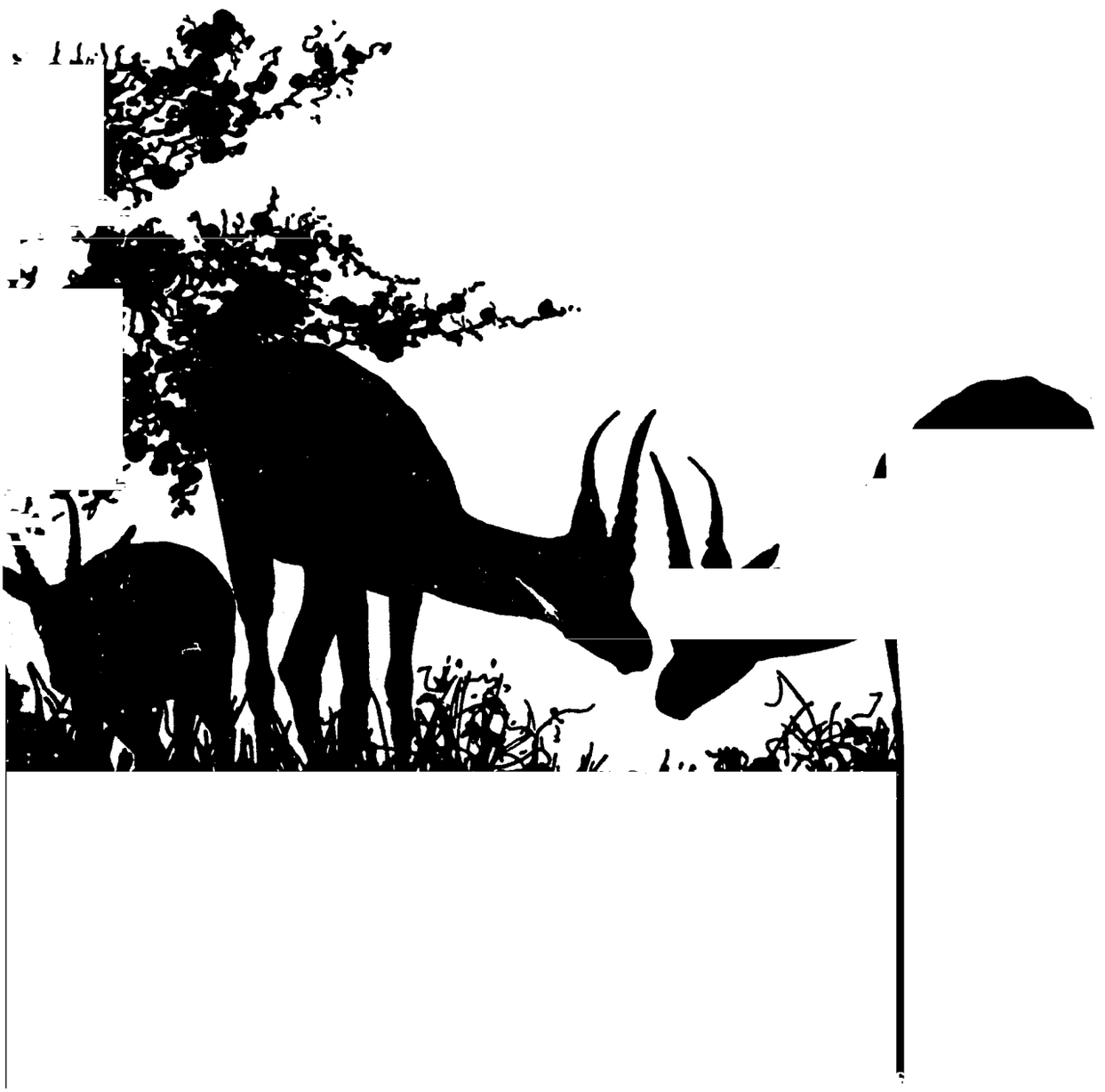
RANGE DEVELOPMENT AND RESEARCH IN KENYA



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SUMMARY AND RECOMMENDATIONS

The challenge is how to sustain rangeland productivity and still provide for more and more people. The drought of 1983 to 1984 cultivated interest in breeding drought-tolerant sorghum and millet. The record harvest of maize in 1986 stimulated concern for greater grain-storage facilities. Food production, storage, and distribution are national problems in Kenya. There are lessons from development successes and failures in the past that should motivate researchers and implementers to consider economic, political, social, and ecological matters in project design. Rangeland systems are best used for producing big herbivores (livestock and wildlife) that serve people's needs.

About 80% of Kenya is rangeland. About one-third of Kenya's livestock and many crop-livestock farmers and pastoralists depend on rangeland. Rangeland serves more than the people who make their livings from it: it is a watershed that ensures water supplies for Kenya's rural and urban people; and it is home for the wildlife that are central to tourism, the country's principal earner of foreign exchange.

As Kenya's human population increases, so does the need for livestock and range resources. International demands for livestock products are growing. If yields from the rangelands were increased, there would be more food and income for Kenyans and greater opportunities to earn essential foreign exchange through the export of livestock products.

Rangelands in Kenya are threatened. Land use in Kenya is changing, which has reduced the range's ability to produce. Semiarid rangelands attract people from highly populated areas. Land worked by pastoralists is being subdivided among family members or to provide a place for the people moving in from other areas. Families find themselves with smaller shares of the range and are forced to change their traditional methods of working the land.

In the process, two kinds of previously uncultivated land are being put under the plow. One is semiarid rangeland that will not be able to sustain crop production. Another is streamsides and lowlands that produce crops occasionally. These "wetter" areas used to provide pasture in dry seasons and droughts.

In 1975, about 50 million hectares were available for livestock grazing. About 12 million livestock units could have been sustained under proper range management. The amount of land available for grazing by 1990 may decline to about 48 million hectares. Concern exists about whether these changes will result in more or less food production from rangelands by 1990. As the use of arid and semiarid lands intensifies, food production could decline because of the uncertainty of rainfall for crops. The pressure threatens the fragile land, which may take a lifetime to recover if not managed with care.

RECOMMENDATIONS

Group Ranches Where ecological potential will sustain a family unit, group ranches should be subdivided. However, when rangelands cannot sustain a sedentary family unit, subdivision should be discouraged.

Grazing Blocks	Additional studies are needed within grazing blocks to identify development procedures that will enhance productivity and environmental quality.
Commercial/ Company Ranches	To maintain or enhance production, grazing associations and cooperatives should be encouraged whenever large ranches have been subdivided.
State Rangelands	Research into developing state lands for livestock and wildlife production should be encouraged.
Range Livestock Nutrition	The nutritional values of diets selected by livestock from the different vegetation types during different seasonal conditions are not adequately known. Although volumes of data are available for animal responses to pen-feeding trials, only meager information is available about animals that graze the natural vegetation.
Ranch/Range Systems	Research should be initiated that focuses first on feeding the family and second on selling products for profit. A total-system approach that incorporates the people's need for livestock, crops, and tree products should be pursued through research, extension, and management of semiarid and arid rangelands.
Multidisciplinary Research	Seasonal precipitation, soil moisture, plant/water relations, forage production, and stocking and destocking of semiarid and arid rangelands in Kenya have not been researched on the same rangeland at the same time. Timing and coordination of research on different components of the system are critical.
Erosion and Top-soil Distribution	Predictive equations must be developed for soil loss on Kenya rangeland. Research is needed to quantify soil physical properties, slope, vegetation cover, botanical composition, previous management history, soil movement, etc.
Defoliation Effects on Plants	Additional research is needed about the frequency and intensity of defoliation of modular units of grasses, forbs, and shrubs as they respond to grazing or burning.
Small Animals	Populations of rodents and insects in Kenya's grasslands are not generally understood. Their role in forge removal, seed consumption, and predation should be researched.
Socioeconomics	Planning should be done with people -- not for them. Successful system strategies used by groups on small, private landholdings should be investigated and publicized.

Marketing	The current pricing strategies are detrimental to pastoralists, and a more favorable system should be developed. The effects of restrictions on the movement of agricultural products within Kenya should be researched.
Training/Education/Extension	Curricula for range training should include rural sociology, communication skills, and dryland farming. Degree programs at the universities should overcome their biases against holders of certificates and diplomas in range training. Refresher training should be required for all range professionals. An intern program for all new range employees is needed. Fresh graduates should be under the guidance of experienced range officers for some time before they are put on their own. Research results should be published more often in African scientific journals.
Monitoring Range and Wildlife	Range monitoring should be coordinated by the National Range Research Station. A central data-storage and -retrieval center should be established so that users can have easy access to the information. Training sessions, workshops, and seminars should be developed so that confidence and understanding can unite the various monitoring teams. There should be more collaboration and cooperation among investigators at different research stations and between investigators within different government departments to reduce duplication of effort and increase information exchange. Training sessions should be conducted to develop interdisciplinary cooperation.

WELCOME ADDRESS

Wilson Nguyo

It is a pleasure for all of us at Egerton College to have you here for this workshop. On behalf of the principal and the entire college community, I welcome you warmly to Egerton College.

This campus is rather removed from the major urban centers. This has the advantage of a relatively clean and rather refreshing environment. More important, however, the usual attractions to be found just around the corner of any major town are notable by their absence. Workshop participants therefore will find themselves devoting nearly all their attention to the workshop business. Nevertheless, I do hope you will find our facilities sufficiently attractive for you to want to come again.

In general terms, 80% of Kenya's land surface is rangeland. It is too dry for normal crop and intensive livestock production. Up to the beginning of the 1960s, the rangeland was used for what could be described broadly as range use: pastoralism, ranching, and wildlife. In particular, crop farming was restricted to the 20% of the land with sufficient rainfall and suitable soil for unirrigated crop production.

The inception of the land-settlement program in the early 1960s started a new era in Kenya. The migration of people from areas of high population density to less-populated areas, which began in the 1960s, has continued to date. Exacerbated by the rather rapid population growth of 4% per year, the subvision of land that started with large-scale mixed farms in high-potential areas has spread to the rangelands. The rather common sight of tilled land and stunted maize plots where beef cattle and wildlife once roamed freely supports this contention. No doubt you have already observed this in the months of June and July between the Escarpment and Nakuru as you drive to and from Nairobi.

At the same time, the demand for crop and livestock products for both domestic consumption and export to earn much-needed foreign exchange has continued to rise. One might argue that there is still room for further intensification in the use of the high-potential land, and I would agree with such an argument to some extent. But the pressure to bring more land into cultivation and to increase the output of livestock products per unit of land is very great.

Clearly, rangelands represent a most-important growth point of the future. They must support a higher livestock population and even contribute to increased crop production through irrigation. That is the only way they can support more human population and contribute to rising standards of living of these people. Rangelands must do this while ensuring soil and water conservation in these areas and avoiding desert encroachment. At the same time, rangelands must continue to support wildlife, not only to ensure the preservation of our national heritage and provide recreation but also to sustain the flow of vital foreign exchange from tourism.

How are the rangelands to achieve all this? Clearly, this is where research comes in. Researchers must seek the appropriate means to apply the art and science of range management to achieve greater output per hectare on a sustained basis and more recreation at an affordable price.

Among the questions to be answered, one may cite the determination of the most effective approaches for:

- the management of natural vegetation to achieve optimum sustainable output while ensuring conservation of soil and water

- the control of bush and other unwanted vegetation

- the introduction, through breeding or other means, of more productive, more nutritious plant types that also will provide for better soil and water conservation, not forgetting the need for trees for fuel, construction, and other uses

- the introduction, again through breeding or other means, of livestock types that are more efficient in the use of the forage

- the involvement of all the communities of the rangelands in the design and implementation of plans for more-efficient use of the rangelands

- the design and implementation of an efficient marketing system for the products of rangelands

- the provision of the basic infrastructure such as roads, water, and even schools, health facilities, and community centers

- the continued resassessment and readjustment of range-development plans in relation to the technical, environmental, economic, and human needs of the rangelands.

In short, because of the immense relative size of the rangelands, the increasing population pressure on high-potential land, and the heavy dependence of Kenya on agriculture, rangelands provide a kind of frontier, a growth point, the hope for the future. It is up to you to make this hope a reality. Looking through your program, I am convinced that you have made a good start in the right direction.

I note, in particular, your schedule of presentations includes a variety of subjects such as climate; sociology; economics, marketing, and credit facilities; education, training, and extension; and wildlife and recreation, alongside the traditional range-science topics. I believe this is a recognition of the true multidisciplinary nature of range science. I must commend you for adopting a multidisciplinary approach. I also note the inclusion of discussions of managerial, organizational, administrative, and technical empirical research in your program. These all are very important facets, and you will need all of them in your efforts to solve the puzzle of increasing the productivity of the rangelands.

But, to be successful in fulfilling the expectations of increasing the productivity of rangelands, the recognition of the multidisciplinary nature of range science is a necessary but not sufficient condition. You must weld all these different facets into a united whole. The challenge for you is how to integrate hydrology, agronomy, agroforestry, sociology, recreation, economics, and traditional range science into a harmonious whole for the improvement of the living standards of all Kenyans.

The value of your research will not be judged by the number and volume of publications (although these are important), but by the contribution it makes to the productivity of rangelands and the improvement of the economic and social welfare of those concerned.

We at Egerton College will be partners with you in this notable but difficult task. We shall work with you in research, education, and training as well as limited extension.

Judging by the schedule of this workshop, I note you are on the run. I wish you every success in this endeavor.

I now have the pleasure of declaring this workshop officially open.

KEYNOTE ADDRESS: OPPORTUNITIES FOR RANGELAND DEVELOPMENT

Harold F. Heady

"Constraints" might have been a better word than "opportunities" in the title, but all of us know that problems are opportunities. This word was selected because it is positive and forward looking. In order to take that forward look, one must be aware of a certain amount of background material. One must know history in order not to repeat historical mistakes. Therefore, the aim of this paper is to review selected range-management trends briefly, to give their current situations, and to state what I believe should happen next. Prediction of the future of rangelands under the likely continued economic stringency and increasing demands on natural resources is not my intent. The emphasis will be worldwide in order to avoid intrusion into the very fine papers on the program.

