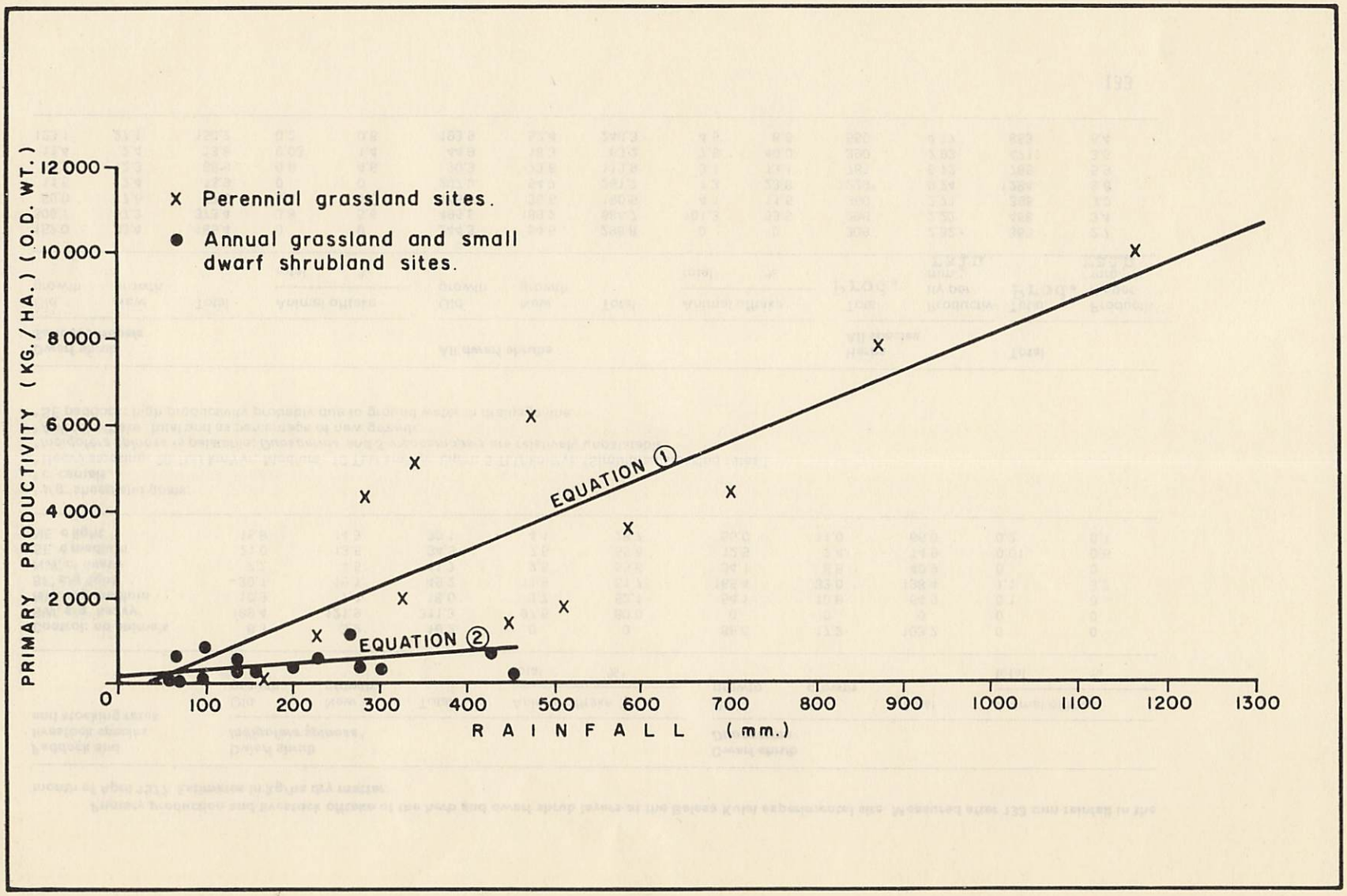
Primary production measurements made in the Balessa Kulal livestock stocking trial plots in April 1977, in conjunction with animal offtake observations are shown Table 15. At the time, these results were thought to be inclusive owing to their high variability between plots, although they gave indications of the general levels of production resulting from known rainfall (133 mm in this instance) and offtake due to known stocking rates with camels and sheep and goats. It was noted that the high variability in production was probably due to the heterogeneity of the vegetation, particularly in the relative areas of drainage line occurring in each plot. More recently in further stocking trials, with the concomitant production and biomass measurements, it seems probable that through stratification of the plots into vegetation community blocks (e.g. annual grass, Indigofera spinosa stands etc.), that consistant production and offtake values can be obtained. However, these will relate to individual vegetation communities and not to demarkated plots communities. With knowledge of the relative areas of the different communities within each major vegetation type, these results can be extrapolated over wide areas within the region.

Figure 22



Rainfall/primary productivity relationships (annual productivity) for (1) perennial grasslands (2) annual grasslands

Figure 23



Relationship between seasonal productivity of (1) perennial grasslands, and (2) annual grasslands with seasonal rainfall since the last dry period.

Table 14

Primary production and livestock offtake of the herb and dwarf shrub layers at the Balesa Kulal experimental site. Measured after 133 mm rainfall in the month of April 1977. Estimates in kg/ha dry matter.

Paddock and livestock species and stocking rates	Dwarf shrub *Indigofera spinosa*[4]					Dwarf shrub *Duosperma*				
	Old growth	New growth	Total	Animal offtake		Old growth	New growth	Total	Animal offtake	
				total	%[5]				total	%
Control: no animals	6.3	3.9	10.2	0	0	86.0	17.2	103.2	0	0
SW. s/g[1] heavy[3]	189.4	121.9	311.3	97.5	80.0	0	0	0	0	0
NW. s/g medium	10.9	7.1	18.0	3.7	52.1	54.1	10.8	64.9	0.1	0
SE. s/g light	30.1	19.1	49.2	11.9	61.7	165.4	33.0	198.4	1.1	3.2
NW. c[2] heavy	7.2	4.5	11.7	2.5	55.6	34.1	6.8	40.9	0	0
SE. c medium	21.0	13.5	34.5	7.5	55.6	12.5	2.4	14.9	0.01	0.5
NE. c light	15.8	14.3	30.1	4.1	28.7	55.0	11.0	66.0	0.2	0.1

[1] s/g: sheep and goats.
[2] c: camels.
[3] Heavy stocking: 20 TLU km²/yr; Medium: 10 TLU km²/yr; Light: 5 TLU km²/yr. (Simulated stocking rates.)
[4] *Indigofera spinosa* is palatable; *Duosperma* and *Sericocomopsis* are relatively unpalatable.
[5] Animal offtake: total and as percentage of new growth.
[6] SE paddock: high productivity probably due to ground water in drainage line.

Dwarf shrub *Sericocomopsis*					All dwarf shrubs					Herbs All species		Total	
Old growth	New growth	Total	Animal offtake		Old growth	New growth	Total	Animal offtake		Total Prod.	Productivity per mm rain	Total Prod.	Productivity per mm rain
			total	%				total	%				
152.0	33.4	185.4	0	0	244.3	54.5	298.8	0	0	309	2.32	363	2.7
306.1	67.3	373.4	3.8	5.6	495.5	189.2	684.7	101.3	53.5	296	2.22	458	3.4
80.0	17.6	97.6	0.3	1.8	145.0	35.5	180.5	4.1	11.5	360	2.71	395	3.0
11.5	2.4	13.9	0	0	207.0	54.7	261.7	1.3	23.8	1229[6]	9.24	1284	9.6
56.2	12.3	68.5	0.6	4.6	90.3	23.6	113.9	3.1	13.1	761	5.72	785	5.9
11.4	2.4	13.8	0.03	1.4	44.9	18.3	63.2	7.5	40.0	390	2.93	471	3.5
123.1	27.1	150.2	0.2	0.6	193.9	52.4	246.3	4.5	8.6	555	4.17	853	6.4

Woodlands: Their Productivity and Exploitation

The background and the problems. Trees have three important roles in the arid zone in northern Kenya, seen from the standpoint of the pastoralist populations. They provide firewood, materials for the construction of houses and livestock enclosures, and they provide browse for the livestock upon which the pastoralists are almost wholly dependent for their subsistence. In addition to these three essential contributions the the pastoral economy, which will be the main subjects discussed in this section, trees are valued for their shade (an important factor in the survival of cattle and small stock in the arid zone) and some for their fruit and other useful products, such as fibre for rope and gum for the gum arabic industry. Their roles in the maintenance of soil fertility and in the reduction of soil erosion and dessication, although of crucial importance; remain to be investigated systematically and will not be discussed here.

The reduction and eventual loss of the tree layer in areas of exceptionally heavy livestock and direct human exploitation almost invariably take place several years after the destruction of the herb layer through over grazing and trampling. Very large areas of rangeland which are now in the intermediate between these two stages of desertification, where the soil surface is almost totally denuded but where the tree populations are relatively unharmed, can be seen in the Samburu and Baringo Districts of Kenya. Indeed it appears that, in the process of degradation of the wooded grasslands of the arid and semi-arid zones of Eastern Africa, a stage is passed through in which the reduction or removal of the grass results in vigorous growth of small trees, mainly Acacia species. This is due to the lack of root competion for the seedling trees and the absence of grass fires which normally limit tree growth and effectively maintain the patterns of scattered trees, or of woodland and grassland mosaics, characteristics of under-graded rangelands in East Africa. In the semi-arid grasslands of Kenya the destruction of the herb layer through overgrazing frequently leads to the growth of tree and shrub thickets, such as the Acacia mellifera thickets of Longido in northern Tanzania and Baringo and Samburu in Kenya. In the arid regions with less than 300 mm mean annual rainfall, covering a large proportion of northern and eastern Kenya and also substantial areas in Somalia and southern Ethiopia, the low and erratic rainfall does not support a sufficient biomass density of trees to enable thickets to form, despite the absence of grassfires, except along some seasonal watercourses. The most extensive vegetation community across more than 200,000 km^2 in north eastern Africa are the relatively open dry shrublands (as defined by Pratt and Gwynne, 1977) in which the small trees Acacia reficiens

and Acacia mellifera are dominant or co-dominant. Within the IPAL study area these communities constitute 26 percent of the area, while the two Acacia species, together with several others, occur as the dominant trees in a further 60 percent of the region which is occupied by annual grassland and dwarf shrubland (Herlocker, 1979).

Over the greater part of Marsabit District, in which the IPAL studies are taking place, the herb layer has been affected to varying degrees by overgrazing. In the vicinity of wells, springs and boreholes, which provide perennial sources of water, the grasses have been greatly reduced or almost totally removed. In the south west of the district, inhabited by the Rendille people, the denuded soils extending outwards from the settlements for as much as 30 km, may coalesce, as they do between the villages of Korr and Ilaut. In such areas the tree populations have also been greatly reduced but have not been totally destroyed. Nevertheless, the process of excessive tree felling and lopping is continuing, although apparently at a slower rate than the loss of the herb layer through overgrazing and trampling.

The direct causes of tree destruction are clear. Wood is required by the pastoralists for fuel and also for the construction of livestock pens. In the areas of human and livestock concentration, tree felling is taking place at a rate which is faster than the recruitment of young trees to the woodland populations can take place. Although there are normally many young and repressed trees available for recruitment to the mature tree populations in such areas, their growth above half a meter in height is normally prevented by the browsing of goats. The main indirect cause of excessive tree destruction is the increasing settlement of formerly nomadic pastoralists, resulting in the growing impact of tree felling upon the woodlands close to the settlements. As the supplies of wood in and around the villages are exhausted, the people are obliged to travel further each year to obtain it.

In great contrast to the over-exploited woodlands near the settlements, as much as 40 percent of the IPAL study area is occupied by woodlands which are very little used, mainly owing to the lack of security from inter-tribal raiding. Such unexploited regions show clearly the potential productivity of the ecoclimatic zones in which they are situated and provide standards against which the nature and degree of the degradation in the inhabited areas can be assessed.

It is against this background of extremely uneven use of the land resources that the woodland research programme is being undetaken. Essentially the main

question to be answered by the research is: How can woodland exploitation be managed to ensure the maximal sustained production of the tree populations for the benefit of the pastoralist people and the country as a whole? The second question concerns the size and disposition of the existing and potential productivity of the woodlands and hence their potential contribution to the subsistence of the pastoralist populations and to the wider economy. It is clear that the management of the woodlands should only be undertaken as an integral part of the coordinated management of the region's land and other resources. Detailed information is needed on woodland dynamics and productivity on the one hand, and potential human utilization of the woodlands on the other, to ensure rational management of this resource on a sustained yields basis within the overall planning. The management of the tree populations must be integrated with the regulation of land use in general, with water resource management, with settlement policy, with the provision of substitute building and fencing materials and with tree planting, to help accelerate rangeland rehabilitation and the provision of fuel and building materials.

Woodland dynamics and productivity. In order to provide the data necessary for the future management of the tree populations, especially with a view to preventing further depletion and providing an adequate sustained production for the support of the human and livestock populations, two main lines of enquiry are being followed by IPAL. The first concerns the measurement of biomass and production of the main woodland communities, based upon both ecoclimatic zonation and upon human and livestock distribution. The second concerns the establishment of the baselines for a programme for monitoring trends in the tree populations. The two aims overlap since levels of biomass and productivity are likely to be important criteria in assessing change. A third line of enquiry which has been followed by Herlocker and Walther (1981) and which should be extended, is the measurement of human requirements for wood. The fourth line concerns the production and consumption of browse in the support of livestock populations. These four aspects of woodland ecology are discussed in the following sections. In each case the research activities concerned are dependent upon the analysis and mapping of the vegetation communities of the study area by Herlocker (1979) in the initial phase of IPAL.

Woodland species, community and size class structures. The woodland and shrubland communities of the IPAL study areas were described and mapped by Herlocker (1979) in qualitative terms. Within the 200 - 250 mm mean annual rainfall zone the extensive shrubland dominated by the small tree species Acacia reficiens

appear to be relatively homogeneous in species composition, plant density and size class structure. It covers 20.3 percent (4649 km^2) of the study area. The main exceptions to the general homogeneity of this community occur along drainage lines, where there is a relatively high plant density, on lava outcrops within the predominantly sandy plains, along the interzone with Acacia mellifera shrublands and in the vicinity of human settlement, where the herb and dwarf shrub layers may be sparse and the tree density below the average for the community as a whole. The relative homogeneity of this, and the similar Acacia mellifera shrubland zone make it possible to obtain quantitative data on their species and size class structures, as well as on their biomass densities, from samples which are likely to be representative of large areas in the region. To obtain such data a programme of research on the productivity and the successional trends within the important tree communities is in progress which depends upon the measurement and weighing of trees in sample areas of shrubland, the study of growth and foliage production, the description of community species, size and age class structures, and the calculation of biomass density and production for representative areas within each of the major woodland strata.

