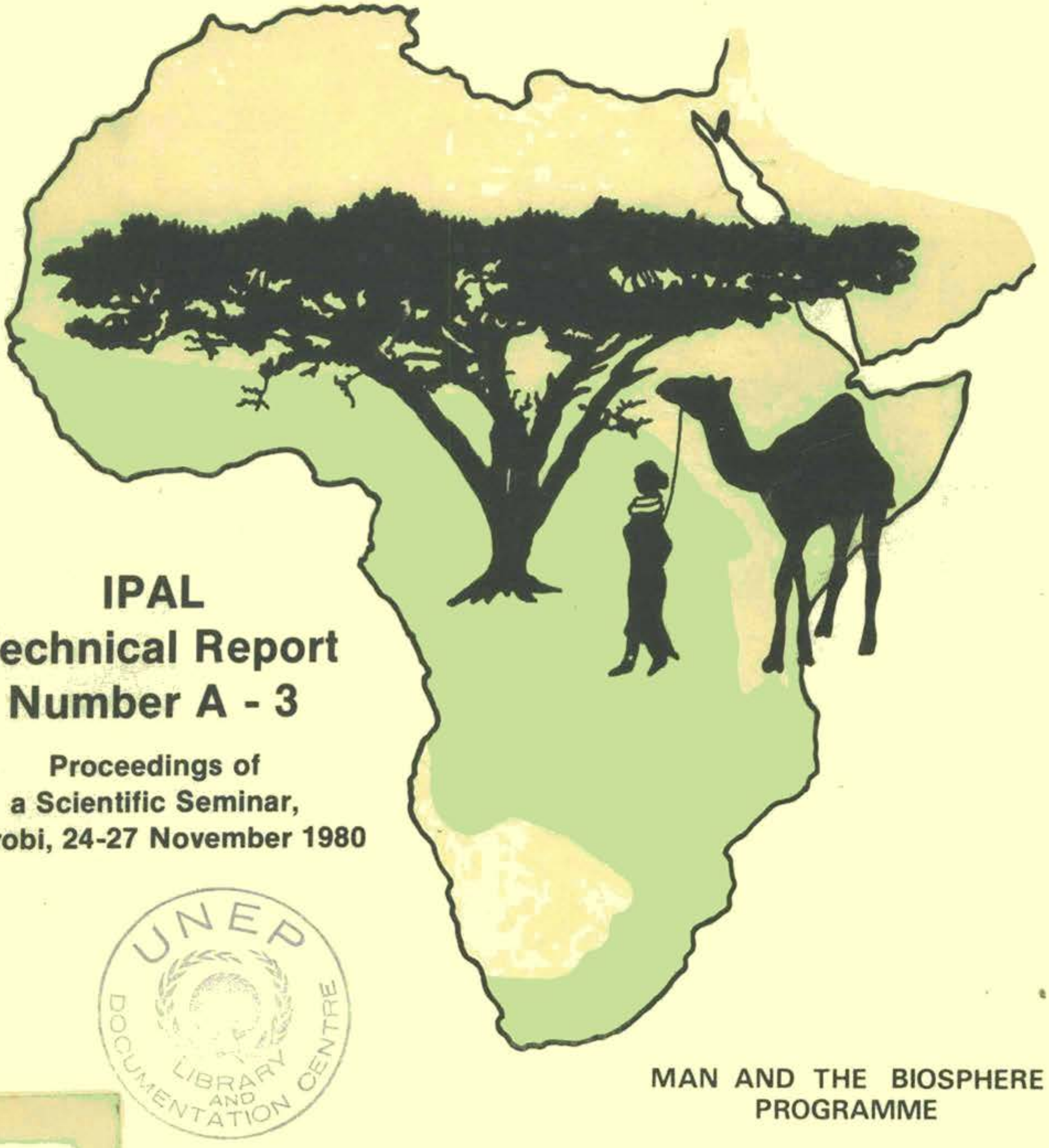
Unesco Programme
on Man and the
Biosphere (MAB)

United Nations
Environment
Programme (UNEP)

Integrated Project in Arid Lands (IPAL)



IPAL
Technical Report
Number A - 3

**Proceedings of
a Scientific Seminar,
Nairobi, 24-27 November 1980**

MAN AND THE BIOSPHERE
PROGRAMME

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

IPAL Technical Report Number A - 3

PROCEEDINGS OF A SCIENTIFIC SEMINAR
NAIROBI, 24-27 NOVEMBER 1980

UNEP - MAB 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, geomorphology and soils: brown

D. vegetation: green

E. livestock and other animal life: red

F. social and anthropological: yellow

CONTENTS

INTRODUCTION

Phase III of the IPAL research programme came into effect on 1 July 1980 and a meeting was held in August 1980 to make plans for this phase. This meeting found it necessary to reflect in a little more detail on past work which would form the basis for the planned work for Phase III. Consequently a scientific seminar and IPAL staff meeting was held from 21 to 27 November 1980 at the UNESCO regional headquarters in Nairobi. It was attended by all IPAL scientists and consultants and participants from Governmental organizations, the University of Nairobi and other interested non-governmental organizations. Also represented at the meeting were the Director of the UNESCO Division of Ecological Sciences, Dr Francesco di Castri, and Dr Colin Lendon, Programme Officer in charge of IPAL at UNESCO headquarters in Paris. The seminar was held immediately after the executive meeting of the UNESCO-MAB Bureau, held for the first time in Nairobi and attended by seven outstanding scientists representing their countries on the Bureau. As several of these scientists were themselves arid-zone specialists, an invitation was extended to them to stay on for the seminar.

The main objective of the IPAL seminar and staff meeting was to act as a forum for scientific information exchange between IPAL staff and interested officials and colleagues from Government, the University and international and non-governmental organizations. The aim was to present some analyses of past IPAL Phase II work which had not been previously published. Similar seminars will be held once a year in the present phase of IPAL.

Following the scientific discussions, IPAL Phase III plans were presented by the scientists concerned. Discussion was structured in such a way as to consider Phase II results and the work plans in the light of the priorities and research preferences of the participants from other Kenyan land-management related bodies.

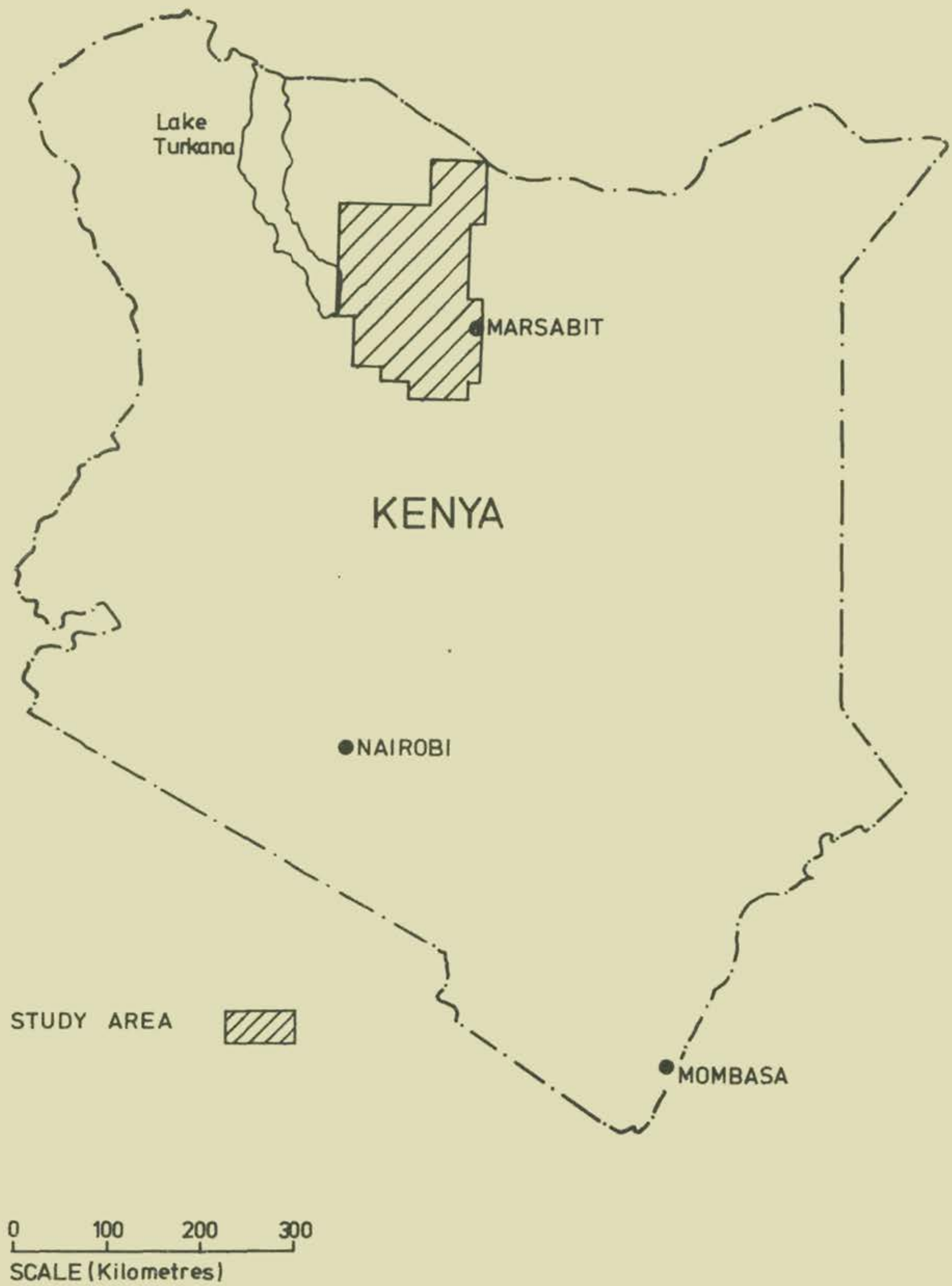
It was, for example, considered desirable that there be some overlap between the scientific information-exchange part of the meeting and the second function, the staff meeting. The latter was a team-planning excercise to finalize work plans for Phase III, with its most important aim being the achievement of a thorough integration of the component parts of the entire IPAL project.

This publication contains the proceedings of the scientific seminar only. Studies are presented as preliminary reports since most of the work is ongoing and will be concluded in Phase III. Only those tasks which had preliminary results were reported on so that this is not a comprehensive record of the studies being undertaken by IPAL. Ongoing work not reported on includes studies in woodland ecology; human ecology of the Gabbra, Turkana and Samburu; research in education, training and effective communication in pastoral areas; survey of surface and ground water resources, soils and geomorphology; climatology; forage intake by insects; aerial survey of populations, migrations and vegetation patterns; relationship between vegetation, rainfall and soils; monetary flow through pastoral economies, etc.

At this seminar no attempt was made to synthesize data as this will be the major task of Phase III of IPAL whose aim among others is to integrate and synthesize all project data and develop resources-management guidelines. This will be the main theme of subsequent yearly IPAL seminars. Papers in this report are arranged in the order in which they were presented.

ECOLOGY/LAND USE

Location of IPAL study area



THE INTEGRATED-ECOSYSTEM APPROACH TO RESEARCH ON THE ARID LANDS OF NORTHERN KENYA

W. J. Lusigi

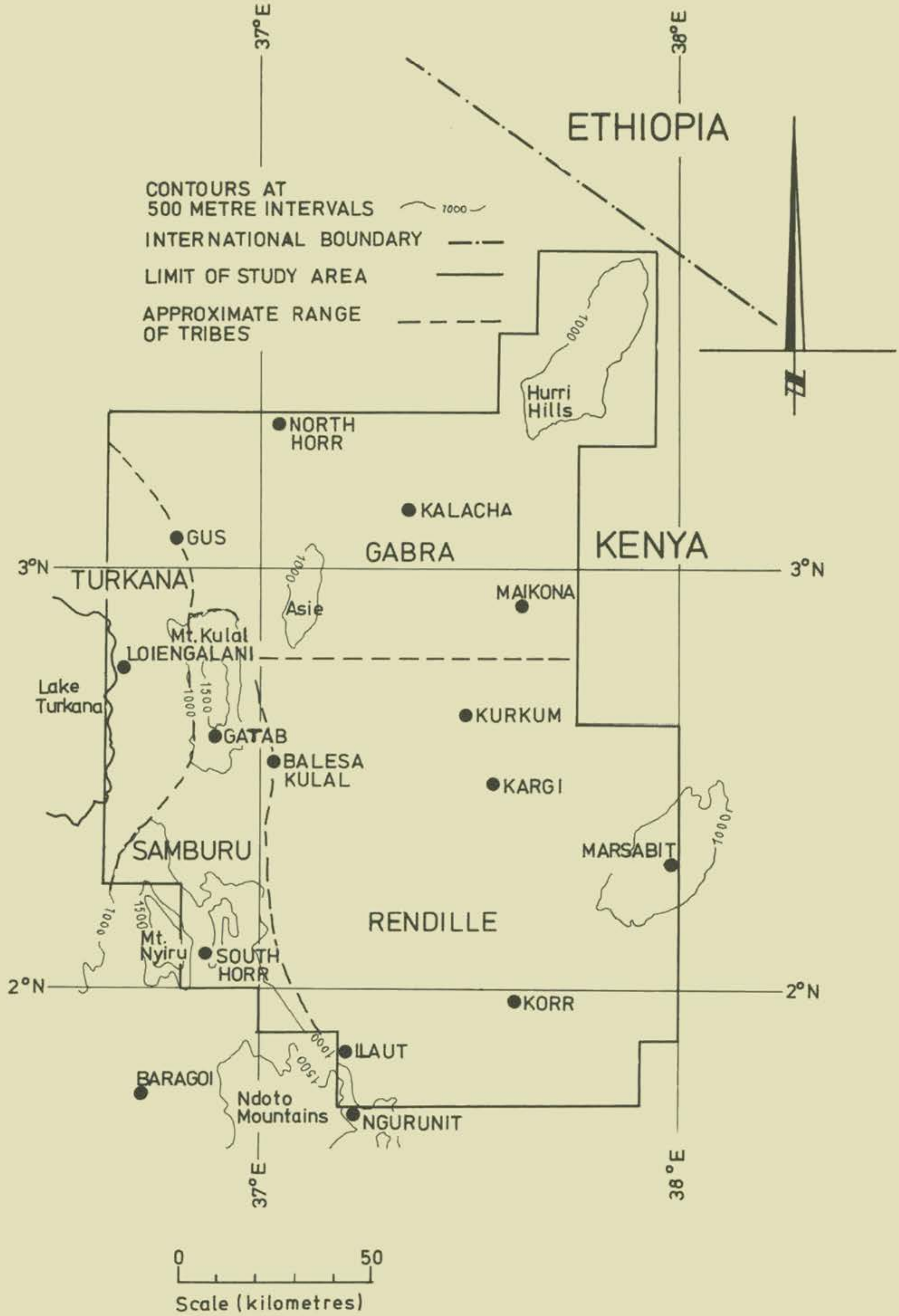
Introduction

The first principle to be recognized in any discussion of arid lands is that they are ecological systems resulting from the integration of all of the living and non-living factors of the environment for a defined segment of space and time. Understanding the ecological basis of productivity in nature means understanding ecosystems. They are complexes of organisms and environment forming a functional whole. The study or management of such complexes requires more than one individual which has led to the concept of interdisciplinary teams for research on and management of natural ecosystems. The purpose of this overview paper is to look at the arid land ecosystems of northern Kenya, some of the ecological problems affecting their productivity, and to show how IPAL's programme of research has been designed to answer some of the critical questions and help find solutions to some of the most pressing problems.

Rapid population growth, limited arable land and shortage of employment opportunities in the industrial and service sectors in Kenya have resulted in a high pressure on the use of the arid land resources. While increased settlement and exploitation of these lands provide a basis for the livelihood of many people who live in these areas, it has also led to overgrazing with resulting serious soil erosion. These areas have also been subject to constant droughts which have resulted in famine serious enough to require famine relief supplies. These factors when combined with traditional farming methods have maintained the economy of these areas at subsistence level. But as population pressures continue rising, such factors as constant overgrazing, denial of fallow and obliteration of wildlife may cause irreparable deterioration.

Recognizing the importance of the arid and semi-arid areas - approximately 88% of Kenya's total land area - and their potential for production of goods and services needed by mankind, and also

The study area



the dangers of erosion and desertification from indiscriminate use, the Government of Kenya has placed considerable emphasis on the proper development of these lands reflected in both the last and present Development Plans.

Since Kenya largely depends on primary production from its land resources, the full potential of this land must be developed by every means taking into account the optimal potential of the land. The development strategies adopted must be acceptable to the local populations and be based on an appraisal and evaluation of the relevant cultural, political, ecological and socio-economic factors. Resources must be balanced against local human needs in both the short and the long term. IPAL's role is to assist by providing scientific information and advice which will be needed in the development of the new strategies.

The extent of rangelands in Kenya

Kenya's economy is largely dependent on primary production from its land resources which are used for agricultural crops, forage, timber, water and minerals. These lands can be classified as crop land, rangeland, forest land, watershed land and mineral land. The rangelands are those lands carrying natural or semi-natural vegetation which provide a suitable habitat for herds of wildlife and domestic livestock. Additionally, some produce timber and all are important watersheds. Rangelands in Kenya are usually characterized as those receiving up to 600 mm of rainfall per annum. They also include areas with more rainfall which have soils and topography unsuitable for cultivation. Continued advances in the basic sciences, land-management techniques and demands for agricultural production will change cost-benefit ratios for alternative land uses, often resulting in the better-watered rangelands becoming used for crop land. However, the greater part of Kenya is arid land and will remain under range use.

The rangelands of Kenya are important resources covering 88% of the total land area of the country. Some 298,000 square kilometres of Kenya's land (about 52% of the whole) is classified as *arid* with a further 110,000 square kilometres (about 19% of the whole) rated as *very arid* and the rest of the 17% as *semi-arid*.

Only 12% of Kenya's surface area gets adequate rainfall for intensive farming on high-potential land. A further 6% of the surface area receives marginal rainfall on what is called medium-potential land. This leaves an aridity balance of 82% of the total surface area.

Climate

Rain is by far the most significant constraint to life in the range areas. The occurrence of distinct wet and dry seasons is most characteristic of these areas. In general there are two wet seasons a year on most of Kenya's rangelands. A bimodal distribution of rainfall with two growing seasons per year significantly increases the potential of the rangelands but unfortunately the rainfall is not reliable.

Although, by default, areas of unreliable rainfall are considered suitable for ranching or other range uses, relatively little consideration has been given to the economics of rangelands development as affected by rainfall.

Drought affecting Kenya's semi-arid vegetation has occurred frequently in recent geologic time. History shows that droughts lie at the bottom of most famines that have occurred in Kenya. These droughts, however, were not very serious as the population of the range areas was scanty. With population growth and the increasing pressures placed on the dry grazing lands in Kenya, drought has become a serious problem that claims lives of both livestock and wildlife.

Few economists attempt to estimate drought losses because of the large number of variables involved in the calculation. Drought losses seldom stop with a clear-cut figure of so many sheep or cattle dead or so many bags of wheat lost. Rather they tend to seep through to affect all areas of the economy.

Kenya's losses due to drought are hard to estimate. Davis (1970) estimated cattle loss in the 1969 drought to be over 100,000 head. The drought threatened Kenya's wildlife populations and the losses in human population due to starvation and disease were unpublished.

Drought losses are therefore diffuse and complicated. They invade almost every enterprise and affect almost every pocket in the country. Short of programming a computer with mass data there is no way of precisely estimating drought losses; it is certain that the nation hit by drought would be much better off if drought had not occurred. From the above estimated losses one could imagine how many miles of road or railroad, how many bridges, houses, educational facilities, these losses could have financed.

The range resource

1. Vegetation

The range area embraces almost all vegetation types from semi-desert to afro-alpine moorland. It excludes only dense forest and derived bushland and some categories of swamp vegetation. The most important types are deciduous woodland, open and wooded grassland, evergreen and thorn bushland and dwarf shrub grassland. For illustrative purposes in this paper six ecological zones are used as described by Pratt, Greenway and Gwynne (1966).

Lands used for grazing purposes, i.e. rangelands, extend through all six ecological zones. Zone I at high elevations is moorland and grassland. It is of limited use and potential for livestock but has high values for wildlife, tourism and water catchment. Zone II is humid to dry-sub-humid and supports forests, bush and derived grasslands. The potential is for timber, wildlife and tourist developments, crops such as pyrethrum, coffee and tea, and intensive pasture developments for domestic animals. Zone III is dry-sub-humid to semi-arid. The vegetation is woodland *(Combretum)*, bushland and savanna with high agricultural potential. Zone IV is semi-arid and is illustrated by *Acacia-Themeda* association. Only the very best has a marginal agricultural potential. It is highly productive range and carries high densities of both livestock and wildlife. Zone V is arid, supporting bush and perennial grasses. Agriculture is limited to favourable soils on topographic situations that receive extra water. Wildlife is important in the dry open bush but the livestock potential depends on practices which discourage bush and encourage grass. Zone VI is very arid and is dwarf shrub grassland in which many of the grasses are annual. The forage is highly seasonal and nomadism is the way of life. Many animal species are well adapted to this area.

2. Wildlife

Wildlife constitutes a very important range resource. Much of the tourist industry of Kenya is based on the scenic panorama and wildlife of the range areas.

Wildlife is the backbone of the tourist industry which in 1978 brought approximately £60,000,000 of foreign exchange into the country thus surpassing any single agricultural export crop. Although national parks and game reserves occupy about 11,000 square miles much of the viewing and hunting takes place on land occupied by pastoralists. These lands are also important in that areas demarcated as parks are not necessarily complete ecosystems and therefore park animals spend much of their time grazing on these lands. The range area has a tremendous capacity for supporting wild animals. The biomass of game animals has been recorded as being up to 100,000 pounds per square mile. The abundance and variety of species indicates that a wide array of ecological niches are filled and that the conversion of a large spectrum of the available plants into animal products is being accomplished. Wildlife has always been utilized by pastoralists as food supplements in times of drought but these advantages can also be exploited more fully through cropping for meat.

3. Man and domestic livestock

The understanding of the ecology of man and livestock on the rangelands is important if developments on the rangelands are to be understood and its lifestyles manipulated towards new standards. Man has been an important component of the range ecosystems for a long time. Through the activities of man there have been various impacts on the range ecosystems and he has been largely responsible for maintaining some parts as rangelands. Because of the highly variable weather conditions in the rangelands man has evolved survival techniques which are difficult to change. It is largely the insecurity of nomadism and other cultural practices designed to ensure survival through droughts which has led the modern world to regard such people as conservative, and this in turn has led to slow development in these areas.

The common basis of all pastoralism in Kenya is a dependence on milk as the staple food. The quality of blood, meat or other foods may vary, but milk always constitutes the major and preferred part of the diet.

The aim of a family living in these areas is therefore to maintain a milk herd which can provide the family requirements throughout the year, including the dry season when the yield of milk per animal is very low. This necessitates a minimum herd size sufficient to survive drought and disease and a preponderance of female animals in the herd which gives it the capacity to increase rapidly whenever conditions are favourable. In the driest areas, or wherever water is scarce, it follows that some degree of nomadism will be a biological necessity of survival. In most tribes the milk herd comprises cattle, though camels are more important in some of the drier areas of northern Kenya. Sheep and goats may also be used for milk but are mostly kept for meat and barter. A flock of about 50 small stock permits a family to consume meat each week without the wastage and the dependence on a total communal feast which would be involved were the regular supply to come from the cattle or the camel herd.

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 of the overgrazing problem must be sought not overtly in enforced stock sales but in effective changes in the traditional system which will free the people from their dependence on milk.

Government policy for the development of arid lands

The underlying philosophy of the Government towards development in the range areas is basically the commitment to the development of these areas as a basic human right and for the benefit of the national economy. An integrated approach to the development and planning of these areas has been stressed together with the need for close co-ordination. While the planning will proceed on the basis of regional analysis considering watershed and agro-climatic areas, implementation will be on a district basis, relying on established administrative systems and ensuring local-level participation in assessing needs and priorities.

Since Independence the Government has emphasized the educational approach instead of forced change. Participation of local people in assessment of needs and priorities has been a very significant feature of this policy. It is also the aim of the Government to fully develop the human resources in these areas through improved health, education, nutrition and local skills of the people.

The productive potential of the rangeland is considerable but this has not been fully utilized especially in terms of crops, animals and wildlife. It is the Government's policy to develop the technological and organizational inputs in order to realize the full potential of these lands. The ecological instability of the rangelands has been mentioned. The Government has also stressed the development of these lands according to their ecological potential. This also includes the conservation of wildlife, water and soils of the rangelands.

Key environmental problems in Kenya's rangelands

In order to realize the planned development in the range areas, it is important to understand the main environmental constraints which limit development in them. Solutions to overcoming these constraints will have to be found as part of the development strategy of these areas.

1. Environmental constraints

A major environmental constraint in the rangelands is the fluctuating and unreliable nature of the climate. Limited and unreliable distribution of rainfall has limited the production of crops and animals on rangelands. Coupled with the erratic rainfall is the low fertility of the soils in these areas further reducing their potential for intensive crop production.

2. Scarcity of resources

Although range areas cover large areas, land is still one of the major limited resources. Because of the fast growing population in the range areas, the amount of land needed to feed a family is very limited. This limitation is also made more acute by the low potential of the land. Another limiting factor here is the availability of water. Given the limited land potential and water availability, then the existing system must be developed to achieve a fulfilment of multiple functions (multiple use) and realistic objectives that would ensure an adequate sustained yield.

3. The contraints of technology

Technology is a severe limiting factor in the ability of man to exploit land and water resources in the range areas. Dry farming systems, development of plant varieties that can best survive in these areas, grazing and feeding techniques, suitable stock and conservation technologies needed for full production in these areas have not been adequately developed to meet the growing demand for food. Traditional technology needs to be studied and improved on.

4. Infrastructure

The lack of an adequate infrastructure in the range areas is a severe constraint to development. An inadequate network of roads means, for example, that goods and services cannot be delivered to where they should be in time. A lack of infrastructure also limits the possibility of providing better extension services to these areas and other basic services like health and schools.

5. Development of human resources

The increase of population on the rangelands to the extent of exceeding their carrying capacity is a serious constraint. The range areas are delicate ecosystems with a very low human-carrying capacity. Although the increase here is probably less than in the better watered areas, it is still very serious in terms of the ability of the land to maintain these people at the present level of technology. The population problem in the range areas is compounded by immigration of people from the higher-potential areas who bring with them land-use systems which are inappropriate to the range areas and so introduce deterioration of the rangelands. Although human resources development in the range area is one of the prime objectives of the Government, it must be recognized that the lack of such development is a constraint on the Development Plan. The range areas also lose some of their most productive people who migrate to urban areas in search of better employment opportunities. The Government's ability to implement projects in range areas is severely limited by staff, vehicles and equipment.

6. The multidisciplinary approach to development

Another constraint on the development of the range areas has been the lack of an integrated approach to development, although this has now been realized in the new Development Plan. Unco-ordinated development of water facilities, animal health improvement facilities and human health facilities have led to a severe deterioration of the environment in the range areas due to over-grazing.

Another problem is the proliferation of unco-ordinated private organizations carrying out famine relief, human settlement programmes and the supply of health facilities. Vital ecological information is lacking in the implementation of these schemes leading to severe environmental deterioration especially where populations are made to settle in ecologically unsuitable areas.

It is against this background that IPAL was set up. The efficient management of renewable resources depends on a knowledge of the interrelations of organisms at various levels of activity and their relationships to abiotic sub-systems. The complexity of the factors leading to environmental deterioration and the complexity of the ecological system dictates that a highly organized and integrated approach be applied to its study.

Objective of the IPAL study

It is not intended here to rewrite IPAL project objectives (outlined in the project document, *Plan of Operation*), but rather to reflect on what should be the direction of IPAL research and possible outcomes of the study. The ecosystem approach adopted by the IPAL study investigates primarily the biological basis of productivity of the system, what factors influence the productivity of the system and how these could be manipulated for improved productivity as opposed to deterioration. The main objective, therefore, is to provide reliable scientific data that would facilitate the development of a resource management plan or model for the ecosystem. Quantitative measurements were a preliminary aim which now must rapidly lead to the study of processes. Both these types of information are necessary to produce a realistic management model that can be tested by examining the effects of manipulation of components on the function of the system as a whole.

Although it is of considerable interest to observe the dynamics of productivity in one ecosystem, it is also necessary to compare these ecosystems. Interpretation of data relative to metabolism and nutrient transformations requires experimental manipulation and comparison of ecosystems that are basically similar. Such experiments are also essential in the understanding of processes. It is for this reason, among others, that IPAL should continue to be part of the UNESCO-MAB-3 Programme so that its results can be compared with the results of similar studies in other parts of the world.

1. The IPAL study area

The choice of a suitable study site is very significant in any ecosystem study if the objectives of the study are to be adequately realized. It is important that the site be representative in order to incorporate all the processes being observed or investigated.

The IPAL study site has been selected to meet these criteria. With an area of about 22,500 km^2 it is sufficiently large and covers the major biotic communities found in the area. From near woodland in the south, where Ngurunit Station is located, it extends northwards up to the edges of the Chalbi Desert. 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. The problems of arid land deterioration are to be observed to various degrees in this area as brought about by both weather fluctuations and the activities of man - grazing of camels, cattle, sheep and goats, human population increase and *boma* construction, etc. The study area is adjacent to Marsabit town, which is the district headquarters, and when the project main station is completed in Marsabit during Phase III it will facilitate exchange of experience with the Government departments operative in the area. Because of the ease of communication and availability of electricity it will be possible to do more sophisticated analyses of data in Marsabit instead of having to rely on facilities in Nairobi. The IPAL study site therefore allows for the processes under investigation to be observed directly in the field where they are taking place.

2. IPAL's research team

At present IPAL's research team is composed of five full-time professionals supported by part-time associate experts and consultants. The full-time experts covering the fields of range ecology, woodland ecology, small-stock ecology and camels and cattle ensure continuity of the field studies. The need for expert and consultant support in different areas depends on the extent of participation of the specialist and on the degree of dependence of the others on the data from that portion of the project. Co-ordination of activities is an important requirement at all levels and for this IPAL has a research co-ordinator and an administrator with a small core of support staff.