FUNDAMENTAL PRINCIPLES

Range management has the particular problem of integrating some of the principles from several different yet related scientific disciplines such as ecology, plant physiology, soil science, animal nutrition, and economics. Perhaps the greatest deterrent to range management is the lack of a cohesive theoretical framework that is specific for the knowledge on rangeland resources. Much information exists in a multitude of papers that are either regionalized or linked to specific and local situations. These papers may or may not be used in the management of particular parcels of rangeland. While most range-management information is of undoubted local value, infrequently has local knowledge and experience been synthesized into basic principles, important generalizations, hypotheses, and theories. Without that generation, range science and rangeland management will remain local and without recognized universal truths.

Since theory and principles are universal, their statement and illustration will help to avoid mistakes that arise from transfer of knowledge. Teaching will be more effective and less parochial, especially for students studying in any foreign country. An organized body of theories and principles will provide the basis for judging the potential of development schemes. Research will become more efficient. There are other values in having a knowledge framework on which to build rather than repeat.

The empirical approach to applying a rangeland practice and measuring or observing what happens needs to be redirected with as much understanding as possible as to why it happens. The basic point of departure for both research and practice should be either to test or to apply the theoretical base. Too much in rangeland-resource management has been trial and error and the repetition of things already done. The principles need to be distilled from existing knowledge in order to launch rangeland-resource management and the profession into a new era of creative research, education, extension, development, and land management.

During the last 15 years, many groups have identified and published "shopping lists" of practical rangeland problems. Emphasis on practical or applied research is needed; but by its concentration on "maintain, restore, increase outputs," it tends to ignore, or nearly so, the basic

concepts and process knowledge. The systems for justifying funds for research, extension, and teaching do not foster an organized body of rangeland theory and principles. "Science" has been used to cover about all that range people do, and we are being criticized because of this liberal and incorrect usage. More basic science is needed.

Almost every subject in range management suffers because of an insufficient theoretical base. Here are some illustrations. The fundamental science of several managerial tools receives little attention, such as the relation of plant succession to range condition and trend, the relationship between soil properties and range sites, and the separation of the causes and effects of landscape change when managerial results are monitored. Another example is the continued argument and confusion over the effects of different seasonal grazing systems while the effects of seasonal defoliation have not been determined. Still another example is the need for widespread development of the relationship between gain per animal and gain per hectare as information fundamental to decisions on stocking rates and proper grazing use. Knowledge on palatability, preference, and food habits is difficult to use and seldom a part of range-management decision making.

It is time that range management reviewed the foundation on which it stands; summarized and analyzed the knowledge available; developed a body of laws, theories, and hypotheses particular to range management; and stopped so much repetition and emphasis on applied research. The two major difficulties should not continue to prevail: the great diversity of rangeland from place to place and time to time, and the intense emphasis on product production rather than rangeland processes.

REPORTING RESEARCH RESULTS

Most new information about field practices comes from practical testing, demonstration, and experience under producing conditions. Many published papers describe these new and altered practices; sometimes mistakes and failures are mentioned, much to the benefit of the profession. There could be more of these reports, especially from development schemes. The Society for Range Management publishes these types of papers in Rangelands. Extension people do the same service in leaflets, circulars, and newspaper articles. This type of writing is scarce in developing countries where it is badly needed and not overabundant in developed countries.

Publications reporting research also are scarce in developing countries. Research is being done, but the publications appear overseas or in forms that are lost or simply filed beyond retrieval. The Society for Range Management and its journal can help in this accumulation of library materials, but it is best done in the individual country or region. The Journal of Range Management is not readily available throughout developing countries, but that will improve as more libraries and agencies subscribe. The next step for the East African Range Society is a regular publication. It will start with the proceedings of this conference.

Another aspect of research reporting that needs strengthening is the practical significance of the results. The researchers and authors of the papers in most instances are the appropriate ones to interpret their work for others to use. Much remains to be done in writing range information, as well as in its storage and retrieval. Granting agencies and

the countries where projects are being developed would do well to include this subject in their planning and budgets.

RANGE INVENTORY, CONDITION, MONITORING, AND TREND

Modern range management started in the late 1800s and early 1900s with research into systems of grazing and plant succession and extensive inventories of the grazing resources on lands, mostly forested, in the western United States. This was a conservation movement not unlike the recent world effort to stop desertification. The procedures used for inventory in that early time were aimed at determining stocking rates that would permit improvement of badly deteriorated rangeland. The concepts of range condition, monitoring, and trend had not been suggested, although the ideas were there in the studies of plant succession and the use of livestock enclosures as a tool to show the effects of grazing.

Another rangeland conservation movement occurred in the 1930s. Extensive drought and severe economic depression resulted once again in inventory of range vegetation, soil erosion, and subsidy through increased technical personnel and funds for research, teaching, and management. The inventory procedures were revised; early enclosures had been lost or were in the wrong places so new ones were established; the Soil Conservation Service began developing concepts and procedures for determining range condition; trend of condition became a practical idea; but the concept and the word "monitoring" were not in common usage.

The latest changes in rangeland inventory, analysis of condition, and writings about monitoring and change began in the early 1970s in the United States with conservationists' demands for environmental-impact statements and in much of the world in concern over enlarging deserts. This is also the period (beginning a few years before 1970) of much interest in range management by Third World countries. Once again, inventory methods changed, but arguments developed over range-condition definition and determination. Much emphasis was placed on monitoring, but the usage has waned of plant succession, other types of vegetational change, and trend. This amazes me because knowledge that the range is either improving or deteriorating makes management decisions easier.

For the last 35 years or more, two definitions of range condition have been used. One gives the relative feed supply as determined by the current growing conditions (for example, as 75% of normal). The other is more ecological and is based on the potential of the site (for example, "fair range condition" expresses that the site is producing only 25% to 50% of its potential, regardless of current growing conditions).

In addition to the confusion over range condition, every change in inventory procedure, every loss of measurements of trend, every change in monitoring and in definition of concepts results in less efficient management than should be the situation. Range managers must not box themselves into never improving measurement techniques, field data, and concepts; but neither should they throw away previous data and conclusions. It is better to revise than to start over continually. In the United States, the earliest two sets of rangeland inventories were seldom used beyond their original need, and many reports have disappeared. Hopefully, the Third World countries will not make these same mistakes in their history.

PLANT RESPONSES TO DEFOLIATION

Defoliation of perennial grasses at various stages during their growth is being studied at a number of research stations. New machinery for measuring transfer of gases and energy and the interest in transfer of photosynthetic and respiration products have made new determinations possible. The principles of food transfer and storage in plants are being revised.

Detailed studies of the physiological and morphological responses of grasses to the time in the growth cycle and place on the plant where defoliation took place were necessary to understand the effects of short-duration grazing and the length of the rest period. The results are not complete for either of these types of research on grasses, and little research is under way on forbs and browse. These types of studies promise to give new interpretations to plant responses, the first that have been made since before 1950; but, in that 36-year period, several new grazing systems have been proclaimed, tested with conflicting results, and sold. Now an understanding of their effects on the major grasses seems at hand, and perhaps we will know why some grazing systems succeeded and some failed.

CHANGES IN RANGELAND-MANAGEMENT TECHNIQUES

Seeding of rangeland began with one or a few species, and monocultures are still common; but in recent years more emphasis has been given to planting mixtures, especially those with native plants included. Control of poisonous plants at one time was a major activity, but now little is heard about the subject. It seems that nearly everyone knows that grazing animals usually leave poisonous plants ungrazed where good feed is available; however, we still do not know for most plants if they are eaten because the animals prefer them or because nothing else is available. Mechanical brush control has become too expensive, herbicides are environmentally dangerous, and controlled fire is the current favorite tool. What might be next? Greater effort to integrate uses? Systems analysis and planning? And how long will these last?

Not only have the preferred range practices changed, they have had to be repeated on the land when they were originally thought to be permanent. Woody-plant control for tsetse elimination does not last without continual maintenance. Conversions from woody plants to grass in Australia, the United States, and Brazil have had restricted success. Sustainable rangeland improvements must be continually maintained. Nature wants to put back what was there before, and our practices should either work in harmony with that biological law or be established on the basis that frequent inputs will be needed.

Sustainable rangeland improvement also requires a sustained human interest and the approval of society. This is true in all societies and especially those in developing countries. The human and economic aspects of rangeland systems have been neglected. This situation seems to be righting itself as indicated by emphasis placed on social factors in recent books, papers published in scientific journals, and papers presented in symposia in several societies. I include it here because the people on the land must agree with and believe in the range planning, the decision making, and the recipients of benefits. This has not been the case in most development projects, and it has contributed to many failures. Old procedures must be improved and new ones found

for gaining the cooperation of the farmer and livestock holder as well as those more interested in the many other uses of rangeland.

INCREASED INTEGRATION OF RANGELANDS, CROPLANDS, AND FORESTS

Livestock, crops, and wood products have been grown together for centuries, usually on a land area no larger than a subsistence farm. As these three kinds of agriculturalists developed their specialized knowledge, they tended to emphasize monocultures of their particular products. Subject-area barriers led to institutional barriers. Often the development schemes for monocultures were large and the small farmer, whose life depended upon multiple cropping, was forgotten.

Perhaps as a result of difficulties and failures of large-scale cropping schemes, livestock projects, and forest plantations, a strong trend has developed to combine the growth of these different types of products on the scale of the village common and small farm. Whether this activity is called "social forestry," "agroforestry," "agro-silvo-pastoralism," or some other name is immaterial. It promises a new and integrated thrust by many phases of agriculture. It applies to farms of any size, anywhere in the world. It starts development where people are in their lifestyles and abilities. Agroforestry takes advantage of the facts that most land is capable of producing more than one product and that the people need more than one product in order to live on the land. The multiplicity of production lines lends stability to the living conditions. The worldwide enthusiasm for agroforestry is more than a passing fad.

Range management, through its professional and scientific cadres, has a key part to play in this multiple use of the land. Most domestic animals in developing countries obtain a major portion of their feed from rangelands. The pastoralism part of agroforestry suggests that more and better-quality feed should be grown on the farms. This calls for new efforts into such problems as finding shade-tolerant grasses and legumes for forages, finding grazing practices that do not damage trees and crops, and obtaining social acceptance of new techniques. Perhaps most important is the development of aridland forestry where the major emphasis is on fodder trees and edible shrubs.

Many problems of practice and for research have been suggested in the literature. Little research has been completed, but may projects are under way on all continents. The subject area has a greater complexity of philosophy and breadth, both social and biological, than any of its parts such as animal husbandry, forestry, and range management. This changing emphasis from monoculture to multiple use reflects a change in understanding toward making full use of the natural resources. A large part of the world is divided into small landholdings and peopled with those who must use their land for multiple purposes in fulfillment of daily needs. Yet most of us are disciplinary, and we look at interdisciplinary action with one eye on what it will do for us. Range managers should enter, organize, and serve the multiple use of all lands where crops, forages, and trees are grown.

INCREASED MULTIPLE USE OF RANGELANDS

Multiple use of land is a fact, and many governments have legislated that the public lands will be used for the benefit of all. Multiple use of private lands results more from the necessity of obtaining certain products and profits. Multiple use makes the most judicious use of the

land for some or all products and services that can be provided. Some lands may be used for one product, but most will have more than one use. Some of the products will have a sale or rental price determined in the market place, such as the price of forage for an animal for a month. Others (water for one) have great values but are not determined by markets. Wildlife and, to some degree, recreation have values partly determined by costs and returns and partly by humanistic, social, and ethical opinion.

These characteristics of multiple use are well known and widely accepted. My purpose is to bring to your attention, once again, the fact that multiple-use values change and that the world has witnessed their shift from strictly economic considerations toward protecting the environment, saving endangered species, and maintaining water quality, air quality, and whole ecosystems. These changes tend to increase the pressure on all rangelands. So do factors such as population growth, the increasing mobility of people, energy shortages, more public involvement in land policies made by governments, or the influx of tourists. Predicting the nature and extent of societal demands on multiple-use lands is required in land planning, and it is accomplished by estimating the impacts of several alternatives. Proper application of planning concepts permits ready adjustment in response to business, economic, and social changes. Rangeland planning needs to increase its awareness of multiple-use alternatives. These might well be in the greater use of wildlife and recreational facilities for profit, in more realistic aesthetic values, and in the trade-offs of opportunities mentioned in the discussion of agroforestry.

RANGE SCIENTISTS AND PROFESSIONALS IN COUNTRY POLITICS

My paper at the Second International Rangeland Congress developed this subject at length. It seems important enough to me to discuss it briefly again here. Range managers, along with other field technicians, make the rules at the level of the field procedural manual. The intermediate level of rule making is at the seat of government, where policy takes the first step toward becoming an action program by agency administrators. Range managers may not be in the key administrative positions and, hence, have less influence over range matters than people in other disciplines. The third and highest level of rules are the laws and edicts of the legislature, parliament, prime minister, president, or country ruler, as the case may be. Seldom do range professionals have influence at this level. Those in authority usually represent urban populations. Much rangeland policymaking goes on without input from range-management professionals. My opinion is that range people should be active in policy determinations beyond their immediate land-management responsibilities. Here is why.

Most countries have numerous agencies with concerns for rangeland, such as parks, water resources, wildlife, and conservation. Range managers should be active and their expertise known in those agencies. A second reason is that the multiple-use demands on rangelands have caused a fragmentation of public action. Rangeland management receives less than its share of attention and is not well understood. Our discipline has lost influence in competition with the great increase in pressure groups that operate at the legislative level of government. The result is that financial support of range-resource interests has been reduced in comparison with other budget items. The real task is to become politically effective without appearing to be politically active at all.

EMPHASIZE RANGELAND RATHER THAN ANIMAL PRODUCTION

Range management puts its major emphasis on the improvement, care, and productivity of the landscape. (I use "landscape" to include soil, vegetation, and animals.) We are trained as ecologists who are concerned with the landscape and as managers who aim to preserve and improve the landscape and who are interested in the husbandry of the users of that landscape, whether they be people or wild and domestic animals. Our principal interest is in habitats.