The field station at Olturot lies at a meeting place of three major woodland communities and is the base for the woodland study programme. The first eight months of this programme have provided early results. In analysing the structure of woodlands for the purpose of understanding their potential diversity and productivity and the changes which take place due to human and livestock influences, three aspects of structure may be examined. As a first approach to the analysis of the Acacia dominated shrublands, a series of observations are being made which will provide structure analyses along gradients of intensity of exploitation from the little used areas adjacent to the Balessa Kulal watercourse, eastwards towards the heavily exploited areas in the vicinity of Kargi settlement and south-eastwards towards the settlement of Korr. The first series of observations has been completed in the Acacia mellifera and Acacia reficiens zones near the Balessa Kulal. The results are summarized in Figures 24 and 25. The data are derived from the woodland trasect which has been carried out according to the method described by Leithead (1979). Both the species and the size class structures have been expressed as trees per hectare and, in the case of the two histograms shown, are the results of a 2 km transect section across Acacia shrubland in which Acacia reficiens and A. mellifera are the dominant species and eight other tree species are recorded.

The results of the transect have been checked by the examination of large scale aerial photographs of the same woodland are overlayed with grids of 1 ha squares.

Figure 24

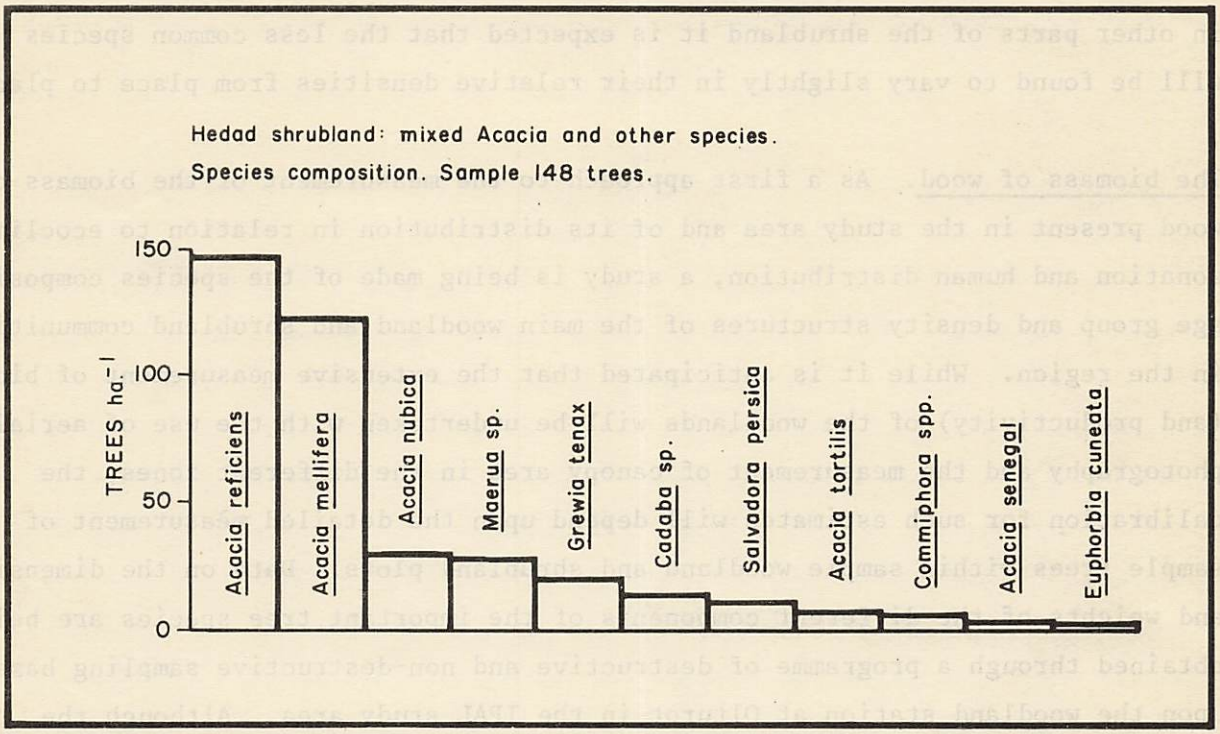
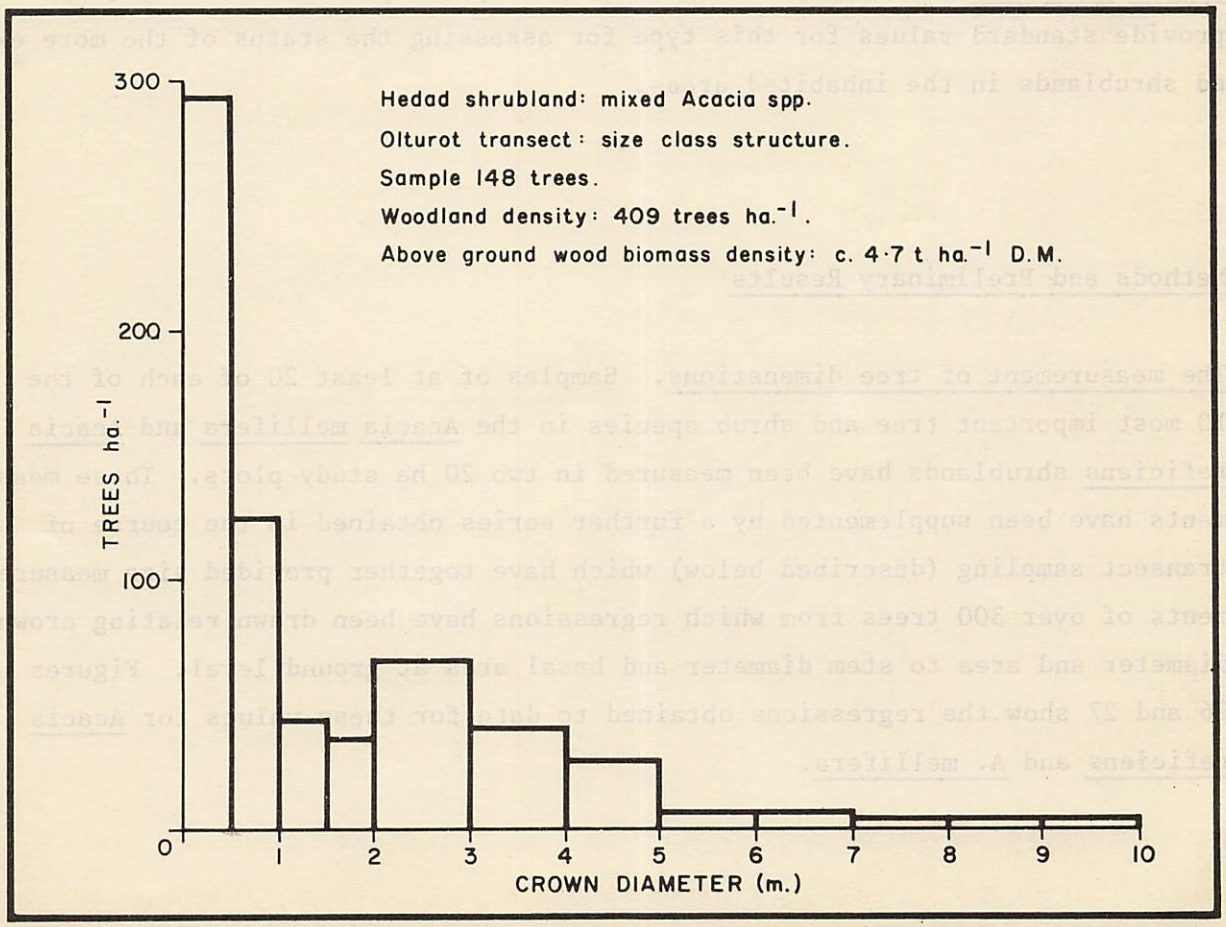


Figure 25



While the species composition histogram reflects the dominance of the two common Acacia species, it is uncertain whether the relative densities shown for the other nine species are significant. From non-systematic observations made in other parts of the shrubland it is expected that the less common species will be found to vary slightly in their relative densities from place to place.

The biomass of wood. As a first approach to the measurement of the biomass of wood present in the study area and of its distribution in relation to ecoclimatic zonation and human distribution, a study is being made of the species composition, age group and density structures of the main woodland and shrubland communities in the region. While it is anticipated that the extensive measurement of biomass (and productivity) of the woodlands will be undertaken with the use of aerial photography and the measurement of canopy area in the different zones, the calibration for such estimates will depend upon the detailed measurement of sample trees within sample woodland and shrubland plots. Data on the dimensions and weights of the different components of the important tree species are being obtained through a programme of destructive and non-destructive sampling based upon the woodland station at Olturot in the IPAL study area. Although the programme is in progress and, in the eight months since its inception has sampled a limited area of woodland, sufficient data have been obtained to provide preliminary values for the composition and biomass density of the very extensive Acacia reficiens shrublands in their relatively unexploited condition, to provide standard values for this type for assessing the status of the more exploited shrublands in the inhabited areas.

Methods and Preliminary Results

The measurement of tree dimenstions. Samples of at least 20 of each of the 10 most important tree and shrub species in the Acacia mellifera and Acacia reficiens shrublands have been measured in two 20 ha study plots. These measurements have been supplemented by a further series obtained in the course of transect sampling (described below) which have together provided size measurements of over 300 trees from which regressions have been drawn relating crown diameter and area to stem diameter and basal area at ground level. Figures 26 and 27 show the regressions obtained to date for these values for Acacia reficiens and A. mellifera.

Figure 26

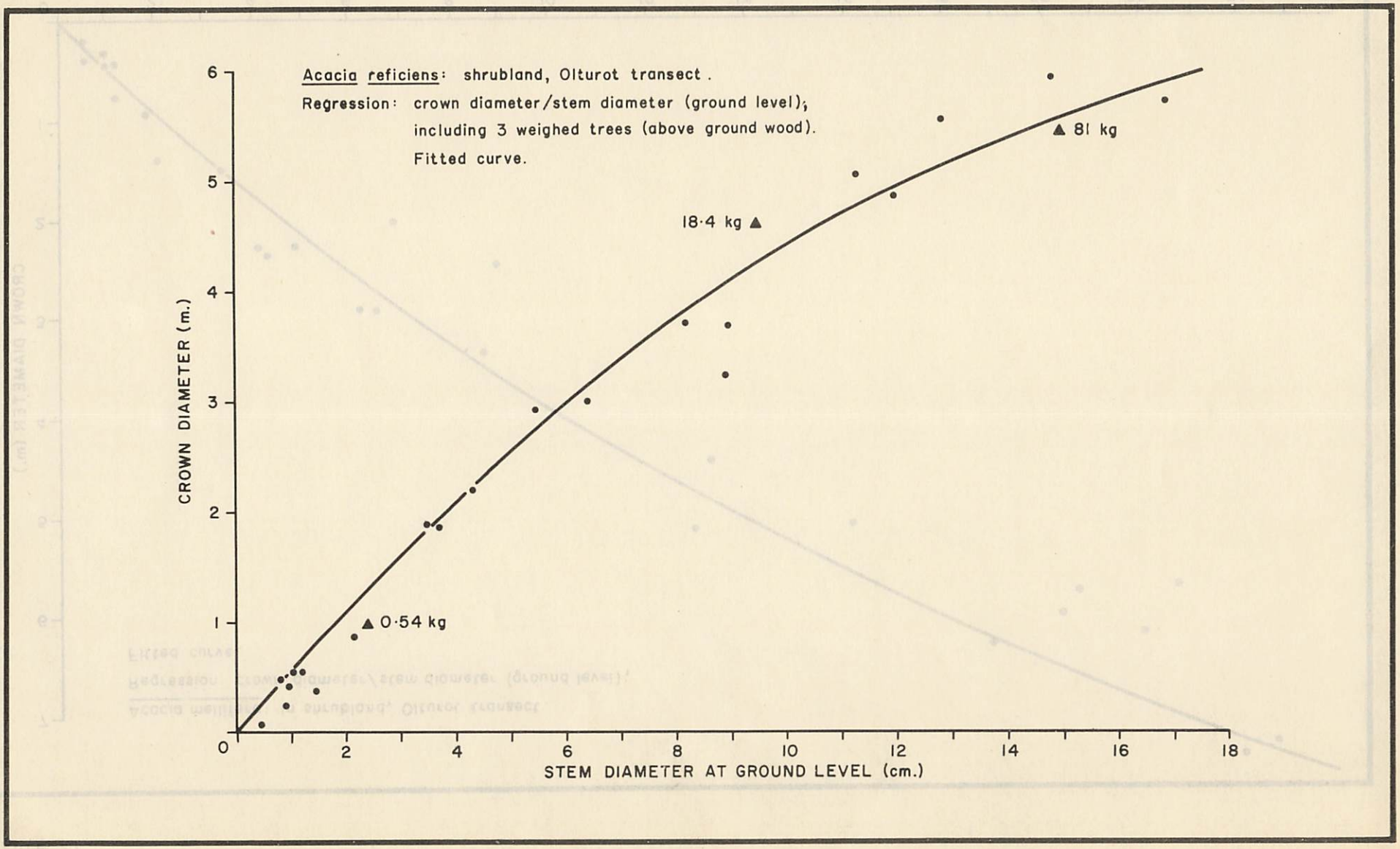
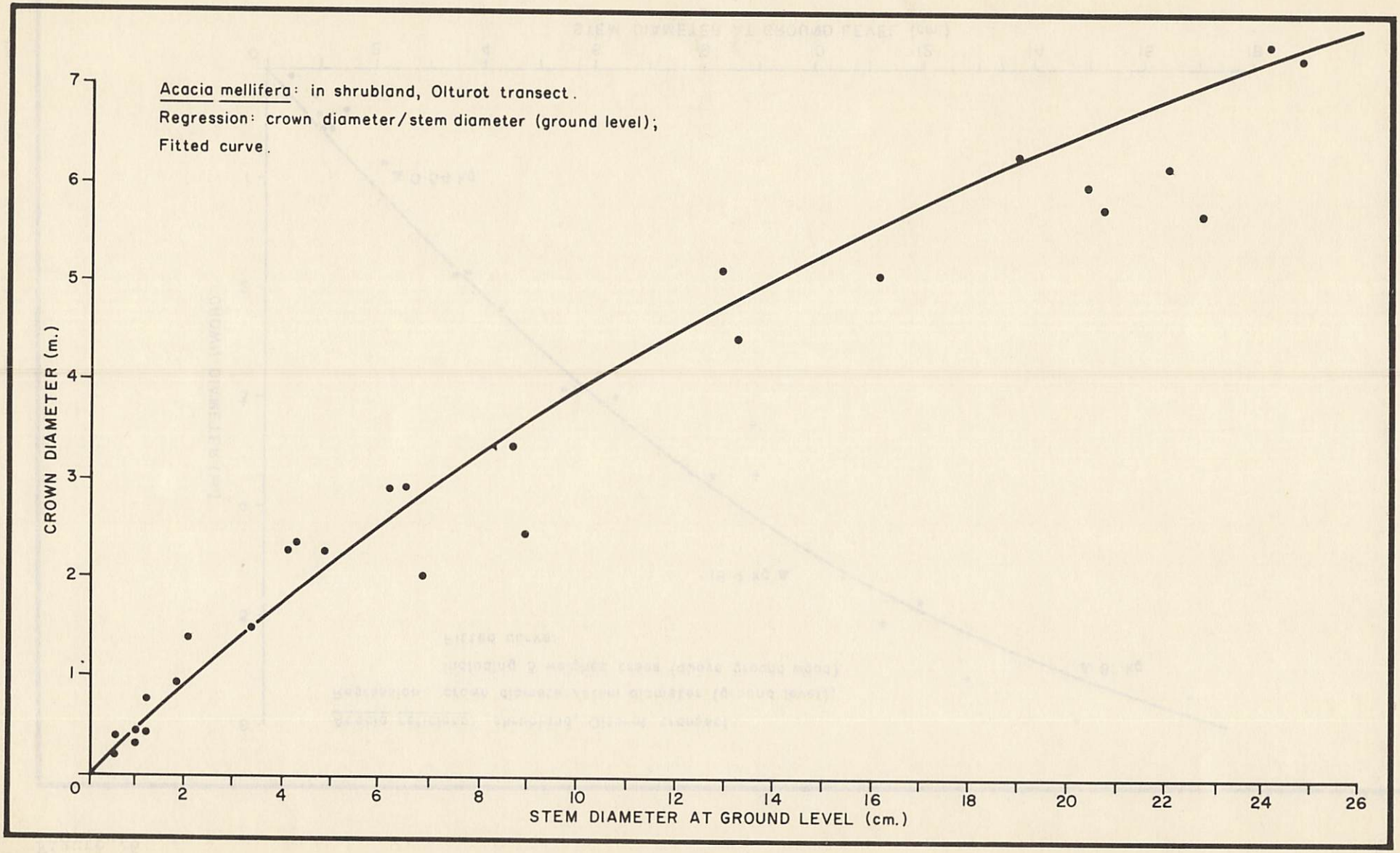