The success of an ecosystem study depends to a large measure on the degree to which participants operate as a team. Individual initiative must be encouraged within a framework that includes sharing of basic data and collection of data, at least partly as a service to others. In Phase III of IPAL, this will be achieved by frequent quarterly meetings of the scientific research team at which common approaches and difficulties are discussed. Although activities of greatest value to the group may be routine for the individual, there will be opportunity for related studies in which individual scientists may make more independent contributions.

In a project like IPAL, there will be some scientists who are not attuned to working on field projects. Substitution of laboratory projects for essential field projects should not occur. Where laboratory studies are essential, for example in the livestock component, these should not be divorced from field participation.

Recruitment difficulties may result in the decision to fit the project to the readily available scientific pool. This tendency must be resisted as it is unlikely that a total ecosystem approach, such as that required by IPAL's mandate, would be successful under such circumstances.

IPAL's scientific programme

In an ecosystem study such as that being carried out by IPAL it is important that research plans be produced by the scientists themselves and these must conform to agreed standards. As the research projects must be closely co-ordinated, scientists have been given ample opportunity to consider each other's plans. Although it is common in a study of this type to find differences of opinion concerning the relative priorities of various aspects of the study, uniformity of treatment is important. It is for this reason that frequent review meetings for scientists have been planned in Phase III so that the scientists can study and decide on these priorities in the face of limited budgets and time.

1. Organization of IPAL research

As the IPAL study centres on the productivity of the ecological system, the research programme has been designed to cover all the major components of the ecosystem. These include research on the abiotic components of the ecosystem - climate, geomorphology, soils, hydrology - and the biotic components of the ecosystem - primary production and secondary production. The activities of man, which as we have observed have significant influence on this ecosystem, are considered under a special human ecology component. The detailed treatment and presentation of these various components will be made by specific scientists in the following papers. I shall, therefore, make only a brief mention of them in this overview paper.

Climate

As already mentioned, one of the most significant factors contributing to the aridity of northern Kenya is the unreliable and irregular patterns of rainfall. Climatic factors contributing to the degredation of these lands must be understood if management plans are to incorporate adequate measures for preparing for droughts and other natural disasters in the area. A climate-monitoring programme was started in the last phase of IPAL and this will continue into this phase. In order to have a good understanding of the climatic picture, it is important that these observations continue at least through one climatic cycle - about 20 years. Shall we be able to achieve this? This is one of the dilemmas of a time-specific funded research project. Monitoring of climate in Phase III of IPAL will be carried out by a consultant from the Kenya Meteorological Department.

Geomorphology and soils

Since the vegetative cover of an area is partly the product of the associated soils and climate, the importance of studying these factors cannot be overlooked. Studies of geomorphology and soils in the study area which were started in the last phase of IPAL will continue. They are carried out by an associate expert attached to the project, and a consultant. A knowledge of the soils, their capability or fertility, their structure and texture and their productive potential is a very significant part of any resource management plan and these will therefore have to be understood.

Hydrology

Water is one of the essential elements of life and in an arid environment this is more obviously so. In order to institute sound grazing schemes and to overcome the present observed deterioration, we must have a sound knowledge of the water resources of the area - both underground and above ground. Work on hydrology which was not covered in Phase II of IPAL will be given priority in Phase III by the hiring of a consultant in hydrology.

Primary productivity

One of the primary indicators of desertification or environmental deterioration in an arid environment is the deterioration of the vegetative cover of the area leading to soil erosion. As the grazing resource is the primary source of livelihood in this area it is rightful that it should receive the greatest emphasis in IPAL research. The primary-production component on IPAL is divided into two parts covering range ecology and woodland ecology, each manned by an expert scientist. The range ecology programme considers in detail the status of the available forage for livestock, its condition and its availability and tries to detect the various trends in its improvement or deterioration. Woody vegetation has also a significant place in this ecological system for not only is it used for fuel, forage and building construction of cattle and resident enclosures, but it is an important source of material for the constructions called *boma* and *manyatta* in this area. Considering the scarcity of woody vegetation in this environment and the length of time it takes to grow, its destruction is a significant factor in desert encroachment and therefore of great scientific and management interest. Management of the vegetation resource is one of the most significant components of an arid land resource management plan.

Secondary productivity

A complete study of the secondary productivity of the ecosystem should measure quantitatively and qualitatively the intake of primary production by herbivores, the proportional transfer of this intake to secondary consumers and losses from the ecosystem through consumer metabolism and other forms of transfer. Equally significant, if remedial measures are to be recommended in the resource management plan, would be a knowledge of what factors affect the efficiency of these transfers. As domestic livestock are perhaps the most important secondary consumers in the IPAL study area, studies have concentrated on the major livestock species in the area - goats, sheep, camels and cattle. These studies are carried out by two animal ecologists.

Since initial observations seemed to suggest that the deterioration of the grazing resource is due to overstocking, it was important to know exactly the number present. This was accomplished through a preliminary aerial survey of the fauna of the area giving the numbers, abundance and distribution of major species. Now studies are concentrating on the more qualitative aspects of determining the efficiency of energy transfers and productivity in terms of milk, meat, etc. Factors limiting the productivity of the ecosystem as a whole, and especially the four main livestock studies, are being emphasized in Phase III. All this information will be significant in developing a resource management model that will ensure optimal productivity without resource deterioration. In some areas rehabilitation will have to precede any management efforts.

Human ecology

Natural ecosystems are integrated ecological systems which produce some elements that are of direct or indirect use to man. These products may be biological, e.g. grain and meat, or physical, e.g. water, but in all cases the distinguishing feature of a natural ecosystem, especially in the arid areas, is the direct involvement of man in the complex set of ecological interactions. Management is defined as the manipulation of the ecosystem by man, whereas beneficial management involves manipulation to maximize the returns to man. Exploitation is management that results in the reduction of the productivity of the ecosystem to mankind over a period of time. The latter seems to be what is taking place in the arid lands of northern Kenya and it is important that the activities of man be understood if there is to be any hope of rehabilitation and proper management of these areas.

Pastoralism is an adaptation to a highly unstable semi-arid ecosystem and its biological and cultural basis must be understood. Social organization affects the patterns of land use and tenure; the kind of animals in the range herd (preference for cattle, camels, goats or sheep and environmental restrictions on kinds of animals) attitudes towards money; dietary preferences (some tribes mix cattle blood with milk while others do not and most pastoralists do not voluntarily eat grain); and attitudes towards wildlife (in the same ecological conditions Samburu (Nilo-Hamites) and Boran (Hamites) are tolerant to wildlife while Turkana (Nilo-Hamites) are very destructive). Any efforts to check the trend towards deterioration in the resources of northern Kenya will involve at least some changes in social organization and structures and it is important that these be understood if any resource management plan is to work.

It is for this reason that IPAL Phase III will have the services of a human ecology expert to study all the activities of man in this region. This will also involve history. Without historical facts as a background for the present ecological setting, there is a risk of making serious mistakes in both management and research because the factors determining the prevailing situation are not understood.

The traditional economy and marketing structures are also being investigated in order to see how they can be incorporated into the modern marketing economy and made to encourage a flow of resources between high potential and low potential areas. This work is being carried out by a graduate student partly financed by IPAL and preliminary results are given in these *Proceedings*.

Conclusion

IPAL research will continue to focus on these major components of the arid land ecological system. Many lessons are still to be learned concerning the processing and interpretation of data on an integrated basis and the most effective means of presenting results.

An added activity of IPAL research is the training component.

Through the offer of fellowships and professional seminars we hope to increase both the local and regional capability to deal with the problem of arid land deterioration. It is hoped that the approach adopted here and the results obtained will be comparable to results from similar studies carried out under the UNESCO/MAB 3 project in other parts of the world.

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PRIMARY PRODUCTIVITY OF THE HERB LAYER AND ITS RELATION TO RAINFALL

D. J. Herlocker and R. A. Dolan

Introduction

Following completion of the vegetation map for the IPAL study area (Herlocker, 1979) research emphasis was placed on the study of primary productivity. This was because of its importance as a determinant of livestock stocking rates and of long-term carrying capacity.

Priority was placed on the primary productivity of annual grassland, dwarf shrubland and perennial grasslands because:

(a) The first two vegetation types are the most extensive within the study area. Combined they comprise 60.0% of the total area.

(b) Perennial grasses are the principal food for cattle (Lewis, 1977); grasses, forbs and dwarf shrubs for goats and sheep (Field, 1978; Field, 1978); and dwarf shrubs for camels (Field, 1978).

(c) The technique for sampling net standing crop of herbaceous (and small dwarf shrub) vegetation is well known, simple, easy to execute and could be used immediately without the need for prior experimentation, testing and calibration (Brown, 1954; Mannetje, 1978).

Methods

Primary productivity was sampled by clipping plants within $\frac{1}{4}$ m^2 quadrats at the peak of the growing season to obtain net standing crops (Brown, 1954; Mannetje, 1978). 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 cessation of the rains, which have a bimodal pattern in northern Kenya (Edwards et al., 1979). Four arid (annual grassland and dwarf shrubland) and five semi-arid (perennial grass-land) sites were sampled.

Clipped vegetation was divided and sacked in the field on the basis of species, standing dead, herbaceous litter, woody litter, and this seasons growth; samples were air dried for one month, weighed and sub-sampled for oven drying, which was carried out at Gatab (IPAL), Nairobi (Kenya Rangeland Ecological Monitoring Unit) and Kitale (Kenya Agricultural Research Institute).

Rainfall was measured by rain gauges placed either immediately inside or within 3 km of each enclosure.

Different aspects of (a) annual rainfall and (b) seasonal rainfall were used to predict primary productivity in (i) annual grasslands and (ii) perennial grasslands. The different aspects of annual and seasonal rainfall measured are given in Table 1. The data was analysed using the stepwise multiple regression analysis programme (XDS 3) available on the University of Nairobi computer.

Table 1. Rainfall measures

Annual rainfall

(i) Total annual rainfall (TAR)
(ii) Rainfall 10 mm/month (R 10)
(iii) Number of months with rainfall 10 mm (Mts. 1)
(iv) Longest consecutive period of months with rainfall 10 mm (Mts. 2)

Seasonal rainfall

(i) Quarterly rainfall - calendar basis (Quat)
(ii) Total rainy season rainfall (TRS)
(iii) This months rainfall (M 1)
(iv) Rainfall for the preceeding two months (M 12)
(v) Rainfall for the preceeding three months (M 123)
(vi) Rainfall since the last dry period* (RLDP)

* A dry period is defined as a month with under 10 mm rainfall, which occurs within what is otherwise a rainy season.

Results and discussion

1. Annual rainfall

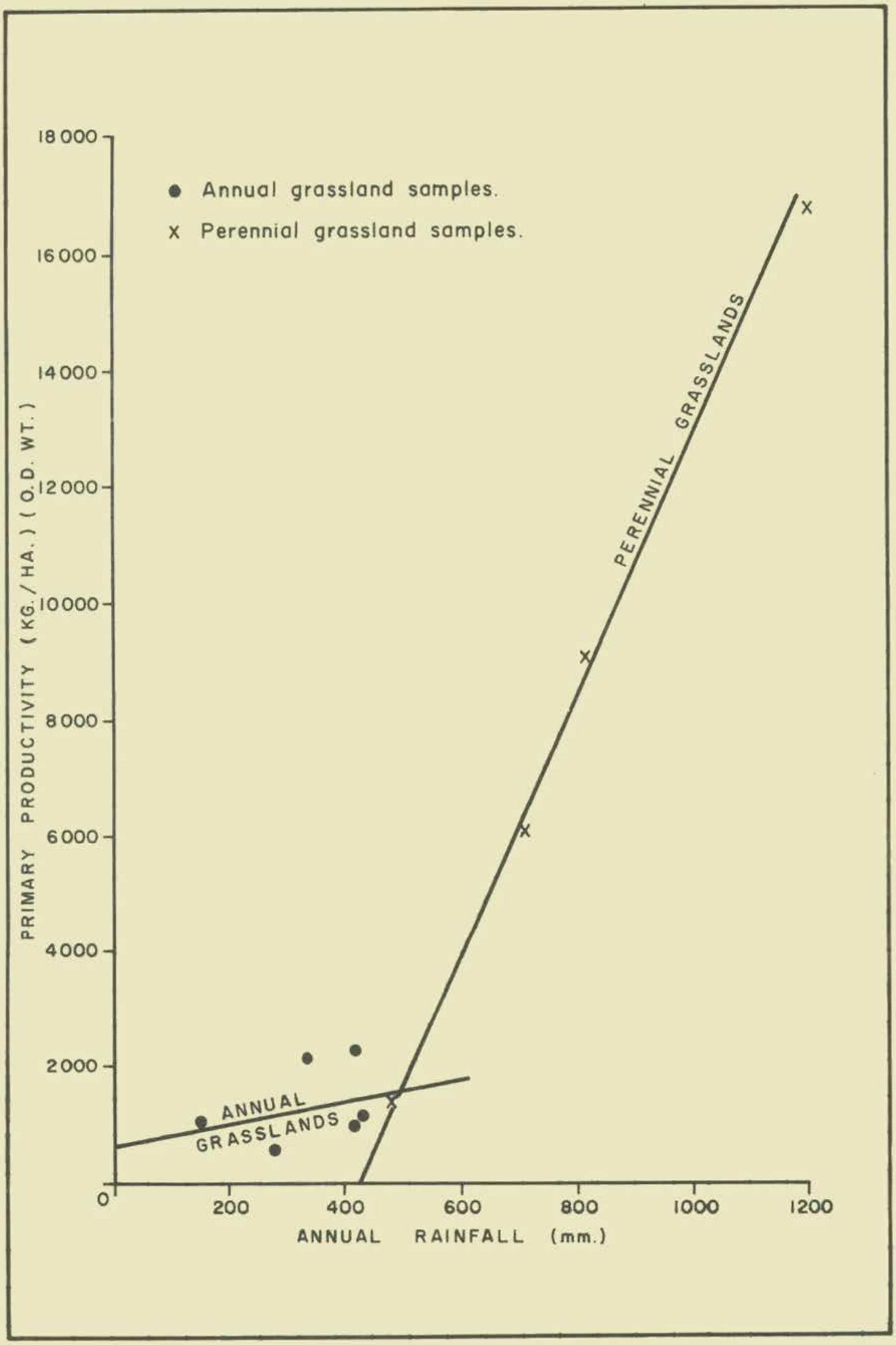
Of the four different aspects of annual rainfall (Table 1) it was found that (i) Total annual rainfall (TAR) and (ii) Rainfall under 10 mm/month (R >10) were highly correlated with each other with an r value not significantly different from 1. The other two aspects of rainfall, (iii) Number of months with rainfall under 10 mm (Mts. 1) and (iv) Longest consecutive period of months with over 10 mm (Mts. 2), accounted for very little of the variation in primary productivity. These findings applied to both annual and perennial grassland alike. Once total annual rainfall (TAR) was included in the prediction equation, for either grassland type, the addition of any other independent variable had a non-significant effect.

Table 2. Total annual rainfall as a predictor of primary productivity

	Annual grasslands		Perennial grasslands	
	Jan.-Dec.	*June-May*	*Jan.-Dec.*	*June-May*
Number of observations	4	5	7	4
Regression coefficient	0.59	1.80	8.09	23.52
Standard error	3.68	5.07	5.37	0.90
Correlation coefficient	0.11	0.33	0.56	1.00

Table 2 gives the regression and correlation coefficients (b and r), together with the standard error of b, for total annual rainfall as a single independent variable predicting primary productivity in annual and perennial grasslands. Results are presented separately for rainfall measured on a calendar year basis (January-December) and on a non-calendar year basis (June-May). The results are shown in Figure 1.

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



Only in the case of the perennial grasslands where measurements were on a June-May basis are the values for b and r significant and with such small sample sizes caution must be exercised when considering such results. However, keeping in mind the small sample sizes throughout, a possible trend in the data is perhaps indicated. Total annual rainfall is a potentially valuable measurement in providing information on primary productivity in perennial grasslands but very much less useful in annual grasslands. Also, measurements on a June-May basis are more useful than those taken on a calendar-year basis.

2. Seasonal rainfall

The correlation coefficients for primary productivity and the different measures of seasonal rainfall are given in Table 3 for both annual and perennial grasslands.

Table 3. Correlation coefficients (r) for seasonal rainfall measures and primary productivity in annual and perennial grasslands

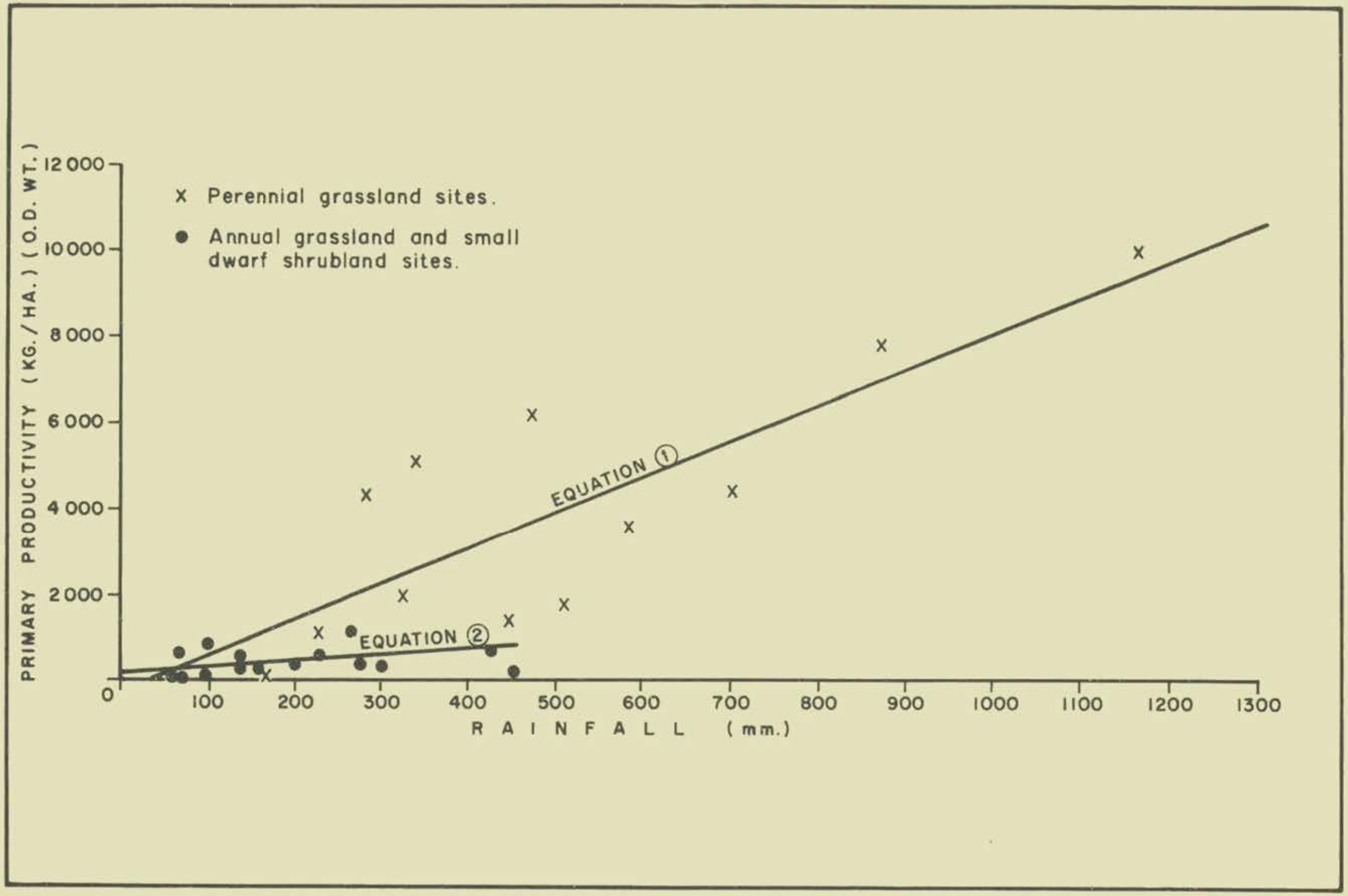
	Quat	TRS	M1	M12	M123	RLDP
Annual grasslands (n=13)	0.47	0.45	-0.07	0.51	0.44	0.20
Perennial grasslands (n=12)	0.67	0.74	-0.02	0.27	0.26	0.82

For the annual grasslands none of the measures of seasonal rainfall is significantly correlated with primary productivity. For perennial grassland, Rainfall since the last dry period (RLDP), Total rainy season rainfall (TRS) and Quarterly rainfall (Quat) were all significantly correlated with primary productivity. RLDP was the single best predictor. Once RLDP was included in the predition equation addition of either TRS or QUAT had no significant effect. The prediction equation was:

Primary productivity = - 217.30 + 8.23 (RLDP).

Both the regression and correlation coefficients for RLDP were significant at the 1% level. The results are shown graphically in Figure 2.

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



As in the case of annual rainfall, seasonal rainfall is a poor predictor of primary productivity of annual grasslands but is a good predictor of perennial grassland primary productivity.

Further work

Analysis of data from this study is not yet complete. In particular, the separate contributions to annual grassland primary productivity of its major components (a) small dwarf shrubs and (b) annual grasses and herbs will be considered in relation to rainfall.

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COMPARISON OF DIFFERENT TECHNIQUES FOR THE DETERMINATION OF LARGE DWARF SHRUB BIOMASS

D. J. Herlocker and R. A. Dolan

Introduction

Duosperma eremophilum, a large dwarf shrub, is the most abundant woody plant within the IPAL study area (Herlocker, 1979). Although it is not a particularly palatable plant it is an important browse for sheep and goats, particularly during the dry season (Field, 1978; Schwartz, 1980). Together with *Aristida* annual grasses and the small dwarf shrub *Indigofera spinosa* it can be expected to be one of the most important contributors to plant biomass, primary productivity and, probably livestock forage as well, in the study area.

Therefore, the study of biomass and primary productivity of this large dwarf shrub species was an emphasized component of the range ecology programme.

The measurement of large dwarf shrub biomass and primary productivity is, however, slow, time consuming work as the individual plants are too large and widely spaced to be sampled in the same way as are grasses and small dwarf shrubs. Instead, two separate field steps are required.

First, individual plant biomass (component and/or total) must be related to some easily measureable attribute of the plant (such as crown diameter) through destructive analysis. Second, a survey of the population structure of the dwarf shrub community is made. Plant biomass of the community is then determined from mean plant biomass and total dwarf shrub density. In the case of new growth (leaves and new twigs), calibration through destructive sampling must be repeated if monitoring of seasonal changes is required or if biomass sampling is moved to sites at different phenological stages.

Thus, logistical and time constraints limit the number and size of the sample, thereby reducing the extent to which the subsequent results can be extrapolated. Therefore, an attempt was made to find a means of reducing time spent in destructive sampling which would also increase the sample size and the applicability of the results.

Methods

A combined study of *Duosperma eremophilum* biomass and comparison of techniques for measuring such biomass was carried out at Ngurunit during five months between December 1978 and November 1979 which represented both wet and dry seasons. Approximately 15 *Duosperma* plants were selected across a wide range of size classes, measured and destructively harvested.

Table 1. Methods and measurements used in correlation with large dwarf shrub biomass

Method of measurement	*Measurement (predictor)*	*Means of measurement*
Size	Crown diameter (D) Total height (H) D^2H Crown area Crown volume (1) Crown volume (2)	
Ten-point frame	Number of pin 'hits' within a biomass category	Frames placed at ½ foot intervals across crown diameter. All pin 'hits' recorded until ground level is reached.
Capacitance meter	Mean reading Total of all readings Reading at centre of crown	Readings taken at intervals of ½ width of the metre across the diameter of the crown.
Photometer	Mean reading Reading at centre of crown	Readings taken at ½ foot intervals across crown diameter from chest height.

Four categories of measurement were made: size, vegetative cover (ten-point frame), moisture content as reflected by resistivity (capacitance meter), and chlorophyll content (photometer). Fifteen different measurements were made (Table 1). Following destructive analysis each *Duosperma* plant was divided into nine component categories, the most important of which were (a) leaves and (b) new twigs which, together, constitute available forage (Table 2).

Table 2. Simple correlation coefficients (r) between the most efficient predictors for each type of measurement of large dwarf shrub biomass.

	June				July			
	C.D.	*ten-pt frame*	*Cap. mtr*	*Phot*	*C.D.*	*ten-pt frame*	*Cap. mtr*	*Phot.*
Leaves (a)	0.89	0.86	0.80	0.84	0.92	-	0.91	0.86
New twigs (b)	0.86	0.93	0.89	0.88	0.90	-	0.93	0.80
a + b = forage	0.89	0.91	0.80	0.87	0.94	-	0.93	0.86
Wood	0.85	0.94	0.88	0.90	0.96	-	0.90	0.74
Total live (c)	0.87	0.94	0.88	0.90	0.96	-	0.91	0.76
St. dead (d)	0.87	0.63	0.55	0.56	0.77	-	0.77	0.40
(c + d)								
Old leaves	0.88	0.92	0.85	0.87	0.92	-	0.88	0.64
Litter					0.91	-	0.91	0.86

	August				November			
	C.D.	*ten-pt. frame*	*Cap. mtr*	*Phot*	*C.D.*	*ten-pt. frame*	*Cap. mtr*	*Phot*
Leaves (a)	0.54	0.50	0.56	0.16	0.89	0.73	0.89	0.74
New twigs (b)	0.77	0.70	0.94	0.07	0.62	0.75	0.68	0.65
a + b = forage	0.74	0.67	0.85	0.11	0.86	0.75	0.88	0.49
Wood	0.92	0.89	0.66	0.17	0.84	0.66	0.72	0.51
Total live (c)	0.93	0.90	0.68	0.17	0.85	0.67	0.74	0.33
St. dead (d)	0.60	0.66	0.28	0.44	0.80	0.40	0.49	0.49
(c + d)	0.93	0.90		0.17	0.86	0.40	0.68	
Old leaves	0.54	0.65	0.25					
Litter	0.52	0.40	0.1					

The relationships between component and total biomass and the various measurements were analysed using the multiple regression analysis programme available on the University of Nairobi, Faculty of Agriculture 'mini-computer'. As the programme does not allow for stepwise multiple regression analysis all independent variables (i.e. all the measurements associated with each technique) were included as predictors of biomass. Further analysis using the XDS 3 multiple regression programme on the main University computer is being done to determine which of the independent variables should be inlcuded and to find prediction equations involving two or three measurements.

Results and discussion

Table 3 gives the multiple correlation coefficients when all independent variables are used together to predict biomass. The size measurements for example consisted of six different measures and these six together accounted for almost all the variation in biomass.

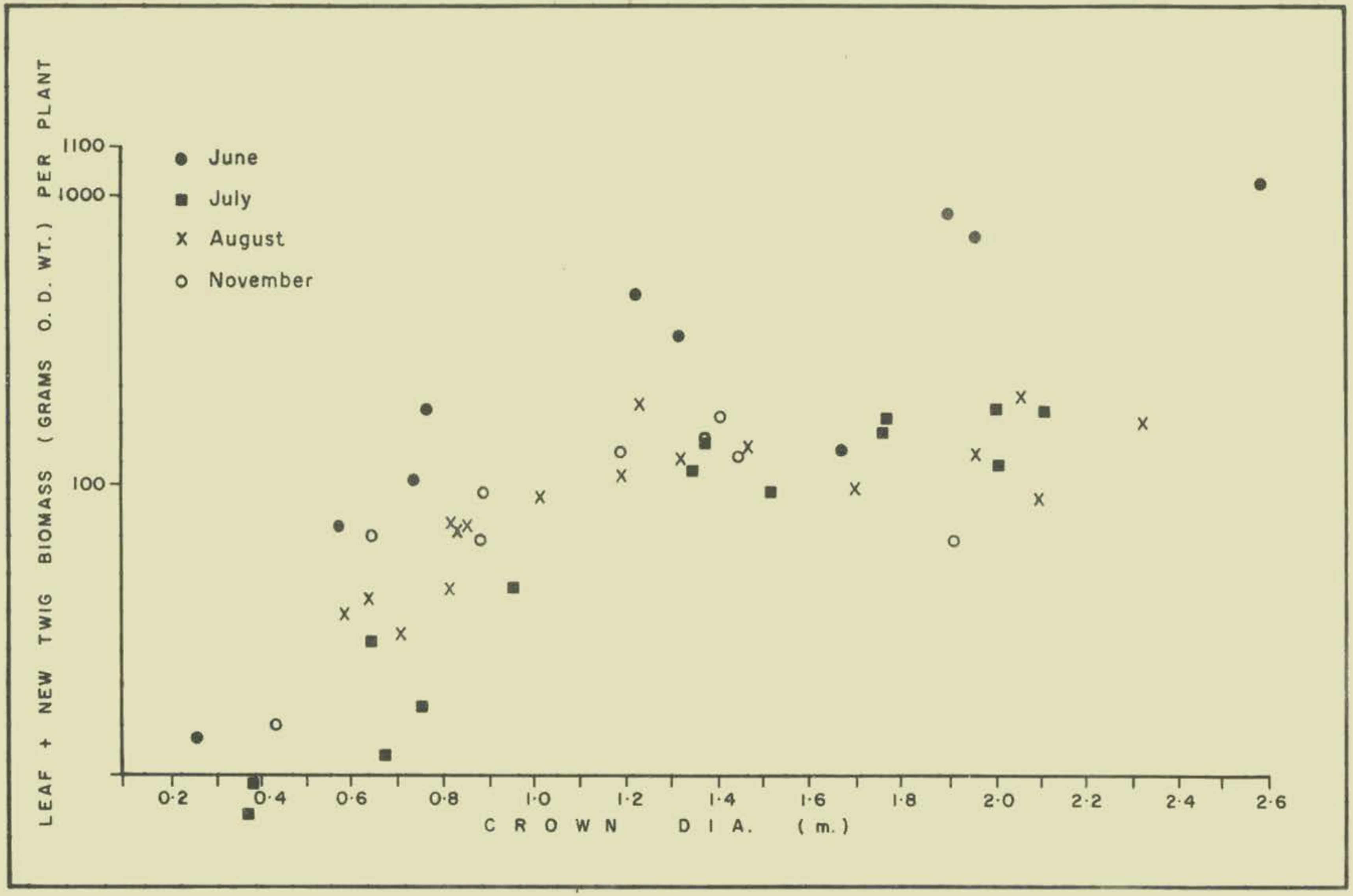
A comparison of the best measurements for each of the four methods for each sample period shows that:

1. All were adequate predictors of component and total biomass in June when foliage was most abundant. Correlation coefficients (r) ranged from 0.86-0.91 (forage biomass; Table 2). The ten-point frame, however, was somewhat better than the rest (r = 0.91).
2. During July (early dry season) the crown diameter and capacitance meter (total readings) measurements became somewhat better predictors (r values for the forage biomass categories were 0.94 and 0.92 respectively). The photometer (mean of all readings) remained adequate for forage biomass prediction (r = 0.86) but decreased in importance for woody biomass prediction (r = 0.74; Table 2). The ten-point frame was not used in July.