Other professions have overlapping interests with range management. They include animal science, which is concerned with the feed that the rangeland produces; wildlife management, which has major interests in feed, vegetational cover, and water; and veterinarians, who are disease oriented but include nutrition and management in their interests. Technicians in all the natural-resource disciplines sometimes find it necessary to operate in more than one discipline. Range professionals should work with those in other disciplines but, at the same time, not abdicate their areas of expertise to the others.

The subject-matter emphasis in our teaching programs is probably the best way to make us proficient and different from the other associated fields. Understanding of biological systems needs to be enlarged, as do the sociological and economic aspects of rangeland ecosystems. We could do with fewer recipes for seeding, brush control, grazing systems, etc., and do with more understanding of the processes set into motion when these manipulations are put in place. The processes are biological, sociological, and economic in nature. Our job is to understand and manage rangeland systems and processes. We must not get trapped into serving only one interest, namely production of livestock.

THE IMPORTANCE OF PROFESSIONAL JUDGMENT

Daily, all of us are in situations where we must make considered and value judgments. Judgments may be necessary because there is not enough time to consult the library or to do research. Often the information does not exist or it exists for a similar set of conditions somewhere else. An example of the situation is found in many proposals for rangeland developments. They start with the need for inventories of soils, climate, vegetation, wildlife, erosion, water, domestic animals, reproductive rates, costs and benefits, demographies of people -- the list is almost endless.

These inventories tend to oversample and become incomprehensible because of great detail and unnecessary measurement. Judgment is required to select the right parameters for specific hypotheses and goals. Once that is done, then the intensity of sampling must be selected. The next step, adequate funding presumed, is to collect the data and analyze it. This takes time and, considering the vagaries of climate, the data may be no better than judgments by experienced persons.

Every range manager should aim at becoming so well acquainted with landscape characteristics that very few sample data are needed to start development work. The best large-scale example of successful use of professional judgment that I know was the development of pastures, water, roads, and new stands of grasses through brush control and seeding, and the stipulation of grazing schedules in a 2-million-hectare area of cold semidesert in the western United States. Very little inventory was made. Improvements were made according to topography and

soil depth, and most of that was determined by judgment of where machines could travel and which were the sites with the highest potential. Most of us do not fully use our own good common sense about rangeland conditions and issues, thereby increasing the costs and time of our accomplishments.

SUMMARY

Ten subjects may be too many for this paper (or any paper, for that matter), but they are items that concern me about the future of range management. Here they are in short statements with no significance attached to their order of presentation.

- Range management has a shortage of fundamental principles, and too few persons are attempting to develop basic theory and laws. There is need for relevant basic research.

- Researchers should interpret the practical significance of their successful and unsuccessful research results. These interpretations are not sufficiently published nor well stated.

- Rangeland inventory has changed over the years, range condition is confused with different definitions, trend is not easily determined, and off-and-on monitoring leave our understanding of vegetation and its response to grazing in a state of chaos.

- New techniques and further research into plant responses to defoliation are needed to give new insight into grazing management.

- Rangeland improvements have changed in their relative importance and value, and very likely they will change again.

- Integration of rangeland, cropland, and trees in what is commonly called "agroforestry" is a promising new approach to improving the welfare of farming people; but the required cooperation among disciplines will be difficult to achieve, and a basic research foundation is still an opportunity.

- Multiple use of rangelands will increase, causing continued controversies over land use.

- Range scientists and professionals should be more active in country politics.

- More emphasis should be given to the solution of rangeland problems rather than to the products produced, especially livestock.

- Range people need to develop and exercise their use of professional judgment. Excellent judgment, in many instances, is better than a drawerful of too-detailed data.

PRODUCTION SYSTEMS

GROUP RANCHES IN KENYA

Peter L.K. ole Sadera

ABSTRACT

Organized grazing schemes were first established in Kenya between 1944 and 1956 under the auspices of the African Land Development Board (ALDEV). Although the system did not succeed in producing viable grazing schemes, it provided experiences necessary for modification of other types of systems that would suit social, traditional, and other aspirations of the pastoralists.

Group ranches, which were first established in 1964, are therefore modifications of grazing schemes. Group ranches generally can be described as production enterprises in which a group of people who jointly have freehold title to land maintain agreed stocking levels and herd their livestock collectively while continuing to own them as individuals. Membership in the group is based on kinship and traditional land rights. The objective is to establish a system that allows the modernization of livestock husbandry and still preserves many of the features of the traditional way of life

- to avoid causing too great or abrupt a break with the past
- to allow for people's subsistence while avoiding social frictions

Under Phase I of the Kenya Livestock Development Project (1968 to 1974), 41 individual ranches and 15 group ranches were developed or given development and operational loans. A few more individual and group ranches were financed under KLDP Phase II. A large portion of Phase II funds was used for rescheduling loans after the drought of 1975 to 1976.

The main constraints were lacks of capital, qualified managers, and proper books of accounts. Currently, many of the group ranches are being subdivided into individual land units, some of which would be unviable as livestock-producing ranches.

BACKGROUND

Grazing Schemes

Establishment of a form of better land use goes back to the mid-1940s when the colonial administration initiated what was known as ALDEV (African Land Development). In the plan, pastoralists were organized ethnically or traditionally into large, organized grazing areas that were known as "grazing schemes." Examples were Itong, Konza, and Ndeyia in Kajiado, Narok, and Kiambu districts respectively.

Grazing schemes were established with grant money, and the only facilities provided were dipping and water. Rotational grazing was not strictly enforced in order to induce the pastoralists to remain in the schemes. However, due to climatic conditions (wet or dry), the pastoralists who were in the habit of migrating according to the weather pattern continued to move out of the established grazing schemes; and the British administration did not have much control of the situation because the traditional chiefs were not prepared to part with the traditional way of life and, therefore, did not support the administration. Consequently, the schemes merely existed by names.

In about the mid-1950s, when the emergency regulations were being relaxed, a major land-use policy was put into operation in the African areas. The policy, involving land adjudication in the mainly agricultural areas on high ground and in the organized grazing schemes in pastoralist districts in the low regions, became known as the "Swynnerton Plan."

Many grazing schemes were opened up in various districts throughout the colony and protectorate of Kenya. Each grazing scheme had a livestock officer in charge. All the monies for development were in the form of grants, although the participants were expected to provide free manual labor.

Grazing schemes were established as models of proper land use and livestock management in the hope that the pastoralists would be convinced of the necessity to reduce their livestock numbers, to overcome overuse of land resources, and to reduce soil erosion to manageable levels. For example, the Konza grazing scheme in Kajiado District consisted of approximately 26,000 acres (10,526 ha). Initially, it included 16 families. The veterinary department took a livestock census with full support from the provincial administration before the scheme was accepted. Each family was allotted a livestock quota and signed an agreement to sell surplus stock. Failure meant automatic eviction from the scheme. Before the settlers were allowed to move into the scheme, the external perimeter was fenced, four internal paddocks were fully fenced with cedar posts and barbed wire, two plunge dips were constructed, and three boreholes were drilled and equipped. Each borehole had a 10,000-gallon water tank and troughs. Masai manyattas (homesteads) were constructed at strategic positions to facilitate rotational grazing at 3-month intervals. No animals were allowed to move into or outside the scheme. Annual inoculation of animals against contagious bovine pleuropneumonia (CBPP) and rinderpest was free and compulsory. The participants also were advised to inoculate their livestock against blackquarter and anthrax. Each member was forced to pay a certain percentage of money realized through cattle sales to be used to purchase acaricides and to pay the salaries of borehole operators and dip attendants.

Although the Masai were suspicious at first of the objectives of the colonial administration, they appreciated the services provided in the scheme -- particularly dipping and annual inoculation of livestock -- because they reduced deaths due to tick-borne diseases. As a result, livestock numbers increased considerably beyond the capacity of the scheme. As would be expected, families with large numbers of livestock refused to sell the surpluses and preferred to quit the scheme. Initially, four families quit the scheme; subsequently, movement out of the scheme became part and parcel of the management. The last six families left in the height of the 1960-61 drought, and the scheme was subdivided into eight individual ranches of varied sizes in 1964.

Transitional Group Ranches

Group ranches were established more or less along the same lines as grazing schemes, except that it was recognized that an Act of Parliament was required to legalize ownership and occupation of land and to enable the participants to get monies from financial institutions for development and operation. However, while the debate on the pros and cons of group ranches continued locally and at the seat of government in Nairobi, the range-management extension staff at Kajiado decided to

start individual ranches as an experiment to test whether the Masai would accept delineation of their land

- to enable the extension staff to demonstrate models of modern ranching in each location in the district with the sole purpose of bringing about the desired changes

- to make the Masai aware that demarcation of land was now a reality

In about 1963, the first individual ranches were started: six at Sultan Hammud, eight at Kajiado, six at Ambiseli, and four at Olooltepes, all in Kajiado District, and four at Itong in Narok District. The Agricultural Finance Corporation (AFC) reluctantly agreed to give development and operation loans on the strength of the respective county council minutes of allocating the land because land adjudication had not taken place. The individual ranches were successful, and the authorities in Nairobi and the local Masai were convinced that, if group ranches were established, they would succeed equally.

Registration of group-ranch participants and demarcation of group ranches started in Kajiado District in 1964. The small range-management crew ran into a lot of technical problems, particularly in deciding on appropriate sizes and numbers of members for the ranches. However, by 1965 the pastoralists were used to the exercise, and demarcation of boundaries (on the 1:50,000 map sheets) and registration of members went on smoothly. The group ranch was accepted as a better concept than the grazing scheme for developing ranches in pastoralist areas because

- The ranches would be adjudicated and registered. Subsequently they would get freehold titles, thereby enabling them to get loans from financial institutions.

- There would be no landless Masai adults at the time of demarcating the land since all Masai would have equal shares, regardless of whether they owned livestock.

- Proper planning and management of pastures and other land resources would be possible.

- Overuse of land resources by livestock would be minimized because each family would be given a stock quota before joining the group.

As an experiment, one group ranch named "Poka" near Emali on East Kaputiei in Kajiado District was established in 1965. It had 8,816 hectares and 30 registered members. As each family moved to the ranch, its stock was counted and it was assigned a stock quota based on a percentage. For example, if a family had less than 30 head of cattle, it was allowed to increase its stock to 45 head (a number considered to be enough to sustain a family of six); and if a family had more than 400 head of cattle, its stock was reduced by a certain percentage to give room to less-fortunate members. The system was discussed at length, and it was approved unanimously. When the registered members were settled, financial projections were worked out by the range-management extension staff, which enabled the group ranches to get development and operation loans. The system seemed to have worked out successfully that time.

Group Ranches, Phase I

Group ranches came to be defined as production enterprises in which a group of people jointly have freehold title to land, maintain agreed stocking levels, and herd their livestock collectively while continuing to own them individually. Membership in a group was based on kinship and traditional land rights. The objective was to establish a system that would allow the modernization or modification of livestock husbandry and still preserve many of the traditional ways of life

- to avoid causing too great or abrupt a break with the past
- to allow for people's subsistence while avoiding social frictions

An official Registrar of Group Representatives was appointed under the Land (Group Representatives) Act of 1968 and empowered to incorporate group ranches and generally regulate the whole group movement. The representative -- a committee -- is responsible for the management of the ranch, employing paid managers as necessary with assistance from the range-management extension staff.

As a result of initial successes of Poka Group Ranch, which was funded by the Agricultural Finance Corporation from internal finances, a number of group ranches were established in Kajiado and Narok districts.

Kenya's government formally approached the World Bank to finance livestock production. The first credit, which came to be known as Kenya Livestock Development Project, Phase I, was implemented in 1968. The objective of the project was to increase beef production by providing credit for four different types of ranching enterprises (individual, cooperative, group, and company). It also provided facilities and services for livestock marketing, range-water development on communal land, and disease control. Under this project, credit also was extended for the first time to traditional pastoralists to assist them in the transition from subsistence to a market-oriented economy.

The plans for Phase I called for development of 10 individual, 20 commercial, 20 group, and 10 company ranches. But at the end of the project, the following ranches had been developed: 15 group ranches and 41 individual ranches in Kajiado; 42 commercial ranches in the traditional European ranching areas of Laikipia, Nakuru, and Machakos districts; and 10 new company ranches, mainly in Coast Province. As it turned out, AFC found it easier to finance individual ranches than group ranches in Kajiado.

Group Ranches, Phase II

The Kenya Livestock Development Project, Phase II, was prepared as a result of the generally encouraging experience of the pilot project. Phase II was appraised in October and November 1972, and credit negotiation began in July 1973 due to delays in obtaining the necessary financial commitments from donors. The project was designed as a broadly based integrated program to increase beef production in Kenya over 5 years through ranch development.

The implementation of Phase II started in late 1974; and at the close of 1976, after the severe drought, it was facing a lot of problems. Group ranchers moved in search of better pastures and water, abandoning what they called "AFC steers" -- those purchased with loan money. Boreholes were left unattended. Engines and vital spare parts were stolen,

pipelines were tampered with, and a number of plunge dips were cracked. As a result, other group ranches that were ready for financing became reluctant to take loans; consequently, new development projects came to a standstill. A review mission was set up in 1976, and the project received major revisions. A number of recommendations were made to improve the financial viability of the ranches, such as rescheduling loans and employing qualified managers, accounts clerks, and other personnel.

The original target was to finance 60 group ranches; however, the World Bank review mission revised the target to 29 group ranches. At the close of the project in December 1982, a total of 27 group ranches had been financed.

Benefits to Group Ranches

It was particularly interesting to note that the local Masai elders, at long last, agreed to part with the old traditions and, without being forced, to accept demarcation and registration of their land. It was also of particular interest when they agreed to mortgage their freehold titles with AFC to get loan money for development activities -- a big risk, since failure to repay the loans would result in the loss of their land. AFC loan money was spent as follows:

- for development of water resources such as boreholes, surface dams, and springs

- for purchase of improved breeding stock

- for purchase of immature steers for fattening and sale to service the loan money

As stated earlier, Phase I was considered a success, and the implementers of the project were convinced that a better method of improving and managing semiarid and arid land had been found. It also appeared, in broad terms, to suit management of pastoralist land units. However, in subsequent years, because a large population of uneducated voters was concentrated in the group ranches, politics became more pronounced. The local politicians started to divide the group-ranch participants and form small splinter groups according to age group, clan, etc.