Acacia reficiens: shrubland, Olturot transect.
Regression: crown diameter/stem diameter (ground level);
including 3 weighed trees (above ground wood).
Fitted curve.
▲ 81 kg
18·4 kg ▲
▲ 0·54 kg
CROWN DIAMETER (m.)
STEM DIAMETER AT GROUND LEVEL (cm.)
0
1
2
3
4
5
6
2
4
6
8
10
12
14
16
18

Figure 27

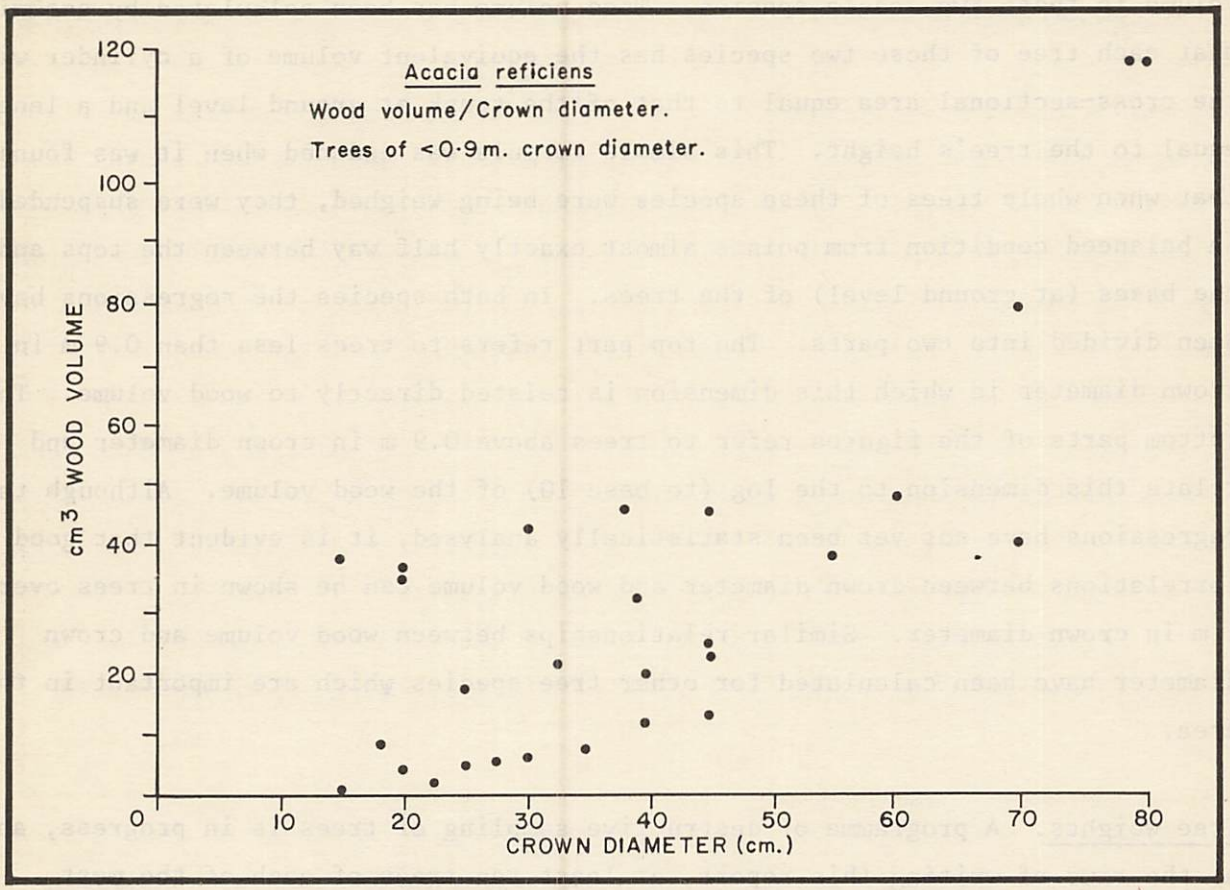

Acacia mellifera: in shrubland, Olturot transect.
Regression: crown diameter/stem diameter (ground level);
Fitted curve.
CROWN DIAMETER (m.)
0
1
2
3
4
5
6
7
2
4
6
8
10
12
14
16
18
20
22
24
26
STEM DIAMETER AT GROUND LEVEL (cm.)

Figures 28 and 29 show further regressions relating crown diameter to wood volume in these two Acacia species. Wood volume has been calculated by assuming that each tree of these two species has the equivalent volume of a cylinder with the cross-sectional area equal to that of the trunk at ground level and a length equal to the tree's height. This simple formula was deduced when it was found that when whole trees of these species were being weighed, they were suspended in balanced condition from points almost exactly half way between the tops and the bases (at ground level) of the trees. In both species the regressions have been divided into two parts. The top part refers to trees less than 0.9 m in crown diameter in which this dimension is related directly to wood volume. The bottom parts of the figures refer to trees above 0.9 m in crown diameter and relate this dimension to the log (to base 10) of the wood volume. Although these regressions have not yet been statistically analysed, it is evident that good correlations between crown diameter and wood volume can be shown in trees over 1 m in crown diameter. Similar relationships between wood volume and crown diameter have been calculated for other tree species which are important in the area.

Tree weights. A programme of destructive sampling of trees is in progress, and at the time of writing this report, at least ten trees of each of the most important species in the Acacia woodlands and shrublands have been weighed fresh after prior measurement and are being dried to obtain air-dry weight estimates. Sub-samples will be oven-dried. Each tree is divided into trunk, branches, old and new growth twigs, and leaves. New growth and leaves, which are potential fodder for livestock are divided into those below 1 m above ground level (i.e. sheep and goat fodder) and those above 1 m (camel fodder). As a preparatory measure several trees of typical size and shape of the species Acacia reficiens, A. mellifera and A. nubica were weighed complete in March 1981, before the rains, when they were leafless. This preparation provided initial practice in tree weighing and indicated the simple formula for estimating wood volume (and weight) from the dimensions. The wood and bark samples obtained enabled estimates of specific gravity (fresh and dry) to be made for each species, so that wood biomass could be derived from wood volume.

In figure 28 three measured and weighed examples of A. reficiens are shown in the regression graph. Taking into account the specific gravity (dry) of the wood of this species (1.39), it is apparent that the formula used for wood volume estimation gives good correlation with the weight for the three trees. This correlation will be checked by further weight data that have been obtained recently

Figure 28


Acacia reficiens
Wood volume/Crown diameter.
Trees of <0·9m. crown diameter.
cm3 WOOD VOLUME
CROWN DIAMETER (cm.)
0
10
20
30
40
50
60
70
80
20
40
60
80
100
120

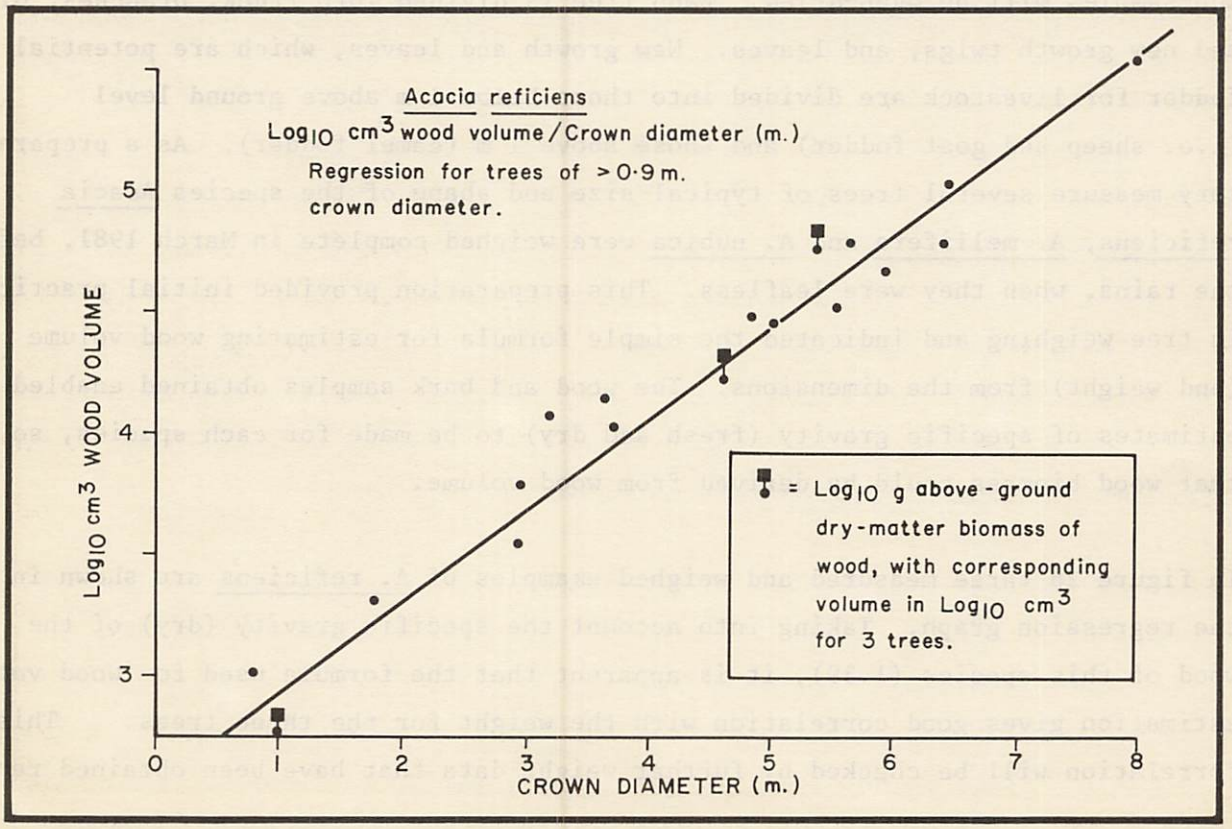
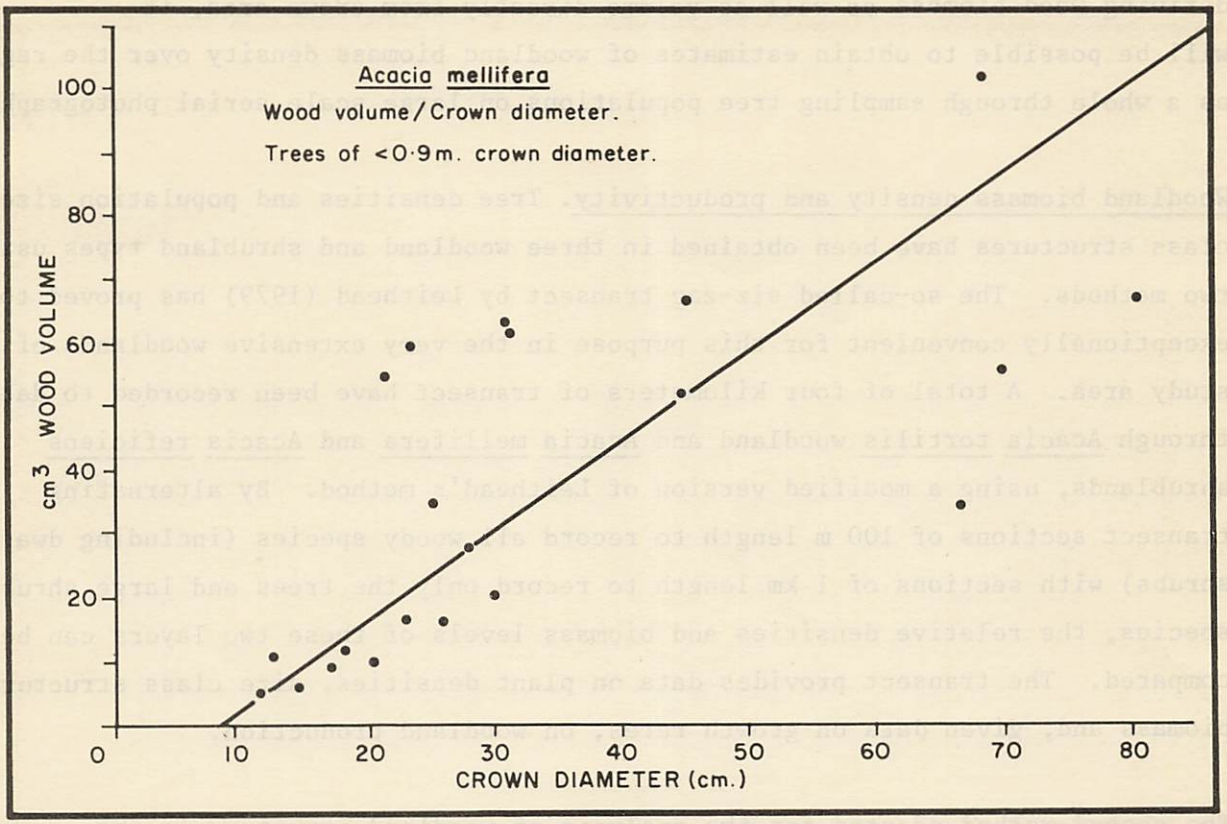
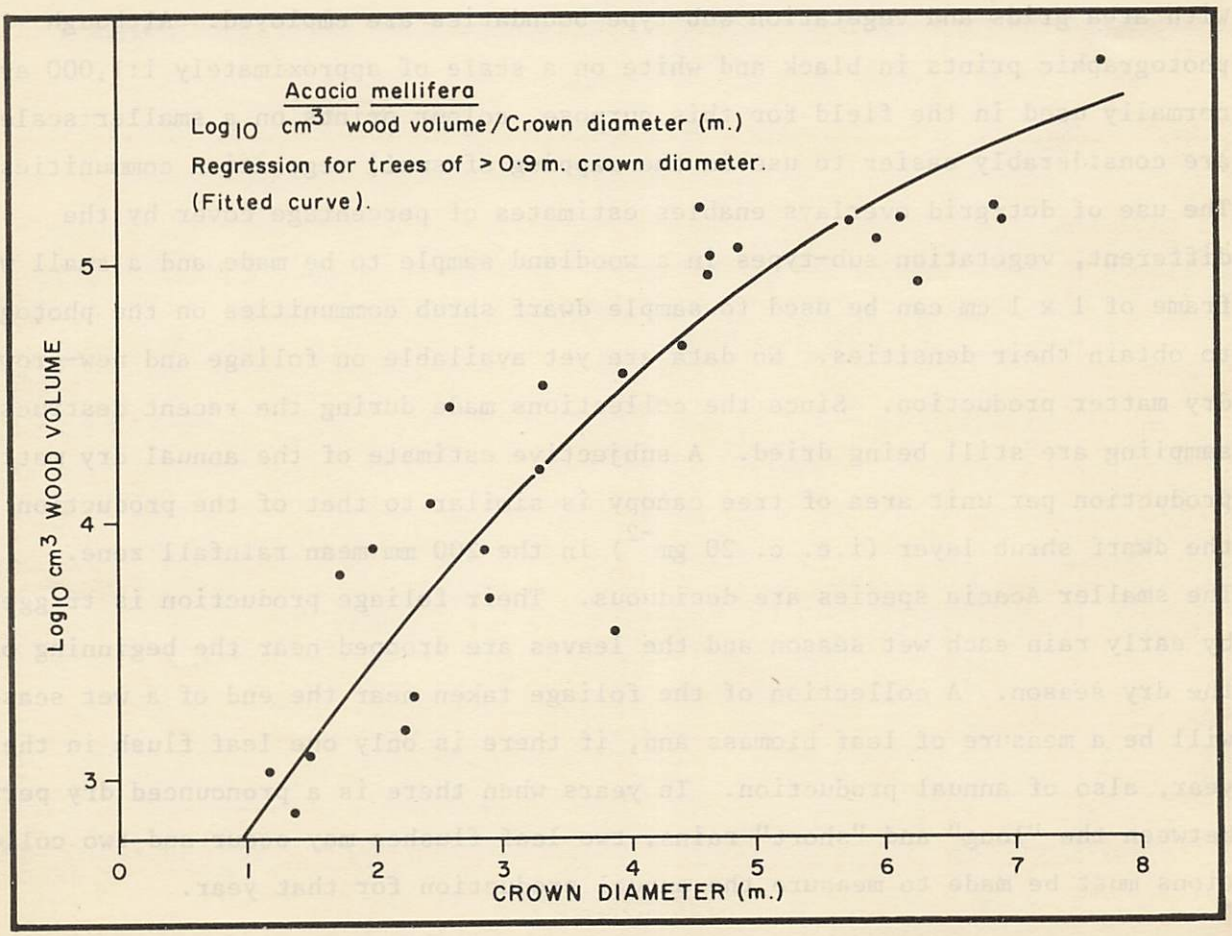