Table 3. Duosperma multiple correlation coefficients

	June				July			August				November			
	Size	10 pt. frame	Capac. meter	Phyto-meter	Size/ wt.	Capac. meter	Phyto-meter	Size/ wt.	10 pt. frame	Capac. meter	Phyto-meter	Size/ wt.	10 pt. frame	Capac. meter	Phyto-meter
Y1 Leaves	0.99	0.79	0.72	0.82	0.90	0.88	0.74	0.83	0.27	0.38	0.19	0.91	0.81	0.84	0
Y2 New twigs	0.99	0.86	0.85	0.83	0.91	0.90	0.67	0.78	0.51	0.89	0.02	0.60	0.66	0.50	0.63
Y3 Leaves & new twigs	0.99	0.85	0.80	0.85	0.91	0.89	0.74	0.87	0.48	0.73	0.04	0.88	0.80	0.81	0.54
Y4 Old wood	0.99	0.90	0.82	0.85	0.96	0.87	0.57	0.95	0.79	0.67	0.03	0.82	0.80	0.60	0.32
Y5 Total live	0.99	0.90	0.84	0.86	0.97	0.88	0.59	0.96	0.81	0.69	0.03	0.83	0.80	0.62	0.34
Y6 St. dead	0.99	0.43	0.45	0.68	0.93	0.76	0.17	0.68	0.90	0.34	0.22	0.94	0.80	0.41	0.15
Y7 Live & st. dead	0.99	0.85	0.81	0.83	0.96	0.85	0.42	0.96	0.81		0.12	0.89	0.81	0.57	0.31
Y8 Old leaves					0.93	0.87	0.74	0.66	0.65		0.07				
Y9 Litter								0.51	0.46		0.04				

Figure 1. Relationship between crown diameter (m) and leaf + new twig (forage) biomass of *Duosperma eremophilum*



3. During November, a fairly comparable period in terms of dryness and amount of available forage, crown diameter and capacitance meter (total readings) were again the best predictors. (The r values for forage biomass were 0.86 and 0.88 respectively; Table 2). The ten-point frame was a poor predictor and the photometer was the worst predictor of forage biomass (r = 0.75 and 0.49 respectively).

4. Correlations of predictors with biomass categories were lowest during August which is dry season. (The r values ranged from 0.11-0.85 for forage biomass). However, the crown diameter and ten-point frame showed good correlations with live wood (r = 0.92-0.89 respectively) and total biomass (r = 0.93-0.90 respectively) and the capacitance meter showed adequate correlations with forage biomass (r = 0.85). The photometer gave the poorest correlations with forage and woody biomass categories (r = 0.07-0.16 for forage and 0.17 for woody and total biomass; see Table 2.)

Thus the best measurements for correlation with component and total biomass of large dwarf shrubs are:

1. Crown diameter for all biomass categories except for forage biomass in the dry season.

2. Capacitance meter (total reading) for all categories except for woody biomass in the dry season.

The ten-point frame was a poor type of measurement during the dry season (although better for woody than for forage biomass). The photometer was adequate only during periods of relatively abundant foliage and was the worst measurement overall.

The data for all sample periods (June to November), using the best measurement for each method of measurement, were then combined in order to determine relative usefulness for providing correlations with forage biomass considering the further destructive sampling usually necessary for calibration. These data have not yet been analysed statistically, but have been presented graphically.

Figure 2. Relationship between capacitance meter readings (total per plant) and leaf + new twig (forage) biomass of *Duosperma eremophilum*

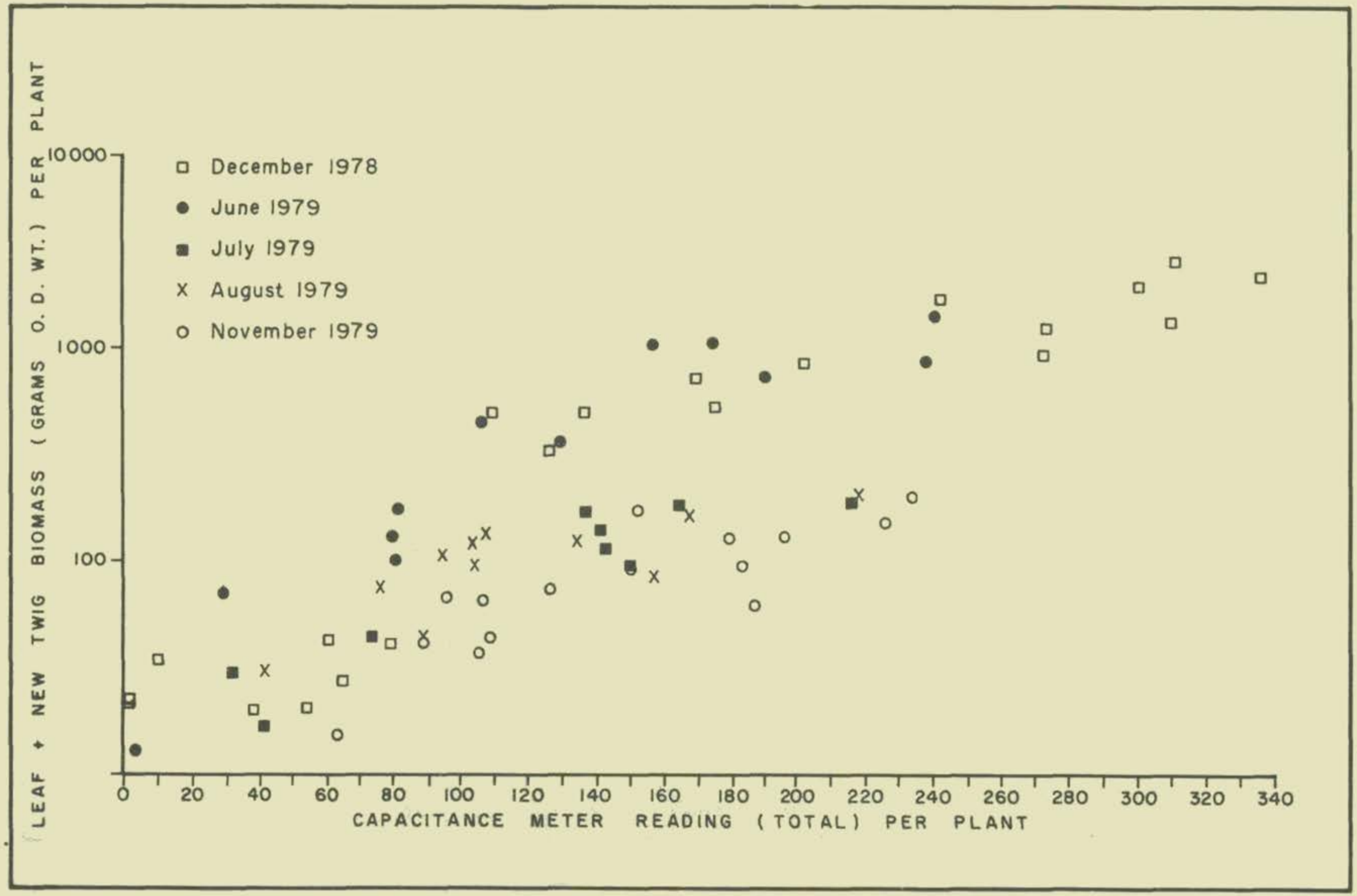
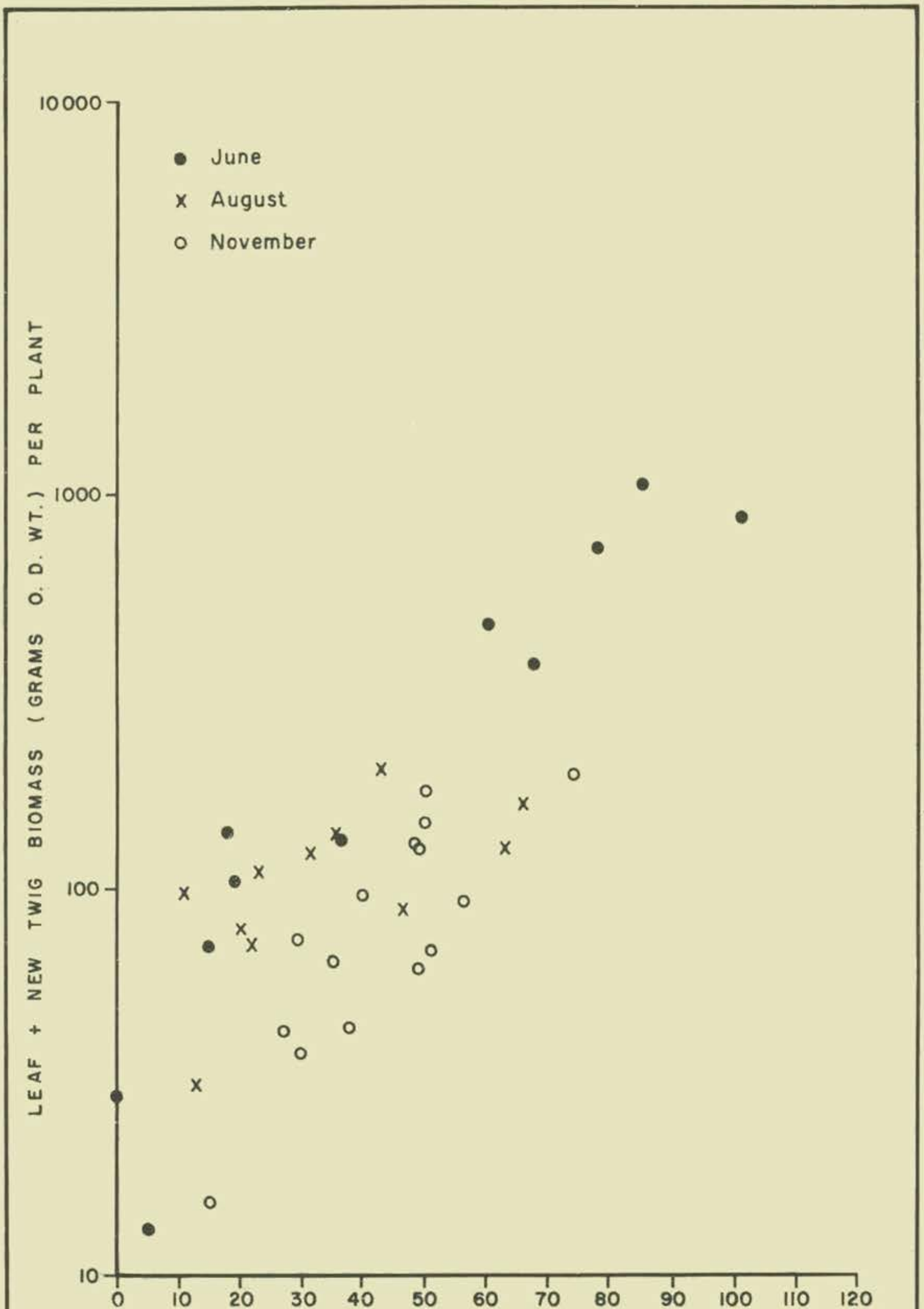


Figure 3. Relationship between total number of ten-point frame 'hits' and leaf + new twig (forage) biomass of *Duosperma eremophilum*



Data for crown diameter and photometer measurements presented in graphical form showed correlations with forage biomass which varied widely between different months (seasons). An example is shown in Figure 1. However, data for capacitance meter and ten-point frame measurements, when graphed semi-logarithmically (Figures 2 and 3), show fairly continuous and uniform relationships for all seasons. Thus it is probable that the relationship with forage biomass for each of the two measurements is capable of being expressed by a single regression equation. This relationship is then useable for determining forage biomass of *Duosperma eremophilum* without further destructive analysis at any time of the year.

Thus crown diameter measurements are not useable for repeated sampling of dwarf shrub forage biomass without repeated calibrations requiring destructive analysis, and photometer measurements are probably not useable either. However, both capacitance meter and ten-point frame measurements do appear useful for this purpose.

Of these two methods of measurement the capacitance meter is the best as its measurements remain more uniformly correlated with forage biomass throughout the year and because it is a much faster method than the ten-point frame (approximately 15 minutes per plant for the ten-point frame compared with 1-3 minutes per plant for the capacitance meter).

Further statistical analysis is underway.

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A PRELIMINARY STUDY OF THE RELATIONSHIP BETWEEN VEGETATION, SOILS AND LAND USE WITHIN SOUTH-WESTERN MARSABIT DISTRICT

D. Walther and D. J. Herlocker

Introduction

The ultimate impact of the process of desertification is expressed in the productivity of the land, for which range condition class is an indicator. Type, degree and history of land use, which are the causes of a particular range condition class, also describe the nature of the desertification process. Therefore the two objectives are closely related.

Objectives

Overall objectives of the IPAL are to determine criteria for defining range condition and the principal processes of desertification in the study area. Specific objectives covered in this paper and applicable to vegetation only were:

1. To determine the relationship between vegetation, soils and relative levels and types of land use.
2. To isolate specific vegetation and soil indicators of each range condition class which are reliable and quickly and easily measured.
3. To clarify the type, degree and history of land use associated with each range condition class.
4. To determine the productivity of each range condition class.

The research area

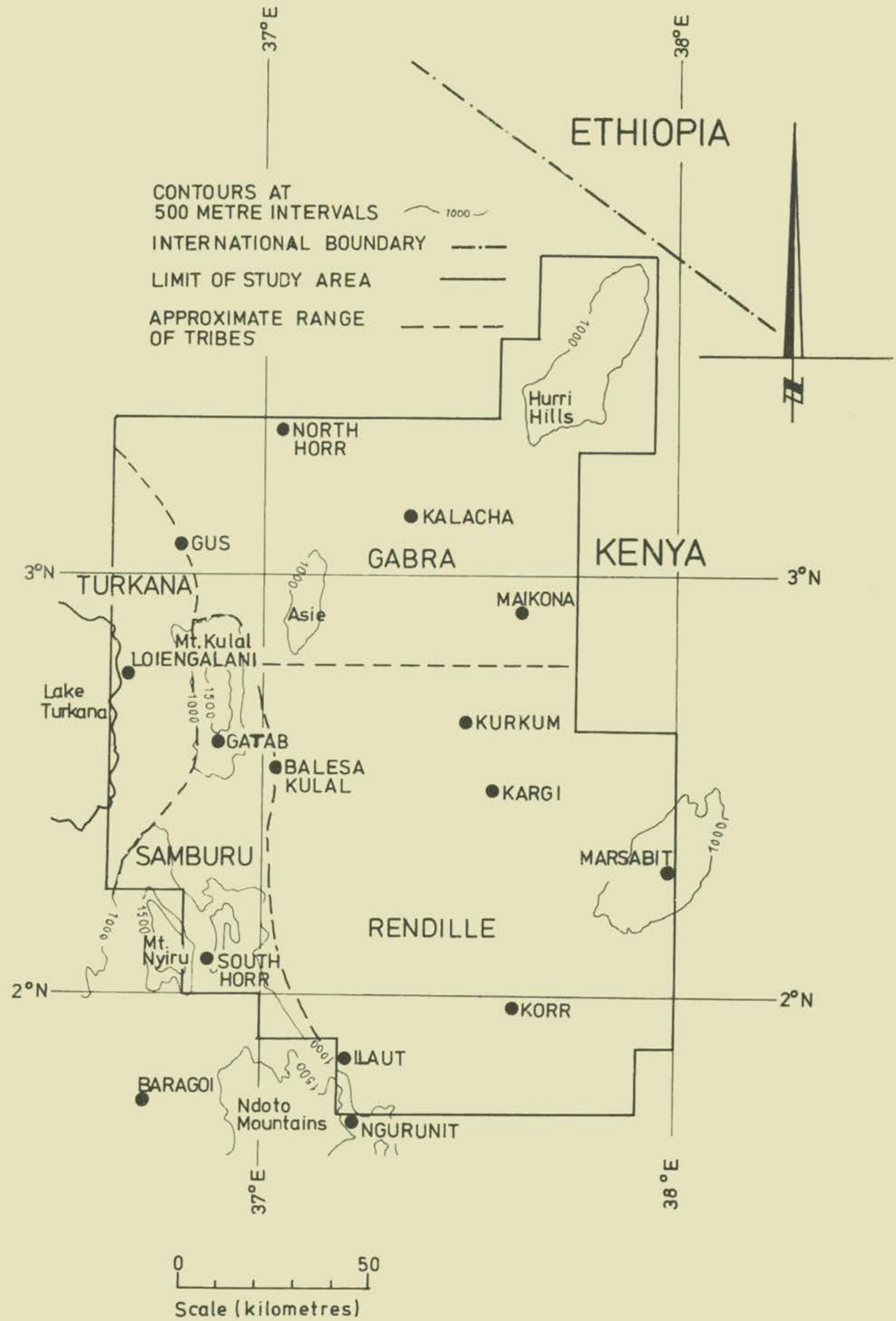
1. Choice of study area

The Korr area, in the south-east part of the IPAL study area was chosen for the beginning of this study because:

(a) It has been intensively used for some time and is the centre of apparently increasing environmental degradation.

(b) It made up part of the large area under study by the then TLMP from whom a landrover was obtained to enable the study to be carried out.

The study area



2. Brief description of study area

The Korr area is centred on a low group of gneissic hills surrounded by quaternary sediments. A series of wells and a bore-hole provide a permanent water supply. The major land units are:

(a) Ridge and upper slope (deciduous *Commiphora* bushland with dwarf shrub understory),

(b) foot slope (dwarf shrubland), and

(c) sedimentary plain (dwarf shrubland). (Vegetation data are from Herlocker, 1979.)

Methods and measurements

1. Site selection

Sample sites were chosen, so that they covered a range of 'apparent' land use impact levels ranging from 'heavy' to 'light' within similar land units. Criteria were subjective; sites were chosen according to:

(a) How they 'looked',

(b) knowledge of past and present use,

(c) distance from permanent water and from shops.

The basic assumption was that sites with little vegetation cover, much bare soil, proximity to permanent water and a known history of intensive use were under 'heavy' use, whereas sites with the opposite characterization were under 'light' use. A second assumption was that the full range of 'heavy', 'medium' and 'light' use impact levels existed within the Korr area. However, should this not be so, the sites sampled within the Korr area will then simply form part of a gradient of land use impact the lighter use areas of which - outside the Korr area - can be sampled later.

2. Methods and measurements

Three vegetation strata were measured at each site: herbaceous, dwarf shrub, and trees/shrubs. Five different sampling methods were used: point centered quarter method (Cottam and Curtis, 1956), Bitterlich stick (angle gauge) (Grosenbaugh, 1952; Cooper, 1957), ten-point frame (Levy and Madden, 1933, Brown, 1954), and fixed area plots (Mueller-Dombois and Ellenberg, 1974). The latter were $40m^2$ and $1m^2$ in size. These sampling methods were used to measure cover %, density, frequency, height, crown diameter and human use (Table 1).

Table 1. Useful indicators for relative land use impact
Korr area 1980

Type of indicator	*Very Significant*	*Significant*	*Not so Significant*
% of bare soil:	X	-	-
% of vegetation cover:			
Trees and shrubs	X	-	-
Dwarf shrubs	X	-	-
Herbs and forbs	-	-	X[1]
Average crown diameter:			
Total trees and shrubs	X	-	-
Species of trees and shrubs	X	-	-
Dwarf shrubs	-	X	-
Human used plants:			
Used trees and shrubs	X	-	-
Dead plants:			
Herbs and forbs	-	X	-
Age structure:			
Trees and shrubs	X	-	-
% of plants in total sample (PCQ)[2]			
Height up to 50cm	X	-	-
Height up to 100cm	X	-	-
Species composition in % of total:			
(selected trees and shrubs)	(X)	X	-
Plants per ha:			
Trees and shrubs	-	-	X
Dwarf shrubs	-	-	X
Herbs and forbs	-	-	X
Density of trees and shrubs:			
Number of plants up to 50cm	X	-	-
Number of plants up to 100cm	X	-	-

(1) Only dry condition experience.

(2) Present sample includes only 1 site; further work intended.

Categories of human use of trees and shrubs (use) were: (a) no visible use, (b) bark cut or stripped off, (c) branches cut, (d) trunk cut off below 1m height, (e) trunk cut off above 1m height. Vitality categories were: (a) evidence of sprouting, (b) little evidence of sprouting, (c) no evidence of sprouting, and (d) dead plant.

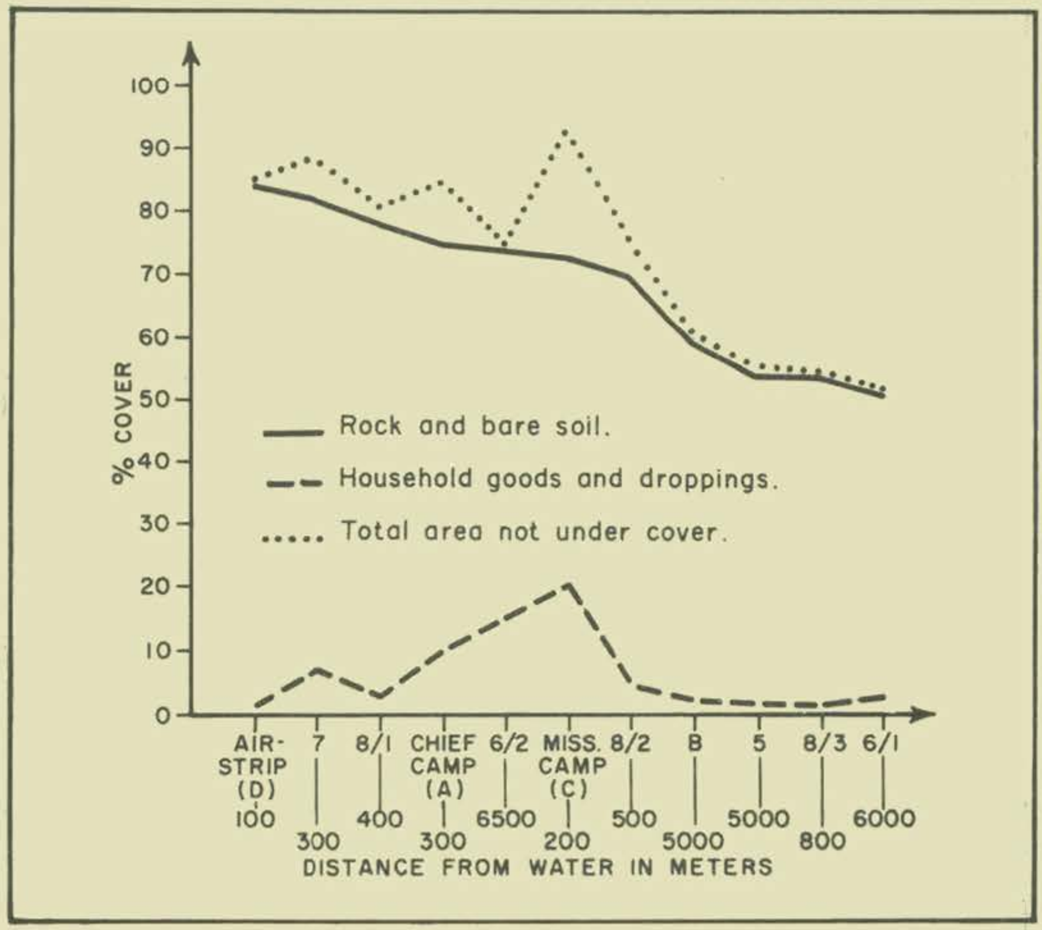
Size, weight and compositional characteristics of the herbaceous layer were not sampled as too little rainfall had fallen during the time of the study for any significant growth to have taken place.

Thirty (30) sample plots were placed systematically at intervals chosen so that the sample site was adequately represented by the sample.

3. Time involved

This study began in January 1980. To date it has involved 80 man-days field work and 70 man-days office work.

Figure 1. Relationship between % total area (% cover) of rock and bare soil, % cover of household litter and distance from water



Results

1. Presentation of data and findings

All sites were arranged in order of decreasing percentage cover (area) of rock and bare soil. Figure 1 shows the relationship between (a) % cover (area) of rock and bare soil, (b) % cover of household litter, and (c) distance of site from permanent water. There is no clear pattern between the latter measurement and any vegetation characteristic but the amount of household litter is closely related to that of rock and bare soil.

Figure 2. Relationship between % cover of dwarf shrub vegetation and % cover of rock and bare soil

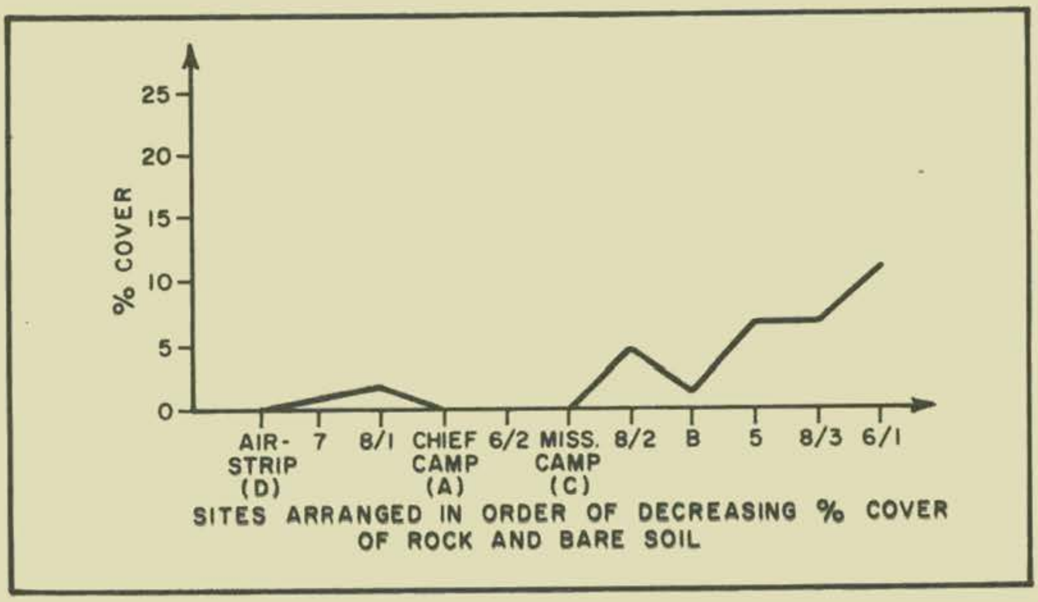
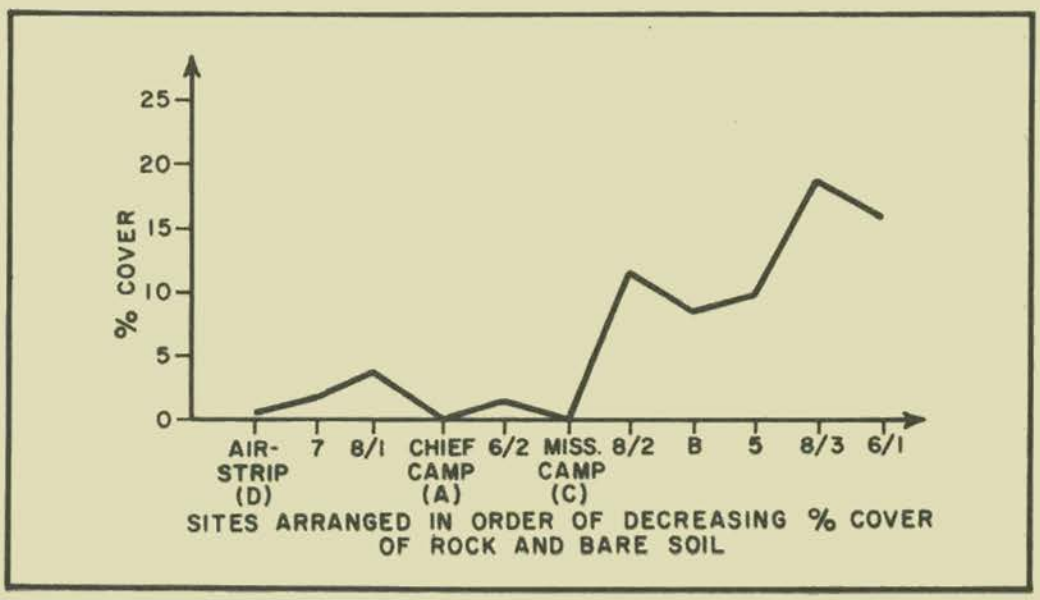


Figure 3. Relationship between % cover of trees and shrubs and % cover of rock and bare soil



The vegetative cover of dwarf shrubs and of trees and shrubs (Figures 2 and 3) shows a significant negative correlation with % of rock and bare soil. The more heavily used 50% of the sites show uniformly low vegetative cover. The other sites show cover to increase with decreasing % of rock and bare soil.