The politicians started compulsory registration of new members, mainly "morans," against the wishes of the majority of previously registered members. To counter registration, the registered members decided to subdivide some group ranches, irrespective of whether the new individual ranch units would be viable. In the search for quick action in effecting subdivision, members of group ranches persuaded the local land-control board to let them pay colossal sums of money to registered private surveyors to carry out the work.

The problems of subdivision and the continuation of group ranches as they were planned are yet to be solved. There are just too many interested parties with varied ideas.

Table 1 shows the position of group ranches in Kajiado District. It should be taken as a model of what is happening in group ranches throughout the country. Narok District is even worse because, although no official authority for subdivision has been given to ranches in high-

and medium-potential zones, nearly all have subdivided and rented large portions of land for growing wheat, barley, and maize.

As table 1 shows, the carrying capacity of Kajiado ranches range from 4 ha to 8 ha per stock unit, depending on ecological conditions and climate. The better ranches are in Ecological Zone IV, while the others around Lake Magadi are in Ecological Zone V.

Though membership in a few ranches fell due to deaths and possibly migrations, there was an overall increase in membership of 2% between 1982 and 1984. This was caused by registration of second-generation people (sons of original shareholders). This has been the main reason for demands for subdivisions in the ranches. Among the 51 ranches, 29 voted for subdivision -- 57% of all the ranches in Kajiado. For seven of the ranches that favored subdivision, the District Range Office has assessed the feasibility of subdivision and(or) subdivision already has been done.

Several ranches have been registered and incorporated in various parts of the country. Some have never operated as group ranches, yet they are among those demanding subdivision because of the current wave of individual ownership. Table 2 shows the distribution of group ranches and their average sizes.

CONCLUSION

The overall performance of group ranches throughout the country has been declining, mainly due to lack of finances from the Agricultural Finance Corporation to enable the participants to purchase improved stock and provide services such as water, tick control (dips), and firebreaks.

Apart from a few ranches in Kajiado, for which development and operation loans were rescheduled in 1979, none of the registered group ranches have received new loans; therefore, frustration has resulted. Some of the group ranches resorted to subdivision so their members, as individuals, can approach other financial institutions for funding. Subdivision is now being discussed in most district-development committees; and, in most cases, subdivision gets the green light, regardless of the ecological zones in which the ranches are situated or the viability of units resulting from subdivision.

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Table 1. Status of group ranches in Kajiado.

Ranch name	Total ha	Reg. members 1962-1984	Recom. ha/SU[a]	Subdiv.[b] status
Phase I				
1. Poka	8,926	30-30	6	+
2. Kiboko	15,870	67-64	7	-
3. Olkarkar	10,280	64-93	7	-
4. Merueshi	18,546	71-125	6	-
5. Mbilin	14,723	64-89	4	-
6. Mbuko	18,477	89-88	7.5	-
7. Nkama	39,760	456-490	4.5	-
8. Arroi	18,692	113-107	6	-
9. Imaroro/Mashuru	19,483	335-381	6	-
10. Erankau	8,985	88-90	6	-
11. IImamen	12,194	94-125	5	-
12. Emarti	13,211	91-126	5	+
13. Empuyiankat	15,270	76-98	5	+
14. Embolioi	24,000	204-302	6	+
15. Olkinos	6,020	106-115	5	+
Phase II				
16. Rombo	38,365	512-760	5	?
17. Kuku	96,000	544-604	6	?
18. Kimana/Tikondo	25,120	167-168	6	-
19. Osilalei	38,629	435-419	5	?
20. Oldoinyo Nyokie	68,566	162-247	8	?
21. Kilonito	25,685	122-174	5	-
22. Shompole	62,689	366-366	8	?
23. Olkiramatian	21,612	200-187	8	?
24. Enkaroni	11,378	190-336	5	-
25. Nkoile	6,208	171-271	6	-
26. Esokuta	4,109	72-65	5	-
27. Olkiloriti	6,109	72-65	5	-
28. Oloiyankalani	9,606	88-117	4.5	-
29. Elang'ata Wuas	59,497	414-658	5	-
30. Olkeri	24,852	164-222	5	?
31. Torosei	46,445	165-165	5.5	?

Table 1. Status of group ranches in Kajiado (continued).

Ranch name	Total ha	Reg. members 1962-1984	Recom. ha/SU[a]	Subdiv.[b] status
Phase III				
32. Ewaso Kedong'	52,136	484-484	5	?
33. Loodo-Ariak	57,065	0-500	5	-
34. Oldoinyo Orok	28,701	322-322	5	-
35. Sajiloni	15,711	450-450	6	-
36. Enkorika	15,923	317-369	6	-
37. Olomunyi	10,057	151-157	6	-
38. Olgirra/Oloototuruguru	12,925	151-157	6	?
39. Meto	28,928	408-425	5	?
40. Lolong'uswa	38,282	472-472	6	?
41. Mailua	63,026	642-642	6	?
42. Oloolarashi/Ogulului	147,050	1,031-1,031	6	?
43. Mbirikani	125,893	210-922	7	?
44. Selenkei/Emotorok	74,794	150-400	6	?
45. Kitengela/Oloolotikoshi	18,292	229-233	5	+
46. Nentanai	3,692	51-51	6	?
47. Bartimaru	19,645	225-324	6	?
48. Saikeri	7,531	114-114	6	?
49. Olosho-Oibor	3,000	127-127	6	?
50. Olchoro-Onyorei	3,687	144-144	6	?
51. Kipeto Kisaju	4,945	44-100	6	+
Kajiado District Grand Total	1,520,917	11,664-14,588	5.8	

[a]One stock unit (SU) = 450 kg live weight or a combination of various classes and(or) types of herbivores totaling that amount in weight.

[b]Subdivision status: + = voted for subdivision and a DRO feasibility study has been completed; - = voted for subdivision but feasibility study has not yet been completed; ? = not voted for subdivision.

Table 2. Distribution of registered, incorporated group ranches.

Province	District	No. of Ranches	Average size (ha)
Rift Valley	Kajiado	51	29,822
	Narok	33	16,428
	Samburu	27	12,315
	Laikipia (Mkogodo)	11	4,905
	Baringo	3	13,860
	West Pokot	4	13,490
Nyanza	South Nyanza	6	2,674
Eastern	Embu	2	760
	Kitui	5	4,004
Coast	Taita	5	6,458
	Kwale	6	48,812
	Kilifi	6	17,256

GRAZING BLOCK DEVELOPMENT IN KENYA

Richard M.M. Muriuki

ABSTRACT

This paper describes grazing blocks as they were developed, are being developed, or are proposed in the northern parts of Kenya rangelands; the areas; and what is involved in that development. It also outlines the underlying criteria for that development and the general objectives of the production system. The historical background of the areas included in grazing-blocks development is outlined since the time of Kenya's independence.

The paper also summarizes donor and development agencies, including of the government of Kenya, and their roles. Different stages of development planning and implementation are explained, and mention is made of evaluation and monitoring agencies.

Range-management extension services for the grazing blocks are also explained, the paper summarizes development achievement from 1969 to today in all areas affected, and it offers proposals for the future.

The paper ends with a discussion of some issues concerning grazing-blocks development from social and ecological points of view.

INTRODUCTION

Description

For our discussion, the "grazing block" is a communal grazing land that has been defined by physical boundaries and developed for use by livestock and wildlife. Development, in this context, means

- provision of water supplies
- demarcation of pastures with motorable access tracks
- provision of range-management advisory services in or near the block
- recommendations on carrying capacities and grazing treatments

Generally, a grazing block is about a 500,000 ha, give or take 200,000 ha.

Areas Affected

Grazing blocks are or have been developed in areas where the land has not been adjudicated and officially registered. Particularly, they have been developed in the North-Eastern Province and Isiolo District in the Eastern Province. They have also been proposed for Marsabit in the Eastern Province, Turkana District in the Rift Valley, and Tana River District in the Coast Province. The main criterion determining whether rangeland should be developed into grazing blocks is its potential class. Lands that cannot be developed into better or more intensive ranches seem to qualify for development into grazing blocks.

Initially, these lands are owned by clans, subtribes, or whole tribes that roam the entire area of the block in transhumant migrations over a season or year. In years of average climatic conditions, these geographical areas, the people, the vegetation, and the animals form a

complete ecosystem for the tribe, subtribe, or clan that is stable and largely self-sustaining.

Accommodation of Change

Over the last several decades, many interventions have been introduced into range areas that have tended to reduce the effects of human and livestock diseases and, consequently, have led to increased human population. These increased populations need more food, which calls for increased production from the rangelands. The traditional production systems seem to have approached the limit of what they can produce; therefore, better production methods are needed to keep abreast with the demands of the people. In quest for this increased production, grazing-block development was conceived and has been tried in some of the areas mentioned above. Furthermore, the northern rangelands have a comparative advantage in production of beef, either for direct supply to the slaughterhouses at Athi River and Mombasa or for providing immatures to the ranches in Rift Valley and Coast provinces for fattening.

Justification and Objectives

The government of Kenya's stated objective for the rangelands is that they "shall be conserved and developed, and where necessary rehabilitated, along sound management lines with the aim of increasing the national income through increased production from these areas" (Ministry of Agriculture, 1973). Thought, time, energy, and money spent on planning and developing grazing blocks is founded on the belief that these rangelands (and even others) actually can produce more meat and probably other products if managed in keeping with good ecological principles and if the pastoralists use improved animal-husbandry and animal-health practices. That is, the rangelands have a potential which can be exploited to produce more than they are producing today. That is why the original (and probably even today's) ultimate goal in the management of the grazing blocks, according to Fred H. Mass (1970), was

> ...to develop, increase, stabilize, and manage water storage potential and livestock use in a manner that will increase forage use and stabilize livestock production at the optimum practical level. It will mean maintaining good forage production on all areas being developed and to improve and maintain forage production on presently deteriorated areas. This will be brought about by increasing and maintaining vigor, density, and composition of forage production of plants on these lands through natural methods.

The natural methods envisaged included

- distributing cattle in the block to ensure that animals make full use and optimum gains
- resting forage plants after use to allow them to regain vigor
- distributing handling facilities to encourage animal distribution
- giving consideration to people's cultures

Later on, other authors elaborated the original management objectives to include flexibility, simplicity, wildlife conservation, vegetation

reserves, etc.; but, essentially, these later additions emphasize the original objectives.

Generally, the objective of grazing-block development was to increase range production and, subsequently, income in the areas affected (Ministry of Agriculture, 1973).

General Development

Since grazing-block development began in North-Eastern Province and similar works extended to Isiolo District in Eastern Province, many conceptual and physical changes have taken place. In the North-Eastern Province, nine blocks have been developed fully and another five have been developed partially. In total, these cover approximately 5,969,840 ha, or 47% of the province. In Isiolo District, two blocks have been developed covering 931,000 ha; another two, covering 1,238,440 ha, are in progress.

In other districts, very little work has been done other than generating proposals for suitability. This is largely due to lack of funds for capital development.

BACKGROUND

Shifta Disturbances

At about the time of Kenya's independence, political activity in the northern areas of Kenya (inhabited by the Somali, Borana, and Rendille ethnic groups) culminated in the "Shifta" war, which lasted until about 1968 when the Arusha Accord was signed by the governments of Somalia and Kenya. During that time, northern areas were ravaged of human and livestock populations; and, by the time the Shifta activities ended, the areas needed reconstruction to be able to support the people and contribute to the economy of the nation.

Development Tempo

The government of Kenya approached various donors for assistance to develop the country's livestock industry. The United Nations Food and Agriculture Organization and the Development Fund (FAO/UNDP) Range Management Project started range-research and range-survey activities in 1966 and in some areas, including Isiolo and Marsabit. The World Bank and Swedish International Development Agency expressed willingness to finance water development in part of North-Eastern Province; but, before that was done, the government of Kenya commissioned a social administrative study of the North-Eastern Province. The study was completed in 1969 by R.J.H. Chambers (Ministry of Water Development, 1978). The government's main objectives were

- to increase beef production and thus improve the standard of living of all Kenyans as well as providing foreign exchange

- to protect wildlife resources

- to stabilize nomadic people and improve their living conditions within the national framework

These objectives were to be met by addressing the following needs, which formed the project goals:

- increase rangeland carrying capacity by about 25%
- improve facilities for livestock movement and marketing
- survey and develop water resources
- provide technical services such as range management and veterinary services

Development Avenues

The pilot project, Phase I, was planned in 1969 and 1970; and by 1970 implementation already had been started in Mudogashe West, East Mudogashe in Garissa District, and Kalalut Block in Wajir District.

In his conclusions of the administrative and social study of the project area, Chambers (1969) made broad observations and specific recommendations that are as valid today as they were then. Unfortunately, however, the planners and the implementers either never referred to these recommendations, or they did not attach much importance to them; so they overlooked some of the problems the project was to face in later years.

As for the Isiolo, Marsabit, and Tana River districts, they benefited from the resource surveys and development recommendations of FAO/UNDP but not from actual development during Phase I, which lasted from 1970 to 1974. Phase II, from 1974 to 1981, covered a good part of the North-Eastern Province (sponsored by the United States Agency for International Development) and Isiolo District (sponsored by the Canadian International Development Agency).

PROJECT PLANNING AND IMPLEMENTATION

Agencies

Briefly, a number of Kenyan government agencies and donor agencies were involved in the planning and implementation of the massive livestock development program of which the grazing blocks were just one component.

Ministry of Agriculture. Before the reorganization of Kenya's government in 1974, the Ministry of Agriculture included the Range Management Division, the Department of Water Development, and the Project Coordination Unit, all of which were directly involved in the project. After the 1974 reorganization, the Ministry of Water Development was formed and became responsible for the Range Water Section, which was servicing the project. Valuable coordination was lost in the transition and has not yet been re-established.