Acacia reficiens
Log10 cm3 wood volume/Crown diameter (m.)
Regression for trees of >0·9m.
crown diameter.
Log10 cm3 WOOD VOLUME
CROWN DIAMETER (m.)
= Log10 g above-ground dry-matter biomass of wood, with corresponding volume in Log10 cm3 for 3 trees.
0
1
2
3
4
5
6
7
8
3
4
5

Figure 29


Acacia mellifera
Wood volume/Crown diameter.
Trees of <0·9m. crown diameter.
cm3 WOOD VOLUME
100
80
60
40
20
0
10
20
30
40
50
60
70
80
CROWN DIAMETER (cm.)


Acacia mellifera
Log10 cm3 wood volume/Crown diameter (m.)
Regression for trees of >0·9m. crown diameter.
(Fitted curve).
Log10 cm3 WOOD VOLUME
5
4
3
0
1
2
3
4
5
6
7
8
CROWN DIAMETER (m.)

and similar correlations will be obtained for another seven species. By deriving wood biomass as well as volume directly from crown area, it will be possible to obtain estimates of woodland biomass density over the region as a whole through sampling tree populations on large scale aerial photography.

Woodland biomass density and productivity. Tree densities and population size class structures have been obtained in three woodland and shrubland types using two methods. The so-called siz-zag transect by Leithead (1979) has proved to be exceptionally convenient for this purpose in the very extensive woodlands of the study area. A total of four kilometers of transect have been recorded to date through Acacia tortilis woodland and Acacia mellifera and Acacia reficiens shrublands, using a modified version of Leithead's method. By alternating transect sections of 100 m length to record all woody species (including dwarf-shrubs) with sections of 1 km length to record only the trees and large shrub species, the relative densities and biomass levels of these two layers can be compared. The transect provides data on plant densities, size class structures, biomass and, given data on growth rates, on woodland production.

The second method adopted for the analysis of woodland structure is the use of large scale aerial photographs of sample areas with which transparent overlays with area grids and vegetation sub-type boundaries are employed. Although photographic prints in black and white on a scale of approximately 1:1,000 are normally used in the field for this purpose, colour prints on a smaller scale are considerably easier to use in the mapping of small vegetation communities. The use of dot-grid overlays enables estimates of percentage cover by the different, vegetation sub-types in a woodland sample to be made and a small wire frame of 1 x 1 cm can be used to sample dwarf shrub communities on the photographs to obtain their densities. No data are yet available on foliage and new-growth dry matter production. Since the collections made during the recent destructive sampling are still being dried. A subjective estimate of the annual dry matter production per unit area of tree canopy is similar to that of the production of the dwarf shrub layer (i.e. c. 20 gm^{-2}) in the 200 mm mean rainfall zone. The smaller Acacia species are deciduous. Their foliage production is triggered by early rain each wet season and the leaves are dropped near the beginning of the dry season. A collection of the foliage taken near the end of a wet season will be a measure of leaf biomass and, if there is only one leaf flush in the year, also of annual production. In years when there is a pronounced dry period between the "long" and "short" rains, two leaf flushes may occur and two collections must be made to measure the annual production for that year.

Although it appears at first sight that the foliage that grows above the reach of livestock will not be available as fodder, this is not true in the case of Acacia tortilis and Acacia mellifera. The fallen leaves of these species are eagerly sought by livestock, particularly by sheep, and in areas of high livestock concentration, are likely to be totally consumed. The same is true of several other common tree and shrub species. In order to obtain a measurement of fallen leaf biomass, twenty leaf collection trays, each of 0.5 m^2 area, have been placed under the canopies of Acacia reficiens and Acacia mellifera trees in the 20 ha study plots. These litter samples will be compared with the foliage production estimates obtained from the destructive sampling of similar trees. The fruits of Acacia tortilis are an important source of protein for livestock. Trees normally fruit twice each year and the fruits are eaten soon after they fall by sheep, goats, cattle, camels and wild ungulates. Collections of fruit were made from 20 A. tortilis trees in the Olturot area. The dry weight of fruit varied from 4 kg to 33 kg per tree with an average of 12 kg. Further collections will be made with the object of estimating the nutritional value of this fruit crop to the livestock populations in the area, since it is thought to be a critical factor in the survival, growth and reproduction of the domestic herds, expecially in drought years. In the 20 ha Acacia shrubland study plots at Olturot, over 200 trees of seven species have been labelled and their dimensions measured with the object of obtaining growth data at yearly intervals and relating it to actual rainfall measured within the plots. Destructive sampling of other trees in the same vicinity will provide a measure of rainfall-related foliage and new growth production. Although the results of these growth and production experiments will not be available for another two to four months at the time of writing this report, some data are available from less comprehensive experiments initiated by D.J. Herlocker and H.F. Lamprey which provide preliminary estimates of wood production in the woodlands and shrublands in the 200 mm mean annual rainfall zone. These estimates are derived from measured increments in the stem, and crown diameters of several Acacia tortilis trees after a period of 2 years, the stems being measured at marked levels at breast height and the crowns on aerial photographs of known scale. The mean diameter increment of 25 stems on eight trees over one year was 4.25 mm. For the same trees, the mean annual diameter increment of the crowns was 22 cm. The stem increments are consistent with those obtained elsewhere in East Africa in this species (W.G. Dyson, pers. comm.)

The inspection of several cross sections of Acacia tortilis, Acacia reficiens and Acacia mellifera stems in the study area shows what appear to be annual

growth rings which are somewhat variable, but which have an average width of about 3 mm, giving a mean annual diameter increment of about 6 mm. From large scale aerial photographs of Acacia shrubland taken in 1977 and 1981 the mean annual crown diameter increments of 10 Acacia mellifera and 10 A. reficiens trees was 23.8 cm and 24.2 cm respectively. On the dimension regressions these correspond with a stem diameter increment of about 6 mm. From this limited but corroborative evidence it can be deduced that an average annual growth increment of 6 mm in stem diameter is taking place in the Acacia reficiens and A. mellifera populations in the study area. This estimate is subject to verification from the results of other growth measurements to be made on these tree populations. Applying this value to the dimension regressions, an age scale can be added to the size and weight scales and from this, annual estimates of volume increment for trees at various growth stages can be adduced. Thus an Acacia reficiens tree with a crown diameter of 2.5 m and stem diameter of 5.0 cm (age 8 years) will have a wood volume of approximately 3.16 cm^3 and a wood dry weight of c. 4.4 kg. It will have an annual wood volume increment of c. 820 cm^3 and an annual wood dry weight increment of c. 1140 g over its ninth year of growth.

Applying the wood volume and annual volume increment values to a woodland of known size and age structure (in which Acacia species predominate), both biomass and wood production estimates can be obtained. Thus, the Hedad dry Acacia shrubland, with the size class structure illustrated in Figure 28 can be shown to have an above ground wood biomass of 5.7 t ha^{-1} dry weight, and an approximate increment of 375 kg ha^{-1} y^{-1}. Using the area estimates for the shrublands and bushlands of the IPAL study area given by Herlocker (1979) and assuming a homogeneous density, the 6027 km^2 of these two communities combined (26.3 percent of the study area) would have a wood biomass or the order of 3.4 million tonnes and an annual wood (dry weight) production of some 226,000 tonnes. A corrected estimate will be available when a number of qualifying factors have been calculated. These will include the additional biomass and production in the remaining 63.7 percent of the study area and relatively low biomass in the vicinity of the settlements.

The wood requirements of pastoralists. In his report on the prospects for tree planting in Marsabit District, Synnott (1979) discussed the use of wood for fuel in the arid and semi-arid zones. Requirements are known to vary greatly from one region to another, but it is apparent that the Rendille and Gabra pastoralists, with their traditional diets of uncooked milk, sometimes with fresh blood (in the case of the Rendille), have a low annual requirement for firewood, possibly

amounting to 0.1 m^3 of solid wood equivalent. This may be compared with the normally assumed annual fuel wood consumption in agricultural areas in Africa of 1 m^3 per person. Now that the diet of pastoralists in northern Kenya is changing to include increasing proportions of grain foods, it can be assumed that their need for firewood will increase. In the near future it can be anticipated that the relatively small firewood requirements of the pastoralists will not have an important impact upon the tree populations, except in the immediate vicinity of the settlements.

In contrast, as Synnott's report indicates, the use of wood by the Rendille and Gabra people for the construction of night enclosures appears to be very high. Taking into account the frequent moves made by nomad families and the need to fell more trees after each move, the requirement of wood for this purpose was estimated by this author (from data provided by Hunting and Lewis, 1979 and Hussein Yusuf, personal communication) as 1.5 - 3.0 m^3 $head^{-1}$ yr^{-1}. From an example of two manyattas of the Gabra people, occupied for 1 and 2 weeks respectively, each of 17 huts, with an average of 4 - 5 people per hut, these 70 - 80 people had constructed bomas which contained 15,700 kg of wood, equivalent to c. 40 m^3. Allowing for six moves per year, each person would account for between 1170 and 1350 kg (780-900 kg dry weight) of wood annually. On the basis of this consumption rate and the calculated wood production of the Acacia reficiens shrublands (375 kg ha^{-1} yr^{-1}), the 30,000 pastoral people in the IPAL study area would obtain their wood requirements for fencing from the annual production from approximately 1080 km^2 of shrubland (less than a quarter of the total area of this single tree community)without reducing its standing crop biomass. On the face of it, taking the tree populations of the region as a whole, it would appear that there is no threat to the woodlands from over-exploitation. Unfortunately, this is not the case. Through the extreme concentration of the wood consumption in the vicinity of the settlements, tree populations are being almost totally destroyed by progressive felling outwards from each centre at rates which not only exceed the annual production but steadily reduce the standing crop biomass as well.

In a study of relatively sedentarised Rendille people in a degraded village environement at Korr, Walther and Herlocker (1981) estimated that the annual consumption of wood for livestock fencing by the average household was approxmately 432 kg. With four people per house, the annual consumption per head was estimated at 108 kg (dry weight). This low rate of wood consumption is most likely to be due to the extreme scarcity of trees in the village neighbourhood.

Nevertheless, even at this low level of use, these authors estimated that the 350 families to be found within the village area of 78 km^2 cut live wood at a rate of 3,500 kg^{-2} yr^{-1} (dry weight). Although this rate of consumption per hectare amounts to less than 10 percent of the production of the Acacia reficiens shrublands (per ha) in the uninhabited areas, it evidently exceeds the rate of production in the inhabited areas. This situation clearly illustrates the benefits to be gained from conserving woodlands in their most productive state and of ensuring that their exploitation is made as even as possible across the whole region, rather than being concentrated around the settlements.