Figure 4. Relationship between relative density of trees used to some extent by humans and % cover of rock and bare soil

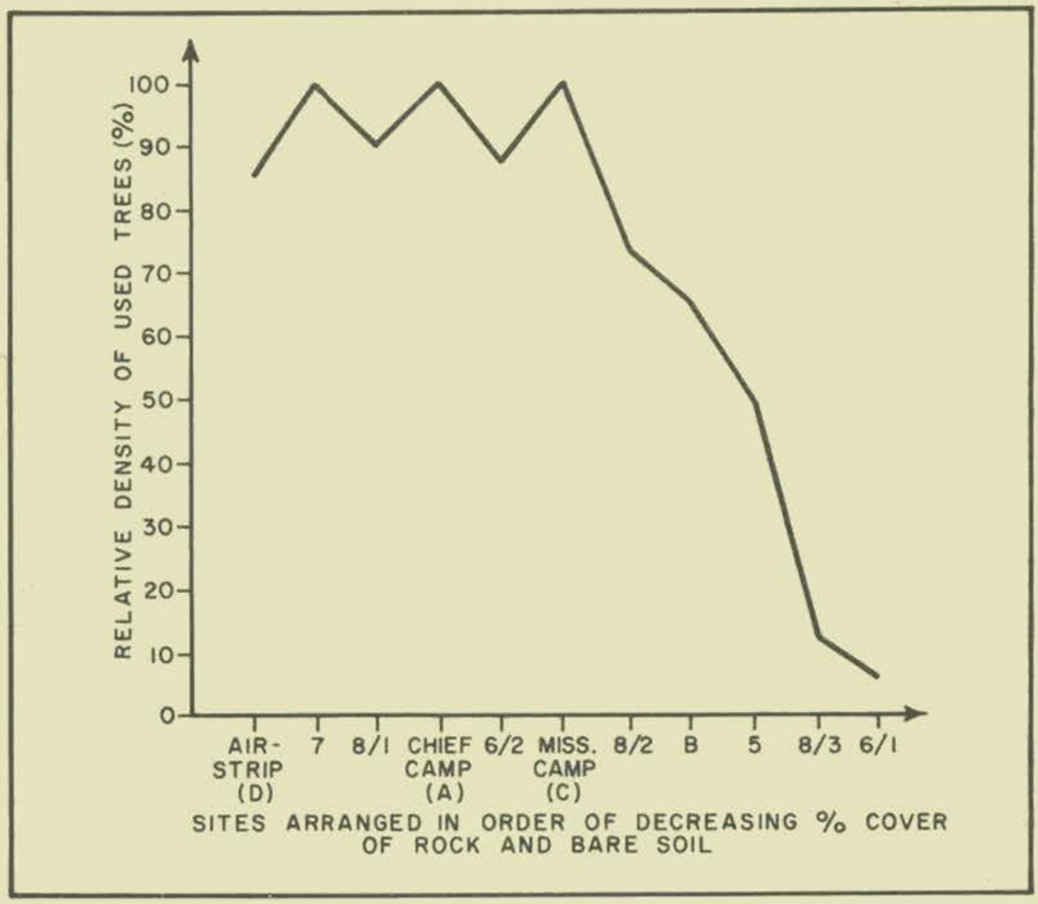
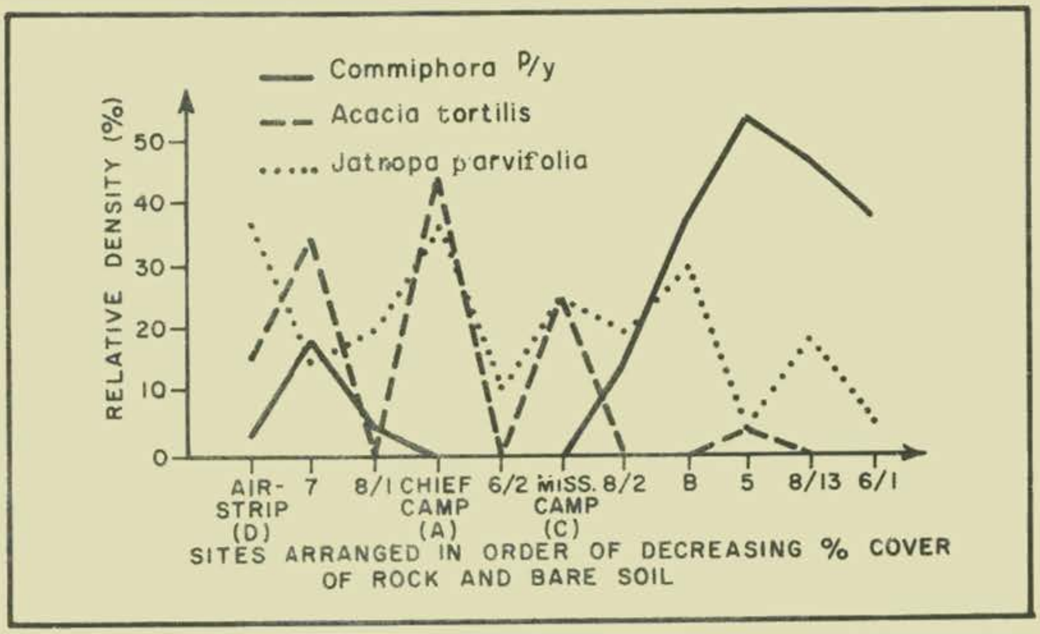


Figure 4 shows the % of all trees used by humans to any extent. Use remains uniformly high for the 50% of those sites having a high % of rocks and bare soil. There is a notably sharp decrease in use for the remaining sites. A somewhat similar pattern occurs when the % cover of dead herbs and forbs is considered (graph not shown). This is probably due to the trampling effect on the more heavily used sites.

Figure 5. Relationship between relative density of some tree and shrub species and % cover of rock and bare soil



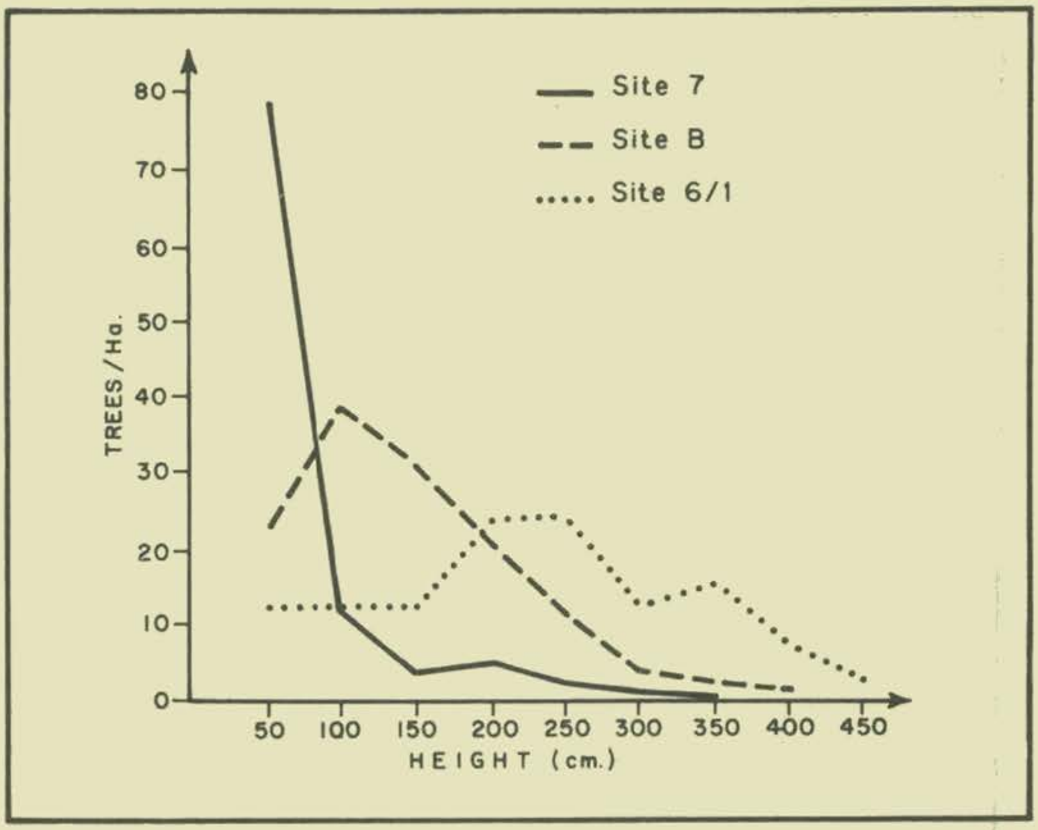
The relative densities (%) of three tree/shrub species (Figure 5) appear to be correlated with % rock and bare soil as well. *Commiphora* (p/y)* is scarce on the more heavily used 50% of the sites but quickly increases in importance thereafter.

Acacia tortilis relative density shows the reverse pattern: high in the heavier used areas and low to non existent in the lightly used areas. *Jatropa parvifolia* shows a general decrease in relative density with decreasing levels of rock and bare soil.

Stand structure of trees and shrubs (Figure 6) also appears to be well correlated with the % of rock and bare soil on a site. Site 7, which has a high % of rock and bare soil, supports a large number of small trees and a low number of large trees. This pattern reverses gradually with decreasing % of rock and bare soil and shown by site B and finally by site 6/1. Both density and tree height are important here.

* This is a so-far unidentified species of *Commiphora*. We have designated it p/y because of the purple branches and yellow trunk.

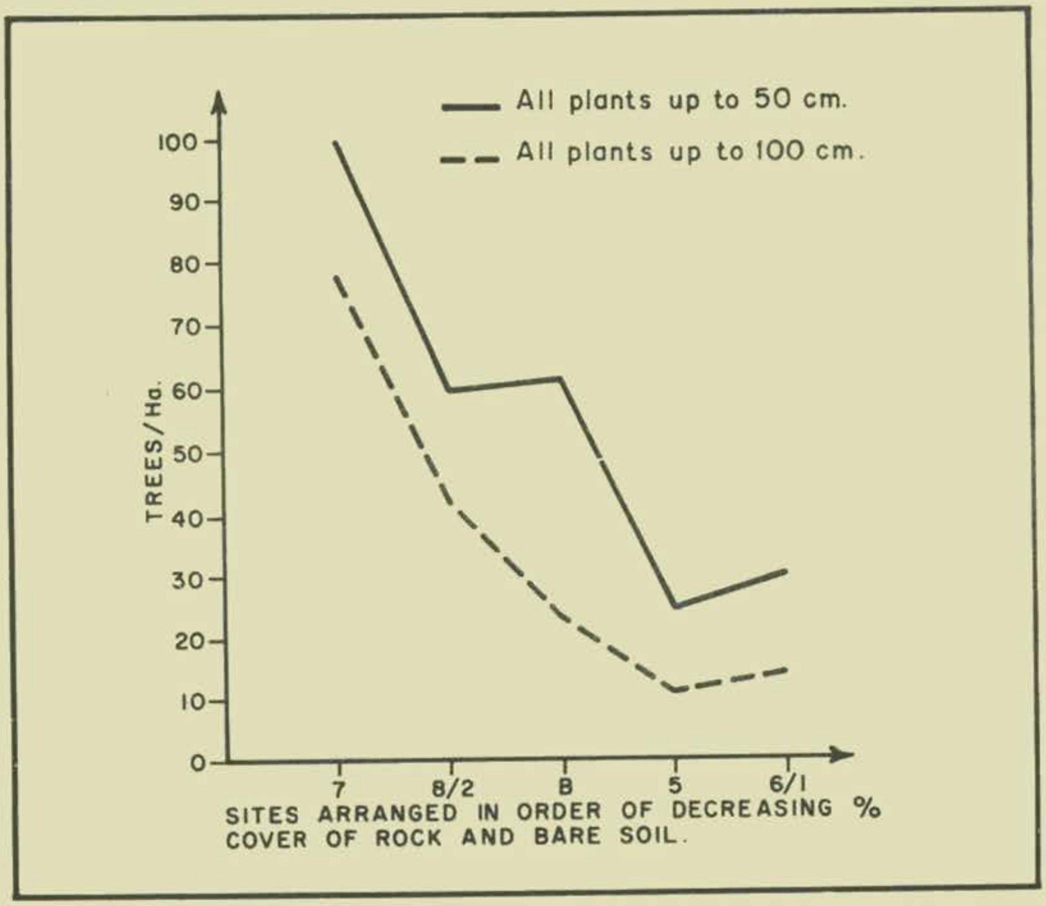
Figure 6. Tree and shrub stand structure as related to % cover of rock and bare soil



A comparison of density of trees below 50cm and 100cm height respectively (Figure 7) shows a positive correlation with % of rock and bare soil on a site.

Average crown diameters of (a) trees and shrubs and (b) different species of trees and shrubs (not shown in figures) are negatively correlated with % of rock and bare soil on a site, i.e. crown diameters are largest on a site with the lowest % of rock and bare soil.

Figure 7. Relationship between tree and shrub density (below 1m height) and % cover of rock and bare soil



Discussion

1. Indicators of range condition

It was first assumed that land impact was related to distance from permanent water. Therefore all sites were arranged so that all other vegetation, soil and household litter measurements were related to increasing distance from permanent water. No particular relationship was shown. Therefore sites were then arranged in order of decreasing % of rock and bare soil (Figure 1). This time definite patterns in vegetation and household attributes emerged which varied (either positively or negatively) with the % of rock and bare soil. This supports an assumption that % of rock and bare soil is a good indicator of the degree of land use impact.

The good correlations between the % of rock and bare soil and all measured vegetation and household litter attributes, several of which were obviously caused by varying use levels, indicates this measurement to be a primary indicator of relative level of land use impact in the Korr area. Most of the other measurements could be used as well except that either they are too time consuming or assume the presence of a particular characteristic (such as tree crown diameter) which may be eliminated under heavy use. Probably the best other measurement is that of % of tree/shrub cover.

2. Vegetation/land use relationships

Vegetation attributes are either positively or negatively related to the degree of land use impact as reflected by the % of rock and bare soil. Positively related attributes are stimulated while negatively related attributes are suppressed in some way by land use.

For instance, heavy use of a site is generally reflected in high levels of cutting and lopping of trees, which results in denser, smaller trees with smaller crowns and less cover. Increase in stand density due to heavy use is because woody regeneration - particularly for such species as *Acacia tortilis* and *Jatropa parvifolia*, is stimulated by the removal of larger trees.

Heavy use by livestock (grazing, browsing, trampling) reduces the total amount as well as vegetative cover of herbaceous and dwarf shrub vegetation. Average crown diameter of dwarf shrubs is also reduced. Light use produces the opposite effect.

The relationship between vegetation attributes and land use impact is also continuous (as in a gradient) or discrete (as when definite boundaries between use lands occur). An example of a continuous (gradient) relationship is that where the relative density of *Jatropa parvifolia* decreases gradually with descreasing land use impact. The abrupt drop in the % of trees and shrubs showing human use after site (miss. camp) is a good example of the latter situation.

Thus, the % of all trees and shrubs used by humans and the relative density of *Commiphora* p/y show discrete distributions with abrupt changes in pattern after site (miss. camp). This is probably because there is a distance beyond which people do not like to go from the *manyatta* to do such cutting. The dense stands of *Acacia tortilis* regeneration within these same sites show a direct response to such cutting. Subsequently this pattern is also discrete. However, the more continuous distribution of *Jatropa parvifolia* probably indicates a slower response to removal of the other tree species with numbers building up more slowly on cut areas.

3. Review of methods

Two sampling methods have proven to be fast and reliable. The ten-point frame gives fast and reliable information on herbaceous and dwarf shrub vegetation cover and on the % of rock and bare soil. The Bitterlich stick (angle gauge) is similarly useful for tree and shrub cover.

However, for density or size-related measurements, trees and shrubs are best sampled by the point-centered quarter method or by using fixed area plots. Both methods, but particularly the latter, are much slower than the ten-point frame or angle gauge. Therefore, when quick initial assessments of range condition class are required, the ten-point frame and angle gauge are recommended. Further, more detailed information - particularly on woody vegetation - will require the other methods.

4. Further work

We now know there are certain indicators of land use impact in the Korr area - as well as vegetation/land use relationships - which can be measured using certain field techniques.

However, the Korr area is representative of only a small part of the study area. In order to determine indicators and classes of range condition for other more representative types it is necessary to expand this study throughout a large part of the Hedad plain.

Work is also required to clarify the type/degree and history of land use associated with each range condition class. To date the following has been accomplished:

(a) Archival research on past use of the area.

(b) Interviews with local residents (for the same purpose).

(c) Survey of offtake of wood for *manyatta* construction and for fuel-wood use. The former required destructive samples of several old *manyattas*.

(d) Comparison of old and new aerial photos for comparing occupance frequency by *manyattas*.

However, more information is needed from:

(a) IPAL and TLMP aerial census data.

(b) Further comparison of old/new aerial photos.

(c) Results of work carried out by historical researchers in the area.

The soils and morphodynamic components of this study are being carried out by Mr Van Kekem and Dr Maeckel respectively.

Co-operation has been initiated between the German Space Remote Sensing Lab, Kenya Range Ecological Monitoring Unit and the Regional Remote Sensing Centre, Nairobi in the mapping and monitoring of range condition classes through landsat imagery. Preliminary field and laboratory work have been carried out.

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LIVESTOCK

AN INTRODUCTION TO THE LIVESTOCK ECOLOGY PROGRAMME

H. J. Schwartz

General Background

Nomadic pastoralism, famine and ecological degradation seem to be inevitably linked if one reviews the literature on the subject of arid-land utilization in the past three decades. It was common practice to place the blame for this association of negative phenomena entirely on the nomadic pastoralists. Total lack of ecological perception and stubborn resistance against progress characterized the nomad in the eyes of planners, administrators, politicians and often enough even scientists. As a result of this the favourite techniques to deal with nomads were compulsory destocking and severe restrictions on seasonal movements. Forced translocation of whole pastoral groups, settlement of expanding agricultural populations, introduction of commercial ranching and establishment of national parks and reserves only aggravated the situation. These led to concentration of nomadic populations in areas of lowest ecological potential, increased overstocking and to diminishing returns from the remaining pastoral rangelands, which in turn caused reduced self-sufficiency and a growing famine risk in many of the nomadic livestock production systems. It is only more recently that an awareness of the rationale behind various aspects of nomadic husbandry techniques and land use practices has begun to grow.

Aims and objectives of studies in livestock ecology

The short-term objective of the livestock ecology studies was to observe and record the role of traditional nomadic livestock production as one major factor of the ecology and economy in the selected study area in the south-western quarter of Marsabit District, Kenya. This objective is still valid during the on-going phase III of IPAL. The long-term objective was and still is to create base data to assist the development of management plans for the whole region in order to prevent further degradation of the range, to aid the recovery of already degraded areas, to secure the subsistence of the pastoral population and to achieve a better integration of Kenya's arid and semi-arid areas into the national economy. More than half of Kenya's total livestock population is kept in these areas and with the rapidy growing demand for food in the country it has become a vital necessity to exploit the productive potential of these areas much more intensively but at the same time much more cautiously.

Primary productivity (range) and secondary productivity (livestock) are generally very low although seasonal abundance of forage and animal products occurs. The key question for any development-oriented programme of livestock ecology studies is therefore whether and by which means the production of food for human consumption from arid and semi-arid rangelands can be increased and whether a sustained-yield production on this higher level is possible.

To answer the key question four consecutive phases of research are necessary:

1. Identification of factors which limit the productivity of domestic livestock under the present traditional management system practised by nomadic pastoralists.
2. Experimental minimization of identified limiting factors through improved management.
3. Assessment of increased productivity by comparison of improved versus traditional management.
4. Cost-benefit analysis of the improved management considering present prices and market structures and such changes in prices and market as can be expected in the future.

Demonstration and large-scale implementation of the suggested improved management cannot be seen as becoming phase 5 of the research programme since they require careful integration into national and district development plans and have to be established in a much larger context than any research project can provide.

Component studies and work programme

The various component studies are carried out in an identical way for the four livestock species dominant in the study area, i.e. sheep, goat, cattle and camel. The work programme for the different species differs mainly in observation intensity or more specifically in the frequency of observations. The work is carried out on three different levels, i.e. intensive experimental work in herds owned by the project and kept in the immediate vicinity of the project's sub-stations, low density monitoring in associated local herds and monitoring of livestock numbers and distribution over the whole of the study area by aerial and ground survey.

1. Experimental work in the project-owned herds

- Recording of animal performances such as growth rates, milk yields, mortality, birth rate, abortions, mating frequency, age and sex structure
- Monitoring of the available forage on the experimental pastures
- Monitoring of seasonal changes in food preferences in terms of botanical composition of the diet and the parts of plants which are utilized
- Monitoring of seasonal changes in feeding behaviour
- Monitoring the total intake of organic matter
- Monitoring the seasonal changes in nutritive quality of the ingested diet
- Determination of the *in vivo* digestibility of seasonally important fodder plants (goats only)
- Monitoring of the health status of the herds
- Postmortem examination of all animals which die of natural causes

Previous experience has proved that the techniques and routines which had been adapted to the particular field conditions are satisfactory for an accurate assessment of herd productivity and all factors affecting it. They can be applied by supporting field staff without any difficulties after a short period of on-the-job training.

2. Low-density monitoring of associated local herds

The main purpose of this component study is to obtain data from a larger livestock population for comparison with trends recorded in the experimental herds to assess whether these trends are representative for larger areas. Data collected in these herds are growth rates, mortality, birth rate, age and sex structure and cropping rate. Data are collected four to six times per year.

3. Numbers and distribution of livestock in the study area

Data on numbers and distribution of livestock were gathered in connection with an aerial settlement count which was conducted at two-monthly intervals for two full years. Only those animals kept in the settlements were counted on each occasion. This allowed total stock counts during and after the rainy seasons and on certain ritual occasions and differential counts during the dry seasons when large proportions of the herds are kept on pastures away from the settlements. Each count covered an average of 82 settlements achieving almost total coverage of the study area. This programme has been discontinued since it was felt that sufficient data have been collected.

Programme implementation, January 1978 to October 1980

The first year was needed to establish the necessary infrastructure for the experimental work, i.e. establishing experimental herds, training of supporting personnel, adaptation of experimental techniques to the particular conditions in the field, and setting up routines for recording, sampling and analysis. Analytical support facilities could be secured from the University of Nairobi, the Veterinary Research Laboratories of the Ministry of Livestock Development and the Kenya Trypanosomiasis Research Institute through close co-operation with scientists in these institutions.

1. Goats

In March 1979 the full work programme was started in a herd of project-owned goats at Ngurunit. All work was focused on the identification of factors limiting productivity under traditional management. The herd was given into the care of a locally recruited Samburu herdsman who made all necessary management decisions, i.e. choice of pastures, length of grazing day, frequency of watering, etc. The only interference from outside was a single factor treatment, a regular deworming of a small group within the herd.

After a full seasonal cycle of observations phase 2 of the investigations was started by establishing a second goat herd parallel to the first one in which a comprehensive programme of preventive medicine, treatment and improved hygiene was carried out.

In August 1980 a third and fourth herd were set up in Korr, approximately 50 kilometres north-east of Ngurunit, an area which differs significantly in rainfall, vegetation and history of land use and is one of the two major dry season grazing areas in the study area. The programme executed there is identical to the one at Ngurunit. It was fully implemented in October 1980. Work on phase 3 of the goat programme, i.e. assessment of the increase of productivity through improved management, and phase 4, cost-benefit analysis, are to be started in May 1981 when the results of phase 2 become available.

2. Sheep

One can safely assume that the factors limiting sheep productivity are almost identical to those identified in goats. Work on sheep was therefore begun in phase 2 in August 1980 in Korr (see above). Two herds were formed, one under traditional and one under improved management. The work programme is identical to the goat programme. Once the first seasonal cycle of observations is completed (September 1981) adjustments towards improved management can be made if necessary.

Low density monitoring of animal performances has been carried out in six associated local herds with a total number of approximately 600 sheep and 800 goats. Two of the herds were semi-sedentary at Ngurunit and the other four at Korr. This activity was begun in May 1978.

3. Camels

Due to the limited funds it was not possible to establish a project-owned camel herd of a size adequate for experimental work. For that reason a programme for a one-year disease survey in camels was designed which offered enough advantages to some local herd owners to permit regular experimental work in their herds. Preliminary work on this programme was started in August 1979 and a routine was established by April 1980 (see A. J. Wilson, Camel diseases, in these *Proceedings*). The programme combines low density monitoring of animal performances with a health survey and a low level management input. It is satisfactory as far as it goes but needs to be expanded to the full-scale work programme as outlined above. Two more herds of 130 and 160 animals respectively which are kept under improved management on commercial ranches outside the study area are included in the same programme and are available for further comparative studies.

4. Cattle

Studies of cattle have been deliberately left out so far since neither adequate funds nor manpower were available. The only data on cattle which were collected to date was numbers and distribution recorded during the settlement counts.

PRODUCTIVITY LEVELS OF THE GOAT HERD AT NGURUNIT

A. B. Carles

Introduction

The previous paper outlined the philosophy of the livestock programme.

The objective for the first phase of the goat component was to measure the levels of the main production parameters and to identify their main sources of variation within the traditional management system. The parameters that were selected were fertility, mortality, body growth and lactation.

This paper will describe in general terms the observations that were made on the goat herd during the first phase at Ngurunit, namely March 1979 to February 1980, and will outline the programme that has been set up for the second phase.

Materials

Over a period of approximately 6 months prior to March 1979 goats were purchased from the herds around Ngurunit, and by March these numbered some 60 breeding females and 18 mature males (of which 16 were castrates). A Samburu herdsman from Ngurunit was given the care of this herd, and he made all the management decisions and used only the traditional systems and materials, with one exception - a small group was selected within the herd and routinely drenched with an anthelmintic (mebendazole).

Methods

1. Fertility

Daily records were made of all matings, abortions and live births. The technique for detecting matings was the use of the 'Sire Sine' raddle harness.

Analysis of these records will enable the various sources of reproductive failure to be categorized as follows:

(a) Females exposed to the male but not mated indicated the level of anoestrus,

(b) females mated but not producing an observed foetus indicated levels of failure between the stages of fertilization and late pregnancy,

(c) females which conceived a foetus but did not produce a viable kid indicated abortion rates,

(d) females which produced a viable kid indicated fertility rates.

2. Mortality

(a) A daily inventory was kept of all deaths, and for as many cases as possible a postmortem examination was made at the earliest opportunity by a trained assistant resident at Ngurunit. The record of this examination followed a system which enabled anyone who is familiar with the normal state of the body organs to describe, in a predetermined manner, the extent to which any organ departed from the normal so that a veterinarian could subsequently make a reasonable diagnosis. As well as the general description of the postmortem findings, samples of any tissue thought to be abnormal were preserved in 10% formalin.

(b) In addition to postmortem examinations a number of specific examinations were carried out to monitor the incidence of the diseases that were expected to be of major importance. These inlcuded the following

- Serology (at approximately 4 monthly intervals) for *Brucella melitensis* infection.
- Strongyle egg levels in faeces (at approximately 2 month intervals) to indicate the extent to which the pasture is being infected and the incidence of infection in the herd.
- Total worm burdens in the abomasum. Small and large intestines were obtained from as many postmortem examinations as possible to obtain direct estimates of total worm burdens and the relative incidence of the different species of strongyle.
- Blood smears for piroplasms and trypanosomes after the rainy period.
- Packed red cell columns at 1-2 monthly intervals during the last 6 months to monitor the anaemic status.
- Detailed haematology at the beginning and end of the second dry season, primarily to interpret more accurately

the results of the field estimates of packed cell volumes.

3. Growth

Body weights of all animals were recorded under standard conditions at 14 day intervals.

4. Lactation

Estimates of the milk yields were obtained every fortnight by the hand milking of the left half of the udder morning and evening one one day, and then repeating the process for the right side on the second day. This was always done by the same person.

5. Nutrition

The monitoring of dietary habits and nutrient intake was carried out concurrently by other investigators.

6. Analysis

(a) Initial analyses have had to be confined so far to the general description of mean levels and variances, giving indications of the general patterns for the individual parameters.

(b) Final analysis

- Fertility and mortality

  If the quantity of data is eventually sufficient for reasonable age-specific estimates of these two then the construction of a life table may be warranted. Certainly the identification of the main causes of variation and some indication of their relative importance will be possible.

- Growth

  It is intended to construct growth curves for individual animals using the von Bertalanffy or Gompertz equations, and then, by subjecting the estimates of the curve parameters to an analysis of variance for non-orthogonal data, to obtain estimates of the level of effect of the main sources of variation, and of the growth curve parameters corrected for these effects.

Results

At this stage only very provisional results are available, principally from the fertility, mortality and specific disease monitoring studies. The changes in herd size during the 12 month period (Table 1) show that despite an above average proportion of breeding females at the start, the herd decreased in size by 11% during this Phase, despite only 4 animals having been cropped. The cropping level represents a turn-over of 4% which is extremely low for small ruminants.