Ministry of Water Development. The Ministry of Water Development was formed in 1974 from the former Department of Water Development within the Ministry of Agriculture. Two sections of the ministry were to be devoted to livestock development: the Range Water Section, and later, the Ranch Water Section. Somehow, the new ministry had other big, important projects to attend to, and the livestock sector never received due attention and services. In fact, some differences began to develop between the planners, implementers, and even the donors. However, quite good progress was made in some areas where cooperation was maintained.

Treasury. The treasury was responsible for coordinating project funds between the ministries and the donors and for ensuring that the laws and regulations pertaining to external funding were observed.

Other agencies. Other government agencies that were involved in the project included the Kenya Rangeland Ecological Monitoring Unit of the Ministry of Wildlife and Tourism, whose main role was to monitor the deterioration or improvement of the rangeland ecology due to livestock development. Its main interest, apparently, was wildlife habitat and numbers. This unit was responsible to the parent ministry but supposed to provide feedback information (after analysis of data) to those implementing the project.

The International Livestock Centre for Africa became involved during Phase II. It was supposed to monitor project components in small units, whereas the monitoring unit's activities were concerned with regions. It was supposed to work closely with the implementing agencies and undertake specific research and studies.

Donors. It may not be necessary to enumerate all donors involved in the livestock-development projects, but the following were involved in grazing-block development:

- the U.S. Agency for International Development (USAID) sponsored the North-Eastern Province

- the Canadian International Development Agency (CIDA) sponsored the Isiolo Project and the Kenya Rangeland Ecological Monitoring Unit

- the World Bank acted as a kind of coordinator for all donors

Planning

Initially, the planning team for grazing-block development for the North-Eastern Province, during Phase I, was located in Nairobi and consisted of a range management specialist, a water engineer, and a hydrogeologist. The team members were USAID expatriates. As part of the agreement, they had to have Kenyan counterparts who were to take over the project when the expatriates left. At the field level, the planning team had a crew of surveyors and technical assistants for field data collection.

The team considered the recommendations of the social and administration study (Chambers, 1969) and decided on an area to be developed as a grazing block. After surveys and other data were collected, the team determined what was required for the block. How many stock units was the block capable of carrying? What was the best grazing system? Were there underused areas? If so, why were the areas not in use? If it was for lack of water, how much water was required and where would it serve to the best purpose? What form of water development was best -- temporary, medium duration, or permanent? Were all areas accessible to both graziers and government range-management personnel? If not, what would be the best pasture layout? What was the best placement of water? What were the optimum distances between watering points? The answers to these and many other questions led the planners to their recommendations. Of course, to get some of the answers they had to consult with the extension personnel and the local graziers.

The team then sent a development proposal to the head of the Range Management Division, the director of water development, the district range officer, and the provincial range officer for approval. If necessary, amendments or corrections were made. When the proposal was approved by the head of the Range Management Division and the director of water development, it was ready for implementation. Theoretically, that was the planning path. However, in some instances, those in charge of implementation acted differently from what was planned; at other times, differences arose during planning, and what was carried out depended on who gave the orders (for example, for the movement of machines). This problem was prevalent in the Isiolo Project.

Implementation

Physical implementation. Personnel and equipment for the site and construction were moved mainly by the Range Water Section of the Ministry of Water Development. The other parties involved received information about progress through visits. This proved to be the most difficult exercise of all because it involved too many people and machines, frequent machinery breakdowns and poor mechanical services, cumbersome government procurement procedures, and reluctance of qualified personnel to work in the remote north.

Extension installation. Usually, a block's personnel needs were known in advance. Generally, there was one technical officer (block manager), two technical assistants (assistant block managers), a driver, and a watchman. In later years, when the blocks were a bit larger, the number of technical assistants sometimes went up to four. So far as possible, the personnel were provided at the time of construction so they could become familiar with the area and its facilities. They were placed initially in an adjacent block from which they could monitor the programs of their future area of operation.

Besides personnel, physical facilities -- housing, transportation, and camping gear -- were needed. Housing was provided through the Ministry of Works; but when they could not cope with the work, the Ministry of Agriculture and Livestock provided funds for constructing temporary houses in the more remote areas.

Extension services and block management. As a block's facilities and personnel were installed, the local district officer and the local chief were supposed to organize a block committee to be the forum at which seasonal and long-term grazing plans would be formulated, agreed upon, and enforced. The committee also was supposed to register the graziers who would use the block and collect water-use fees.

The district officer was the committee's chairman, the chief its vice-chairman, and the block manager its secretary. Members included local leaders, graziers' representatives, and religious leaders. If well constituted, the committee should be strong enough to make decisions that would be respected by the local stockmen.

PROGRESS -- 1970 TO 1986

Phase I -- Pilot Project

Phase I, from 1969 to 1974, concentrated mainly at Mudogashe West, Mudogashe East, and Kalalut blocks. The Mudogashe blocks are in the

Garissa District, and the Kalalut block is in Wajir District. Together, the three blocks cover 742,660 ha.

The development of these blocks can be summarized as follows:

Block	Area (ha)	Trackways (km)	Boreholes	Pans
Mudogashe West	227,690	447	Nil	26
Mudogashe East	282,500	449	5	18
Kalalut	232,470	300	4	26
Total	742,300	1,196	9	70

This development cost Ksh. 3.87 million, and the funds were supplied by the World Bank, the Swedish International Development Agency, and the government of Kenya.

Phase II

North-Eastern Province. For the North-Eastern Province, Phase II (1974-1980) covered six new blocks: four in the Wajir District and two in the Garissa District. It also included extension of the Kalalut block that was established in Phase I, and partial development of one block in the Wajir District, two in the Garissa District, and two in the Mandera District.

Phase II progress is summarized in table 1. Clearly, some work still remains to complete the blocks that already have been started. The pace of development had to be rescheduled to fit in with the government of Kenya's budget, because of the heavy expenditures required. The second phase of the project was financed by a USAID loan for U.S. $9.42 million. Of course, the government of Kenya contributed cash, personnel, equipment, and housing.

Isiolo District. Initially, four grazing blocks were proposed for the Isiolo District: Garba Tula (452,720 ha), Sericho (478,370 ha), Yamicha (588,980 ha), and Merti (649,460 ha). These blocks were to be developed with aid from the Canadian International Development Agency (CIDA). Garba Tula and Sericho are now fully developed, Yamicha is in progress, and Merti has not been started. Somewhere along the line, the Canadian aid was withdrawn; and since the current development is financed by the government of Kenya, physical development is slow.

All the infrastructural development of the Isiolo blocks took place from 1977 to 1986. Except for the surveys and proposals done by FAO/UNDP, no actual construction or installations took place during Phase I. Essentially, the block development in Isiolo is similar to that of the North-Eastern Province in agencies, modes of construction, management, and general range-management administration.

Under the original agreement, CIDA was to provide Canadian $2.4 million for range and water development at Isiolo and to provide for consultancies and technical services. I have not been able to get the figures for the actual amounts spent from this original proposal before CIDA aid was discontinued.

Actual developments undertaken on the Isiolo project can be summarized as follows:

Block	Area (ha)	Trackways (km)	Boreholes	Pans
Garba Tula	452,720	440	3	8
Sericho	478,370	217	1	9
Yamicha	488,980	709	4	2
Merti	649,460	-	-	-

Besides these facilities for the pastoralists, other facilities have been developed: housing, vehicles, a mobile pastoral-training center (aided by CIDA), and above all, the staff to run the extension service.

Other areas. As mentioned earlier, there are proposals to develop more areas under the grazing-block program. The districts proposed are Marsabit, Tana River, and Turkana. Implementation of the program will depend on its receiving high priority in the donors' or government's budgets.

DISCUSSION

Views have been varied about the benefits, desirability, usefulness, social impact, ecological impact, etc., of the grazing-blocks concept. Quite a few reports have been written on the subject by the evaluation and appraisal mission, and progress reports have been made by donors. Unfortunately, none of these reports has been comprehensive or convincing.

Social Impact

Take, for example, the sociologists who generally tend to agree that we ought to leave the pastoralists to manage on their own. For centuries, the pastoralists have been on their own and have not made their conditions better without outside or government intervention. The pastoralists are the poorest of the Kenyan population because their land resources offer very few alternatives. They are the first to suffer the effects of drought, and their only resources are the stock, which soon or later start to die, followed by the pastoralists themselves. They either have to move to some other place or be given famine relief. The pastoral system is fully stretched and can take very little extra stress. The development of pastures and water resources is an effort to accommodate a few more people, but it might appear ecologically risky and socially probably unacceptable. Socially we must honor the way of life of the pastoralists, but we must not stay so aloof that we intervene only when disaster is looming or has struck. That approach would be patronizing. The pastoralists should be given the opportunity to use modern range management with the understanding that they are mostly illiterate and, therefore, often must be taught by younger people who have learned about it. They should be accorded the dignity of shaping their destiny when it is still possible to do so, not during disaster when that capability is threatened. If we do not continue to develop the land so it can cater to a few more, we somehow will have to expand famine-relief handouts, and we probably also will have to expect that people will die.

Ecological Impact

Ecologically, the northern rangelands are very fragile and must be treated with care; those lands will have to support the expanding population if no more settlements are started elsewhere or if their people must live permanently on famine relief. Those lands therefore must be

made to produce more by further range development, especially areas that are currently underused or in irrigation schemes along the rivers. Maybe in the future, some industries can be placed in these areas to provide employment. Rangeland development demands the greatest ecological awareness. If we have that ecological awareness, the planners should only be alerted about it and be told not to plan for disaster.

The approach should be scattered development, encouraging even, light distributions of settlements and livestock. Along with the development, there should be simultaneous ecological monitoring for positive or negative changes. This will be possible only if monitoring crews reside within the project areas, and if their findings and warnings are enforced by those in administration to halt any range deterioration and to support only practices that promote healthy range trend.

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Table 1. Phase II progress.

FULLY DEVELOPED BLOCKS

Block	Area (ha)	Trackways (km)	Boreholes	Pans
Kalalut (extension)	177,500	-	Nil	3
Buna	309,400	900	Nil	12
Ajao	436,250	600	Nil	21
Giriftu	414,300	425	2	22
Tarbaj	330,300	632	1	16
Dadaab West	393,750	502	4	11
Udhole	296,390	316	Nil	24
Total	2,357,820	3,425	7	109

PARTIALLY DEVELOPED BLOCKS

Block	Area (ha)	Trackways (km)	Bore-holes	Pans (planned)	Pans (completed)
Sabule (Wajir)	468,890	600	8	13	Nil
EllLein Dadaab East (Garissa)	765,875	388	7	9	1
Takaba (Mandera)	662,800	370	4	5	6
Rhamu (Mandera)	1,441,040	490	Nil	22	6
Total	2,869,715	1,248	19	49	13

COMMERCIAL RANCHES IN KENYA

Robert K. Langat

ABSTRACT

Commercial ranching in Kenya started after the colonial administration enacted laws that allowed for freehold and long-term leasehold grants of land for agricultural purposes. Most of the ranches were established in the higher-potential rangelands of Machakos, Nakuru, and Laikipia districts. The immigrant settlers were largely ex-soldiers of the two World Wars. At about the time of Kenya's independence in 1963, there were about 150 commercial ranches covering one million hectares and producing high-quality beef cattle and sheep. More ranches have since been started, especially in the previously unoccupied statelands of the coastal hinterland. The ranches in the new areas came to be referred to as "company ranches," while those in the traditional ranching areas were referred to as "commercial ranches"; but, in both cases, the ranches were made up of individual, cooperative, or company ranch ownerships. Many of the long-established ranches have been purchased by groups of Kenyans and subdivided into units that would be unviable as commercial ranches, while some ranches in the Coast Province have been facing financial problems due to the effects of recurrent drought, inexperienced management, unavailability of fattening steers, and lack of working capital. In spite of these problems, commercial ranches play a major role in red-meat production in the country.

BACKGROUND

Before 1900, most of the land in Kenya was under natural pastures used for livestock grazing by nomadic pastoralists. The building of the Kenya-Uganda railway, which was completed in 1901, provided communication for extensive inland areas. Beginning in 1902, the colonial administration enacted laws that allowed for freehold and long-term leasehold grants of land for agricultural purposes. From this time, commercial ranching started as part of large-farm-sector development. By 1914, successful cattle and sheep production had become established in Laikipia and Naivasha based on cross-breeding of local and imported stock. This encouraged more settlers to take up ranching in Nakuru, Machakos, and Laikipia districts. Moreover, the colonial government encouraged ex-soldiers of the two World Wars to take up farming, including ranching, in Kenya. The commercial ranches occupied only 2% of the total range area, but they achieved a very high standard of animal husbandry and became suppliers of good-quality beef. Before Kenya's independence, it was estimated that there were about 150 commercial ranches covering one million hectares in the three districts mentioned above and the adjacent areas. More ranches have since been started, especially in the unoccupied coastal hinterland. On the other hand, several older commercial ranches have since been bought by Kenyans and subdivided into units that are unviable in many cases as commercial ranches. The coastal ranches and the issue of subdivisions are discussed in other sections of this paper.

TYPES OF COMMERCIAL RANCHES

The term "commercial ranching" has been used to describe ranches in the traditional ranching areas of Laikipia, Nakuru, and Machakos districts that previously were owned by immigrant population. The term "company

ranches" has been used to mean new commercial ranches, particularly in land previously unoccupied in the statelands of coastal hinterland.

These terms were used during the life of the Kenya Livestock Development Project (1968 to 1982). This was to distinguish between the long-established ranches, which require less development funds, and those that were being started fresh. In fact, all of these are commercial ranches and are made up of the following types of organizations for land ownership:

- Individual ranches. An individual ranch is owned and operated by an individual who is the registered proprietor of the land and has given his herd a market-oriented structure.