The main management goal with respect to the tree populations should be to ensure that no woodlands are exploited at rates exceeding their annual production levels and that the woodlands in the inhabited areas should be given sufficient protection to allow them to regain their potential biomass densities and productivity. In anticipation of the recommendation in the foregoing report on substitute materials for boma construction, the Project invented and constructed a circular livestock enclosure made out of bamboo brought in from the slopes of Mt. Kenya 300 kms away, where it grows abundantly. This enclosure, made of individual bamboo hurdles, 2 m long and 1.5 m high, is easy to construct with the aid of local labour, is strong, flexible and portable. It appears to have a useful life of about three years, about ten times as long as that of a thorn boma and it is effective in enclosing cattle and discouraging predators. About 100 cattle, 40 camels or 300 sheep and goats can be kept in a boma of about 25 hurdles. Other advantages are that it harbours very few parasites; that it can be carried, six hurdles at a time, on a camels back; and it is accepted by the pastoralists as an effective and practical enclosure. Its disadvantages are that it costs the equivalent of US$ 6.00 per hurdle to make, mainly in transport charges for the bamboo. This is more than the Rendille herdsmen are prepared. The cost of two hurdles is about the same as the sale price for a sheep or a goat, and although many families could afford this price, they have a an understandable reluctance to spend money when thorn trees are available free, albeit often at some inconvenience.

In a short publication on the problem of night enclosures in north-eastern Africa (Lamprey, 1981), the author suggests that it would cost approximately US$200,000 to provide bamboo fencing sufficient for the whole Rendille tribe for three years. Since this is not a large sum in comparison with other research and development costs in the region, it appears to be a feasible

measure of direct practical value in arresting desertification and one which would provide local employment in construction work.

Livestock Night Enclosures

As we have indicated in the previous section, the limited information which exists on the use of wood by pastoralists in northern Kenya, as well as the evidence of the spreading zones of tree destruction around the settlements, strongly suggest that the construction of livestock night bomas is a major cause of localised desertification. The question as to how necessary bomas are in the pastoral economy led to an investigation which was carried out in 1980.

Since it was understood that bomas are built to protect domestic animals from large predators at night, an enquiry was undertaken into the influence of large carnivores upon animal husbandry in the region. The results and conclusions of this study, carried out by a consultant specialist on the biology of large carnivores, was published in the IPAL technical report series (Kruuk, 1980) and can be summarized as follows:

1. A survey was made in western Marsabit District over a 4-month period to assess the amount of livestock taken annually by carnivores and the circumstances under which the animals are killed. The way in which people of 4 different tribes protect their livestock was described, especially the construction of thorn fences (bomas) and suggestions were made for improvements.
2. The economically important predators are spotted hyaenas, lions and black-backed jackals, though striped hyaenas, cheetah and wild dog are also present.
3. There are significant differences between the carnivores, in their selection of livestock; lions take mostly cattle, spotted hyaenas mostly sheep and goats, the other predators only sheep and goats. Spotted hyaenas take relatively more young animals than lions, and jackals take mostly young lambs and kids. Annual predation rates (all predators) vary between approximately 2% and 10% according to locality.
4. Overall, most livestock is killed in the day-time when grazing (72%) only spotted hyaenas kill more often at night. Ninety per cent of all kills are made outside the protection of bomas.

5. The main function of the bomas is to prevent livestock from straying as as well as to exclude predators.
6. Rendille herds suffer more predation inside the boma than the herds of Samburu or Gabra. Samburu animals are the best protected at night, and Samburu bomas are also the most solidly built ones.
7. There is less predation in 'manyattas' (villages) with dogs, than in those without them.
8. There is large variation between tribes in boma size, shape and structure, but less variation within the tribes. There are significant tribal differences between the numbers of huts per manyatta, the length of boma per manyatta and the length of boma per individual hut.
9. Overall, there is a correlation between the number of huts in a manyatta and the length of boma, and large manyattas are not more efficient in use of boma-material than small ones (except when comparing manyattas of fewer than 4 huts).
10. Recommendations are made for experiments with alternative materials for boma construction, for the use of pesticides to prolong the useful life of bomas by combating ticks, and for research on the use of dogs and the occurrence of rabies.

GEOMORPHOLOGY AND SOILS OF THE IPAL STUDY AREA

The soils of the IPAL study area have been described at the reconnaissance level by Sombroek (1980) and are presently being surveyed more intensively by Van Kekem. However, as yet, there is little information in this regard. A map of the Geomorphology of the IPAL study area (Figure 30 Appendix II has just been published by Sinda (1980) and an intensive study of the Geomorphology of the Korr Area has just been completed by Sogomo.

In general, soils of the area reflect (a) climatic zones; (b) topography; (c) geology; and (d) geomorphological processes.

There is a broad correspondence between the major geological and geomorphic units within the study area. An extensive plain (Hedad, Koroli, Kaisut) composed of quarternary sediments derived from pre-cambrian gneiss occupies the centre of the study area. Two major ecological units are comprised; piedmont plains at higher levels and sedimentary plains at lower levels. Soils are generally sandy loams but become finer textured and saline to the northeast - especially in the lower drainage lines. An extensive system of old stabilized sand dunes fringes the northern most edge of the plains. This central large plain drains gently north- north eastward into a large lacustrine plain system and eastward down the Milgis River drainage. The lacustrine plain system comprises three elevational levels the lowermost of which receives drainage waters from a 17,720 km^2 interior drainage basin, much of which lies within southern Ethiopia. This overlies the old Chalbi Lake Bed and is characterized by poorly drained, excessively saline, clays which either crack or are puffy at the surface. The old lake bed remains uncovered along the perimeter of the Chalbi Desert and represents the intermediate levels. These have shallow, well drained excessively calcareous fine sandy clay loams over massive hard pan. Higher levels may have stony desert pavement.

Flood plains and low terrace alluvial plains occur along the major seasonal drainages such as the Balessa Kulal and Milgis Rivers and at the junction of the plains and lava footslope areas. Soils vary in texture as well as age. Much of the Milgis flood plain for instance is composed of relict soils formed by past river distribution systems.

Large mountains rise on all sides of the central plain. 1500 - 3000 meters elevation and are principally volcanic (Marsabit, Kulal, Huri Hills) although those in the southwest are precambrian gnesisses (Ndotos, Nyiru, Oldoinyo Mara) from which come the sediments forming the central plain.

The soils of volcanic mountains are related to the major geomorphological units which are elevationally defined. Well drained and friable throughout, they are deep red to dark brown clays at higher elevations, shallow dark reddish brown clay loams with stony and rocky components at middle levels and very shallow to moderately deep dark brown calcareous stony clay loams with saline-sodic tendencies at lower elevations. Rocky and bouldery surfaces are also common. Similar soils to the latter occur throughout the stony to bouldery olivine basalt plateau and step faulted scarps.

The major primary vegetation types within the IPAL study area reflect a climatic zonation closely related to elevation and aspect. Inconsistencies in this zonation, such as the lack of a shrubland zone between bushland and dwarf shrubland in the southwest, are often attributable to soils. Soils are also the principal determinants of the smaller, more localized tertiary vegetation types within the context of a climatic zone. An example would be a topographically related sequence of different soil-vegetation units of a hillside catena.

Soil texture plays an important part in vegetation distribution within the study area. Soils developed from lavas tend to be loamy to clayey in texture whereas those developed from gneissic materials tend to be sandier.

Sand soils in such arid environments have higher permeability, less surface runoff, deeper penetration and thus more water available for plant growth than do loamy clayey soils.

Therefore, a gradient from sandy to silty to clayey soils within a generally similar arid environment results in a gradient of decreasing soil moisture reflected in vegetation ranging from tall, dense, woody, perennial and deeply rooted to short, sparse, herbaceous annual and shallow rooted.

Type and rate of soil erosion also may reflect different factors such as climate, slope, vegetative cover, and soil texture and structure. Again, little is known of the erosion potential within the study area. However, some general observations can be made. Overall, erosion is probably in equilibrium with the

climate except for areas of concentracted settlements and use where it is accelerated. The settlements of Korr and Kargi are good examples.

Erosion will probably be relatively little throughout the arid desert pavement areas because of widely distributed use and protection against wind and water by the surface layer of stones. Continued use of the sand dunes along the southern edge of the Chalbi Desert will probably cause accelerated wind erosion through loss of vegetative cover and through trampling.

CLIMATE STUDIES

Rainfall

A major environmental constraint in arid and semi arid land is the fluctuating and unreliable nature of the climate. Limited and unreliable distribution of rainfall limits the productivity of these systems in terms of both crops and livestock. Monitoring of the climate in the study area preceded the inception of IPAL in 1976 at low intensity and an adhoc basis. It has now been put onto a routine schedule as follows.

There is a network of forty two raingauges (Figure 31) at thirty six sites. Two gauges are read automatically every five minutes, fifteen are read daily and twenty five are storage raingauges read monthly. At two sites readings from daily gauges are compared with those from storage gauges. There are approximately 1,325 monthly records of rainfall data available from this network since 1976. Results from the first two years data are presented in IPAL Technical Report B - 1 (1979).

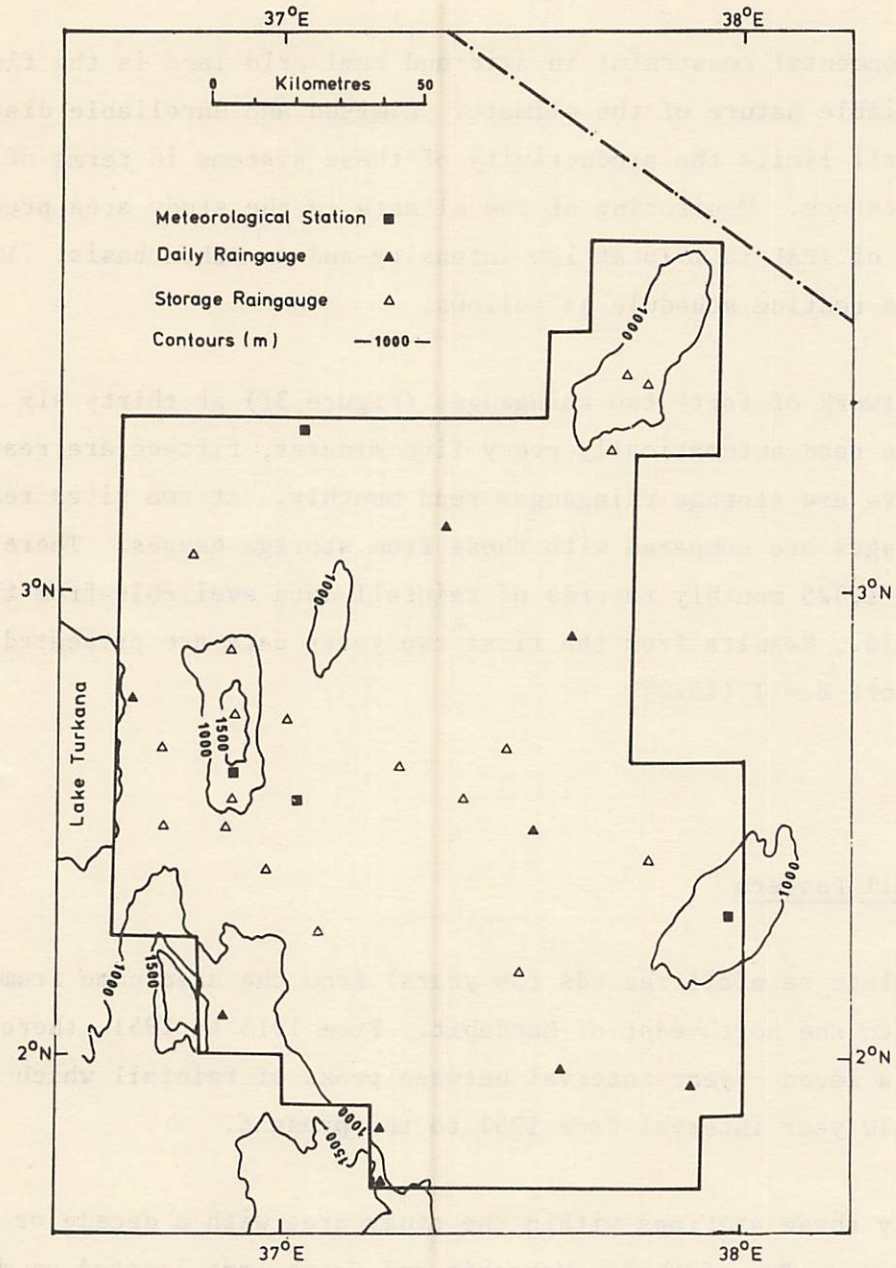
Annual Rainfall Pattern

The most complete rainfall records (56 years) from the area come from Moyale, about 180 Km to the north-east of Marsabit. From 1915 to 1951, there appears to have been a seven - year interval between peaks of rainfall which changed to a 4, 6 or 10 year interval from 1951 to the present.

There are only three stations within the study area with a decade or more of rainfall records. Two of these, Marsabit and Gatab, are located on mountains and the third, North Horr, is adjacent to the Chalbi desert.