Table 1. Inventory of goat herd from 10.3.79 to 9.3.80

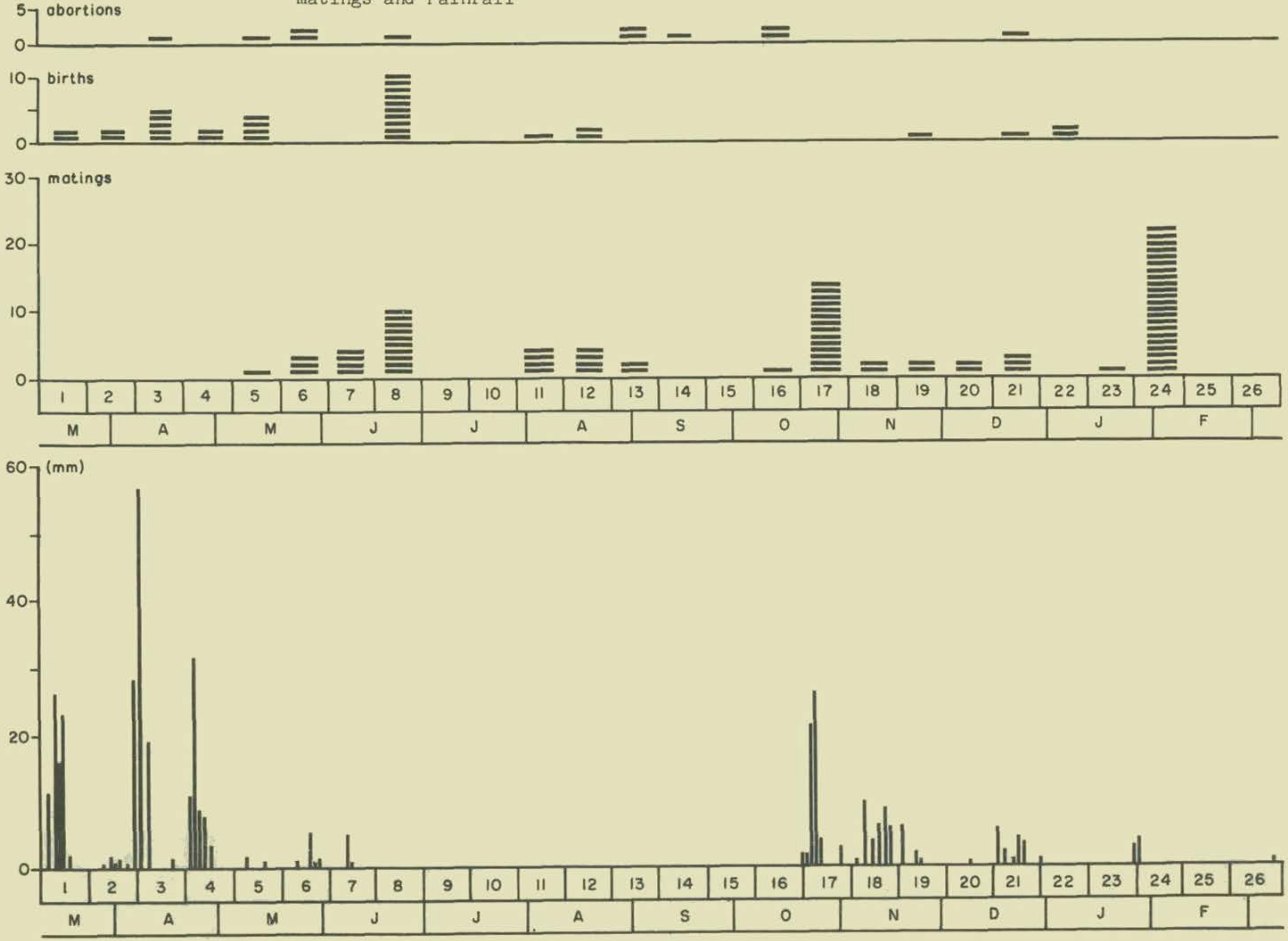
Number present at 10.3.79		Additions		Losses			Number present at 9.3.80
		Birth	Purchase	Death	Predators	Slaughter	
Breeding females	56		2	8	3		47
Breeding males	2						2
Mature castrates	16			11		4	13
Immatures	17	32		16	2		18
Total	91	32	2	35	5	4	80

1. Fertility

During the year 32 live births and 11 abortions were recorded (this latter figure is undoubtedly less than the actual level). The distribution of these with respect to matings and rainfall is shown in Figure 1. 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.

Figure 1. The distribution of live births and recorded abortions with respect to matings and rainfall



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 2) 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 2. 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

Unfortunately the situation in the field was such that the material required for positive diagnoses of the causes of abortion was not available but it is extremely likely that infection with *Brucella melitensis* is responsible for the majority of these abortions, and possibly also contributes to the low conception rate.

2. Mortality

Of the 36 deaths, postmortem examinations were made on 26 and of these it was considered that a diagnosis could be made for 22. The distribution of these amongst the age groups are shown in Table 3. It is immediately apparent how important pneumonias were, and particularly contagious caprine pleuropneumonia, the main (or probably the only) type of interstitial pneumonia.

The other aspect of interest is the possible importance of two parasitic conditions (coenurus cerebralis and hepatitis cysticercosa) due to the presence of the larval phases of tape worms occurring in the domestic dog, and possibly feral Canidae.

Table 3. The incidence of diseases amongst age groups for animals examined postmortem

Disease	Age group: Birth - Weaning	Weaning - 12 months	Over 1 year	Total
Pneumonia				
- interstitial	9	2	1	12
- alveolar	-	-	1	1
- bronchial	2	-	-	2
Coenurus cerebralis	-	1	1	2
Hepatitis cysticercosa	-	-	2	2
Miscellaneous	-	1	2	3
No diagnosis	3	1	-	4
Totals	14	5	7	26

Note: Total deaths during the period 10.3.79 to 9.3.80 were 45, of which 35 died of disease, 5 from predation, and 5 were slaughtered.

3. Specific diseases

(a) Helminthiasis

On four occasions during this period faeces samples from the whole herd were examined for helminth eggs. The results (Table 4) show a remarkably high faecal output of strongyle eggs throughout the year. It also shows that bimonthly dosing was inneffective.

Table 4. Strongyle egg counts in faeces of undrenched and drenched goats

Date	Undrenched				Drenched			
	Number of goats			Mean epg	Number of goats			Mean epg
	Total	0 epg	≥500 epg	± SD	Total	0 epg	≥500 epg	± SD
21.1.79	11	2	7	1027±1317				
28.7.79	51	8	16	380±372	21	3	9	419±219
8.12.79	50	1	35	857±679	21	17	0	38±80
8.2.80	45	8	19	500±468	17	9	2	259±578
2.3.80	67	13	41	1373±1421	15	14	0	27±103

Note:

1. Dosing regime changed form 8 to 4 weekly on 14.8.79
2. 0 epg = zero eggs per gram
3. 500 epg is an approximate pathogenic threshold
4. No corrections were made for late pregnancy or early lactation as the numbers of such females varied very little between samples.

The relative incidence of different strongyle species found in the total contents of the abomasum and small intestine (Table 5) shows that just three species account for almost all those present - *Haemonchus contortus, Trichostrongylus colubriformis,* and *Trichostrongylus probolurus.*

Table 5. The proportional incidence of strongyle species in the abomasum and small intestine

Location	Species	Number of samples	Mean ± SD (%)
Abomasum	*Haemonchus contortus*	6	98.4 ± 3.9
	Trichostrongylus axei		1.6 ± 3.9
Small intestine	*Trichostrongylus colubriformis*	5	40.0 ± 54.8
	Trichostrongylus probolurus		59.4 ± 54.2
	Bunostomum trigonocephalum		0.6 ± 1.3

(b) Blood parasites

On three occasions blood smears were prepared from the whole herd, and screened for piroplasms and trypanosomes. The findings (Table 6) gave no evidence of parasitaemias.

Table 6. The incidence of blood piroplasms and trypanosomes

Date	Numbers positive for parasites			Total number	Technique
	Marginal bodies	Babesia	Trypanosomes	examined	used
8.2.79	3	-	-	84	Thick and thin blood films
28.7.79	5	-	-	70	" "
8.12.79	1	-	-	79	Buffy coat smear

(c) Anaemia

The results of the first three surveys of packed red cell volumes (Table 7) confirmed the clinical diagnosis of anaemia, and again showed the difference produced by dosing.

Table 7. The means $\pm$ SD of the packed cell volumes for undrenched and drenched goats

Date	Undrenched	Drenched
9.12.79	24.2 ± 4.1	27.4 ± 3.6
9.2.80	26.7 ± 3.4	29.2 ± 3.2
30.3.80	26.6 ± 4.5	28.3 ± 3.3

In order to more accurately interpret the data on packed cell volumes, a full haematological examination was made at the beginning and end of the dry season. From these, estimates were obtained of the mean corpuscular volume and the mean corpuscular haemaglobin concentration (Table 8).

Table 8. The numbers of goats, and the means $\pm$ SD, for the mean corpuscular volume (MCV) and the mean corpuscular haemoglobin concentration (MCHC), for undrenched and drenched goats at the beginning and end of the dry season

Parameter	Age group	Undrenched				Drenched			
		9.12.79		2.3.80		9.23.79		2.3.80	
MCV	0-4m	3	20.2±2.06	4	17.6±3.36		-		-
	4m-1yr	8	16.3±1.40	7	17.2±0.95	4	16.8±0.48	4	19.1±3.46
	>1 yr	44	17.3±1.94	41	17.8±2.02	17	17.3±1.71	16	18.2±1.45
MCHC	B-4m	3	36.3±2.02	4	32.0±3.67		-		-
	4m-1yr	8	33.9±2.58	7	34.4±1.61	4	33.7±0.78	4	31.4±3.86
	>1 yr	44	34.6±2.28	41	34.2±2.62	17	34.5±1.26	16	34.8±2.36

The levels are below that expected for both these parameters indicating a microcytic hypochromic anaemia. Strikingly the difference between the drenched and undrenched groups are negligible at the time of the first examination. At the time of the second examination, there is just a suggestion that the mean cell volume may have improved in the younger animals that were drenched, but more data will be needed to clarify this.

(d) Copper status

As a possible cause of the microcytic hypochromic anaemia was copper deficiency, sera were analysed from the whole herd for copper levels. These ranged from 0.65-0.92 ppm, which are all in the normal range.

4. Growth

Due to the low fertility rates and high mortality rates there has not been sufficient data during this Phase to describe growth over the main part of the curve, nor to examine the degree to which various factors have affected it.

5. Lactation

The analysis of lactation yields has only reached the stage of overall means and variances. The striking points that emerge from these are that there is no evidence that the length of lactation is a serious constraint, although clearly the total yields are low (Table 9). The other remarkable point is the considerable increase in yield that regular drenching produces - of the order of 35%.

Table 9. Lactation performance

Lactation parameter	Group Undrenched	Group 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

Conclusions

It is clear from these results that the productivity of this goat herd during this 12 months period has been extremely low. Despite a mere 4% offtake the herd decreased in numbers by some 10%, and the total biomass also decreased.

Noting that the year had a rainfall level above the average and that the forage on offer was also above average, it is likely that the main causes for this low productivity were brucellosis, contagious caprine pleuropneumonia and helminthiasis.

Phase II

It would seem appropriate to close by outlining the programme for the second Phase which has just been initiated, and has been based upon the findings in the first phase.

1. Objectives

These have been enlarged to cover the following:

(a) The repetition of the observations on the traditional herd for a second 12-month period.

(b) The establishment of a herd in which the performance of the goats approaches their genetic potential within the limits of the energy and protein available from the natural vegetation.

(c) The repetition of the observations on these two groups in 3 other habitats which (with Ngurunit) would cover all the major habitat types in the study area.

(d) The addition of a sheep component in two of the new habitats.

2. Methods

(a) To establish routine health programmes for the treated groups to minimize the effects of the infectious diseases that had been identified in Phase I.

(b) To regularly supplement the diet with sodium chloride, calcium, phosphorus, copper and cobalt, and vitamin A three months after the end of green feed, and to attempt to make water accessible once a day to minimize any limitation of performance due to deficiencies of these.

3. Records

These are to follow the pattern established for Phase I.

GOAT NUTRITION

A. N. Said

Introduction

The goat nutrition component of the IPAL project consists of the study of the digestibility and nutritive value of browsing plants and browsing characteristics of goats in the western half of Marsabit District, Kenya. This paper gives an outline of the goat nutrition component in terms of the approaches to the study and a brief reporting on some of the results achieved so far.

Approaches to the study

1. Listing the commonest browsing plants utilized by goats within the study area.
2. Investigating browsing characteristics of goats:

(a) time and duration of intensive activity,
(b) types of preferred browses.

3. Determining feed intake levels and digestibility of the ingested feed:

(a) outdoor experiments using chromic oxide as the external reference substance to calculate intake and lignin in both browses and in faeces to calculate digestion coefficients,
(b) indoor experiments on plucked samples using *in vivo* digestibility experiments and the Tilley-Terry *in vitro* digestion techniques.

4. Determining chemical composition of plucked samples:

(a) proximate analysis,
(b) minerals profile,
(c) lignin to calculate dietary preferences,
(d) correlation, if any, between preferential browsing and a particular nutrient or nutrients in the browses.

Methodology

Feed intake and digestion of the browses by the outdoor goats were done using 4-5 goats. The goats were fed chromic oxide capsules - 1.5g - twice a day for seven days. Faecal output (FO) was calculated:

$$\text{FO g DM} = \frac{\text{External indicator fed}}{\text{\% external indicator in faeces}} \times 100$$

from grab samples.

$$\text{Dry matter consumed} = \frac{\text{Weight of internal indicator in faeces output}}{\text{\% internal indicator in browse}}$$

The indoor experiments consisting of the *in vivo* digestibility trials on plucked browses and *in vitro* digestion of the same samples are done at the Department of Animal Production Kabete. The normal procedure in the *in vivo* trials has been adopted. This consists of the preliminary feeding period of 7-10 days and the collection period, also of 7-10 days. The usual data recorded are of browse offered, left, and ingested, and of the faeces output. Analyses are done on samples of browses offered and left and on faeces samples using bulked samples. Digestion coefficients are then calculated. Chemical analyses for proximate composition and for minerals are done using the established standard methods.

Results

Proximate analyses of plucked samples have been done to enable calculation of dietary preferences study. Some of the results of the *in vivo* digestion studies are given in Tables 1, 2, 3 and 4.

Table 1. Chemical composition of three browses whose digestion coefficients are given in Tables 2, 3 and 4

Browse	% Dry matter				
	Crude protein	Ether extract	Crude fibre	Ashes	Nitrogen-free extract
Indigofera cliffordiana (May 1979)	18.4	2.8	16.7	18.8	43.3
Indigofera spinosa (May 1979)	15.5	3.7	23.5	12.8	45.1
Duosperma eremophilum (Sept. 1979)	16.8	2.4	14.6	25.5	40.7

Table 2. Digestion coefficients of *Indigofera cliffordiana* collected 10-25 May 1979

Goat no.	Dry matter	Organic matter	Crude protein
24	46.7	55.7	78.1
35	46.3	56.7	75.9
51	-	-	-
Mean	46.5	55.2	77.0

Table 3. Digestion coefficients of *Indigofera spinosa* collected 10-25 May 1979

Goat no.	Dry matter	Organic matter	Crude protein
33	51.8	59.4	71.0
27	41.7	47.1	69.9
44	41.2	47.9	66.8
Mean	44.9	51.5	69.2

Table 4. Digestion coefficients of *Duosperma eremophilum*

Goat no.	Dry matter	Organic matter	Crude protein
27	33.5	72.4	62.9
24	44.2	76.3	70.2
35	41.6	78.9	69.9
Mean	39.8	75.9	67.7

Some of the results of the outdoor experiments using chromic oxide and lignin as reference substances are given in Table 5.

Table 5. Ingested dry matter (DM) and digestion coefficients of browses of trial 1-5 (means of 3-5 goats).

Date	Trial	No. of goats	IDM g	Digestion coefficients % DM	OM	CP	CF	NFE
31.8.78	1	3	953	36.3	36.4	48.0	27.0	42.7
15.12.78	2	5	1131	72.7	77.6	76.4	53.6	88.3
12.7.79	4	4	788	25.5	34.1	40.2	21.2	44.7
6.8.79	5	4	647	17.2	28.8	35.1	14.0	43.1

Integration of the study will consist of the biomass data, dietary preferences, intake and digestion studies, animal productivity and health, migration pattern and social economics aspects.

CAMEL DISEASES IN SELECTED AREAS OF KENYA

A. J. Wilson

Introduction

Few systematic studies have been conducted on diseases of camels in Kenya. This is surprising as some 600,000 camels are present in northern Kenya and they are essential for the livelihood of the people who live there. Information is available on camel diseases in southern Ethiopia (1) and in North Africa (2).

A study was initiated in the IPAL study area with the following aims:

(a) identification of the major diseases in camels with emphasis being placed on epidemiology

(b) identification of the possible role of camels in the transmission of zoonotic diseases

(c) a study on the effects of a comprehensive disease control programme, once major constraints have been identified

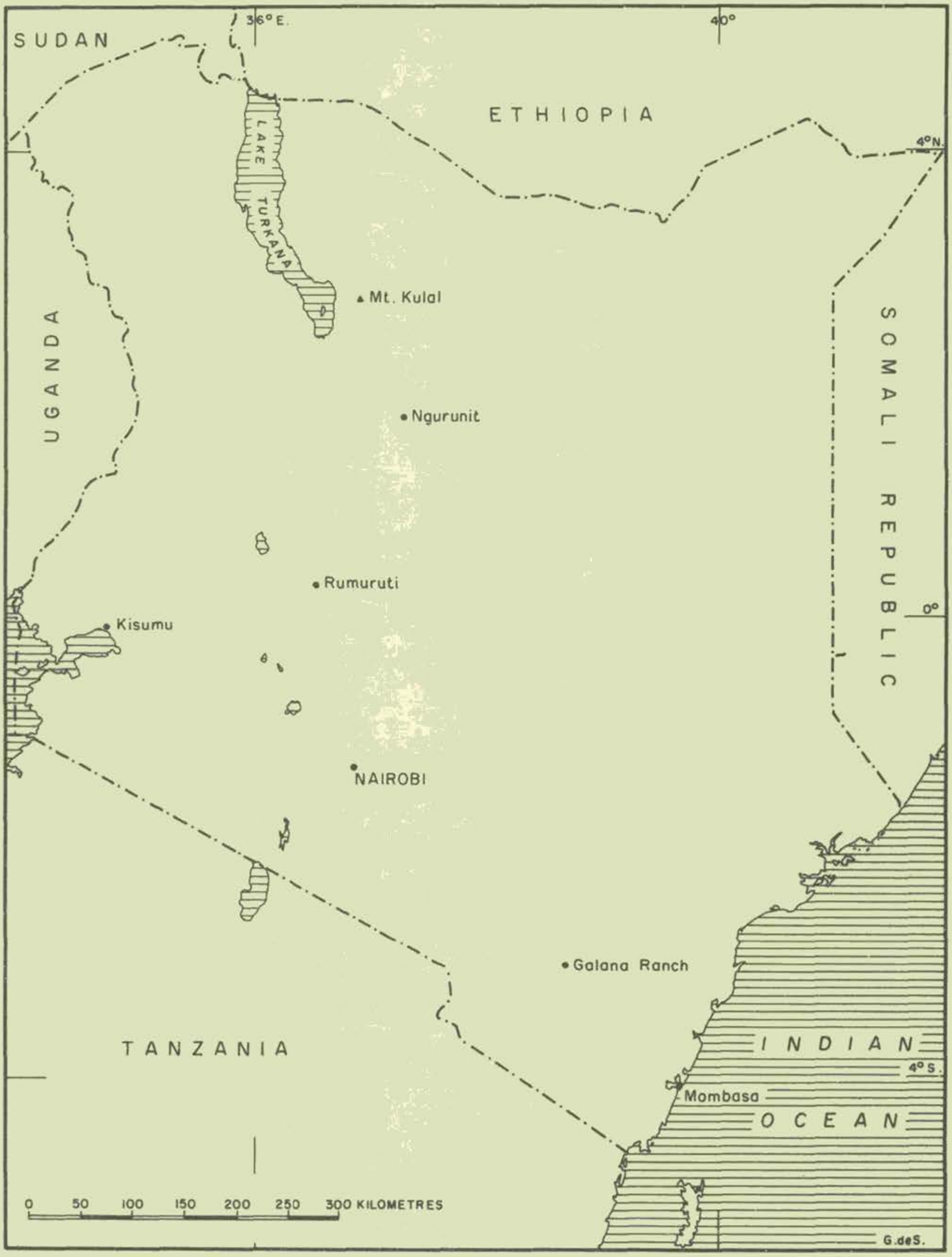
(d) application of the findings on camel herds in the IPAL Project area.

This paper describes the completion of aims (a) and (b).

Materials and methods

1. Study areas

Camels were sampled from 4 areas in Kenya, as shown in the map. Area 1 is the area around Mount Kulal at an altitude between 700 and 200 metres with an annual rainfall of between 100 and 600mm. Area 2 is around Ngurunit at an altitude of 700 metres with an annual rainfall of between 300 and 700mm. Area 3 is at Ol Maisor, Rumuruti at an altitude of 1890 metres with an average annual rainfall of 580mm. Area 4 is Galana ranch at an altitude of 270 metres with an average annual rainfall of 550mm.



SUDAN
36° E.
40°
ETHIOPIA
4° N.
LAKE TURKANA
Mt. Kulal
UGANDA
SOMALI REPUBLIC
Ngurunit
Rumuruti
Kisumu
0°
NAIROBI
Galana Ranch
TANZANIA
INDIAN
4° S.
Mombasa
OCEAN
0 50 100 150 200 250 300 KILOMETRES
G.deS.

The main vegetation types of all four areas are as follows:

Area 1. Evergreen forest leading into perennial grassland and then bushland and dwarf shrubland.

Area 2. Bushland and dwarf shrubland.

Area 3. Grassland scattered widely with *Acacia* spp.

Area 4. Thick bushland to the east passing into light *Acacia* and *Commiphora* to the west.

2. Herd structures

The herd structures of the animals sampled are shown in Table 1. Four hundred and sixty two camels were sampled regularly, 21 from area 1, 171 from area 2, 111 from area 3 and 159 from area 4.

Table 1. The numbers and structures of the camel herds sampled from the four study areas

Herd	*Adults (>4y)*		*Young adults (<4y)*			*Calves*	
	Male	Female	Male Castrate	Male	Female	Male	Female
1	1	9	2	2	2	2	3
2	4	69	29	21	26	6	16
3	4	55	6	13	13	13	7
4	4	67	7	27	13	18	23

3. Sampling frequency

The animals of herd 1 were sampled monthly, those of herds 2 and 4 every 2 months and those of herd 3 every quarter. The sex, age and number of every animal were recorded at each sample.

4. Samples

The following samples were obtained from each animal. The laboratory procedures undertaken are also summarized. The sampling period commenced in August 1979 until November 1980.

(a) Anticoagulant blood sample for haematology, rodent inoculation to detect trypanosomes and preparation of blood films for tick-borne disease parasites.

(b) Serum sample to detect the presence of antibodies against trypanosomiasis, foot and mouth disease, rinderpest, camel pox and brucellosis.

(c) Faeces for determination of helminth egg levels and helminth larval culture for identification.

(d) Ectoparasite counts and collection to determine tick loads and species.

Other disease conditions present were also recorded when observed.

5. Management

The management of all 4 herds is summarized on Table 2. Herd 2 was maintained under traditional management. Herds 1, 2 and 4 were under private ownership and had some degree of veterinary input.

Table 2. A summary of the management procedures undertaken in the four camel herds

Herd	*Ownership*	*Grazing pressure*	*Inputs* acaracide	anthelmintic	antibiotic
1	IPAL	+	Monthly	2 monthly	*
2	Traditional	+	NIL	NIL	NIL
3	Private	-	*	*	*
4	Private	-	*	*	*

* as required on clinical evidence.

Results

1. Haematology

The normal haematological values for camels as quoted by Salaheldin et al. (3) are used for reference.

Packed cell volume (PCV)

The PCV was used as a measurement of anaemia. Anaemia was observed throughout the study period in all herds, being most severe in herds 1 and 2. The anaemia was microcytic in type, which is associated with chronic blood loss.

White blood cell (WBC) levels

Camels in all herds showed a generalized increase in WBC levels (leucocytosis) throughout the study period. Differential counts showed a lymphocytosis and an eosinophilia. The former is associated with sustained immunological stimuli and the latter with parasitism.

Trypanosomiasis

Trypanosomes of the *Trypanosoma brucei* group (probably *T. evansi)* were isolated from camels in all herds throughout the study period. A summary of the point prevalence rates is shown in Table 3. Herd 1 showed the highest prevalence.

Table 3. A summary of trypanosome point prevalence rates (%) in camels from all herds at sampling times from August 1979 to October 1980

Herd	*Sampling Dates*										
	1979		1980								
	Aug.	Dec.	Jan.	Feb.	Mar.	May	June	July	Aug.	Sept.	Oct.
1	20.0	50.0	60.0	35.0	50.0	40.0		10.0		10.0	10.0
2	14.2	15.2		10.0	4.1	6.0		5.0			
3							5.3				18.8
4							2.2		1.4		

Four distinct disease patterns were detected.

1. acute characterised by sudden death - *rare*
2. chronic associated with low PCV and emaciation - *common*
3. chronic associated with normal PCV and no clinical signs - *common*
4. no disease even in the presence of many carriers - *common*.

3. Internal parasitism

Haemonchosis

Camels in all herds showed the presence of strongyle eggs in the faeces throughout the study period. When samples were cultured from all herds, *Haemonchus* was the most common helminth present. Camels of herds 1 and 2 showed much higher levels of eggs than those of herds 3 and 4. Increased levels of eggs were detected over the period December 1979 to March 1980 in samples from herds 1 and 2.

Other internal parasites

The percentages of animals infected with other internal parasites are shown in Table 4. Helminths of the genera *Trichuris* and *Strongyloides* were common in animals of herds 1 and 2. Helminths of the genera *Moniezia* and *Ascaris* were also detected in some animals and 2 animals in herd 2 showed coccidial oocysts.

Table 4. Summary of percentage of animals infected with internal parasites (with the exception of strongyles) in all herds

Parasite	*Herds*			
	1	2	3	4
Trichuris	52	32	9	-
Strongyloides	28	9	5	6
Moniezia	14	7	1	-
Coccidia	-	1	2	-
Ascaris	-	1	-	-

4. External parasitism

Ticks

Camels in all herds showed varying degrees of tick infestation with those in herds 1 and 2 having the highest levels. The commonest species varied according to study area, *Hyalomma dromedarii* being the most common in areas 1 and 2 and *Rhipicephalus pulchellus* the most common in areas 3 and 4. *H.truncatum,* a known toxin producer, was detected in all areas in low levels. The nostrils, eyes, ears, mammary gland and inguinal area were predilection sites.

No tick-borne disease parasites have been detected on examination of blood slides.

Other ectoparasites

Sarcoptic mange (caused by *Sarcoptes scabei* var. *cameli*) is common, especially in young camels, in all herds.

Infestation with the camel fly (family Hippoboscidae) is common in herds 1-3 and can cause acute distress.

5. Serology

Antibodies were detected against a number of diseases. These results are summarized in Table 5. Most animals in herds 1 and 3 show antibodies to trypanosomiasis indicating that the disease is very widespread and is endemic. The incidence of reactors to brucellosis is low in all herds. Camels of herd 1 show no reactors against camel pox in contrast to a large number of reactors in herds 2 and 3. A few animals in herds 2 and 3 showed antibodies to foot and mouth disease.

Table 5. Percentage of animals which are sero-positive to brucellosis, camel pox, foot and mouth disease and trypanosomiasis during 1980

	Disease (% sero-positive)			
Herd	Brucellosis	Camel pox	FMD	Trypanosomiasis
1	10	NIL	NIL	100
2	10	70	2.7	-
3	3	90	2.4	73
4	3	-	-	-

- to be undertaken

Mortality

The annual mortality and main diseases implicated are summarized in Table 6 in all herds. Mortality in herds 1, 3 and 4 is low and is much higher in herd 2. Important disease conditions which cause mortality include malnutrition, trypanosomiasis, camel pox and acute bacterial conditions. The role of predators should not be over-estimated.

Table 6. Percentage mortality and main causes of death (if known) in all herds during 1979/80

Herd	*Annual mortality* (%)	*Cause of death (if known)*
1	4.5	Enteritis
2	10-15	*Predator/tryps/pneumonia
3	2.8	Camel pox/tryps
4	4.6	Predator/tryps/mastitis

* Malnutrition plays a dominant role

7. Major disease constraints

The following major disease constraints have been identified with main symptoms:

Trypanosomiasis - anaemia, abortion, mortality, loss of production.

Haemonchosis - anaemia, loss of production.

Ticks - irritation, secondary infection, anaemia, toxicosis.

Mites - irritation, loss of production.

Camel fly - irritation, loss of production.

Camel pox - calf mortality, loss of production, secondary infection.

Bacterial disease (mastitis, pneumonia) - mortality, loss of production.

Malnutrition may play a role in all or some of these diseases in some areas including those in the IPAL Project area. However, the role of nutrition is uncertain.

Discussion

A number of important disease constraints to camel production have been identified in camel herds both within and outside the

Project area. Therapeutic treatment is available to cure or alleviate most of these conditions. A study on the economic effects of these diseases on production could therefore be initiated - see aim (c) in Introduction.

To maximize on the partial removal of disease constraints, a removal of some restraints to offtake should occur. Without the latter, desertification may be worsened by veterinary input stimulating the production of more animals.

Trypanosomiasis is generally recognized as the most important disease of camels (1, 4) causing great economic loss. This view is confirmed by the findings of this study. Camel pox is known to cause heavy mortality (up to 50%) in camel calves in susceptible populations (5). Results of serology (Table 5) show that some isolated herds (herd 1 in this study) may have no contact with the disease and thus are highly susceptible. In other herds, camel pox is endemic (herds 2 and 3) and in these cases clinical effects may be masked by immunity. Internal and external parasites probably play an important role in generalized loss of production.

The haematological results are probably mainly due to the long term effects of parasitism. Many causes of anaemia have been listed in this paper. Trypanosomiasis leads to sustained immunological attack which could explain the generalized lymphocytosis (see haematology).

Conclusions

1. A number of disease constraints to camel production have been identified in selected herds in different areas of Kenya. These include trypanosomiasis, haemonchosis, tick, mite and camel fly infestations and camel pox.

2. Brucellosis is the most important zoonotic disease which was identified. However, the incidence of this disease is low.

3. A study on the economics of maximum veterinary input could be undertaken with ease. The benefits of such a study could be nullified unless constraints to offtake are also studied and partially removed.

Acknowledgements

I wish to thank all IPAL staff who made this study possible. In particular I wish to thank Dr J. Schwartz and Dr C. R. Field without whose stimulation and assistance this study would never have been made. The assistance of Mr J. Evans, Rumuruti and Mr G. Powys, Galana Game and Ranching Co. is also acknowledged.

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A SUMMARY OF LIVESTOCK STUDIES WITHIN THE MT. KULAL STUDY AREA

C. R. Field

Introduction

There are several references both indirect and direct in past Project proposals to the need for livestock studies as a component if IPAL. Thus in the UNEP/MAB/IPAL Project Document Phase II (1976) the following long term objectives are relevant:

(a) to identify the causes of ecological degradation

(b) to document and measure the agents and processes of degradation,

(c) to asses carrying capacities and management regimes.

Among immediate objectives Phase II includes (a) to carry out a survey and investigation of arid zone ecosystems supporting human populations, (b & c) establish base line descriptions and successional trends, and (d) carry out experimental management under controlled stocking by livestock.

In response to these needs the Senior Ecologist drew up a proposal entitled 'The management of herbivores for the conservation of woody vegetation in the sub-desert region of Northern Kenya' (Field, 1976). The proposal concentrated on browsing herbivores, in particular the camel. There was an applied research phase involving studies of the distribution, population size and dynamics of large browsing herbivores using the techniques of both aerial and ground surveys. There was a proposal to investigate browse utilization as a component of this study. Techniques involved feeding observations, chemical analysis of the diet and assessment of ecological impact in enclosures. A development phase was also proposed. This involved the measurement of camel production and assessment of the value of different animals to the indigenous people. This phase further envisaged the need for management of livestock, and four possible approaches were suggested.