- Cooperative ranch. Cooperative ranches are made up of several families and derive their authority from the Ministry of Cooperative Development under the Cooperative Societies Act. Membership is by subscription of share capital. Some cooperative ranches are similar to company ranches except that they may use trustland. Others are former commercial ranches where ownership has changed into the cooperative form.

- Company ranch. A company ranch's land is leased from the government or a county council by a group of people who purchase shares in the company. They also may operate on freehold land owned by the company. The livestock are collectively owned, and usually a manager is employed for the ranch. Legally, this is limited-liability company and is governed by the Companies Act. There are three types of company ranches:

  1. Private company ranch. A private company ranch is a limited-liability company with limited members (maximum of 50).

  2. Public company ranch. Basically, a public company ranch is the same as a private company ranch except that its shares are open to the public. Shares are sold to the public up to the authorized value; for example, an authorized share capital may be 100,000 shares of Ksh. 20 each. The number of shareholders varies from time to time through sales and purchases of shares.

  3. Directed agricultural company ranch. This type of ranch is a limited-liability company in which the number of shareholders is not limited but the company is limited by shares. The act governing this type of ownership aimed at solving the problem of hidden partnerships. Its directors include a government agent who is entitled to majority vote without any rights to payment of dividends. Because of majority vote, he has the power to veto any resolution of the directors. In a district, the district range officer is the agent.

TRADITIONAL RANCHING AREAS

The traditional ranching areas, as indicated earlier, have been located in the higher-potential rangeland areas of the Laikipia, Makuru, and Machakos districts. These ranches were owned largely by European settlers during the colonial times. Acquisition of these ranches by Kenyans has been going on since independence. Most of those involved have organized themselves into partnerships, companies, or cooperatives for the purpose of raising equity capital and loans to purchase land and

develop it. In other cases, individuals invest in land purchases. For many people, the primary reason for buying land or shares in a land-purchasing group is to obtain ownership of a plot of land. Some buyers may be landless, others may be trying to improve upon their present land holdings, and some invest in plots as speculators, anticipating selling their plots for a profit. However, many of the ranches are bought to operate as company or cooperative ranches. Each shareholder may be allocated a small plot for personal use, but the remainder of the land is used for grazing the company's or cooperative's jointly owned livestock. Where there is poor management and misuse of the company's assets, the stockholders feel that they would be better off if they controlled their own plots, and this leads to total subdivision.

A few, largely mismanaged ranches, were taken over from the European settlers by government parastatals, such as the Agricultural Development Corporation, and managed as national farms. Some were purchased through Settlement Fund Trustees of the Ministry of Lands and Settlement and later sold to cooperatives. The latter group are found mainly in Machakos. Subdivision of ranches often leads to unviable units with resulting bad consequences on productivity. Some of the new owners try to cultivate for crops and, in the process, they destroy the vegetation. The chances of getting a crop are less than 30% because of the inadequate and erratic rainfall that characterizes the rangeland. Depending upon the number of registered shareholders and the size of the ranch, the plots ultimately allocated to each shareholder range from 1 ha to 4 ha in Laikipia. Similar trends are found in the other two areas, yet the carrying capacity is 4 ha per livestock unit. It is estimated that 38% of old commercial ranches have been subdivided. Table 1 shows the status of subdivision of the ranches.

NEW RANCHING AREAS

The coastal hinterland has been largely unoccupied by human population due to lack of water and infestation of the tsetse fly. The area inside the wet, narrow, roughly 15-km strip is semiarid rangeland. Continuous use of prophylactic and curative trypanocidal drugs since the early 1960s has enabled the keeping of cattle in the tsetse-infected areas with some measure of success. However, water development has been the main limiting factor and the most expensive investment in the ranching enterprises here.

Most of the vast area of the hinterland falls under stateland status, and leases have to be obtained from the government before the areas are used for ranches or other enterprises. The first ranches started in 1964 and 1965 (Taita and Lualenyi ranches, respectively), but the major thrust for development came under the first Kenya Livestock Development Project between 1971 and 1974.

Before a ranch was started, feasibility studies were carried out to identify vegetation (especially dominant forage species) and to determine wildlife composition, population, and the feasibility of water development. These feasibility studies to determine range-resource potential and viability of the production units were followed by allocation or allotment of land to organized groups for livestock-production (ranching) purposes. The mode of allocation of stateland and open trustland areas for commercial ranching is as follows:

- The Range Management Division identifies land suitable for ranch development.

- The Ranch Management Division identifies and organizes groups with interest in forming a ranching company or cooperative society of the area or district.

- The District Agricultural Committee (DAC) and District Development Committee (DDC) approve the development of the area. At the same time, the interested groups form companies. In the case of trustland, the application needs the approval of the relevant county council before going to DAC and DDC.

- The district range officer and a planner set up a program to produce ranch plans on the basis of priorities. At the same time, the recommendations of DAC and DDC are forwarded to provincial authorities for approval. The Range Management Division, Ministry of Water Development, and Agricultural Finance Corporation (AFC) are involved in preparation of ranch plans.

- The proposed ranching company applies for letter of land allotment from the commissioner of lands. It also applies, with assistance of the Range Management Division and AFC staffs, for a loan from AFC. The lease comes later, after the area has been surveyed.

Status of Commercial Ranches in Coast Province

Currently, Coast Province has 30 operating commercial ranches, but most of them use only the small part of their land where water is available. The ranches also tend to be understocked due to lack of capital for buying stock or unavailability of fattening steers. The supply of immature stock from northern and northeastern Kenya has been inadequate, though the ranches were planned for this type of enterprise to take advantage of the quick turnover of the steer-fattening operation. A few ranches such as Lualenyi, Taita, Kulalu, and Galana are well stocked. Lualenyi and Taita have become cow-calf operations by increasing their breeding herds, while Kulalu and Galana still depend largely on steer-fattening operations.

Other constraints that have slowed down development or caused financial hardships in the ranches were as follows:

- Drought. The drought of 1974 to 1976 made several ranches lose many livestock. This was a major drawback, especially for the ranches that had just started operation.

- Shareholder equity. The ranches were expected to raise at least 20% of their capital-development costs. The rest was financed through loans from the Agricultural Finance Corporation (AFC). In many cases, shareholders were poor and found it difficult to put up equity. Subscription of shares was very small and mostly through the contribution of livestock. This resulted in high-risk loan/equity ratios and financial problems.

- Management. Few managers had the necessary qualifications and experience. Moreover, many of the ranch directors had no experience in running large-scale ranches.

- Beef pricing. Beef prices and, consequently, livestock sale values did not increase with the rate of inflation, so the cost of inputs increasingly reduced the ranchers' gross margins.

- Damage by wildlife. In most ranches, wildlife create havoc by destroying water facilities and killing livestock. The wild herbivores also compete with livestock for forage and harbor disease-transmitting ticks, etc.

- Stock thefts. Cattle rustlers, at one time, became common in Taita and Lamu ranches. In both cases, the cattle were suspected to have crossed into the neighboring countries.

IMPACT OF RANGE-DEVELOPMENT PROJECTS ON COMMERCIAL RANCHES

There has been one major range-development project in two phases. It was sponsored by the World Bank and other donors. The project was called the Kenya Livestock Development Project. The first phase, which started in 1968 and ended in 1974, had the objective of increasing both marketed red-meat outputs and incomes of the human population living in rangeland.

This first project was considered a success since it developed more ranch units than planned: 108 ranch units developed, including 15 group ranches, against a total of 60 planned. Following this success, a larger and more complex second phase of the project was planned. It lasted from 1975 to 1982, after an extension of two years from its original closing date of December 1980. It provided for the development of group ranches, commercial ranches, feedlots, and communal grazing land in North-Eastern Province and wildlife areas in Masai Mara, Amboseli, and Nairobi Park. It also provided for improvement of livestock-marketing facilities and technical services, including staff training. The complexity of this second phase contributed to making it less successful than the first phase.

The Kenya Livestock Development Project was a major booster of commercial ranches. Nearly all the ranches in Coast Province came about as a result of this project. Commercial ranches in the traditional ranching areas were assisted to carry out incremental developments, such as water supplies, and to purchase more livestock in the first phase. The project assisted 93 ranches (42 existing ranches, 10 new ranches, and 41 individual ranches in Kajiado) during the first phase. In the second phase, 377 units were developed, including 303 individual ranches in Kajiado that were not included originally in the project but were accepted later. The remaining units were 55 ranches in the traditional ranching areas and 19 ranches in the new areas.

DISCUSSION

Commercial ranching in Kenya has been a source of good-quality livestock, including the improved Boran and Sahiwal breeds of cattle. Many ranches are being subdivided to meet the needs of the increasing human population whose inherent wish is to own an individual parcel of land. But the needs of these people for red meat -- the major source of protein -- must be considered. Subdivisions of land in arid or semiarid land need to be checked to avoid a shortage of red meat in the near future.

The ranches in the Cost Province have started only recently. The ranches listed in this paper cover a small percentage of the land that can be developed in this area for meat production. Moreover, the existing ranches use only a portion of their land because the other portions are not developed yet. There also are a few other possible

ranching areas in Eastern Province. The ranches already proposed (some already having letters of land allotment) and the total covered are:

Location	No.	Area (ha)
Taita	8	90,000
Kwale	1	32,000
Kilifi	3	100,000
Tana River	10	385,000
Lamu	4	70,000
East Kitui Statelands	4	340,000
Meru	3	55,000

In addition, individual ranches that are scattered in various parts of the country should be encouraged to operate on commercial basis.

The commercial ranches are outlets for livestock from the northern and northeastern drier rangelands since the immature stock are brought to these ranches for finishing before slaughter. This helps reduce grazing pressure in these dry areas and, in effect, reduces or stops possible desertification, as well as providing ready markets for the pastoralists' livestock. The nation had much to gain by sustaining and encouraging commercial ranching.

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Table 1. Status of ranches in traditional ranching areas.

District	Number of ranches	Subdivided ranches	Partially subdivided or in progress	% subdivided or being subdivided
Machakos	26	1	6	27
Nakuru	66	16	10	39
Laikipia	41[a]	16	2	44
Totals	133	33	18	38

[a]Figures include only those assessed recently by the district range officer. Ranches (excluding mixed farms) are about 60 in Laikipia (ILCA, 1979).

Table 2. Operating commercial ranches in Coast Province.

District	Ranch	Type of ownership	Size (ha)	No. of share-holders
Taita	Taita	Company	41,000	50
Lualenyi	Lualenyi	Company	43,460	52
	Sagala	D.A. Company	18,515	50
	Rukinga	Company	34,000	48
	Kasigau	D.A. Company	21,189	173
	Maungu	D.A. Company	21,619	110
	Mgeno	D.A. Company	21,232	356
	Wananchi	D.A. Company	8,500	-
	Mkuki	Company	2,060	7
	Choke	Partnership	10,000	2
	Kishushe	Cooperative	24,282	90
	Wangala	Individual	2,025	1
	Ndara	Individual	2,060	1
Kwale	Taru	Company	20,720	50
	Kenya Triangle	Company	81,750	17
	Lunga Lunga	D.A. Company	61,975	99
	Dokata	Company	10,400	-
	Mwambeja	D.A. Company	40,760	16
Kilifi	Giriama	Company	25,000	50
	Kulalu	Parastatal (ADC) and Kilifi County Council	80,000	
Tana River	Ida Sa Godana	Cooperative	51,000	99
	Giritu	D.A. Company	42,340	360
	Wachu	D.A. Company	30,725	90
	Kitangale	Company	23,540	50
	Galana[a]	Company	607,000	11
Lamu	Amu	Cooperative	25,000	228
	Witu-Nyongoro	D.A. Company	32,000	118
	Nairobi	Company	23,000	4
	Bujras	Individual	8,000	1

[a]Galana ranch straddles the Kilifi/Tana River district boundary with 27,600 ha in the Kilifi District. It uses about half of the ranch for beef cattle production; the rest is undeveloped.

RANCH PLANNING IN KENYA

Z.J. Mwangi

INTRODUCTION

It is now apparent to many countries that realistic planning is a prerequisite to any successful implementation of development programs or projects within any sector or subsector of the economy. Planning charts a course of action for the future with an aim of achieving a consistent, coordinated set of operations that will yield desired results. Kenya's rangeland comprises more than 80% of the land mass, and its varied resource endowment calls for proper planning if sustained production is to be fostered and degradation halted.

Agricultural planning in Kenya, in a rural context, had its main origin in the 1950s with the publication of the Swynnerton Plan (Swynnerton, 1954). The practice gathered momentum after the attainment of independence in 1963; and since 1964, planning for the total economy has been undertaken through the 5-year national development plans, in which the agricultural sector figures prominently. During the post-independence period, emphasis and direction in overall planning has changed, and strategies have been revised and reoriented to fit both the global economy and national aspirations. One of the notable changes has been the swift change in emphasis from capital-intensive projects to those relying on available local resources to meet basic human needs. Planning for and developing the arid and semiarid lands also has received much more attention than in the past.

PAST RANCH AND RANGE PLANNING

The earliest organized, wide-scale ranch planning occurred from 1946 to 1962. Specific schemes for known areas were marked for definite infrastructure developments or certain range treatments such as bush control. A more intensified development plan (Swynnerton, 1954), sandwiched into this period, advanced the planning exercise by targeting yearly production offtakes from the schemes to be developed.

However, it was not after 1963 that ranch and range planning received much more emphasis in Kenya with the establishment of the Range Management Division. The government of Kenya then quickly signed an agreement in 1964 with the United Nations Settlement Fund to strengthen and staff the Range Management Division.

The division was created mainly to address itself to planning and developing the vast Kenya rangeland. Its major task was to develop a plan for stratified livestock production on a national scale. Its first plan was submitted to the International Development Association for financing in 1965. This was later to develop into the first Kenya Livestock Development Project, from 1968 to 1973, which was followed by a second phase from 1974 to 1983.

Ranch planning as an art has changed very much over the period. The initial plans were global; that is, they were not detailed enough to allow for sufficient economic analysis. While the plans were useful for infrastructural developments, they remained unacceptable for loan-processing purposes. This proved costly and time consuming since

funding for ranch development can be based only on well-thought-out and financially acceptable proposals.