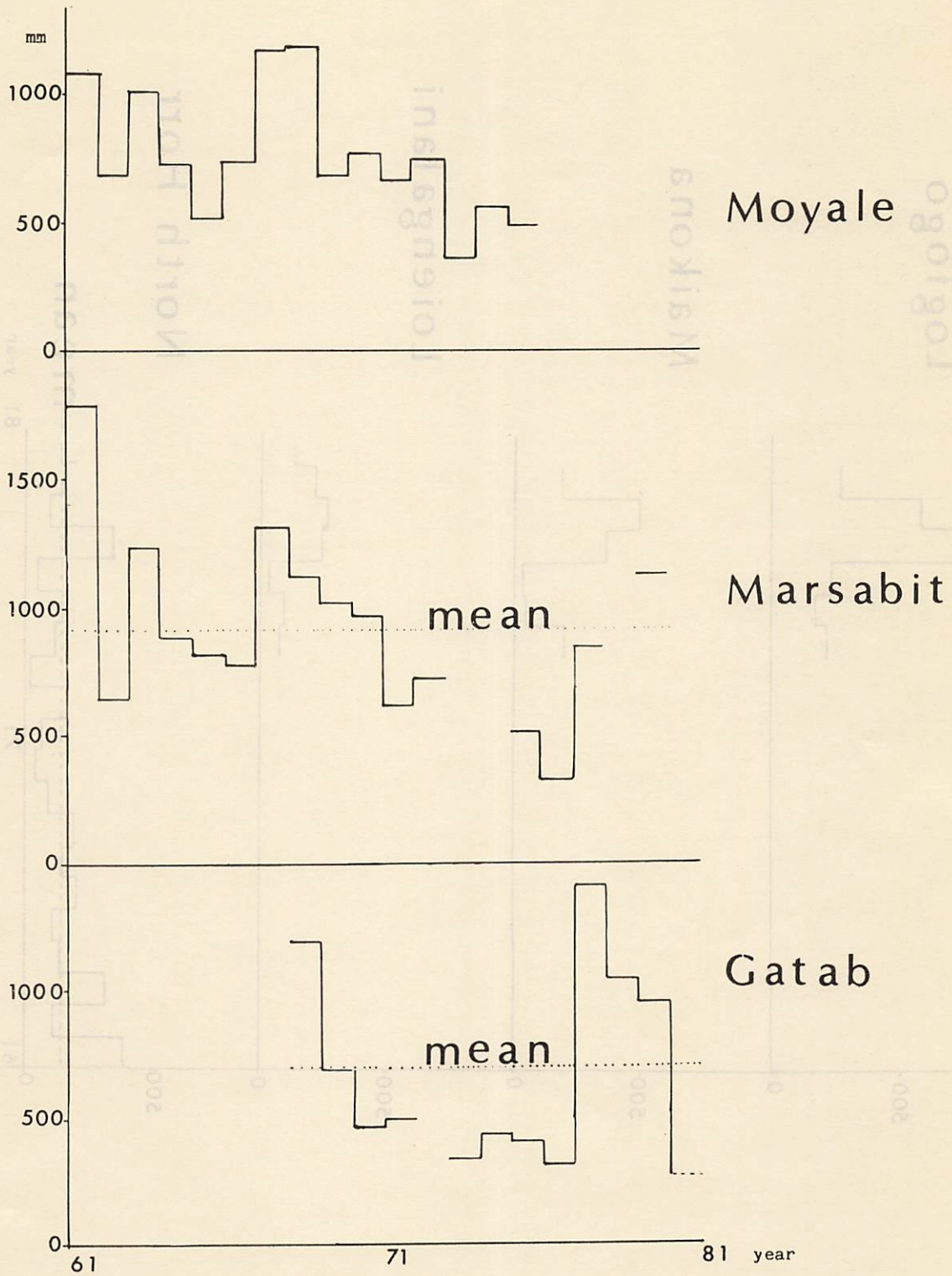
Annual totals for these three stations and four other new stations are shown in Figures 32 and 33. Moyale lies outside the study area but its data are relevant to the regional pattern.

Figure 31



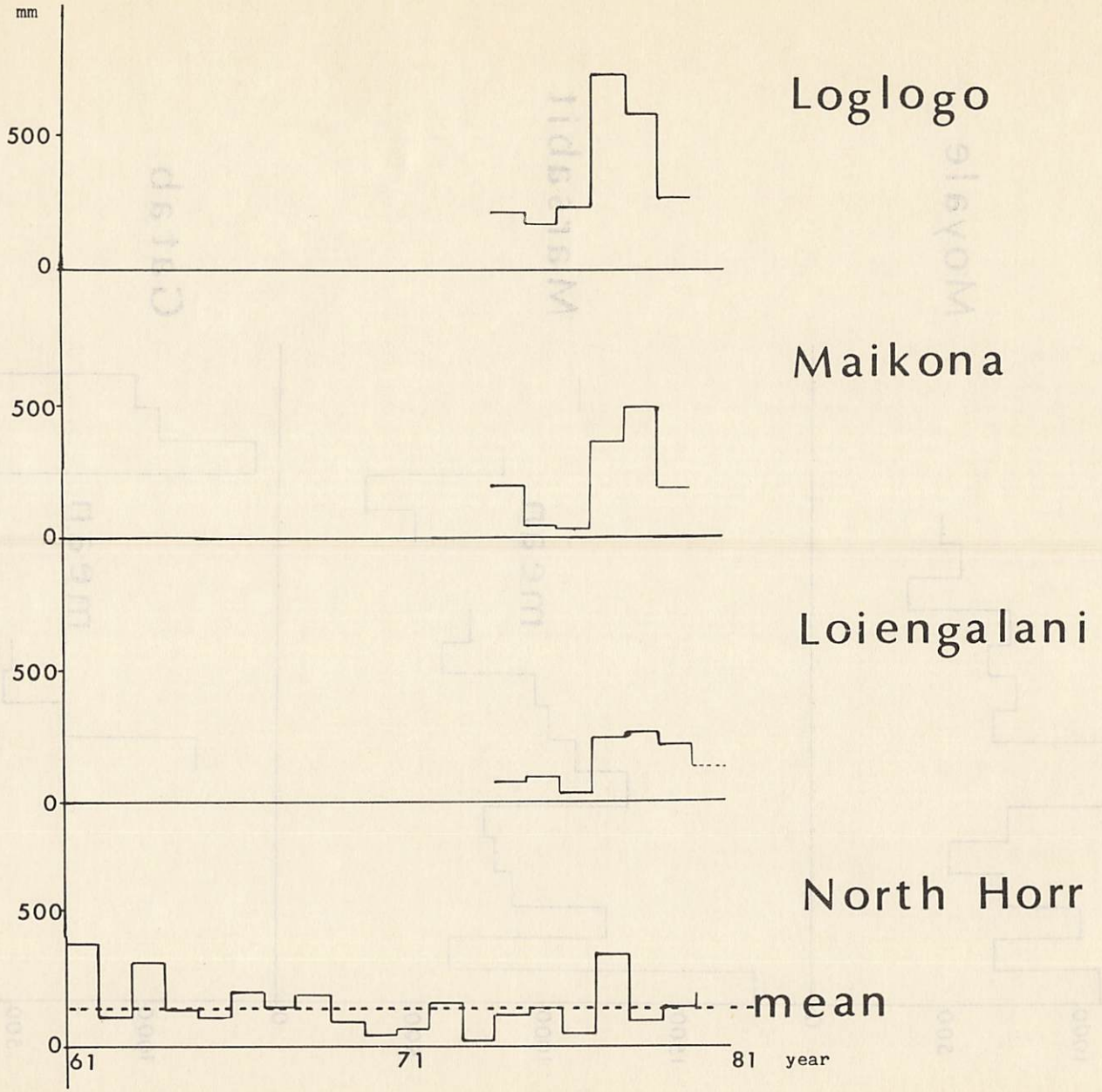
Distribution of raingauges

Figure 32



Rainfall histograms for three stations

Figure 33



Rainfall histograms for four stations

High rainfall levels were recorded in 1961 and, with the exception of Moyale, they were the highest recorded. There followed a dry year at all stations (1962) and then another moderately wet year (1963). Both 1964 and 1965 had below average rainfall at the three gauges which were then operating. By 1967, however, higher rainfall was again being recorded, except at N. Horr, and this persisted until 1968. There then followed eight to ten years of below average or drought conditions at all stations with exceptionally dry years in 1973 and 1976.

From the similiarities in the rainfall patterns recorded from the four different gauges it is apparent that the whole study area lies within a larger rainfall zone which extends over the greater part of northern Kenya including Moyale.

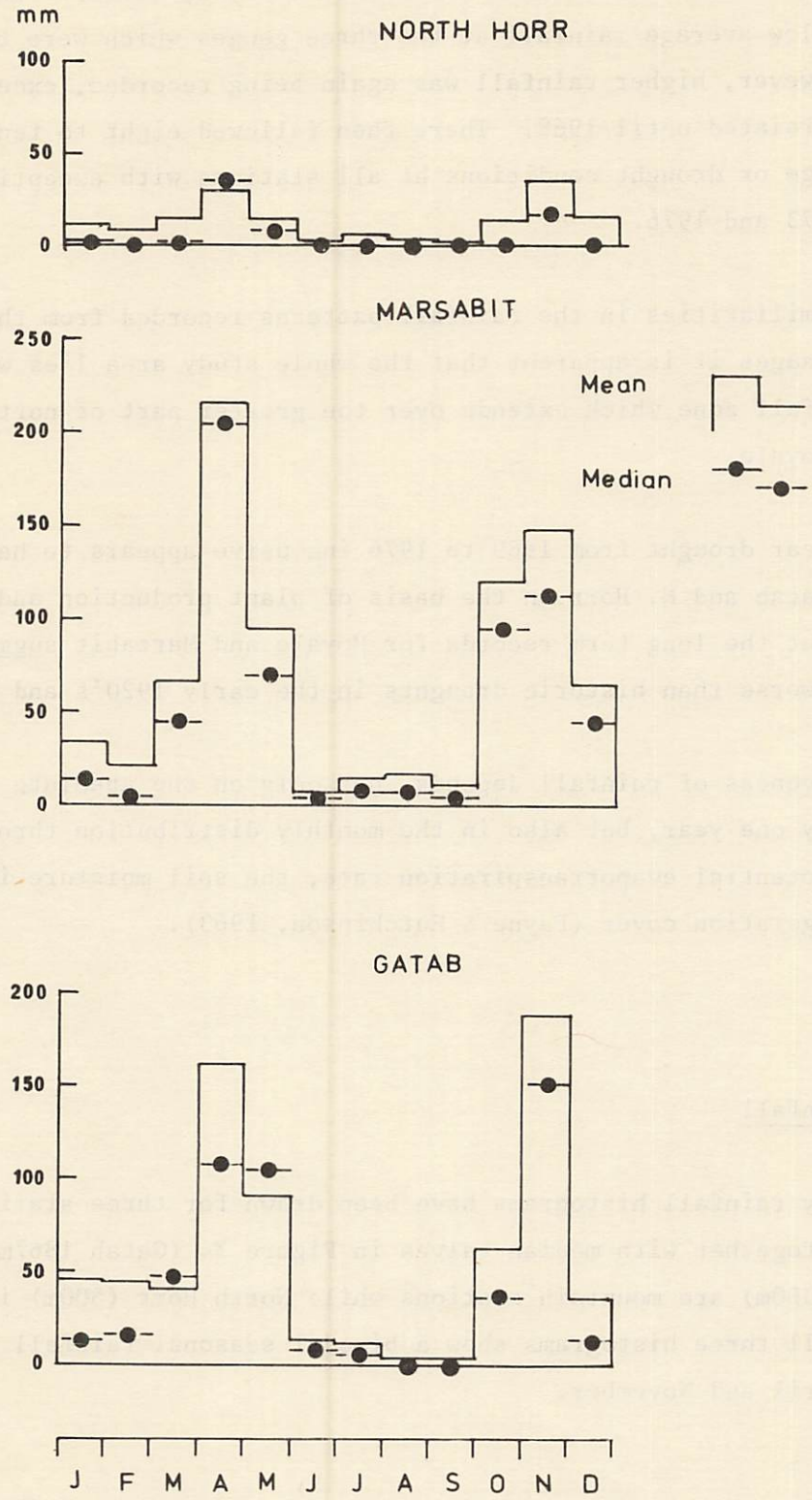
The eight year drought from 1969 to 1976 inclusive appears to have been severe at Gatab and N. Horr on the basis of plant production and livestock mortality but the long term records for Moyale and Marsabit suggest that it was little worse than historic droughts in the early 1920's and 1930's.

The effectiveness of rainfall depends, not only on the absolute amount that falls in any one year, but also in the monthly distribution throughout the year, the potential evapotranspiration rate, the soil moisture infiltration rate and vegetation cover (Payne & Hutchinson, 1963).

Monthly Rainfall

Mean monthly rainfall histograms have been drawn for three stations in the study area together with median valves in Figure 34 (Gatab 1867m) and Marsabit (1360m) are mountain stations while North Horr (500m) is a lowland station. All three histograms show a bimodal seasonal rainfall pattern with peaks in April and November.

Figure 34

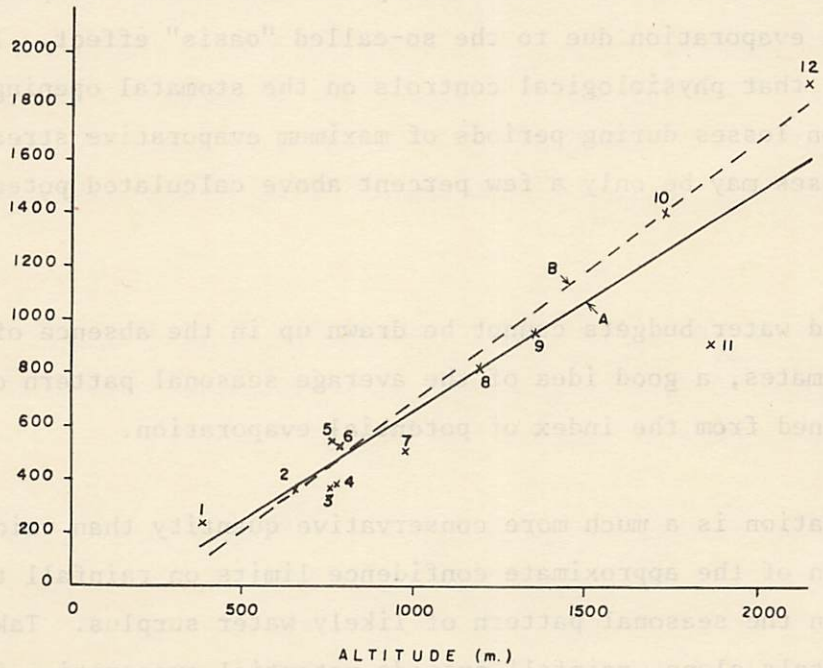


Mean monthly rainfall

Rainfall and Altitude

The IPAL study area is bound by two Mountains - Mount Kulal (1867 m) and Mount Marsabit (1360 m) which form important catchment areas in the study area and consequently exert an influence both climatically and in the grazing pattern. The storage gauges have been deliberately concentrated on the slopes of Mount Kulal to determine the effect of altitude on rainfall. The complete rainfall records for 1977 are plotted against the altitude of each gauge in Figure 35.

Figure 35



1. LOIENGALANI	7. JUNCTION	LINEAR	REGRESSION
2. BALESA	8. 9KM	A n = 12	r = 0.93
3. SIRIMA	9. LUAI	RAIN = 0.84 x ALT - 178.3	
4. LONGIPI	10. GATAB	B n = 11	r = 0.98
5. EL KAJARTA	11. ARABEL	RAIN = 0.98 x ALT - 283.8	
6. SIRIMANO	12. TOP	(EXCLUDING STATION 11)	

Relationship between rainfall and altitude on Mount Kulal

There is a positive relationship between altitude and rainfall which may be expressed as Rain = 0.84, Altitude = 178.3.

Where rain is the rainfall from 12 stations in MM and ALT is the altitude in meters. The correlation coefficient is 0.93 and it should be noted that the slope of this line is likely to change from one season to the next and from year to year.