This was followed by a proposal for a complementary study on 'The impact of sheep and goats on the vegetation in the arid zone' (Field, 1976). This was funded by the ODM of the U.K. and ran for two years under the supervision of the ODM Smallstock Ecologist. Owing to a shortage of funds the approach, and much of the techniques used, was similar to that of the study on browsing herbivores since by doing so it was possible to pool resources.

In addition to these longer term studies there have been four consultancies in the livestock sector as follows:

1. A short-term consultancy on the grazing ecosystem in the Mt. Kulal area by Dr J. G. Lewis of Hunting Technical Services, U.K., April-June 1977. Emphasis in this study was on cattle.
2. A one-month consultancy on systems analysis and modelling of grazing lands by Dr C. Milner of The Institute of Terrestrial Ecology (ITE), U.K., December 1977.
3. A consultancy on the diseases of camels by Dr A. Wilson, Veterinary Department, University of Nairobi, July 1979 to December 1980.
4. A consultancy on 'The effect of large carnivores on livestock and animal husbandry in South-Western Marsabit District Kenya', by Dr H. Kruuk, November 1979 to February 1980.

Results

Published results from these studies are listed below. In addition a considerable amount of unpublished data has been summarized and presented in the eighteen IPAL Quarterly Reports to date and two Reports of the proceedings of Symposia entitled 'Man and the Environment in Marsabit District'.

IPAL Livestock Ecology Publications

1. Survey and monitoring of livestock numbers and distribution, stocking rates and carrying capacity.

(a) *A report on systems analysis of grazing lands,* C. Milner, 1978 (I.T.E., U.K.) Consultant. August 1978.
(b) *Preliminary report on the Ecology and Management of camels, sheep and goats in northern Kenya,* IPAL Tech. Rep. E la by Dr C. R. Field. February 1979.
(c) KREMU's 1980 Programme for Northern Coordinated Study and a compilation of Herbivore Distributions from five IPAL Aerial Surveys, by Drs P. Kuchar, J. G. Stelfex, D. G. Peden and H. Epp. KREMU, Ministry of Tourism and Wildlife. May 1980.

2. Livestock species reports

(a) *A short-term consultancy on the grazing ecosystem in the Mt. Kulal region, northern Kenya.* IPAL Tech. Rep. E.3 by Dr J. G. Lewis, Consultant, December 1977. This concerns mainly cattle.
(b) *Preliminary report on the impact of sheep and goats on the vegetation in the arid zone in northern Kenya.* IPAL Techn. Rep. E.2 by A. C. Field. April 1978.
(c) *The food habits of camels in northern Kenya.* IPAL Tech. Rep. E.lb by Dr C. R. Field, June 1978.
(d) *Camel growth and milk production in Marsabit District, northern Kenya,* by Dr C. R. Field, in I.F.S. Symposium Volume on Camels, Khartoum, December 1979.

3. Livestock disease reports

(a) *Camel disease at Kulal,* IPAL Report 1, by Dr A. Wilson, Veterinary Faculty, University of Nairobi, August 1979.
(b) *Camel disease at Kulal,* IPAL Report 2, by Dr A. Wilson, Veterinary Faculty, University of Nairobi, May 1980.

4. Other livestock ecology reports

(a) *Report on the state of knowledge on browse in East Africa in 1980,* by Drs H. F. Lamprey, D. J. Herlocker and C. R. Field. Presented at ILCA Symposium on Browse, Addis Ababa, April 1980.

(b) *The effects of large carnivores on livestock and animal husbandry in Marsabit District, Kenya,* (IPAL Tech. Rep. E.4) by Dr H. Kruuk, Consultant, September 1980.

In this paper emphasis will be on those aspects which to date have not appeared in summarized form in published reports.

1. The study area

This has already been described in IPAL Technical Reports B1, D1 and E1.

2. Numbers and distribution of livestock

(a) *Methods of Survey*

The principal method of surveying livestock numbers and distribution has been that of Norton-Griffiths (1975) which involves systematically sampling an area from the air. The relative merits of this method have been discussed extensively (e.g. A workshop on the use of light aircraft. *E. Afr. Agr. for J.* 34, 1969) and although the technique was originally developed for censusing wildlife it has and is being used widely for censusing livestock also (Watson, 1970; Western, 1976; KREMU, 1979). One major advantage of this method over attempts at total counts is that it enables the calculation of confidence limits on the estimates of population size. It is also more economical and less time consuming.

(b) *Results*

Eleven systematic reconnaissance flights (SRFs) have been made of the study area, one of which involved stratification of the area according to density. It has not been possible to combine data from this flight with the rest and it is therefore excluded from the following analyses.

All data from the other ten flights are stored on file at the IPAL Mt. Kulal Field Station and at the ITE, Bangor, U.K. computer data bank which has been carrying out analyses for us.

The ten SRFs spanned the period July 1976 to August 1979. The first flight covered 14,600 km^2 only, omitting the southern quarter of the study area. Three subsequent flights covered an area of 19,600 km^2 while the remaining six flights included the Hurri hills, a total area of 23,000 km^2.

The first two flights in 1976 coincided with extremely dry conditions at the end of the eight-year drought which caused considerable loss of life and livestock in Sahelian Africa. Five subsequent flights were completed in 1977 when rainfall was abnormally high. Conditions of above average rainfall were still being experienced in 1978 and it was not until the last count in August 1979 that dry conditions were resumed. Thus on the basis of rainfall statistics available from the climatological data of IPAL, six of the surveys represent wet season numbers and distributions while four represent dry season numbers and distributions. Rainfall histograms for seven stations are presented (Figures 1 and 2).

In order to compare results from these different sized areas, population estimates have been expressed as densities km^2 as follows:

	Densities km^{-2}										
Month/year	7/76	8/76	1/77	3/77	6/77	8/77	10/77	10/78	4/79	8/79	Mean
Species											
Smallstock	4.34	4.16	19.13	11.38	21.14	13.23	7.55	9.05	15.75	19.03	12.48
Cows	1.25	0.67	0.47	2.20	5.63	2.43	1.86	2.60	3.73	3.83	2.47
Camels	0.50	0.71	3.38	1.09	1.74	1.87	1.15	1.33	1.49	4.77	1.80
Donkeys	0.03	0.01	0.05	0.01	0.10	0.15	0.03	0.01	0.15	0.03	0.05
Oryx	0.20	0.06	0.11	0.03	0.04	0.08	0.05	0.01	0.07	0.10	0.08
Zebra	0.06	0.04	0.12	0.05	0.04	0.09	0.03	0.06	0.05	0.06	0.06
Giraffe	0.05	0.05	0.07	0.11	0.09	0.12	0.06	0.05	0.06	0.05	0.07
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
Gerenuk	0.05	0.10	0.07	0.08	0.03	0.04	0.03	0.00	0.02	0.03	0.05
Ostrich	0.14	0.06	0.05	0.05	0.05	0.11	0.03	0.08	0.10	0.20	0.09

Figure 1. Rainfall histograms for three stations

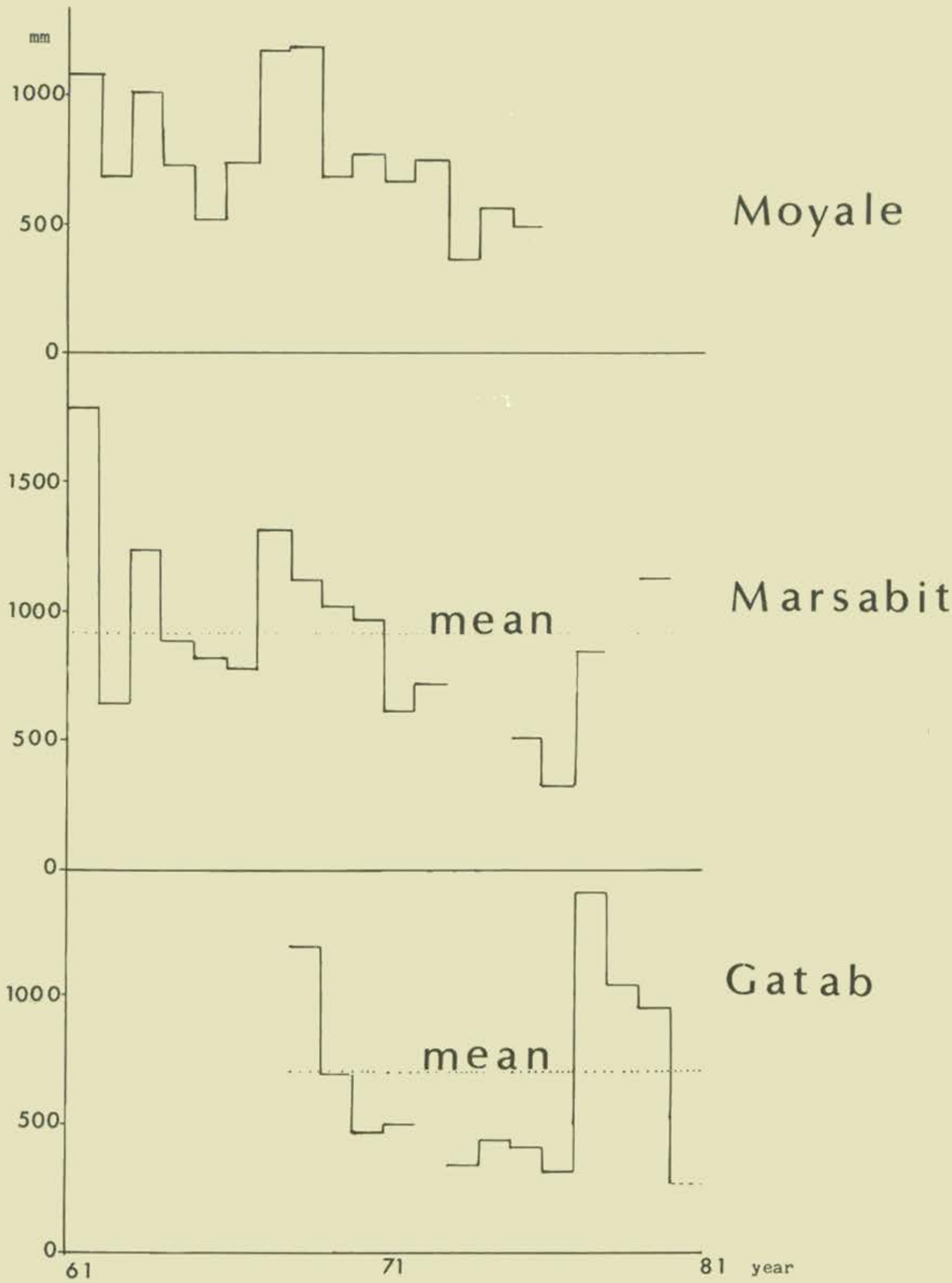
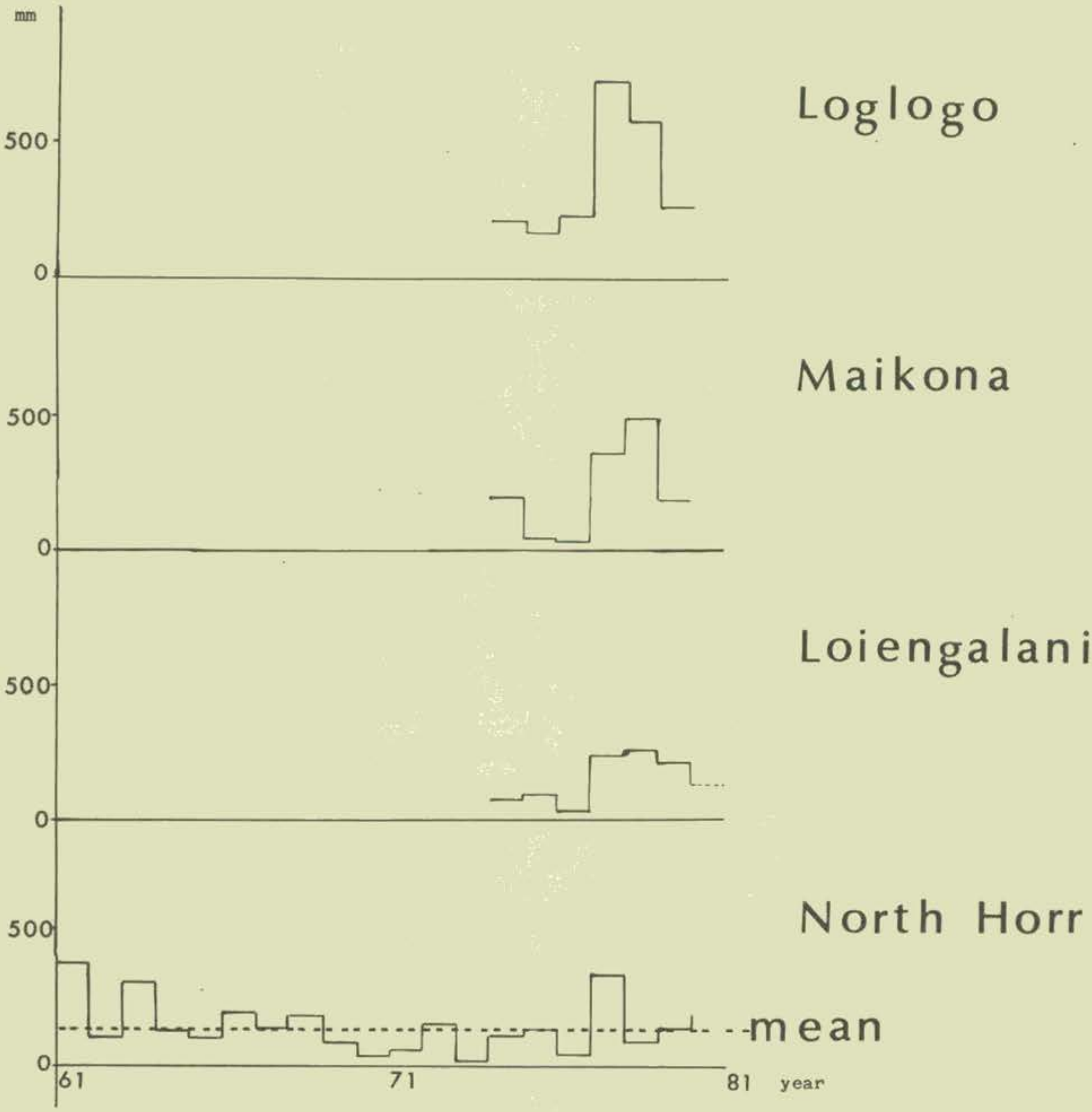


Figure 2. Rainfall histograms for four stations



Mean estimated populations for the study area (23000 km^2) and their size in terms of tropical livestock units (TLU, 250 kg cow) are as follows:

	Est. population	Size/%	Number per TLU	Total	TLUs % of total	
Smallstock	287,040		11	26,095	18.3	
Cows	56,810		1	56,810	39.8	
Camels	41,400	96.8	0.8	51,750	36.3	95.2
Donkeys	1,150		1	1,150	0.8	
Oryx	1,840		2	920	0.6	
Zebra	1,380		1	1,380	1.0	
Giraffe	1,610		0.5	3,220	2.3	
Grants Gazelle	4,600	3.2	10	460	0.3	4.8
Gerenuk	1,150		10	115	0.1	
Ostrich	2,070		3	690	0.5	
Total	399,050			142,590	100.00	

(c) *Discussion*

1. Densities

All livestock were at low densities during the first two surveys and increased subsequently to more than three times the former average densities. Cattle were an exception and they showed an increase after the third survey. There was no such change among wildlife. The reason for this marked increase in livestock densities is attributed to the return of 'fora' animals with the onset of the rains. These animals, amounting to two thirds to three quarters of the total population of livestock, had vacated the area during the preceeding eight-year drought travelling as far as Maralal (95 km) to the south (Oburu, personal communication) and Ethiopia (75 km) to the north.

There are several possible reasons why cattle delayed their return. After the onset of rain, browse suitable for camels and goats would have sprouted first, perennial grasses suitable for cattle later. Wet conditions in highland areas would have been suitable for cattle but unattractive to camels which may have had to move first. Cattle may have moved further away during the drought in search of grazing and therefore taken longer to return and they may also have waited until there was sufficient surface water in the study area before returning.

2. Numbers and biomasses

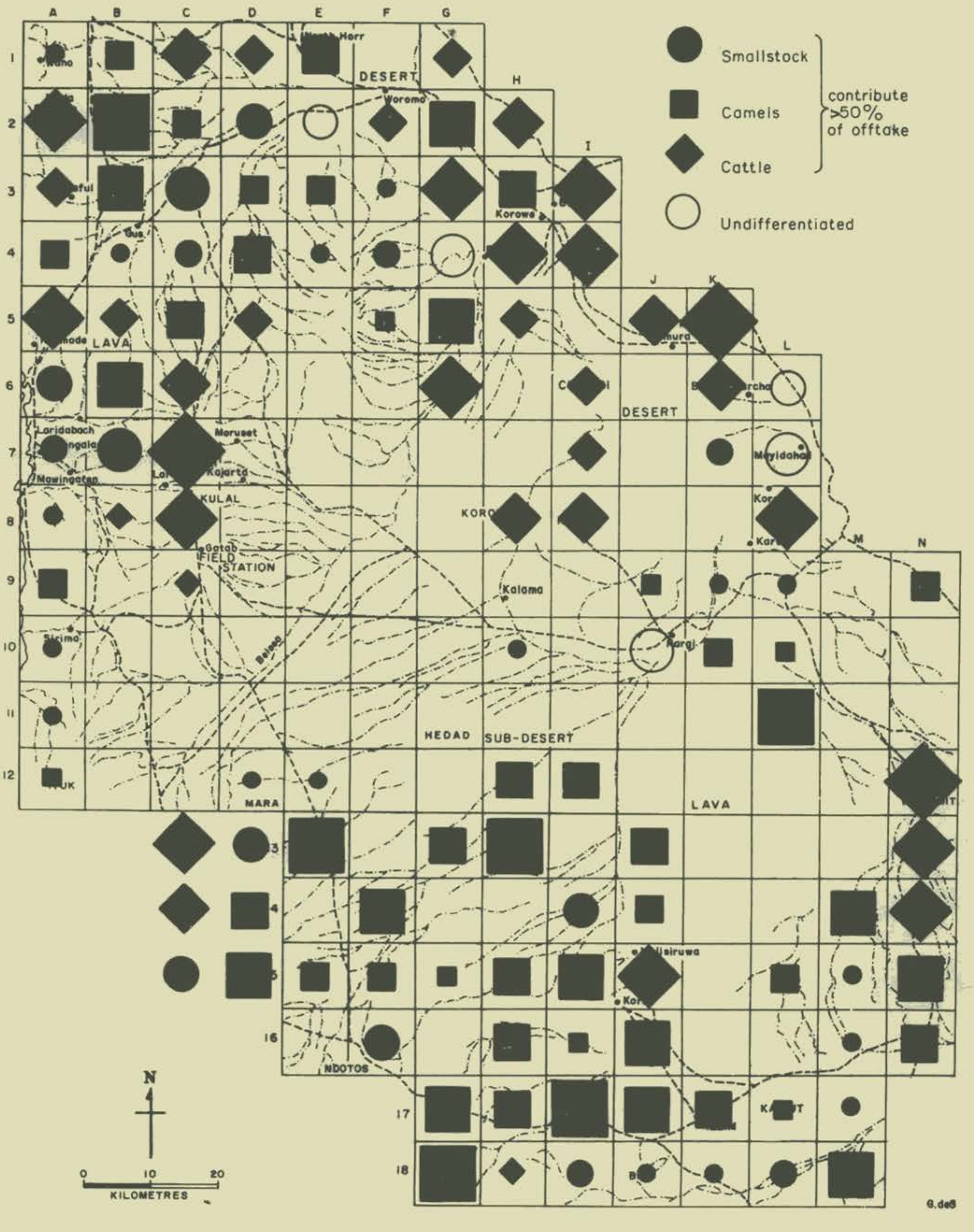
On average there are an estimated 400,000 ungulates in the study area. Of these 97% are livestock and the remainder wildlife. Numerically 72% of the livestock were sheep and goats. However, when expressed in terms of livestock units, smallstock comprised only 18% while cattle (40%) and camels (36%) were the most important. Wildlife comprised 5% of the biomass with giraffe being the most important species.

3. Intake and carrying capacities

Estimated intake (in kg dry matter km^{-2} day^{-1}) by livestock during dry seasons (i.e. the non-growing period when there is no possibility of increased production through grazing) has been mapped for 100 km^2 unit areas. This is on the basis of mean daily intake of dry matter being 0.63 kg for smallstock, 6.3 kg for cattle and 9.1 kg for camels. Those unit areas in which a single category of livestock contributes to more than 50% of the intake have been indicated in Figure 3.

From the map it is apparent that smallstock tend to contribute more in areas of low offtake (e.g. along the shores of L. Turkana). Excluding all unit areas of estimated offtake more than 10 kg per day gives the following percentage contributions: camels 47%, cows 33%, smallstock 15%, and 5% of the area had no dominant species.

Figure 3. Estimated dry matter intake kg $km^{-2}d^{-1}$: dry seasons
(Size of symbol is directly proportional to intake)



It is interesting to note that camels contributed most to intake in the southern third of the study area while cattle contributed mostly around the Chalbi desert and in the highland areas of Kulal and Marsabit.

Mean annual stocking rates in terms of TLUs km^{-2} have been plotted for each 100 km^2 unit area. In the ten surveys no livestock were seen in 13% of the study area while a further 12% had less than one TLU km^{-2}. This was either barren land or insecure country.

Using data published on potential carrying capacities by Le Houérou and Hoste (1977) and Pratt and Gwynne (1977) it has been possible to map areas in which observed stocking rates have been in excess of the recommended rate. This takes into account the increased carrying capacity with rainfall (Figures 4 and 5). Results show that, depending on the author, the areas of excessive stocking vary from 16.3 to 20.9% of the total study area. From 32-37% of these occur in areas of permanent settlement and 54-63% are in areas of permanent water. The remainder may represent 'fora' animals, in particular the highly concentrated Rendille camel 'fora'. Areas of most excessive use are Maikona, Kargi, Marsabit and Ngurunit.

(Text continued on page 103.)

Figure 4. Areas where stocking rates exceed potential carrying capacity (CC) (CC after Le Houérou and Hoste (1977); excess in TLU km^{-2} yr^{-1} = 16.3%)

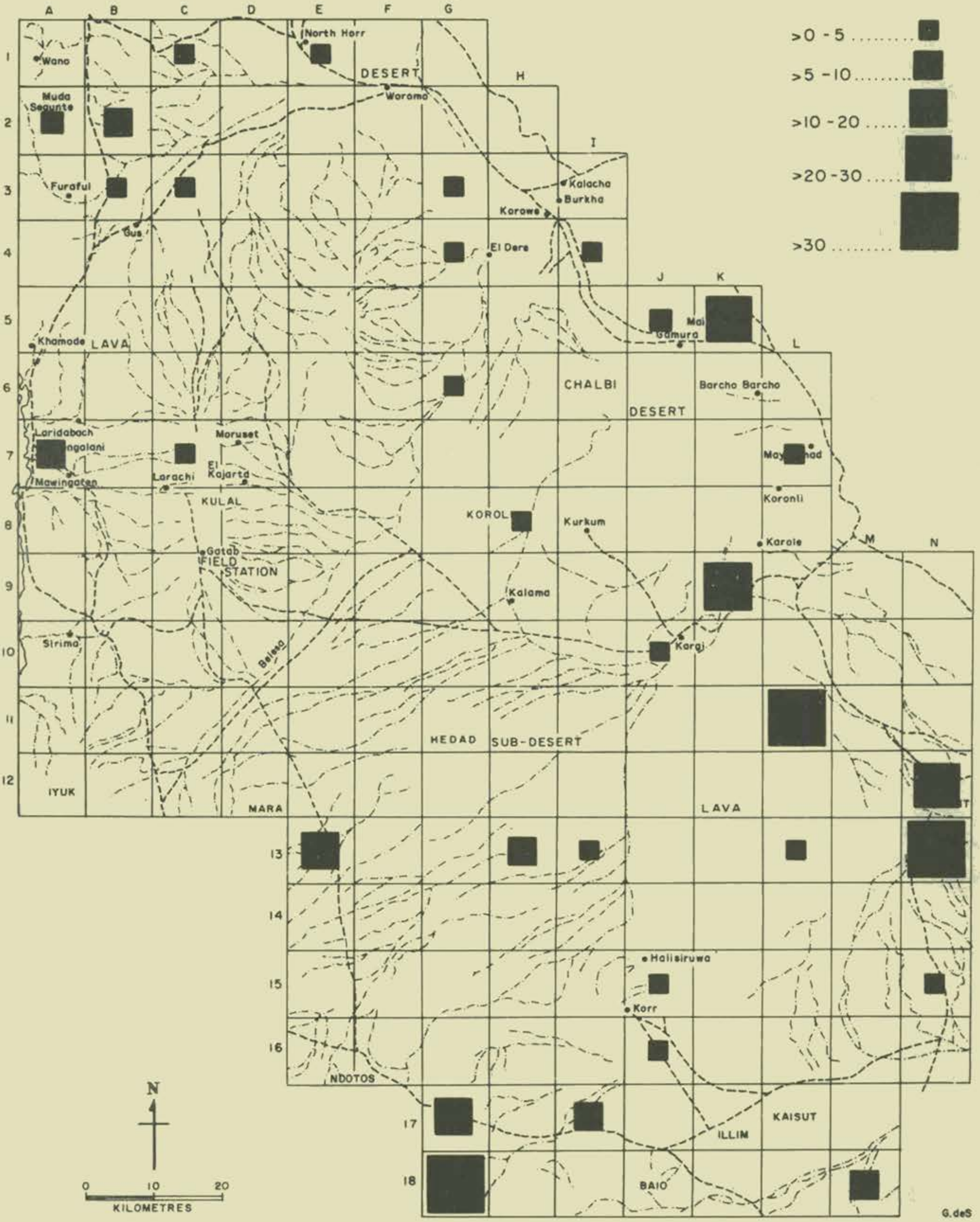
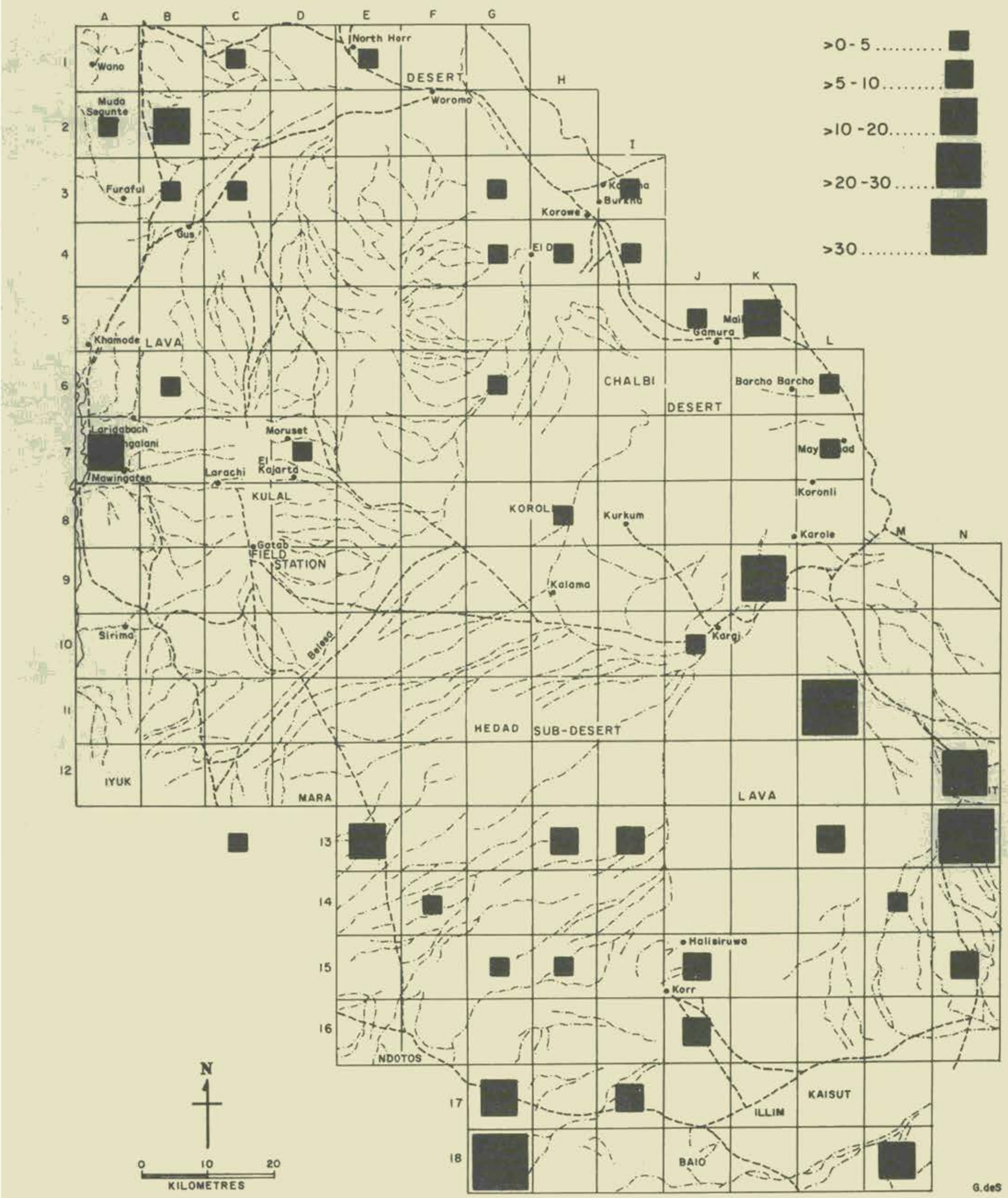


Figure 5. Areas where stocking rates exceed potential carrying capacity (CC) (CC after Pratt and Gwynne (1977) excess in TLU $km^{-2}yr^{-1}$ = 20.9%)



4. Distributions

A computerized mapping programme has been developed to map the distributions of livestock in relation to seven environmental parameters. Two way and three way combinations and contrasts are possible and more complex multiple combinations are theoretically possible but only limited in quantity of data points. One hundred of these maps are available on file.