It was not until 1975 and 1976 that a proper foundation was laid -- through on-the-job field training -- to produce plans that were geared for loan applications. By that time, implementation of the second livestock project was behind schedule by almost four years; as a result, many plans have been produced for funding quickly and theoretically without much consultation or involvement with their beneficiaries.

CURRENT STATE OF THE ART

Two steps must be taken before the ranch planners can come up with a proposal for appraisal and funding: data collection and ranch projections. This presupposes that a project (in this case a ranch project) has been identified and all that is required is to collect pertinent data for use in drawing up an acceptable and implementable ranch plan.

Data Collection

Once a location has been selected for ranch development, the first move is to assemble all relevant information that will assist in the development of the ranch plan. This data is best collected through a questionnaire that incorporates an inventory of existing resources within the area for which plans are being made. It is particularly important to pick out factors or resources that can advance or deter the development of the area as a ranch entity. The questionnaire should call for information about:

- Name of the ranch, its size, its status, etc.

- Location

- Ecology
  a. Agro-ecological zone
  b. Rainfall
  c. Topography
  d. Soil types
  e. Vegetation types

  It is advisable to sketch the extent and coverage of both soil and vegetation types as this will help in determining carrying capacities or different treatments for given sites.

- Intended production or marketable product

- Stock carrying capacity
  a. Present
  b. Potential

- Current land use

- Game types, populations, and concentrations

- Existing problems, if any
  a. Livestock
  b. Social (Is the intended production system acceptable?)
  c. Soils and vegetation
  d. Infestations (insects and other pests)

- Livestock and family populations and distributions

- Present management system
  a. Livestock and pastures
  b. Wildlife
  c. Others

- Itemized appraisal of available resources
  a. Capital developments
  b. Livestock
  c. Moveable items

- Sources of credit, if known

- Market outlets

- Impact statement -- environmental and social. Possible ramifications of the development effort should be highlighted since they may affect the direction, nature, or scope of the program.

A map should be included that indicates the locations of existing and proposed developments, prominent landmarks, features, boundaries, etc.

Ranch Projections

After establishing the resource base, identifying possible development constraints, and considering the target group's wishes and aspirations, then herd and financial projections must be done to establish the viability of the undertaking. Financial rather than welfare approaches have been emphasized since nearly all ranch developments rely on loan funds.

The first step is to establish some basic parameters or coefficients that affect both the nature and level of the intended production. These must be based on actual performance as of the predevelopment period; however, the coefficients can be adjusted according to forecasted improvements in technology over the development period. Such parameters for both cattle and small stock (sheep and goats) include:

- calving, lambing, or kidding rates
  a. percentage for the first 5 years
  b. percentage for the rest of the projection period

- mortality rates
  a. adults
     1. starting percentage
     2. percentage after 20 years
  b. calves, lambs, or kids
     1. starting percentage
     2. percentage after 20 years

- culling rates
  a. percentage of males
  b. percentage of females

- ratio of females to males

- cost per head

The coefficients for small stock will be different than for cattle because the smaller animals call for different management levels and production coefficients.

One basic assumption for both categories of livestock is that the sex ratio at birth and at weaning remains at 50/50.

Stock Coefficients

Stock coefficients must be established for each category of livestock -- bulls, cows, age classes, small stock, and other types of livestock proposed to be maintained on the ranch. Experience based on food consumption has shown stocking units to be roughly:

Animal	No. SU
Bull	1.0
Cow/calf	1.0
Bull or cow, 2-3 yr.	0.6
Bull or cow, 1-2 yr.	0.4
Small stock	0.125

The rest of the projection comprises the six following basic tables.

Table 1 -- herd projection. The herd-projection table applies the parameters already established to the predevelopment stock numbers to project the number of stock over the project's life. If no predevelopment stock exists, then the planner (in conjunction with the ranch owners) must determine the initial capital stock and then project this over the intended project life.

Since the main objective is to balance the feed available and stock within the ranch, the projection must include all livestock -- cattle, sheep, goats, donkeys, etc. -- expected to be maintained within the ranch. The end-of-year stock numbers then are converted to stock units to make them more meaningful. Game also must be allowed for in the projection.

Since fire, droughts, and human error are common phenomena in ranching, a contingency measure also must be included to cover these; therefore, under normal circumstances, projections do not result in absolute balance between livestock requirements and estimated feed within the ranch boundaries at any one given time.

Table 2 -- livestock transaction. The livestock-transaction table has three main components:

- Purchases. All livestock purchases, except for the breeding stock during the development period, must be indicated in this table in both numbers and total cost.

- Sales. The number of all animals to be sold within any given year must be recorded and total revenue from the sales indicated.

- Other income. this is applicable when the project expects to receive income from other sources such as small stock, wildlife, minerals, etc.

Table 3 -- proposed new investments. Capital developments needed for the smooth operation of the ranch are shown in table 3, which includes

breeding stock and capital developments such as dips, houses, office blocks, initial cost of construction of firebreaks and access roads, water infrastructures, logistic support, etc. It is very important at this stage for the planner to work with the appropriate technical specialist in deciding and locating various infrastructures within the ranch.

The purchase of breeding stock is treated as capital acquisition, unlike the purchase of immature stock whose value is realized over a long period. Therefore, purchased breeding stock is capital stock rather than inventory in the development context.

The capital expenditure must be shown for the years in which the investment is to be made. One crucial observation here is that, while past projections have assumed that most capital development can be carried out in 3 to 5 years, this has never been the case. It is impossible to develop a ranch in 3 to 5 years, and no ranching country we know of has accomplished this. A phased-up development program is required if favorable equity is to be maintained. Management levels also call for gradual development rather than one short investment.

The bottom line of table 3 should indicate the net capital to be borrowed after allowing for about 20% of total capital requirements to be raised as equity.

Table 4 -- operating expenditure. The operating-expenditure table groups all operating expenses into a single expenditure. In most cases, the size of this outflow component is second only to capital investment (table 3); however, it runs throughout the project's life, while capital costs are incurred during the investment period. Operating expenditures should include costs of

- top and middle management

- operation and maintenance of
  a. development capital (percentage of base cost)
  b. water
  c. vehicles

- variables -- herdsmen, drugs, minerals, etc., depending on livestock populations on the ranch

- breeding male replacements (Breeding females are selected mainly from the ranch stock.)

- other

Table 5 -- cash flow. A cash-flow projection is required in any enterprise to indicate both the magnitude and timing of monetary resources within the firm. A glance at the bottom line of the cash-flow table should indicate the worthiness of the ranch project. This is important to the ranchers and the financiers since the ranchers are interested in knowing whether they can make money from the new investment while the financiers want to evaluate whether the project is bankable.

Any cash flow table should include

- sources of funds (sales, loans, etc.)

- uses of funds (expenses, debt servicing, etc.)

Current projections take into consideration the 3-year grace period in principal repayment, a 12% to 14% interest charge (depending on whether it is a capital loan or operating-expenses loan), and a 15-year principal repayment period. These considerations have changed over time and are bound to change in the future.

Table 6 -- internal rate of return and net present value. The internal rate of return represents the average earning power of the money invested in the ranch project over its projected life. Net present value indicates the discounted total contribution by the project to the ranch enterprise.

To put it another way, the internal rate of return is the return that allows for a breakeven situation. At the given calculated rate, the project will earn back all the development and working capital expended upon it and pay the investors (ranchers) the indicated percentage return for the use of their money. The internal rate of return helps the investors reaffirm such issues as the earning power of the resources invested in the project and whether the return is higher or lower than the market interest rate.

For a better conclusion on the actual value of the project, the total project should be subjected to a sensitivity analysis.

Sensitivity Analysis

Sensitivity analysis allows the projected output and performance of the project to be tested for risks and uncertainty. The cash flow and internal rate of return should be tested for degree of sensitivity to parameters such as

- lower or higher calving rates
- lower or higher mortality rates
- increase in immature purchases
- increase in capital costs

We are aware of the uncertainty and risks that beset all projects, even though we base project outputs on the best average conditions. This test indicates which parameters make the internal rate of return much more sensitive.

PROCESSING THE RANCH PLANS

Once the plan has been completed at the district level, it is forwarded to the Nairobi head office through the Provincial Range Office. At the head office, the plan is received by the respective section head who scrutinizes it, calling for any further field clarification before preparing it for the Interministerial Planning Committee. The committee's major role is to appraise the feasibility and viability of the plan for loan purposes. This is the last stage of ranch planning before funding. Once the proposal is accepted by the committee, it is forwarded for loan consideration. Plan implementation starts when the funds are available to carry on the developments and to stock and operate the ranch.

CONCLUSION

The approach to ranch planning in Kenya has gone through various changes over time. The postindependence era has seen more emphasis on micro-planning with the intensification of ranch development in the country. However, it was not until the mid-1970s that ranch planning improved enough that plans could be used to test ranch viability.

Ranch planning involves two major steps. The first, assuming that the project has been well identified, is the collection of relevant information that will be used as the base data in the herd and financial projections. The second stage is to lay the plan on paper, mainly in the form of herd and financial projections, and to test it for sensitivity to various risks and uncertainties related to ranching activities.

It is also important, during the later stage, that the grazing and management plans are incorporated in the total plan. The final plan should thus have grazing charts showing the timing and sequence of stock movement or paddock transfers and a map showing the locations of handling and water facilities and any other infrastructure.

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MULTIPLE USES OF RANGELANDS IN KENYA

W.K. Ottichilo and H.A. Mwanda

ABSTRACT

Many rangelands are capable of meeting the needs of multiple users. These needs include keeping livestock, conserving wildlife, recreation, conserving watershed and soil, and producing timber and fuelwood. The importance of each use depends on the stage of development and goals of the particular country or society. In the less-developed countries, the need for protein may outweigh other considerations and dictate livestock production. In the more-developed countries, concurrent demands arise for many products or services. The multiple-use concept is difficult to implement even in the more-developed countries because it requires all possible land uses to be accommodated. However, none of these uses can be optimized without positive or negative impacts upon others. Therefore, it is the task of the range manager/resource planner to integrate all of these uses so that complementary relationships are enhanced and competitive relationships are minimized.

In order to implement multiple-use concepts in rangeland-resource planning and management, it is of paramount importance to know not only where and when two or more products can be produced jointly but also the circumstances under which it is in the social interest to take advantage of the technical opportunities to produce more than one product. Thus, multiple-resource planning should involve the following:

- rational planning for the betterment of both the resource and the users
- information gathering and analysis (both technical and socioeconomic)
- sound and complete problem analysis
- project implementation, evaluation, and monitoring

INTRODUCTION

Though the multiple-resource-use concept has not been infused into the planning, use, and management of most of the world's rangelands, public ranges in the United States are managed under a multiple-use philosophy in which an effort is made to accommodate all the possible land uses for which there is a need or demand (Stoddart et al., 1975). However, before modern intervention into rangeland-use activities (especially in Africa), the multiple-use concept already was practiced. Thus, living in balance with the environment was an integral component of the human culture (Lusigi, 1981).

In many parts of the world, the former balance between the rangeland environment and human activities has been disturbed or is being disturbed by the increasing human population and consequently increased human activities on the rangelands. The rangeland environments are fragile and thus need proper management if their sustained production is to be realized and maintained. In this paper, we have attempted in a modest way to review multiple-use planning and management procedures, particularly those that result in optimal and sustainable production of

the rangelands. We have further described some examples of multiple resource use as practiced on the Kenyan rangelands, noting their successes and failures.

PLANNING PROCESS FOR MULTIPLE RESOURCE USE

The planning process for integrated resource use entails the following steps (Jameson et al., 1982): First, it involves the identification of issues and concerns at hand. This is then followed respectively by development of planning criteria, assessment of resources, formulation of alternatives, estimation of effects of alternatives, evaluation and selection of the preferred alternatives, implementation of the plan, and monitoring and evaluation of the plan. In the context of multiple use of the ranges, the people who depend for their livelihood on these ranges must be involved at all stages of the planning process, and their views and aspirations should form the basis of formulation of alternative uses of the ranges.

ISSUES AND CONCERNS

Identification of issues and concerns is the first step in the planning process, but it does not necessarily precede all other steps in time; some planners may have had previous experience with public participation in activities that enable them to develop a preliminary list of public issues. The identification of issues, concerns, and opportunities follows a six-step procedure:

- Identification of sources of appropriate inputs.
- Recruitment of participants, which should include individuals and agencies.
- Definition of types of inputs needed, including their sources. It is important for an interdisciplinary team to be involved in identifying the issues and concerns and the way they will be used, including the types of inputs needed, before any activities are scheduled.
- Collection of desired input from appropriate parties; that is, talking with knowledgeable informants.
- Analysis of the inputs received content analysis.
- Approval by the responsible officials.

Identifying, analyzing, and screening issues should culminate in the writing of one issue statement, which should summarize the essence of the conflict at hand and the different interests affected by it. The issue statement forms a basis for formulation of alternatives, selection of alternatives, monitoring, and evaluation.

DEVELOPMENT OF PLANNING CRITERIA

Three kinds of criteria shape and direct all aspects of the planning process: public policy criteria (not available in most developing countries), process criteria, and decision criteria. The process and decision criteria must be developed by the planning and management teams. The process criteria establish standards for:

- the quality, accuracy, and reliability of data

- the efficiency and effectiveness of analytical tools

- the conduct of public involvement activities

- the presentation and writing of the plan and its environmental impact statement

The decision criteria are first used in the analysis of the management situation to define a reasonable range of resource-production possibilities. The screening of production possibilities continues in the formulation of alternatives. Here trade-offs among resource outputs are explored, and alternatives deserving further study are identified based upon public demand for these resources and national production goals.