Potential Evapotranspiration

In semi-arid areas where rainfall only exceeds potential evaporation in a few months of the year, actual evaporation is very difficult to estimate. For shallow-rooting vegetation which dies off at the end of the rains, actual evaporation during the dry months is zero. For deeper-rooting bushes and trees with no access to phreatic water, as a first approximation, actual evaporation equals dry season rainfall, if any. In the riverine zone or where trees can tap a shallow water table, transpiration can continue throughout the dry season. With large amounts of advective heat energy available from upwind drier areas, it is to be anticipated that actual evaporation might exceed potential evaporation due to the so-called "oasis" effect. It is likely, however, that physiological controls on the stomatal opening limit the transpiration losses during periods of maximum evaporative stress and actual water losses may be only a few percent above calculated potential evaporation.

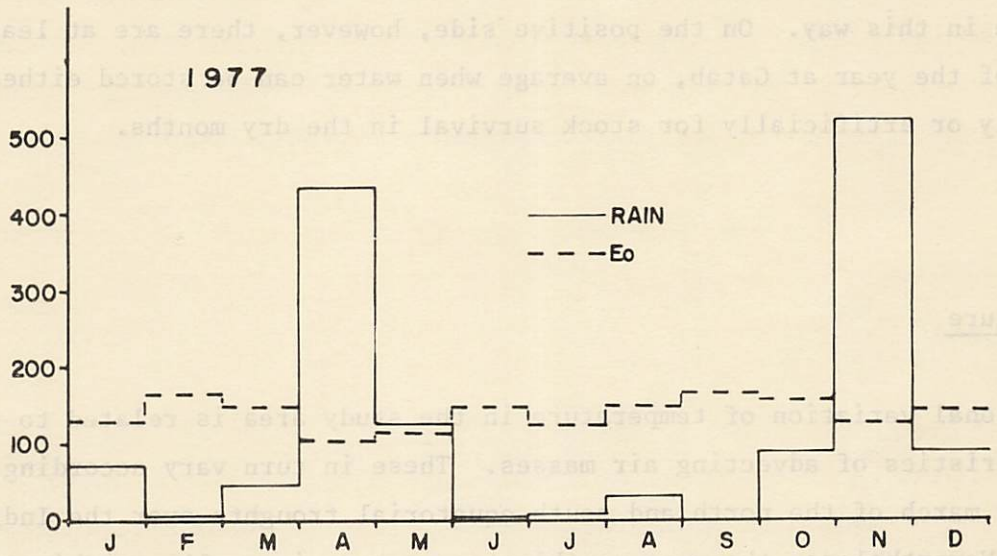
Although detailed water budgets cannot be drawn up in the absence of actual evaporation estimates, a good idea of the average seasonal pattern of water use can be obtained from the index of potential evaporation.

Potential evaporation is a much more conservative quantity than rainfall and with the addition of the approximate confidence limits on rainfall there are slight changes in the seasonal pattern of likely water surplus. Taking the mean rainfall totals alone, rainfall exceeds potential evaporation in only two months, namely April and November. Taking the approximate upper 90% rainfall totals, there are five months when rainfall could exceed potential evaporation, March, April, May, October and November.

In Figure 36, monthly rainfall totals for 1977 at Gatab are shown together with potential evaporation estimates. In this particular year, three months experienced rainfall in excess of potential evaporation, April, May and November.

In terms of potential recharges to groundwater stores, 1977 was clearly as a good year provided that a significant proportion of the rainfall surplus infiltrated. At Balesa Kulal, insufficient data are available at present to comment on the water balance. In general, however, since potential evaporation decreases and rainfall increases with altitude in this region, the

Figure 36



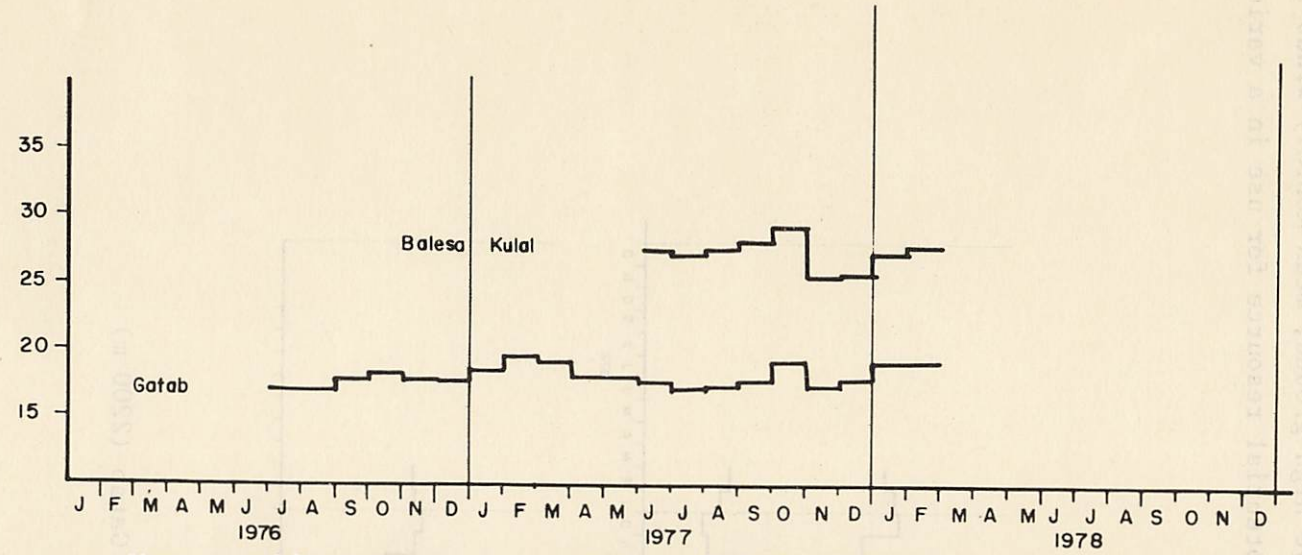
Water Surplus at Gatab

chances of rainfall exceeding evaporation are considerably less on the lower lying parts of the study area. In this context, the most obvious effect of any overgrazing will be to reduce infiltration by compressing the surface layers and removing organic residues. Once infiltration is reduced, rainfall excess becomes a destructive agent in accelerating sheet and gully erosion. In a delicately poised water balance situation, as in the study area, it is very easy to destroy the chances of soil moisture and groundwater recharge in this way. On the positive side, however, there are at least two months of the year at Gatab, on average when water can be stored either naturally or artificially for stock survival in the dry months.

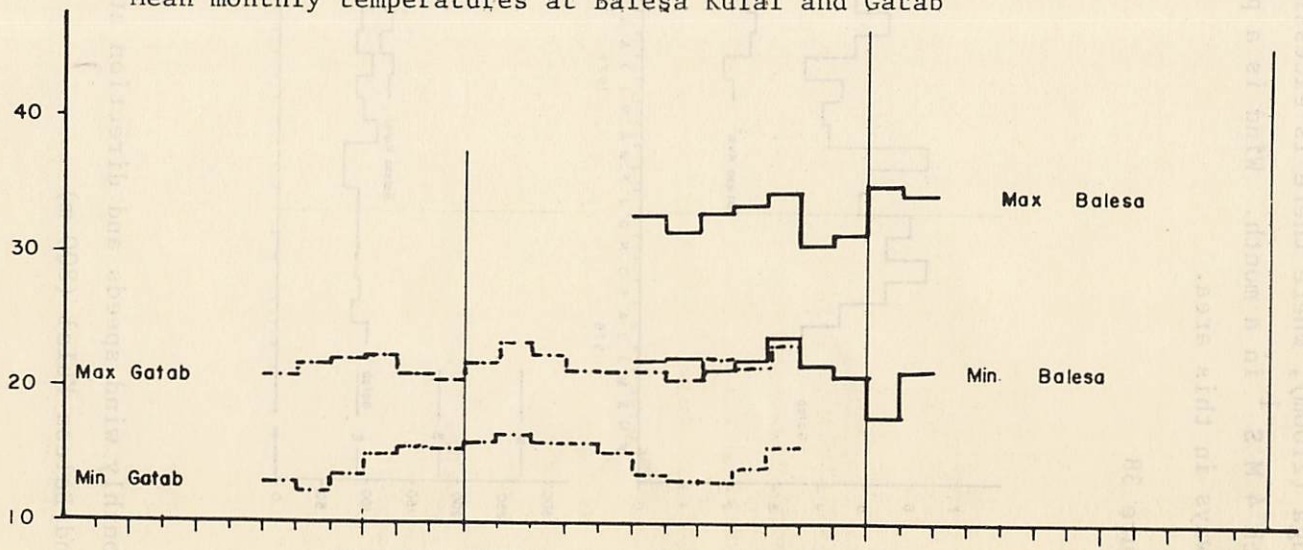
Temperature

The seasonal variation of temperature in the study area is related to the characteristics of advecting air masses. These in turn vary according to the seasonal march of the north and south equatorial troughts over the Indian Ocean. Nevertheless, the mean monthly temperature is small, reaching 4.0°C at Balessa Kulal (600m) and only 2.6°C at Gatab. (Figure 37). The high amounts of solar radiation open up various possibilities of using solar energy in a variety of ways in this environment.

Figure 37



Mean monthly temperatures at Balesa Kulal and Gatab

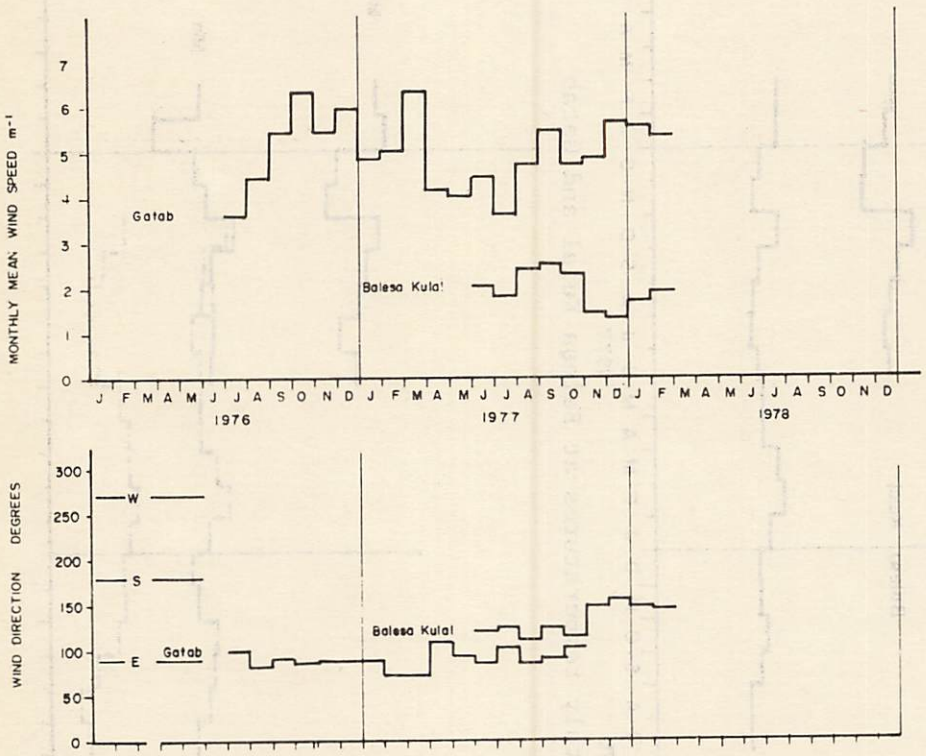


Mean monthly maximum and minimum temperatures at Balesa Kulal and Gatab

Wind

At Gatab (1700m) wind speeds are high due partly to local vertical acceleration in the vicinity of Mount Kulal but mainly due to the funnelling between the adjacent highlands. Thus the period July 1976 to February 1978 the mean monthly wind speed (Figure 38) was in excess of 4 M S^{-1} for all but two months (July of 1976 and 1977). At other high altitude stations in Kenya e.g. Muguga (2100m), where there is excessive high ground, mean monthly winds rarely reach 4 M S^{-1} in a month. Wind is a potential resource for use in a variety of ways in this area.

Figure 38



Monthly wind speeds and direction at Gatab (2200 m) and Balesa Kulal (800 m)

Observations

Although drought may be accepted as a natural phenomenon in northern Kenya, its frequency and the seriousness of its effects upon the lives of the pastoralists is a main concern of IPAL's investigations.

Coetsee (1968) distinguished four types of drought - seasonal droughts, periodic droughts, disaster droughts and droughts caused by man. Seasonal droughts are normal regular phenomena at certain times of the year. During such seasons, rainfall is low and there is a shortage of edible material for livestock. Periodic droughts are unpredictable and may occur at any time of the year. They are always a menace and require constant preparedness and continual planning. These droughts have neither a fixed pattern of occurrence nor regular duration. Disaster droughts are actually protacted periodic droughts. All available feed is used up, and state assistance on a large scale is necessary to save livestock. Soil moisture falls to a very low point where it is not available to plants and a large number of plants may even die. Failure to provide for periodic droughts means that disaster droughts will assume even greater proportions. Droughts caused by man occur when a feed shortage is brought about by overgrazing and/or injudicious use of the range, even though climatic conditions may not be such as to cause drought. In areas where droughts are caused by man, and we believe this is the situation in northern Kenya now, even a seasonal drought will be a disaster.

Although drought has been termed one of the clearest examples of man's hopelessness in the face of the broad scale phenomena of nature, its effects could be lessened by adequate forward planning and the information for the planning could come from meteorological services and intensive weather monitoring such as is being carried out by IPAL.

The constant necessity of the pastoralists of northern Kenya to remain almost permanently on famine relief, has clearly demonstrated the present inability of the traditional mechanisms of adjusting to drought, to cope with the problem. The traditional system must be improved and supplemented in such a way that the pastoralist will always be in a state of readiness to combat drought. The pastoralist with his family is the pivot of his livestock production system. Whether or not pastoralism will change for the better depends on the pastoralist's attitude towards his own activities in this regard. A change in practice entails a far reaching process of physical,

mental and spiritual adjustment - it actually amounts to a re-orientation of the pastoralist as a person. Such a personal orientation will be needed in the pastoralists approach to the problem of drought.

WATER RESOURCES

Future development in Marsabit District will depend upon the availability of water, whether for extending the area available for grazing (when effective grazing control) is instituted), for future settlement schemes or for limited irrigation of crops. Two preliminary reconnaissance studies have been carried out by consultants, one on surface water and the other on underground water. These are briefly summarised below.