Other data in the process of being stored on this computer and shortly to be available for analysis include the following:

(a) Monthly rainfall totals from the rain-gauge network.

(b) Dr Herlocker's vegetation map at three levels of classification.

(c) Dr Sinda's geomorphological map.

The advantage of this mapping programme is that it enables rapid visual assessment of likely livestock and environmental associations and correlations and will minimize time wasted on unfruitful analyses in future.

Wet and dry season livestock mean numbers and standard deviations have also been summarized on a 100 km^2 grid of the study area by a computer mapping programme. The printouts are available on file. Because of the small number of SRFs to date and the clumped nature of livestock (in particular in dry seasons) the standard deviations often exceed the means.

Maps of wet and dry season densities of livestock have been plotted in Figures 6-9 inclusive. 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%

Between-season comparison is invalid because of the different number of surveys. Within-season comparison indicates that smallstock have the widest distribution and cattle the least.

Figure 6. Cattle wet season means km^{-2}, n = 6, 90 squares occupied = 46%

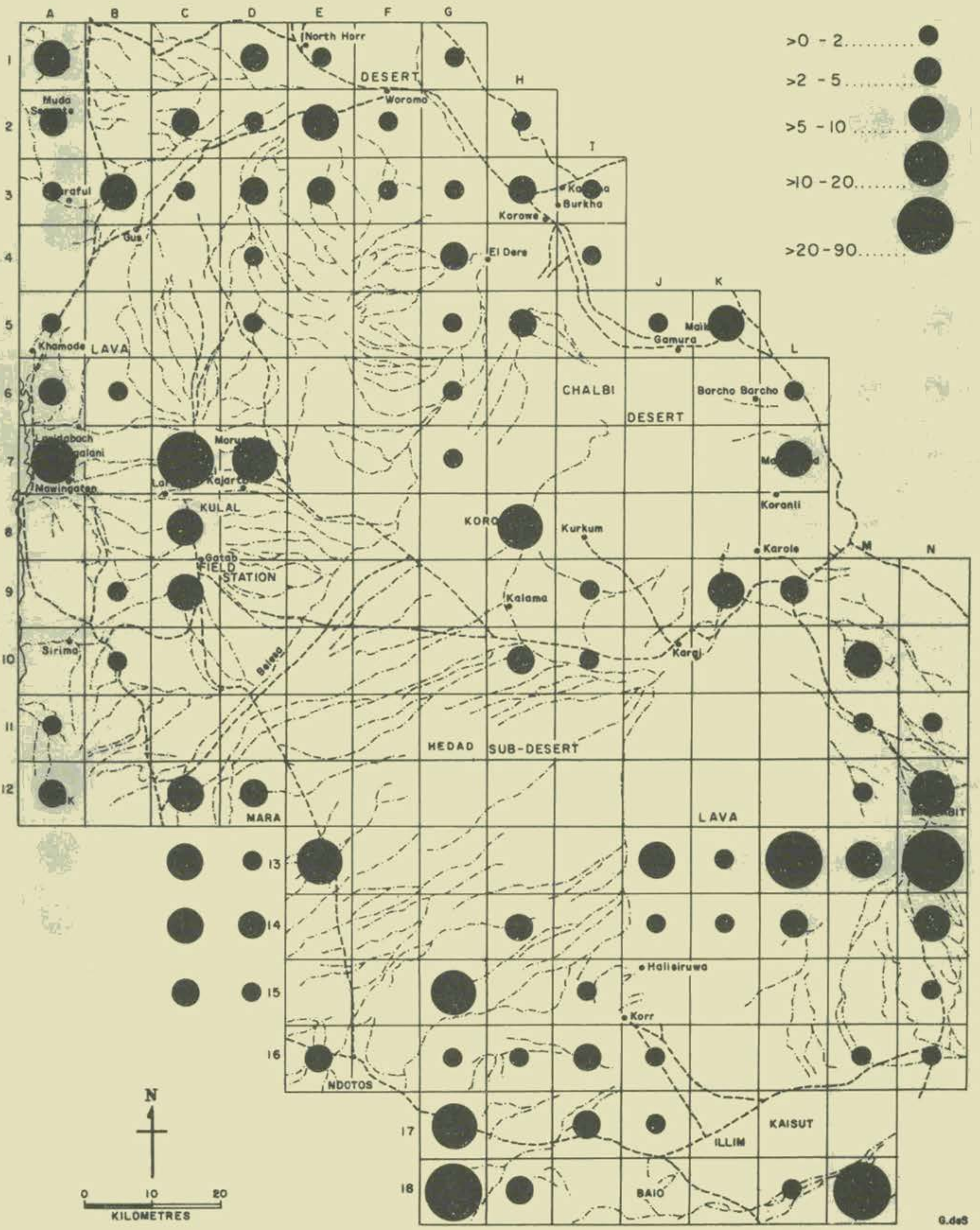


Figure 7. Cattle dry season means km^{-2}, n = 4 or 3, 61 squares or 31% occupied

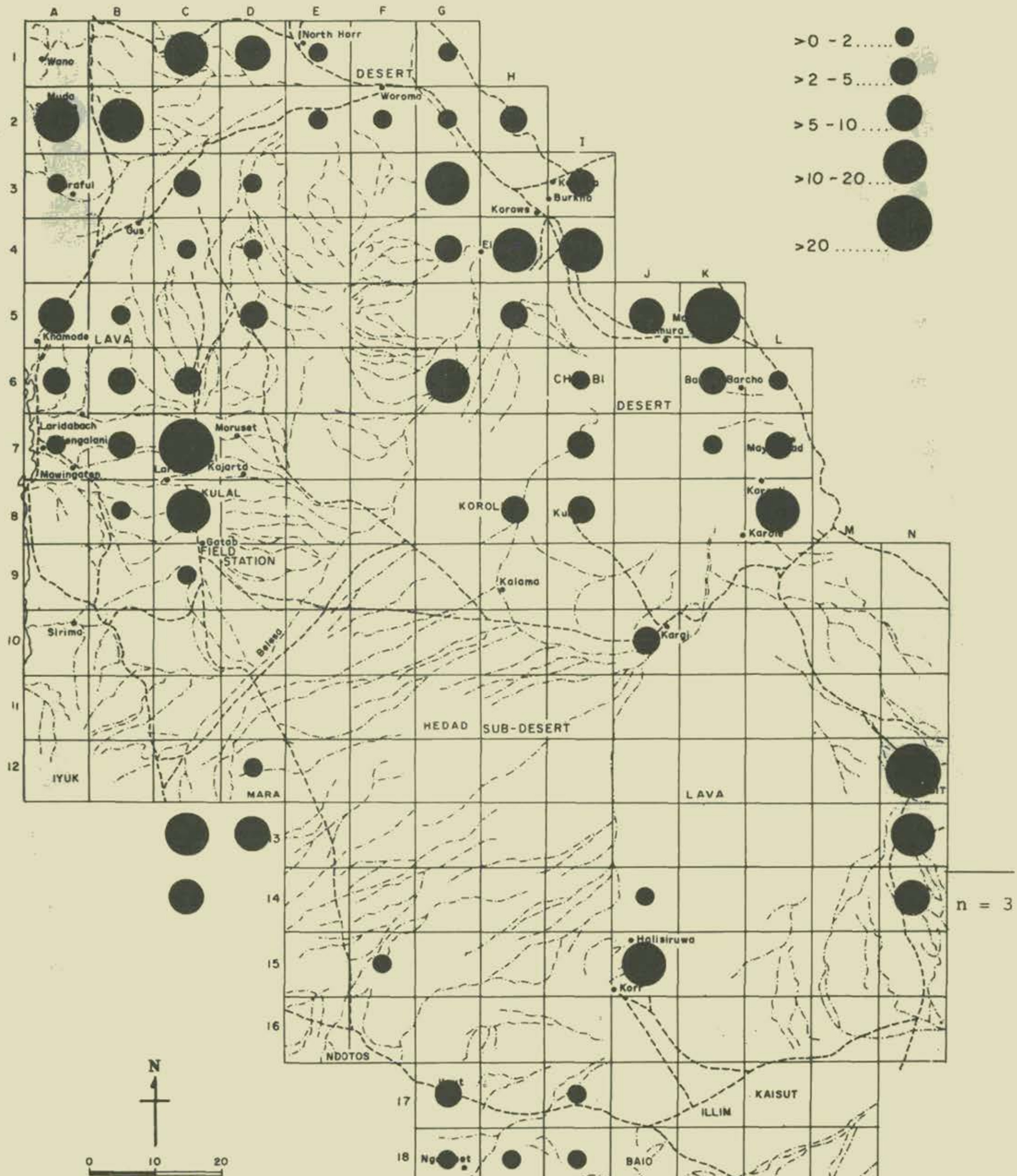


Figure 8. Camels wet season means km^{-2}, n = 6, 100 squares or 51%

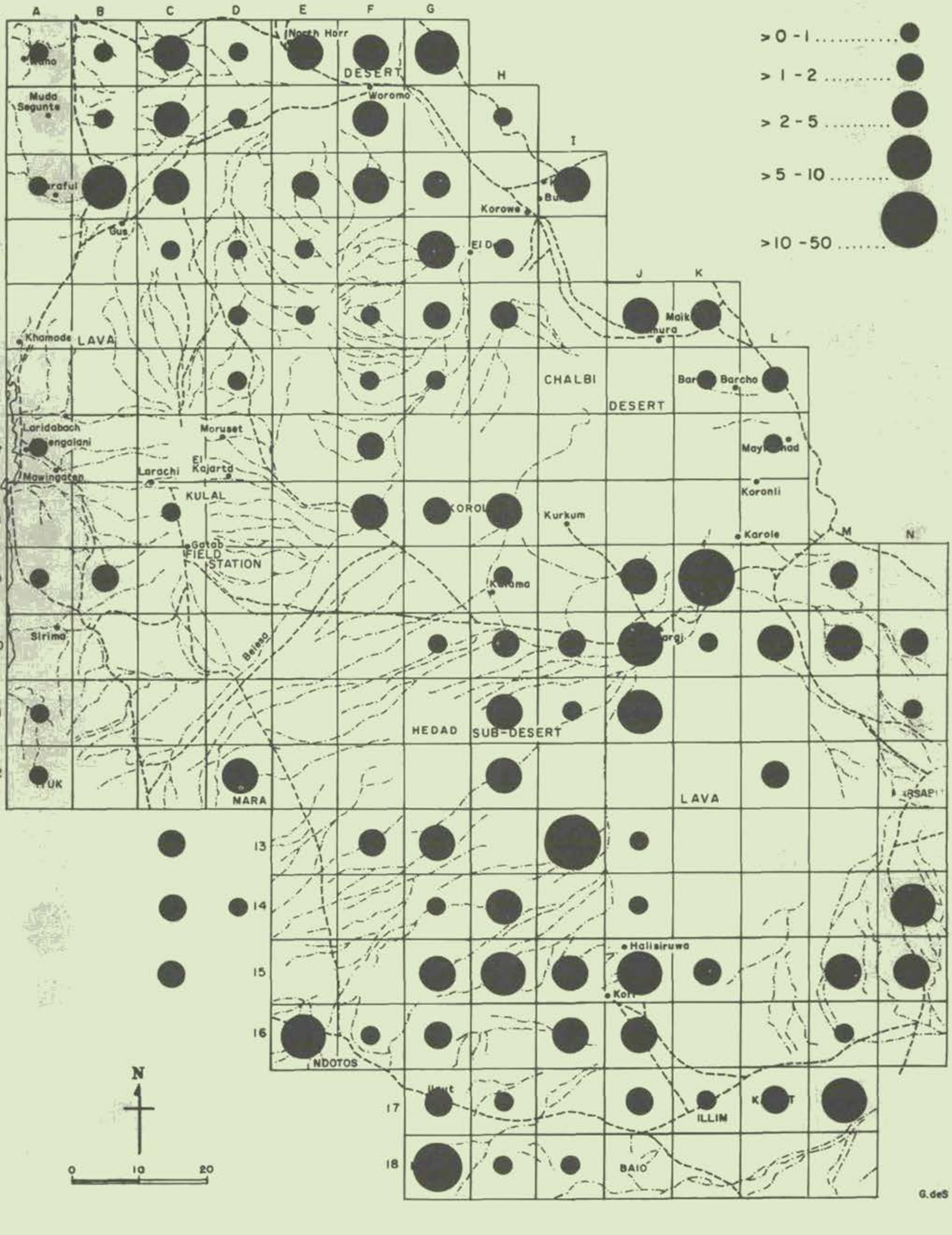
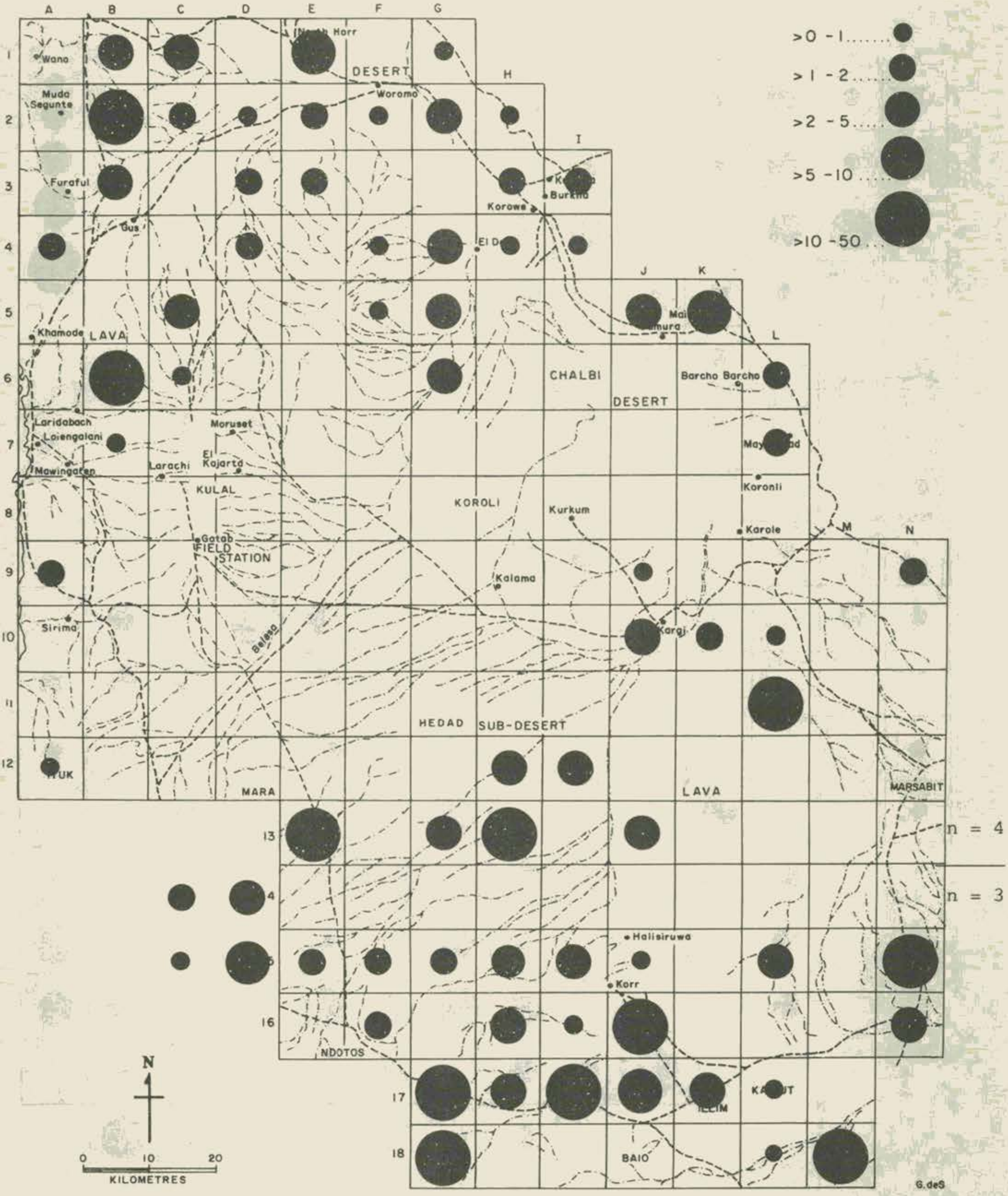


Figure 9. Camels dry season means km^{-2}, n = 4 or 3, 77 squares = 39%



The main concentration areas for the three categories of livestock on the basis of the highest densities recorded in any 500 adjacent km^2 are as follows:

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	____	____
S. Horr	5.3	____	____	____	____	36.6
Kulal	9.9	10.3	____	____	74.9	____
Asie	____	____	____	____	38.1	____
Gus	____	____	____	5.0	____	57.4
N. Horr	____	8.4	4.3	____	____	____
Kalacha	____	9.0	____	8.4	45.6	51.4
Maikona	8.1	10.0	____	____	____	104.0
Hurri Hills	24.0	____	____	____	40.9	____

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

Nutrition

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

1. Observations on food habits and water requirements of experimental herds and some traditional herds.
2. Analyses of the chemical nature of the diet including moisture content.
3. Intake studies.
4. Impact studies.
5. The relationship between diet and herd production.

1. Food habits

Much of the work carried out from July 1976 to December 1977 has been presented in IPAL Technical Reports E1a & b, E2 and E3. 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:

	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.

2. 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 via ILCA to the University of Hohenheim for chemical analyses.

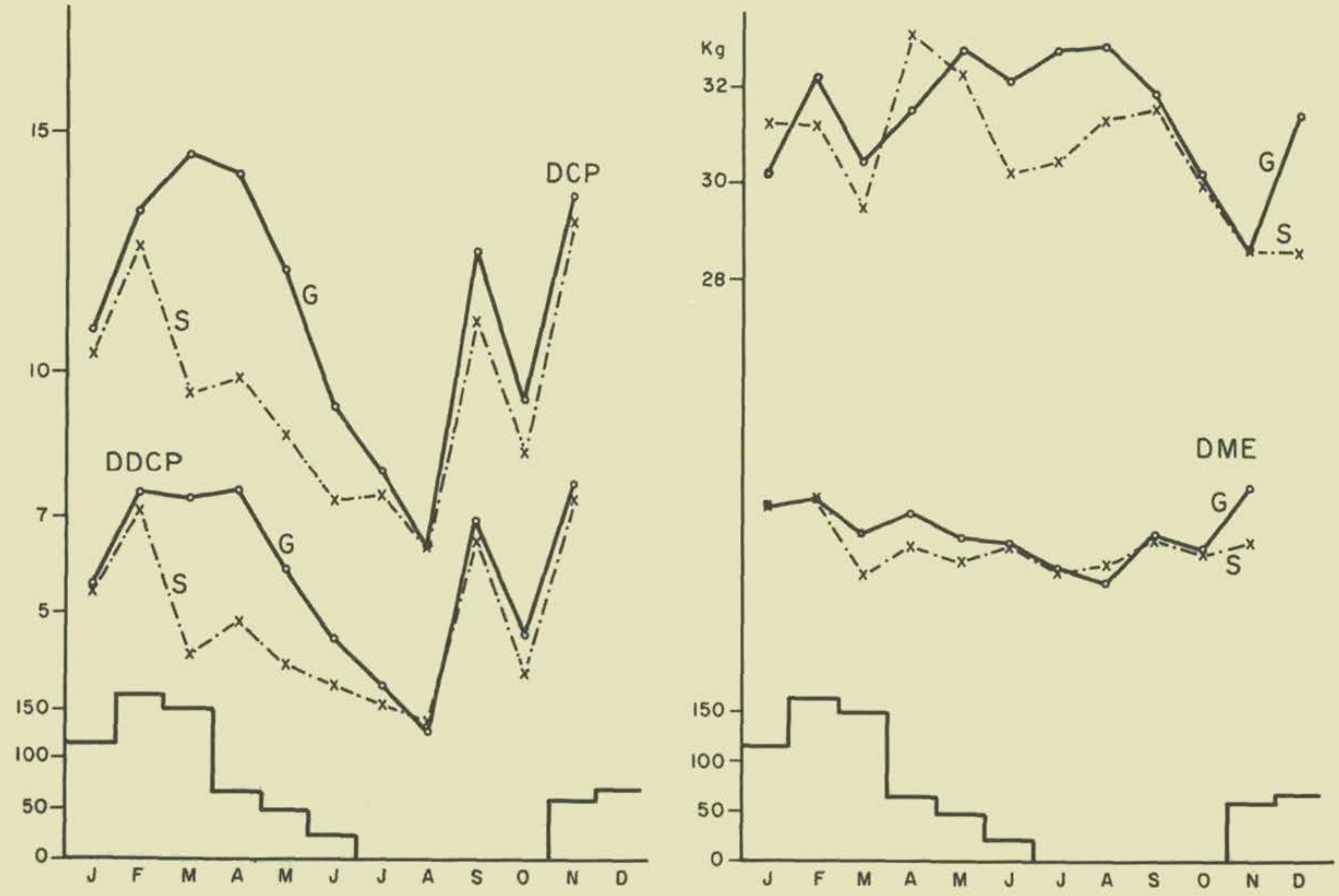
Results of 80% of these analyses (115 samples) are now available. They are in terms of % crude protein, energy, gas production and *in vitro* organic matter digestibility.

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 10). 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).

Figure 10. 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.



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 11) 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.

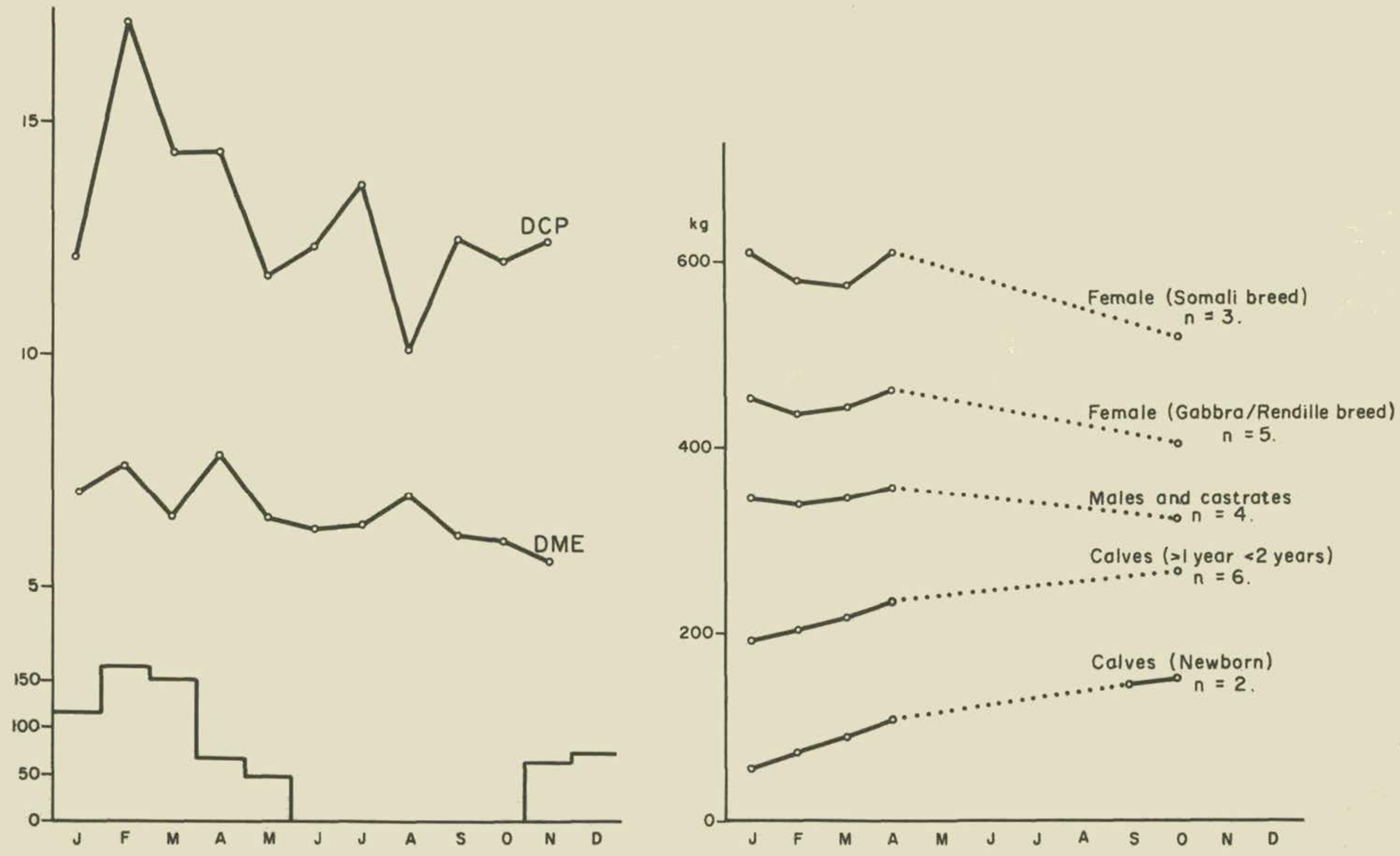
The mean weights of 12 goat does and 9 sheep ewes have been plotted on graphs on a monthly basis (Figure 10). They follow broadly similar patterns except in January and December. Attempts to correlate live weight with nutritional status have as yet been unrewarding but there are a number of variable 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 11) 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 live-weight and has been used during 1980. However the weights indicate an overall decline for all three categories of adults from a peak in April 1979 to a low in October 1979. Weights of calves increased, however, the greatest being among the younger calves which were suckling and therefore only indirectly affected by the dry conditions in the middle of the year.

3. Intake

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

Figure 11. Seasonal variations in dietary crude protein (DCP), metabolizable energy (DME) and liveweight (Kg) in camels. Rainfall histograms are two monthly running totals.



Date	Species	Sex	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	
13.10.79	Camel	Male immature	1.33	
14.05.80	Camel	Male immature	1.61	1.67
19.05.80	Camel	Female adult	1.66	1.67
10.05.80	Camel	Female adult	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	

One further collection from camels has 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 colleciton from the same animal over three consecutive days. Results indicate a small amount of variation between days.

4. 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.

5. 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$\pm$1.9 ml kg^{-1} d^{-1}; males 20.7$\pm$2.0 ml kg^{-1} d^{-1} during June 1978). Camels used for riding purposes including 50% trotting, consumed 0.8-1.0 ml 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.

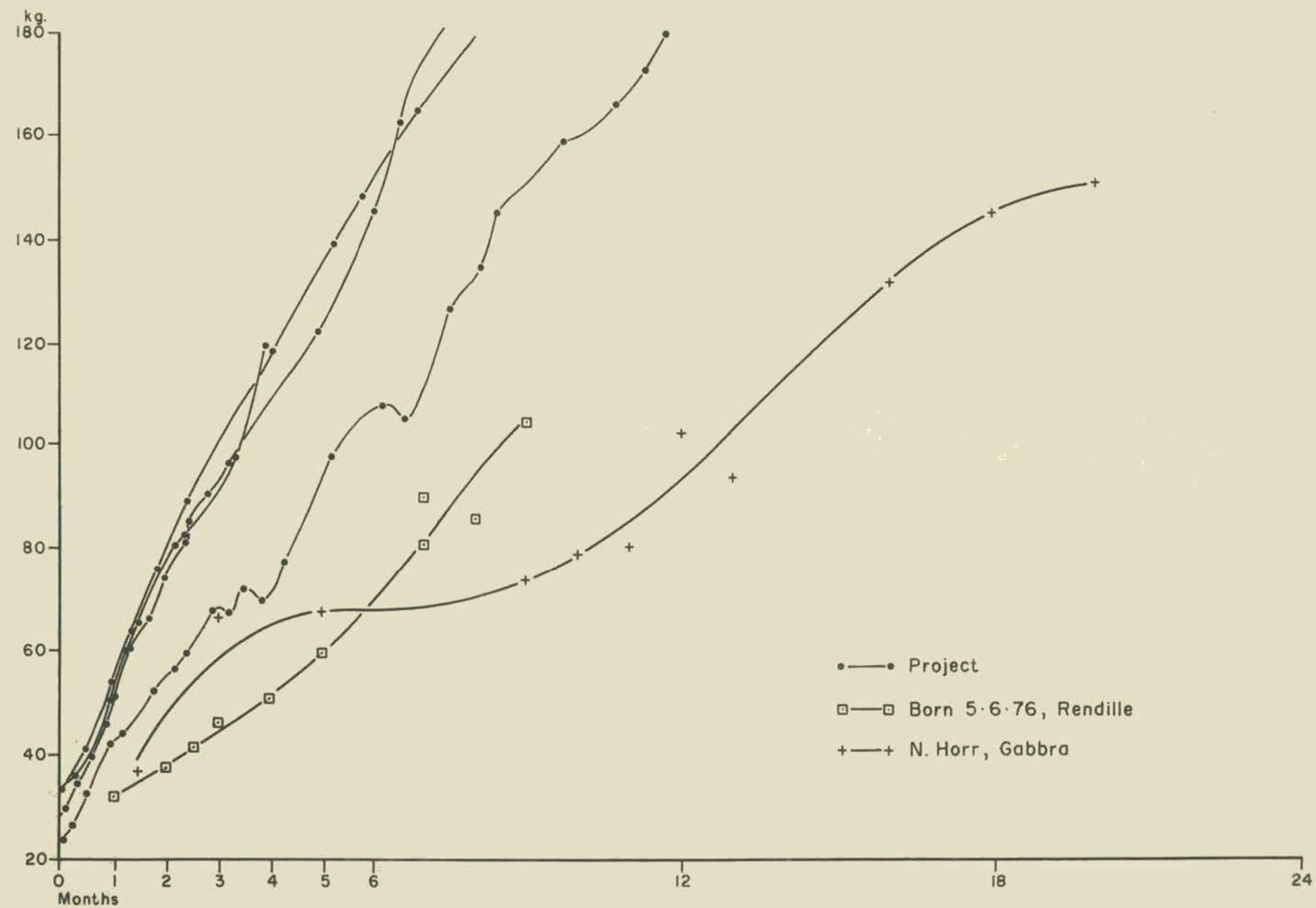
1. Growth
   Weight at birth, liveweight.
2. Milk
   Volume, chemical composition (camels only), duration of lactation, age at weaning.
3. Reproduction
   Age at first kidding/lambing, abortions, births including twinning, calving interval, mating.
4. Mortality
   Diseases, causes of deaths, deaths and longevity.
   Supplementary data have been collected from camels, smallstock and cattle owned by indigenous people as follows:
   (a) Growth. Weight of 300 camel calves and two smallstock flocks.
   (b) Herd and flock compositions by questionnaires.
   (c) Mortality by questionnaires and collection and ageing of about 150 camel skulls. Data from two smallstock flocks over two years.
   (d) 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, E3. They are summarized as follows.

1. Growth rates

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.

Figure 12. Camel growth



Growth rates of camel calves in gm d^{-1} are summarized in Figure 12 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.

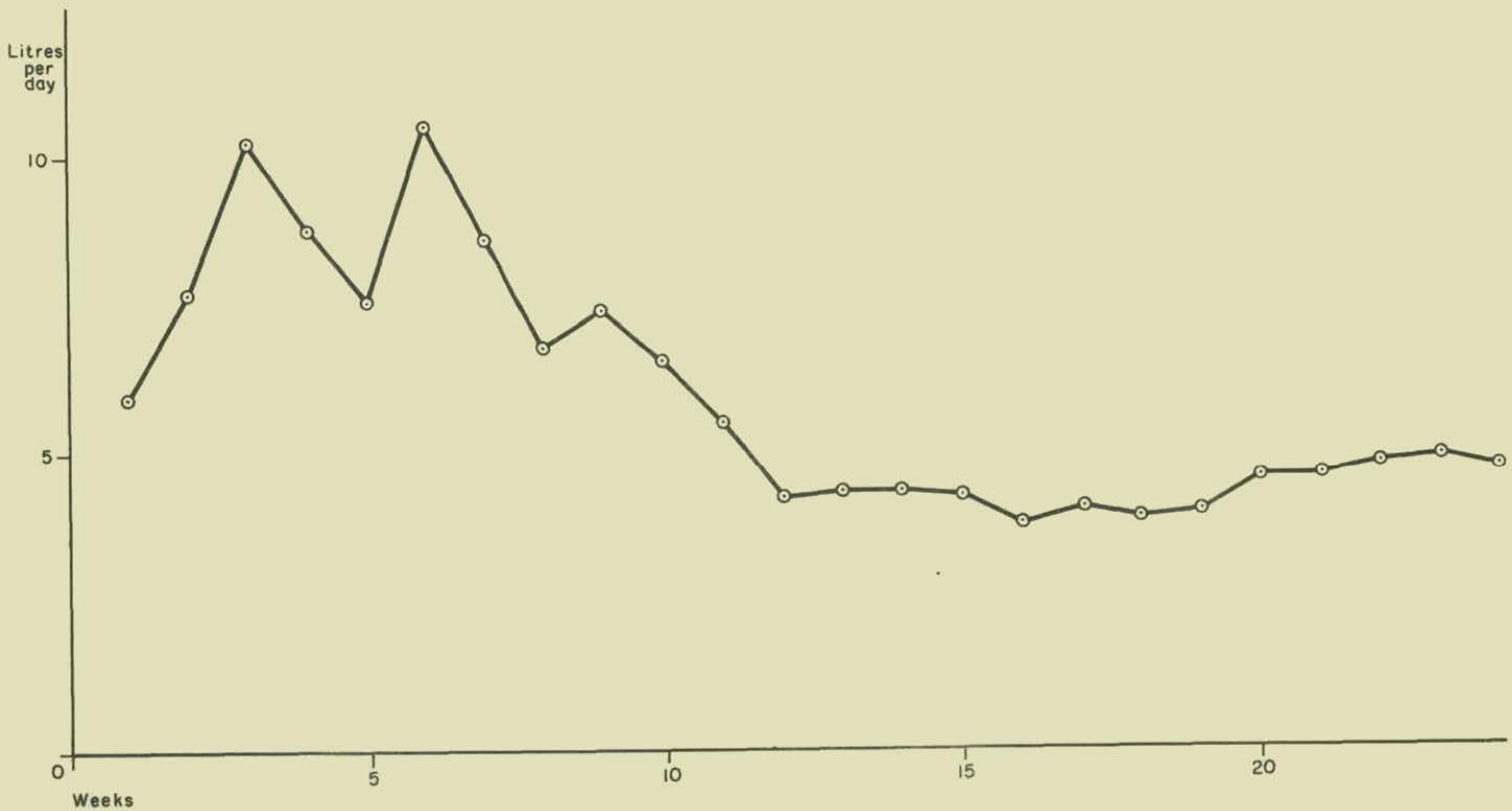
Field (IPAL Technical Report E.2) presents data on seasonal and reproductive influences on weights of mature female goats and sheep. Animals have been separated into age groups based on incisor eruption and whether they are pregnant or lactating.

	Sheep	n	Goats	n	Camels	n
Males	2.26	17	2.07	22	28 ± 3.0	3
Females	2.11	13	1.01	27	34.8 ± 1.4	4
% Twins	12		33		0	

2. Milk production

It has been estimated from data from the IPAL flock that annual milk production by 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. 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.

Figure 13. Camel No. 5. Milk yield



In this study camels lactate for an average of 385 days, daily output ranges from 2.7-4.0 litres while the total produced during a lactation ranges 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 13).

Results of chemical analyses from 80 samples of camels' milk from the IPAL herd are now available. They were collected in 1979 and analysed at the Technical University of Berlin by Professor Steinhauf.

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).

Estimates have been made of Rendille requirements for meat and milk based on information from the literature, the above data 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 5 lactating camels are required to supply a Rendille household with protein needs and 11 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 4 lactating camels and 120 head of smallstock. The exact composition of the owners flocks is important but may vary and still supply the required amount of food.

It is hoped to refine these estimates as further information becomes available. The following points are relevant; firstly additional animals are needed for transport and to fulfil social obligations, e.g. eight camels are required to purchase a bride. 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 and Gabbra 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.

Conclusions

Dr Lamprey is in the process of compiling a final report to UNEP on the conclusions from the work of Phase II of IPAL and it is perhaps premature for me to anticipate fully the form which it will take.

It is clear, however, that there are various alternatives available for the residents of Marsabit District and for pastoralists in general. Some have already decided upon their strategies for survival, others are in the process of adapting strategies while many will be faced with the need to change or perish.

The first alternative is described by Grove (1977) who makes the following remarks. 'Traditional (pastoral) systems do not fit neatly into the framework of a modern state. Nomadic flexibility is an advantage [while] settlement of pastoralists is expedient politically and has *some* economic advantages, but the greater rigidity involves considerable risks of disaster when drought years come again, as they will.' 'Nomadism as a careful pastoral continuum is the least traumatic of human influences' (UNESCO, 1970). Some people will no doubt cling to nomadism as a successfully tried strategy for survival but they will do this in the face of political opposition and they may be required in the long run to conform.

The second strategy involves an extension of the current grazing range into unoccupied areas which are not barren land such as those indicated from the aerial surveys. To achieve this it is necessary for the Government to provide improved security and possibly in some cases water development. With regard to camel distribution, however, water availability does not appear to be a constraint. In order for this to be of long-term benefit it will be necessary to improve the mechanism for offtake of livestock and also where medicine enables the survival of an expanding human population, to educate the pastoralists to plan their families. Otherwise there will be a short-term gain until the unexploited land is also degraded and its productivity reaches the lower level of the already occupied areas.

The third strategy involves close co-operation between planners and pastoralists to develop integrated management plans for the controlled and sustained use of the area. Its success hinges upon the controlled transfer of land tenure from the Government (who currently hold land in trust) to the people in the form of disciplined grazing co-operatives. The same basic prerequisites of a strong marketing policy for livestock accompanying family planning in the home are essential for success. Such integrated management plans are complex and will require a systems approach. IPAL staff have a role to play both in the provision of basic data and in the supply of information gained with experience with regard to the possible success of the various alternative strategies available to the people.

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HUMAN ECOLOGY

MIGRATION PATTERNS IN THE RENDILLE, 1923-1978

R. A. Dolan

The migration histories of five Rendille and two Ariaal settlements were analysed by computer. These oral histories were compiled from interviews with the elders of the seven settlements conducted by N. Sobania in January and February 1979 and presented in an unpublished report (Sobania, 1979). The original data as presented by Sobania was in the form of a series of place names classified by year and season.

In the preparation of the data for computer analysis each place name was first located on a 10 x 10 km grid square map of the area. Some 30% of the locations were found to be outside the present day Rendille homerange (Map 1). All locations whether inside or outside the IPAL study area were included. Each grid square was then classified according to (i) vegetation type and (ii) water availability. The vegetation type classification was achieved with the aid of Dr D. Herlocker's vegetation map of the south-western Marsabit District. Rainfall data from seven stations in the area were used to classify each year as wet, dry or average. The seven settlements, which constitute roughly a 10% sample of the Rendille and Ariaal, were of varying size and had histories of varying lengths, as shown in Table 1. The 56 years from 1923 to 1978 was divided into four historical periods (Table 2).

Table 1. The seven settlements

	Number of houses	*1st recorded year*
Rendille		
1. Dibsahai	77	1923
2. Galdeilan	10	1938
3. Sale	37	1934
4. Uiyam	19	1939
5. Urawen	26	1930
Ariaal		
6. Lokumai	71	1940
7. Masula	53	1943

Map 1

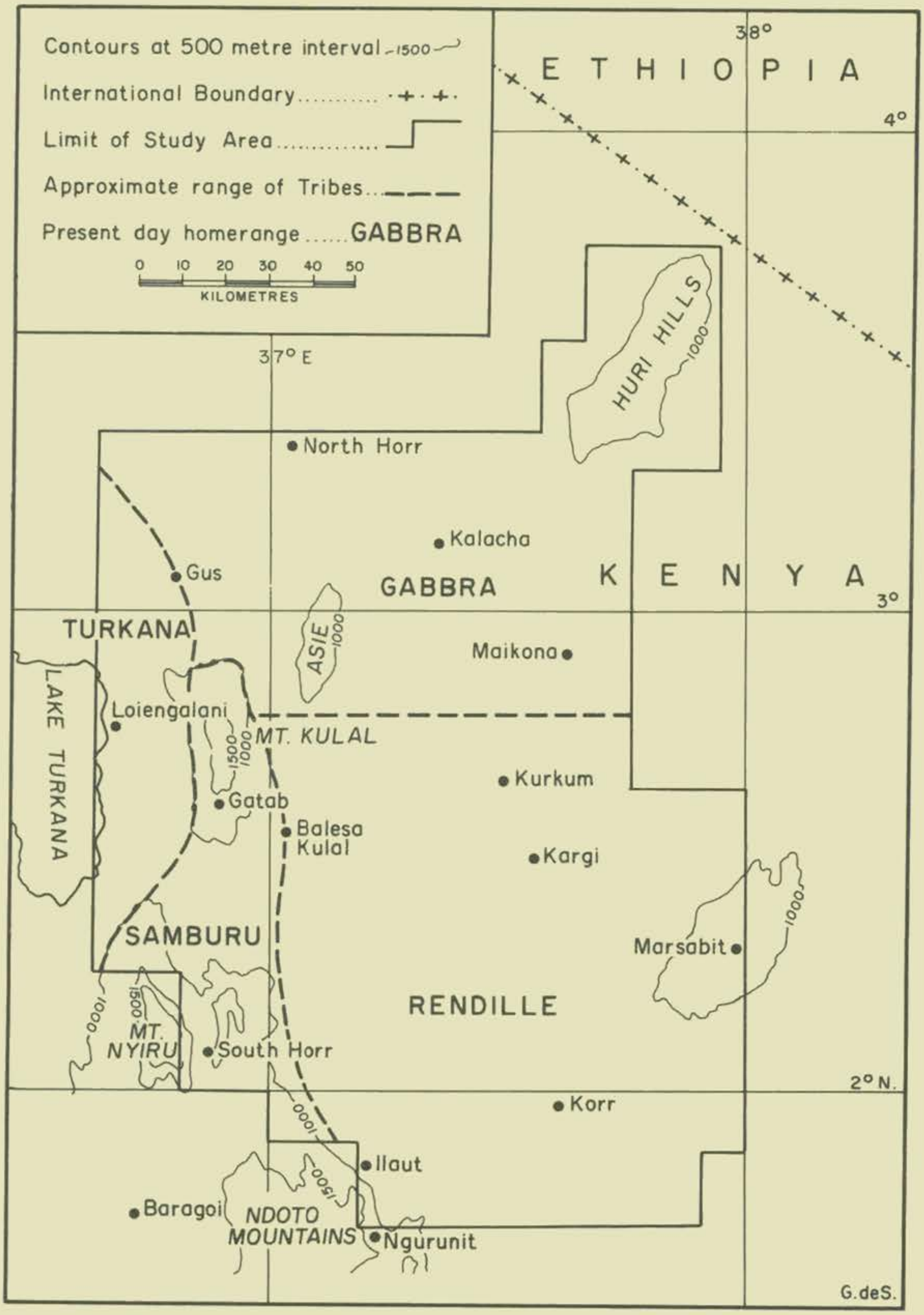
Contours at 500 metre interval 1500
International Boundary
Limit of Study Area
Approximate range of Tribes
Present day homerange GABBRA
0 10 20 30 40 50
KILOMETRES
ETHIOPIA
38°
4°
37° E
HURI HILLS
1000
North Horr
Kalacha
Gus
GABBRA
KENYA
3°
TURKANA
ASIE
1000
Maikona
LAKE TURKANA
Loiengalani
1500
1000
MT. KULAL
Kurkum
Gatab
Balesa Kulal
Kargi
SAMBURU
Marsabit
1000
1000
1500
MT. NYIRU
RENDILLE
South Horr
2° N.
Korr
1000
1500
Ilaut
Baragoi
NDOTO MOUNTAINS
Ngurunit
G.deS.

Table 2. 1923-1978 divided into four periods

Period 1:	1923-1949	Prior to major water development
Period 2:	1950-1962	Dixey Water Development Scheme began in 1950
Period 3:	1963-1970	Post independence
Period 4:	1971-1978	Mission development

Results and discussion

1. Occupation of different grid squares

Occupation densities for each grid square over the 56 years indicated 24 grid squares as being heavily used. Of these 11 could be classified as primarily used in the dry season and 10 as primarily used in the wet season. The remaining four were used equally in both dry and wet seasons. The area around Lake Turkana was used predominantly in dry years. Apart from this one area no obvious differences in migration patterns between wet, dry and average rainfall years were found.

In general the northern areas were used by the Rendille, the Ariaal tending to restrict themselves more to the southern areas. Distinct preferences by certain settlements for particular grid squares were shown.

The percentage of grid squares occupied over the four different periods is presented in Table 3. A drastic reduction in the homerange of the Rendille and Ariaal took place from 1923 to 1978 with the areas around Korr and Korji being very heavily occupied in the final period, 1971-1978.

Table 3. Percentage of grid squares occupied over different periods

Period 1:	82%
Period 2:	69%
Period 3:	55%
Period 4:	27%

2. Occupation of different vegetation types

Table 4 shows the proportion of the study area covered by the shrubland, dwarf shrubland, annual grassland, bushland, and other vegetation types, together with the proportion of time each of these types was occupied. Dwarf shrubland areas were used significantly more often in the wet season while bushland areas were preferred in the dry season. There was no significant difference in the seasonal usage of shrubland and annual grassland. Only the dwarf shrubland showed significantly different usage according to annual rainfall, being used more often in wet years.

Table 4. Occupation of different vegetation types

	% of study area	*% of time occupied*
Shrubland	30	25
Dwarf shrubland	28	17
Annual grassland	27	40
Bushland	12	12
Other	3	5

Table 5 shows the usage of different vegetation types by the seven settlements in the four periods. The difference in the use of shrubland and bushland by the Rendille and Ariaal can be explained by there being a larger proportion of shrubland in the north of the study area while bushland is found in the southern area.

Table 5. Proportion of time spent in each vegetation type for the seven settlements for Periods 1-3 and Period 4

	Settlement Number													
	1		2		3		4		5		6		7	
	Per. 1-3	Per. 4	Per. 1-3	Per. 4	Per. 1-3	Per. 4	Per. 1-3	Per. 4	Per. 1-3	Per. 4	Per. 1-3	Per. 4	Per. 1-3	Per. 4
Decidous shrub-land	0.33	0.24	0.23	0.39	0.21	0.97	0.24	0.38	0.25	0.16	0.12	0.12	0.09	0
Deciduous dwarf shrubland	0.18	0.24	0.04	0.15	0.01	0	0.16	0	0.07	0	0.25	0.28	0.32	0.26
Annual grassland	0.34	0.52	0.49	0.45	0.41	0.03	0.52	0.62	0.55	0.84	0.33	0.06	0.20	0.26
Deciduous bushland	0.08	0	0.06	0	0.01	0	0.03	0	0.01	0	0.19	0.53	0.30	0.49
Other	0.01	0	0.10	0	0.25	0	0.04	0	0.04	0	0.03	0	0.01	0
Outside study area no vegetation information	0.04	0	0.06	0	0.12	0	0.01	0	0.08	0	0.08	0	0.08	0

3. Occupation of different water sources

Areas with a permanent water supply were used more extensively during the dry season than during the wet season, and conversely areas where water was seasonal were occupied more in the wet season than the dry season. These predictable patterns, however, were only obvious over periods 1 to 3. In period 4 areas of permanent water sources, primarily those with mechanical water sources, were the most heavily used irrespective of season. Usage of areas with differing water availability was similar for all seven settlements and did not appear to be related to annual rainfall.

4. Frequency of migration and distance travelled

These results are presented in Table 6. The striking feature was the reduction in both the mean distance travelled and the mean number of migrations per year which took place in the seventies. All seven settlements were considerably less mobile during period 4 than in the earlier periods.

In general the patterns in migration in relation to vegetation type and water availability which could be detected in the earlier periods disappeared almost entirely in the last decade. During this time a change to a more sedentary way of life was obvious. Several factors have probably contributed to this change in life style. Period 4 has seen an intensification in mission development in the area, particularly in Korr. This brings with it the development of reliable water sources, famine relief centres and schools. Security too has been a problem in the last decade. Attacks by *shifta* have constituted a serious threat to all the tribes in the area. This has probably affected the Rendille both directly and indirectly; directly through attacks on their own herds and indirectly through the restriction to their movement resulting from the Turkana, Gabra and Borana to the north and east who are themselves forced south and west by the *shifta*. This decrease in their grazing area has led to a decrease in self-sufficiency and therefore a tendency to rely more and more on famine relief and thus a gradual erosion of the nomadic way of life amongst the Rendille and Ariaal.

Table 6.

(a) Mean distance (km) travelled per year over the four periods for each settlement

	Settlement Number						
	1	2	3	4	5	6	7
Period 1 1923-1949	294	241	183	179	131	235	222
Period 2 1950-1962	278	179	123	173	146	180	122
Period 3 1961-1970	242	154	88	145	150	115	134
Period 4 1971-1978	73	27	28	40	13	35	31

Settlement no. 1-5: Rendille
Settlement no. 6-7: Ariaal

(b) Mean number of migrations per year over the four periods for each settlement

	Settlement Number						
	1	2	3	4	5	6	7
Period 1 1923-1848	6.7	3.5	3.3	2.7	3.2	4.1	6.4
Period 2 1950-1962	8.0	4.3	2.8	3.8	3.7	4.7	8.8
Period 3 1963-1970	7.6	4.7	2.6	4.2	4.0	3.2	5.6
Period 4 1971-1978	2.6	0.9	0.9	0.9	0.5	1.1	1.9

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ECONOMICS OF RANGELAND DEVELOPMENT AMONG THE RENDILLE

G. K. Njiru

Introduction

Other papers in this seminar pointed out the physical, climatic, and topographical features of the Integrated Project in Arid Lands (IPAL) study area (1). This paper will therefore skip this introductory material only drawing attention to the fact that the Rendille occupy the southern half of the area. Their northern border with the Gabbra, the other major pastoral group in the study area, is approximately a line from Marsabit Mountain through the Chalbi Desert to Lake Turkana.

The Rendille are a pastoral people of Cushitic origin who occupy about 13,000 km^2 of some of the most arid rangeland in Kenya (2). They are a small tribe of approximately 11,000 people who keep camels, sheep and goats, and in some places cattle and donkeys. Production of milk, meat, and blood from these animals together with trees, shrubs, and grasses from the surrounding vegetation, supply most of their demand for food, clothing, housing and domestic utensils. Most of them practice horizontal nomadism while an impoverished few practice sedentary pastoralism in the vicinity of permanent settlements. Due to the low productivity of the land, animals must keep moving from place to place. Staying too long in one place will necessitate long journeys to pastures since preferred species of grasses or shrubs within the surrounding area are finished by the animals after only a few days.

The low productivity of the range and the lack of any minerals or sources of income other than livestock, leads to very low standards of living for these nomads. This has been worsened by recent droughts which killed many animals. At present there are many people who do not have enough animals to maintain a viable nomadic existence. Together with their few animals, these marginal family units have become semi-sedentary around the ten or so missions and trading centres which have sprung up in the last one or two decades. High concentration of people and their animals, have accelerated the degradation of the land around these centres due to over use of the vegetation. Indeed, as one moves towards them the vegetation cover becomes increasingly sparse until there is practically bare ground in the immediate environs (2, 3, 4).

The problem

Degradation of the rangelands caused by permanent settlements is only one part of the story. Improvements in human and veterinary medicine, security form tribal warfare, and the provision of famine relief food, are lowering overall death rates, and infant and calf mortality. The resultant increases in human and livestock populations add to the pressure being exerted on the land. Since the animal-carrying capacity of the land is fixed, unless there are changes in technology, increases in animal biomass will eventually result in overgrazing and denudation of the land. This has not happened in the whole of the study area, but is quite definite in many parts of it (5). Prolonged overuse reduces the carrying capacity. Hence a situation is built up where a diminishing resource has to support more and more animals. This forms a vicious cycle and accelerates the process of denudation ultimately leading to desertification and untold human suffering for the nomads whose animals continue producing smaller quantities of milk, meat and blood for food.

What is happening here is not an isolated phenomenon peculiar to the Rendille homeland. It is common to all the arid and semi-arid regions of the world where modern methods of range management are not being applied. Indeed, progressive degradation of these regions of the world was formally recognized as a major environmental crisis at the UN Conference on Desertification in 1977 (6). In unmistakable terms the process of desert encroachment was ascribed primarily to the impact of human activity upon soils and vegetation (7).

IPAL represents an international multidisciplinary attempt to find and demonstrate ways and means of preventing ecological degradation and assure the continued productivity of rangelands (6). Through its various studies IPAL is trying to gain a good understanding of the study area's resource base, population ecology of livestock species and major environmental/ecological patterns. This understanding will then facilitate the formulation of management guidelines consistent with the rehabilitation of the vegetation and with the maintenance of continued productivity of range resources at the disposal of nomadic pastoralists.

The need for an economic study

On completion, these studies will hopefully have discovered the various relationships that exist between the different parts of the ecosystem in which the pastoral nomad exists. Valuable as this information is, however, it is difficult to convert it into practical policy options for implementation by planners and administrators. The information must be transformed 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 therefore calls for close monitoring of all costs and benefits arising from the many experiments aimed at improving productivity of the nomads' livestock which are going on in IPAL.

On the other hand, many practices of animal husbandry and land use which seem grossly counterproductive 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 reoriented 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.

The economic study

The present work is a joint study between IPAL, the University of Nairobi, and the Institute of Agricultural Economics in Hannover, Germany.

1. Objectives of the study

Broadly, 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 commodities 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 (9). An explanation of how this will be done has been given elsewhere (10).

2. Data sources

Both primary and secondary data are being used.

(a) *Primary data*

Data on the numbers of livestock and livestock products traded, the subsistence requirements of nomads, and the amounts of foodstuffs imported are being collected. The same applies to information about Government activities in the area, the livestock and food marketing system, and the potential for developing other sources of income enumerated in objective 1(e) above.

(b) *Secondary data*

Data on primary and secondary productivity of the plant and animal biomass in the study area will come from IPAL publications and materials. The same applies to data on the differences in performance between modern practices and traditional ones and the costs of implementing them. This information will be augmented by any other relevant materials that can be found in the literature.

3. Data analysis

Analysis of the data is to be carried out at the University of Nairobi and at Hannover using computer facilities provided by the two institutions.

4. Progress so far

The study commenced in January 1980. Up to now the researcher has spent most of his time in the study area familiarizing himself with the present biological, economic, and cultural structure of the traditional system. So far the following assignments have been completed.

(a) The writer has familiarized himself with the social and cultural structure of the Rendille by reading extensively about them and about pastoral nomadism in Northern Kenya (12). This has been supplemented by discussions with local elders, chiefs, councillors, missionaries and researchers and participation in conferences.

(b) A preliminary study of IPAL publications was completed and confirmed that the information which will be available is adequate for the purposes of this study.

(c) To give the author, whose background training is in the social sciences, an insight into the working methods of biological sciences, some participation in ongoing studies was felt to be necessary. In the course of the year he has therefore participated in the following:

i. a study to determine the present herd structures of local sheep and goat herds,

ii. a study to determine the effect of veterinary medicine on the productivity of goats and camels,

iii. a study to determine the primary productivity of major vegetation types in the study area,

iv. a study to determine the health status of goats and camels in the study area.

(d) An interview of the District Commissioner, district heads of Veterinary Services, Livestock Marketing, Range Management, Agriculture, Water Development, Trade, Hides and Skins, and Transport.

(e) A survey of the present marketing channels for livestock and livestock products, and for foodstuffs and other items which come from the area. This involved interviewing 33 out of the 35 traders who were trading in livestock/livestock products and/or maize flour, sugar, clothes, etc. in the nine trading centres within the Rendille area between August 1979 and July 1980. All sales of cattle to LMD by Rendille at the annual auction in Marsabit were also recorded by the author who participated in the auction from start to finish. This is a very important outlet for cattle and in this instance Rendille animals worth more than half a million shillings were sold.

5. Preliminary findings

Most of the author's time has been spent in the field collecting data. At the time of writing very little analysis of the data collected so far has been done.

However, in the course of this collection certain things have become increasingly obvious. The first is that however well the Rendille had adapted themselves to life in their desert and semi-desert habitat, recent activities by missions, Government and traders have changed so many things that the traditional adaptive strategies have rapidly become obsolete.

Boreholes, police posts, mission stations, and trading centres, have made certain places so attractive that traditional methods of ensuring that people are constantly on the move so that overgrazing does not occur have failed. As these tend to be sited in the former dry-season grazing areas, animals are left with no pastures upon which to fall during the dry season. This has made the system more susceptible to disaster, such as an extended dry season, and calls for some action if such disaster is to be avoided.

On the other hand new opportunities for earning a livelihood have presented themselves. People can now earn wages or salaries by selling their labour to traders, missions, Government or by migrating for jobs as labourers, herdsmen or watchmen in the high potential urban and rural areas to the south. These opportunities are, however, closed to most Rendille because of lack of education and an inability to speak Swahili. In order to open these spheres to them a way of spreading the required skills must be found.

For the more enterprising person there is yet another way of earning a livelihood. This is by engaging in trade, after selling some livestock or getting a loan in order to raise the starting capital. So far, only five out of the 35 traders in the study area are Rendille and all of them are recent entrants. The failure rate amonst Rendille businessmen is very high. This is mainly because of traditional norms which make it possible for kinsmen to beg away most of a person's stock unless he wants to lose the image of being a 'good man' (12).

For the person without enough animals to provide milk, meat, and blood for his family, it is also possible to exist without being attached to a richer man who then controls his labour. This is by the process of trading whereby he supplements his traditional diet with maize meal, sugar and tea bought by the occasional sale of an animal or skin. However, at present this option is not very attractive. This is because the number of traders willing to buy his animal or skin is very small. If a trader is accessible and is willing to buy the product he is usually only willing to pay a very poor price for it. On the other hand, he sells the maize meal, sugar, tea or tobacco which the nomad wants at exorbitant prices.

This is partly due to a very innefficient trading network where costs of getting an item from the producer to the final consumer are very high. It is also due to the monopolistic position in which the traders, who are mostly Somalis from outside the district, find themselves. In doing this, however, the traders make the terms of trade (the rate at which animals and skins exchange for cereals, sugar, tobacco, etc.) so poor for the nomad that he only trades when there is no alternative.

One is, therefore, not surprised to learn that most trade in animals is done during the dry season when there is an inadequate supply of milk and the only options open to the herd owner is to slaughter an animal or sell it. As traditional methods of preserving meat are very poor, an animal's meat can last only a few days at most. Hence in these circumstances if the flour bought from the proceeds of its sale can last several weeks, one may have to sell the animal even if he can see that it is a very unfair deal. In fact the local slang for selling an animal is *kutupa kwa Somali* which literally means 'throw away to the Somalis'.

If the terms of trade for the pastoralists were improved so that a 35 kilo goat is sold at a sum close to the shs 200 it may fetch at Nairobi instead of the shs 70 which it usually fetches, and a sack of maize meal sells for a sum closer to the shs 150 which it costs at Isiolo instead of the shs 250 to shs 270 at which it is sold, the author is of the opinion that many more animals would be sold. Many pastoralists do indeed like to buy maize meal, clothes, sugar, tea, tobacco, jericans and other goods imported from down country. 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 the same time raising the standard of living, or at least the calorific intake which is at present very low (13).

Acknowledgement

The author is grateful for the very close co-operation he has enjoyed with IPAL scientists and field assistants during the 11 months he worked in the study area.

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11. See (2) and (6) above for the kind of results expected.

12. Here the works of Anders Grum, Neil Sobania, Dahl and Hjort, William I. Tory, Paul Spencer, Pratkin, R. Kauffmann and Asmoran Legesse have proved to be very useful.

13. This is well discussed in Gudrun Dahl's *Suffering Grass*, where she explains why the Borana who are the Rendille's eastern neighbours do not prosper as businessmen. Her explanation applies very well to the Rendille.

14. See W.I. Tory's *Subsistence Ecology Among the Gabbra - Nomads of the Kenya Ethiopia Frontier*. Ph.D. thesis. The Gabbra, Rendille's northern neighbours who are similar to them in their dependence on camels, sheep and goats, get an average of 2,200 calories a day in a very good year. This is not adequate for the often heavy work and long distance walked when grazing.

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