Surface Water

Over a period of four months in 1981, a preliminary survey has been undertaken of the springs, seasonal water courses and dams in the catchment area of south-west Marsabit District, the results of which are now being analysed. The work has included the installation of equipment to monitor the quantity of water flowing in the major seasonal rivers and collected in the dams; to assess the chemical and bacteriological content of water bodies. An assessment is being made of the possible means to make maximal use of the surface water resources. Simultaneously an investigation is being made into the processes of land degradation through surface water movement, using suspended sediment data, chemical leaching data, bed-material data and other information related to chemical weathering, soil erosion etc. Preliminary results indicate very high seasonal variability in river flow with long periods with no surface flow). Data on total dissolved solids and suspended sediments and other attributes are similarly variable during times of flow.

Groundwater

In the Chalbi basin, as in most regions of the world, groundwater occurs at some depth, but limitations in quantity, quality and the energy required to raise it to the surface may preclude its development. Initial results can be summarised as follows:

Records, direct measurements, and resistivity measurements indicate that there are several areas where ground water is fairly close to the surface but has not been developed to even a fraction of its full potential, e.g. Hedad,

Korante, and Balessa Kulal River. In some areas the water is very deep and would be costly do develop, e.g. South east and South west of the Huri Hills, and the Segel and Bora areas.

Most of the groundwater is suitable for livestock, but is not so suitable for human consumption or for irrigation. However there are areas where it is suitable for all uses, e.g. Korr, Kalacha, some springs near Maikona and much of the perched water in the river beds.

The water in the perched or sporadic shallow aquifers (e.g. at Ngurunit) may be limited in quantity and wells in the deeper aquifers may be limited in quality. In some areas (e.g. Korr) the low permeability of the aquifer makes it suitable for wells with only very low specific capacities.

Generally, the regional water tables are just above the bedrock or in the bedrock complex the general surface of which dips towards the Chalbi. However there are some areas where the bedrock is more than 300 m below the ground surface, i.e. beyond the capabilities of the resistivity instrument used. Resistivity measurements indicate that there must be some groundwater leakage out of the Chalbi basin to the west of North Horr but the movement elsewhere is towards the Chalbi.

In conclusion, there is much useable groundwater in the Chalbi Basin. Studies should be concentrated upon the more useable shallow groundwater resources for several reasons. Capital and operational costs are relatively low: These sources are more easily managed by local people: They are less likely to cause environmental damage: They are of better quality for human consumption on and for initiating tree planting and gardens.

Better well-pumping tests should be carried out. Shallow test observations wells should be drilled in some areas now under-utilised, e.g. in the Hedad region.

Studies In Pastoral Economics

Background. One of IPAL's major objectives is to use its findings to contribute to the design of management activities directed towards achieving a sustained balance production and consumption, taking into account the requirements of the growing and (probably) increasingly settled population. The studies already discussed are yielding valuable information on relationships between the various components of the ecosystem and the processes leading to environmental degradation. Although this information is valuable, it is difficult to translate it into practical policy options for implemention by planners and administrators. This necessitates that this information be tranformed into management proposals. For these purposes an economic assessment showing the amount of money to be spent, a monetary valuation of the expected returns and the desirability of these returns in cost benefit terms is necessary. This has called for a close monitoring of all costs and benefits arising from the many experiments aimed at improving productivity of the arid land ecosystem going on in IPAL.

Many practices of animal husbandry and land use which seem grossly counter productive may be necessary adaptations to present economic conditions. These may be inherent to the pastoral production system, or dictated by developments in other parts of the country or even on the world markets and therefore outside the pastoralists control.

Without a proper understanding of these economic conditions and a conscious attempt to change them for the better or, adapt to them, any management proposals recommending changes in present behavioural patterns may not find ready acceptance. This observation is in line with the conclusions of a recent A.I.D. evaluation of their livestock sector projects in Africa (8). The evaluators reached a consensus that for these programmes to have favourable and beneficial impacts on producer populations, national wealth, and environmental conditions, they must be re-oriented to make them more nearly compatible with the social, economic, and environmental realities of arid and semi-arid pastoral regions of Africa.

For these two reasons an economic component in IPAL research activities would seem to be justified. Present economic studies on IPAL are being carried out by Mr. George Njiru of the University of Nairobi.

Objectives of the study. Boardly, the study aims at describing the economic relationships that exist within the Rendille nomadic pastoral ecosystem. Investigations on ways and means of improving the efficiency with which the economic functions of production and distribution of goods and services are provided will be carried out. It also aims at developing a methodology for analysing the development potential for similar arid areas.

Specifically, it is attempting to do the following:

(a) (i) Estimate the annual production of livestock and livestock products available for the satisfaction of human wants like food, shelter, clothing, etc.

(ii) at the same time estimate the quantities of these commodities which are necessary for satisfying subsistence needs under present conditions when 70-90% of the diet consists of milk, blood and meat.

(b) By substracting (ii) from (i) to estimate the quantities of these commodites which are surplus to the peoples' subsistence needs and hence available for marketing.

(c) (i) Estimate the quantities of livestock and livestock products which are marketed and the quantities of maize flour, sugar, and tea imported in a given year.

(ii) Study the marketing channels through which livestock and livestock products (exports), foodstuffs and consumer items (imports), are traded. Suggest ways and means by which the present system can be made more efficient in regard to quality of services rendered to customers, and quantities of goods moved in and out of the area.

(d) Using data from ongoing IPAL studies, conduct a cost-benefit analysis of management interventions which are being experimented on. This will reveal whether they are desirable in terms of good returns for money expended or not.

(e) Investigate the potential for the development of income sources other than from the sale of unprocessed livestock and livestock products. The following will be investigated:

(i) the possibility of developing aloes and Acacia senegal as cash crops,

(ii) the potential for expanding the collection and marketing of honey using modern hives instead of traditional methods which destroy the bees,

(iii) the possibility of locating a small-scale hides and skins tanning or curing factory in the area,

(iv) the possibility of locating an abattoir at Isiolo so that only meat is transported to the consuming centres down country. This is far cheaper than transporting live animals,

(v) whether there could be a market for the many horns and hoofs littered all over new and old settlement sites in the study area,

(f) finally, use data from ongoing IPAL studies to evaluate the viability of development units proposed by a FAO study team in 1970.

Preliminary Results and Observation

The economics studies have run for one year now and most of the data has not yet reached the stage of comprehensive analysis. A few general observations can however be made.

There are several new employment opportunities open to the peoples of these areas like working for traders, missions, and government or as migrant labour in the high potential areas. These opportunities are however closed to the nomads as they lack the basic skills and cannot talk swahili.

There is the possibility to earn a living as a trader although the rate of failure is very high due to a tradition whereby a trader cannot resist assistance to kinsmen when they beg for various commodities which deplete his stock. There are so far only 35 traders in Rendille territory. Only 5 of these are of Rendille origin and the rest are of Somali origin.

The nomads are highly exploited by enterprising middlemen who sell commodities to them at exobitant prices. Although this is partly due to a very in efficient trading network where costs of getting an item from the producer to the final consumer are very high, the prices offered to the pastoralists for their livestock are so low that they only sell when it is absolutely necessary - during droughts.

If the terms of trade for the pastoralists were to be improved so that a 35 kg goat was sold close to the sum of Kshs.200 it fetches in Nairobi (Kenya's capital) instead of Shs.70 given to them for the same and if a bag of sugar was sold to them at close to the Nairobi price of Shs.150 instead of Kshs.270 many more animals would be sold by the pastoralists (Njiru, 1981).

Many pastoralists do indeed like to buy maize meal, clothes, sugar, tea, tobacco, jericans and other goods imported from high potential areas. The main problem is that the terms of trade are so bad that the pastoralist decides to do without these things.

Such an increase in trade would raise offtake, lowering the pressure on the land and at same time improve the living conditions of pastoralists by improving their diet.

EDUCATION, TRAINING AND DEMONSTRATION

"Lack of education and environmental consciousness was identified as a major cause of desertification in Kenya. It was indicated that even though we have the technical know how of the root causes of desertification, little effort has been made to educate the masses and particularly the young generation, on preventive and remedial measures to fight against desertification". (National Environmental Secretariat, 1977). This quotation taken from the recommendations of Kenya National Seminar on desertification underlines the importance of the role of Education and Training in the improvement and stabilisation of production systems in the arid lands.

IPAL's education and training activities are based on the belief that scientific research results are not useful in achieving the desired goals unless they are translated into a form usable by the population affected by the problem of desert encroachment. The aim is therefore to use the findings of the project in education and training for the dissemination of information on rational management.

At the local and national levels, the project has been integrated into the Kenya Government's development plans for northern Kenya and the project is a member of the Marsabit District Development Committee where all matters related to the development of the district are discussed.

In addition to making direct inputs at the district planning level the project in co-operation with the Kenya Institute of Education is investigating through Consultants on the best possible way of incoporating project results and arid land ecology in general into the school curricula for the pastoral areas. This is designed to cover both primary and secondary school levels and later to be extended to Teacher Training Colleges and Institutions of higher learning like the University.

Study grants are being used to enable graduate students from the University of Nairobi and other institution to be attached to the project and to do their research on various components of the IPAL study utilising project facilities and advice.

On the basis of experience gained by the project staff and taking advantage of the logistic base for field-work that has been established, a series of training activities in forms of seminars for decision makers, administrators and

local people are being carried out. Training and orientation courses are being planned for all levels to be carried out at the Project's new headquarters in Marsabit. These courses will include instructions by the IPAL Scientists on all aspects of the Projects work, especially in observation techniques, lectures and demonstrations in arid zone ecology, range management, arid zone forestry and pastoral sociology. The facilities and experience of IPAL are also being made available to visiting scientists and extension officials from other countries in the region.

As communication in the arid areas is particularly difficult due to lack of an adequate road network, also because most of the pastoralists do not read or write, the Project is investigating the most effective way of communiting information to pastoralists. Using the Project as a test case, IPAL in co-operation with the Kenya Ministry of Information and Broadcasting is carrying out a 15 minutes radio programme broadcast twice a week in the Rendille language. The effectiveness of these broadcasts which will be evaluated after six month's cover all aspects of arid lands resource management including the Proejcts work. After each programme an evaluation questionnaire is filled out by the Project's field assistants on the peoples reactions. The Project is co-operating in its work with several national and international institutions based in Kenya.

DISCUSSION

The problem of degradation of the arid lands of northern Kenya is a serious one that needs urgent attention for not only does it involve the threatened survival of a people but because some of the processes of deterioration if allowed to continue may become irreversible.

Although livestock production will probably remain the best use of the arid lands of northern Kenya there will be necessity to consider carefully the type of livestock operations to be carried out. In terms of production it does not seem practical to manage livestock for milk production in an arid environment. The efficiency of conversions of the forage into livestock products for use by the pastoralist might necessitate careful consideration of the suitability of present cattle breeds.

Inspite of common belief, the natural ecosystem is not always the most efficient in the conversion of solar radiant energy in primary production on the transfer of energy into secondary production - (Cook, 1968). A manipulated system may produce more dry weight of plant material and frequently furnishes a diet more conducive to meeting nutritional requirements of the consumers than the native ecosystem. In view of reduced flexibility in the lives of the pastoralists of northern Kenya there is serious necessity to seriously think of range improvements especially in the already degradation where natural recovery would otherwise be too slow.

The Kenya Development programme centers upon the ratification of the rights of the pastoral people to their traditional grazing areas. This is seen as encouraging the social change necessary in order to translate subsistance pastoralism into commercial livestock production and to combat the present overgrazing and deterioration in range condition.

Emphasis is placed now on the type of land ownership not because of the moral issues involved but because without security of tenure there can be little incentive for improvement of land resources. It is quite clear in Kenya today that most pastoral societies feel most strongly the insecurity of their present position. The failure of previous attempts to effecting change in pastoral societies is certainly due in part to the ignorance of the biological basis of pastoralism but it must also be acknowledged that there has been little attempt to understand the Sociological Constraints on the fears and aspirations of the pastoralists.

Local conditions must be taken into account in physical, biological and hydrological planning of the arid lands for optimal productivity of the individual factors that have to be considered in development planning, priority probably should be given to human ecology and ecological approach to land use. This does not imply that the ecological ideas should always prevail, but it does imply that there is a limit beyond which ecological compromise is impossible. In arid and semi-arid areas, for example, schemes are sometimes propounded for the settlement of nomadic populations which, if permitted, would not only fail to realize any long term social or economic benefit, but would cause the destruction of the grazing resource especially during drought.

The initial results of IPAL discussed in this paper will have some application elsewhere in the world. The pastoralist with his family is the pivot of his way of life. Whether or not pastoralism will change to meet the present demands of development depends on the pastoralists attitude towards his own pastoral activities. A change in practice entails a far reaching process of physical, mental and spiritual adjustment - it actually amounts to a reorientation of the pastoralist as a person.

A SUMMARY OF BROAD RECOMMENDATIONS

Although it may seem somewhat premature to offer recommendations before the finalisation of IPAL and before a very thorough evaluation of the Project's findings, it would be inappropriate at this juncture not to provide some indication of the broad management measures that we see as necessary to provide the basis for rehabilitating and managing the resources of Marsabit District. The following is a list of these preliminary recommendations, which should be seen in the light of an integrated scheme for inclusion into the Government's planning for the District.

Establish an institution for training in arid zone ecology and management.

Draw up integrated and inter-disciplinary management plans which would incorporate the following measures:

- continue research and monitoring on the status and trends in the ecology and the social conditions of the region;
- to provide an outlet for surplus livestock, greatly improve livestock marketing facilities;
- as a stimulus to the economy of the region, raise the price of animal products on the markets above their present artificially low levels;
- institute a co-operative livestock management system to be co-ordinated with settlement schemes and rural industries;
- designate areas of intensive management close to settlements where the grazing of livestock will be prevented or reduced to a minimum to promote the rehabilitation of the vegetation;
- where livestock concentrations occur and are likely to cause the depletion of the woodlands through boma construction, provide, as a service, artificial fencing materials;
- within the co-operative livestock management scheme, appoint local qualified and experienced range management officers to regulate grazing with the agreement and participation of the herdsmen;
- by all means possible, disperse the livestock populations widely across the District to reduce the impact of grazing in the settlement areas and make full use of the grazing resources available but not used because of insecurity;
- in order to make it possible to use the present under-used area, greatly improve security against banditry and inter-tribal livestock raiding;

- when the dispersal of livestock becomes possible, provide a system for transporting milk rapidly to the settlements from the dispersed milking herds.
- introduce planned watering points to assist both in the distribution of livestock and reduce congestion in present concentrations.

ACKNOWLEDGEMENTS

The author wishes to offer grateful acknowledgement for assistance and contribution in the preparation of this report from the following:

H.F. Lamprey, C.R. Field, D.J. Herlocker, N. Sobania and G.N. Njiru.

The author is also appreciative of the assistance given by Miss Rosalind Wambui Kabari and Mrs. Margaret Makundi in Typing and putting together this case study.

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Printed by the 'A' Promoter Ltd.
P.O. Box 57694, Nairobi.