RESOURCE ASSESSMENT

Resource assessment includes assembling, organizing, and indexing the existing database plus performing the analyses required to assess the situation, make an initial problem analysis, and set goals and objectives. It also involves identification of new information needs. The resource assessment may proceed in three ways:

- interviews and skilled observation, with limited mapping, by an individual or a team of experts

- a single-purpose survey or inventory (for example, to meet range-management or agronomic needs only)

- an integrated ecological analysis intended to service projects in several land-use or technical-development areas

Acquiring and analyzing information involves filling information gaps through literature searches, interviews, and surveys. Information acquisition for rangeland development is essential for recognizing the central points of interest such as the relationships between the vegetation types and their environment, plants and animals, and the rangelands and the cultivated lands; the integration of feed supplies; and possible conflicts in land use. The parameters for which information is required to effect range development and management planning can be grouped into three categories: abiotic environmental factors, biotic factors, and cultural factors. The cultural factors include the existing infrastructure and settlements and current land use.

Abiotic Factors

The abiotic environmental factors include topography/landform, soils, climate, and water. The mapping and characterization of landform and relief are important because of their influence on soil stability and on land-use and grazing-management decisions. Detailed soil information within an ecological region is particularly relevant to plant growth, erodability, and resource use. Climate information is basic because of its significance in vegetation and soil development and productivity and in determining cropping potential. Lastly, the distribution and availability of water is important because of its impact on how animals and humans use the land.

Biotic Factors

The biotic factors include vegetation, animals, and human society. The goal of a vegetation inventory is to characterize and map ecosystems and ecological conditions as they vary across the landscape so that similarities and differences in the land productivity and potential are more readily understood by the planners and managers. Observations and measurements made in the vegetation inventory include plant growth forms, species composition, plant-community structure, seasonal vegetation productivity, and vegetation condition and trend.

Domestic and wild animals vary significantly among and within species as to their food requirements and preferences, their responses to environmental conditions, their management requirements, etc. The types of data that should be collected specifically for domestic animals include species, breeds, numbers, distribution, structure of the herds, reproduction rates, mortality rates, and probable causes of death. Wildlife assessment for range projects should provide certain data on animal population to make management possible. The kinds of information needed include the following:

- density in terms of numbers or biomass and, where possible, trends
- structure of the population in terms of age and sex
- information on birth rates, mortality rates, mating behavior, etc.
- baseline studies
- attitudes of the local people toward wildlife

All resource assessment is concerned ultimately with management aspects of relevant ecosystems. In this context, the assessment of the people of the rangelands takes on a particular relevance, as they are the principal actors and the ones acted upon in the rangeland drama. Central to understanding rangeland people is an appreciation of their ideal and real behavior. The ideal relates to their goals and deep-seated attitudes.

FORMULATION OF ALTERNATIVES

The information gathered during the first four planning steps (identification of issues, concerns, and opportunities; development of criteria; collection of inventory data; and analysis of the management situation) is combined and analyzed to formulate alternative plans suitable for evaluation and presentation of an environmental impact statement.

The purpose of formulating alternatives is to develop plans that will best satisfy the identified public issues and management concerns and take advantage of resource-management opportunities. The planning team must develop alternatives that attempt to resolve society's increasing demand for scarce resources in the most efficient possible way. The formulation of alternatives takes into account the complementary and competitive relationships among the goods, services, and uses produced. A "no action" alternative, which describes the future condition of the resource if the current management direction continues unchanged, should be included.

The alternative chosen must be economically, environmentally, and technically feasible and provide for the orderly elimination of any backlogs or treatment needed to restore resources for multiple-use objectives. Each major public issue must be addressed in at least an alternative

plan. Each alternative must present the timing and flow of outputs as well as resource-management standards and guidelines. Both management and interested publics should be able to understand the purposes of the proposed management direction.

ESTIMATED EFFECTS OF ALTERNATIVES

Estimated effects of alternatives are expected consequences of implementing an alternative. Examinations of the effects of alternatives are used to measure their consequences -- physical, biological, social, or economic.

EVALUATION AND SELECTION OF THE PREFERRED ALTERNATIVE

In choosing among alternatives -- different social demands for goods and services -- a number of broad public-policy criteria must be satisfied. The evaluation and selection phases of the planning process are concerned with weighing the alternative plans against these broad public-policy criteria. In general, the planning step of formulating alternatives is concerned with devising ways of satisfying social demands, policy requirements, and administrative priorities. The evaluation step is a formal assessment of how well the alternatives accomplish these tasks, especially with regard to policy requirements and administrative priorities. However, the distinction between these two steps of the planning process is thin.

IMPLEMENTATION OF THE PLAN

Implementation is a continuous activity composed of three annual processes: program budget proposals, program budget allocations, and project implementation. During the implementation of each plan, the following minimum requirements must be met:

- The responsible official must assure that annual program proposals and implemented projects are in compliance with the plan.

- Program budget allocations must meet the objectives and be consistent with all applicable standards and guidelines specified in the plan.

MONITORING AND EVALUATION

A system must be designed to monitor work accomplishments, project costs, and receipts. Without this basic data that indicate whether a practice has been implemented, monitoring to determine the effects of the practice makes little sense. The monitoring analysis should:

- identify factors that influence or are influenced by decisions
- help interpret the results and simplify what needs to be monitored

This continuous feedback is vital for keeping track of progress and anticipating problems that may require the program to be redirected or fine-tuned.

SOME EXAMPLES OF MULTIPLE USES OF RANGES IN KENYA

The Kenya rangelands, which form the main grazing land for livestock and wildlife, constitute about 80% of the country's area. About 75% of livestock in Kenya are found on the rangelands -- in 1980 and 1981, 12

million livestock used the Kenya rangelands (Republic of Kenya, 1983). These livestock support over 500,000 pastoral people inhabiting these areas and contribute significantly to the economic development of the country. So, apart from their value as recreational, water-catchment, and crop-production areas, the rangelands provide essential livestock production.

No formal planning process, such as that outlined above, was followed in allocating the Kenya rangelands to various land-use activities; however, the ranges have been put to multiple uses, though not at optimal levels. The ranges are predominantly used by livestock and wildlife for grazing. This use has been facilitated by niche segregation among different species and resource partitioning (Lamprey, 1963). However, the problem of forage competition is a major factor in livestock and game production on the Kenya ranges. Some of the factors that influence competition include similarities of diet, kinds and amounts of forage present, intensity of grazing, and condition of the range. With the ever-increasing human population in these areas, the competition has intensified as a result of the increase in livestock numbers. Thus, a major conflict has arisen about whether the ranges should be used exclusively by livestock or continue to be used by both livestock and wildlife. The crux of the matter in this conflict is that if wildlife is to continue to have access to the rangelands that are now being brought under direct, conscious management, it must yield returns to the ranches that are at least equal to the returns from the livestock and other activities that could replace it. Also, rural landowners must be rewarded for preserving wildlife and compensated for the damage, stock losses, and loss of human life or injury attributed to it (FAO, 1978). Thus, for livestock and wildlife to continue to coexist on the rangelands, there is an urgent need to resolve this conflict through the planning and management process discussed above. With proper and integrated planning, the rangelands still have the potential to be managed for both livestock and wildlife on a sustained-yield basis and for the betterment of the people who reside in these areas.

Parts of the Kenya rangelands have been designated as national parks and game reserves. These parks occupy about 7% of the land area of Kenya. the parks and reserves have been established to conserve wildlife and its environment because they are nonrenewable parts of Kenya's natural heritage and because of their aesthetic value. These areas also are used extensively for recreational activities (game viewing, game photography, etc.) and research. They are visited annually by thousands of tourists who bring into the country a lot of foreign exchange; thus, the tourism industry is very important in Kenya's economy. Tourism is the second-highest earner of foreign exchange in Kenya and has generated many employment opportunities in various sectors of the economy. Apart from tourism, other wildlife-related activities include sport hunting and game cropping. Until the presidential ban on wildlife hunting (Kenya Gazette, 1977), sport hunting was an important activity and source of foreign exchange. The ban on hunting was imposed as a result of a drastic decline in certain wildlife species. Since the ban, most of the wildlife populations have recovered and are thriving. Thus, with the enaction of proper regulations and controls, sport hunting can be reintroduced in Kenya, since it has a high potential of contributing to the economic welfare of the country.

Game cropping has been carried out on a very limited scale in Kenya (Caughley, 1972; Blankenship and Qvortrup, 1974); however, it has the

potential to contribute to the economic welfare of the country. Experience in southern Africa indicates that well-planned and -managed game-cropping programs can be important and viable activities (Wolfgang and Butynski, 1974). Problems that have hindered game cropping include lack of markets for the game products, infrastructure, institutional structure, experienced manpower, and information regarding the population dynamics of the wildlife species concerned (Ottichilo and Andere, 1982). Also, lack of involvement of the local people has further thwarted attempts to introduce game cropping. However, the potential still exists. What is needed is to gather reliable, ongoing scientific information regarding the population dynamics of each species in question in relation to the entire ecological situation and land-use objectives. Also, feasibility studies must be made on the marketability of wildlife products and the possibilities for canning wildlife meat for foreign and local markets. As a whole, Kenya's wildlife has great potential for rapidly increasing returns if managed correctly. Long considered merely an obstacle to good farming and ranching, it is now appreciated as a form of land use, bringing Kenya valuable foreign exchange and capable of useful returns of protein and other products (Republic of Kenya, 1972).

Kenya rangelands also have been used for water catchment, soil conservation, range afforestation, and crop production. Range-afforestation programs have been initiated recently to compact or arrest the deteriorating environmental conditions in these areas. These programs are aimed further at providing extra forage material for livestock and fuelwood for the local people. Research is being conducted on the most suitable tree species (such as Luecaena spp.) to be used. Crop production in the rangelands has been carried out at a very limited level and in restricted areas (usually along river courses or valleys) using local technology. Recently, large-scale crop production based on irrigation has been introduced in some areas (for example, Tana River). These schemes have not been as successful as possible due to technical problems and noninvolvement of the local people in the planning stages. Their long-term impact on the environment has not been clearly assessed. There is an urgent need to reassess the use of the rangelands for large-scale crop production.

While the Kenya rangelands have been put to a range of multiple uses, these uses have not been well coordinated and conflicts are still unresolved on the best form of land use in some of the rangeland areas. There is a need to re-examine some of the uses to which the rangelands have been put and to come up with alternatives based on local needs and demands and land capability.

CONCLUSION

Multiple use of the rangelands should be accorded high priority if these areas have to sustain the ever-increasing human population that resides on them. While the concept of multiple use is hard to implement, every effort should be made to infuse this concept into our national planning process for the rangelands. Of paramount importance is that the people who reside in these areas should be involved in all stages of planning, and their needs and aspirations should be incorporated in the chosen development plans. For the multiple-use concept to be applied effectively, integrated or interdisciplinary resource-planning strategy should also be adopted in all development-planning processes. Also, linear programming, which is a mathematical technique for solving a

problem of allocative choice, should be used in the planning process (Jameson et al., 1982).

Available evidence indicates that the rangelands can offer sustained yields for a range of uses. What is lacking in most countries is the proper political and institutional framework that can coordinate planning and management of the rangelands.

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LAND-USE PLANNING IN KENYA

Moses Ooro Olang and Eliud Maritim

INTRODUCTION

Land-use planning has different meanings to various people, depending on the intended purpose of a plan. Essentially, land-use planning is an apportionment of land resources within their capacities to sustain continued use. Land-use planning, which can be used to devise a proposed method or scheme of action, can be done at various levels depending on the details required. Broadly, there are three categories: ecological, sectoral, and individual; however, they can be used together to achieve desired objectives. In Kenya, land-use planning concepts have been used with various degrees of success.

LAND-USE PLANNING

Land-use planning, in effect, is a systematic analysis of available land resources and the extent to which they can be exploited without impairing their capacities to sustain exploitation. It is a rational way of meeting human needs from the use of land. Lined up behind these human needs are cultural, economic, historical, and functional values attached to land resources. In its basic concept, however, land-use planning is a guideline for the proper apportionment of land resources within their fitness for a defined use.

Objectives of land-use planning are as varied as are the circumstances under which the land resources are to be used. Normally, the objectives are specific to any thought-out adjustments. Broadly speaking, there are three major objectives in land-use planning:

- to apportion land resources according to their abilities to sustain use within ecological tolerance
- to meet specific sectoral development aspirations according to society's values and economic capabilities
- to achieve individual desires in terms of development within a land unit

CATEGORIES OF LAND-USE PLANNING

Land-use planning falls under three broad categories, each with a specific set of considerations and end use:

- ecological
- sectoral
- individual

Ecological

From the point of view of ecology, land-use planning aims at delineating an entire land-resource base into units with distinct ecological components that can support different life systems. Environmental variables, such as climate and soil factors, that tend to sustain specific ecosystems are the major determinants of this category. In Kenya, as well as

in other parts of the world, this approach has been used to map out different ecological zones (Pratt and Gwynne, 1977). In practical terms, ecological zones are useful mainly as a broad framework for more detailed land-use planning.

Sectoral

Sectoral land-use planning entails more detailed analysis of resources and more defined uses than ecological planning. The three major areas considered in this category are agricultural, river-basin, and urban land-use planning.

For agricultural land-use planning, the emphasis tends to be on defining an area on the basis of crop and livestock suitability zones. The main determinants are agroclimatic factors (mainly moisture supply) and soil pattern. The main zone groups, known as agroecological zones, are temperate belts defined according to the maximum temperature units within which main crops can flourish (Jaetzold and Schmidt, 1983). They are based on their probability of meeting the optimum temperatures and water requirements for crops. By using these zones, a land-use planner can identify, in broad outline, the most suitable areas for certain crops.

River-basin planning is not a new concept. Water-resource development offers the attractive prospects of assisting the relatively deprived regions where the environment is harsh (Wiley and Sons, 1981). The physical characteristics of a basin form a relatively cohesive hydrological and ecological system that can be used as a unit for development planning, with water as the central consideration. River-basin planning does not necessarily concern itself with specific, isolated problems such as flood control, irrigation, or hydropower generation; but it does take into account other resources and many aspects of socioeconomic or regional importance (OAS, 1978).

Kenya has three river-basin development authorities mainly concerned with the planning and use of resources within their drainage basins:

- Tana and Athi Rivers Development Authority, which is mainly concerned with the two basins of Tana and Athi that drain the eastern part of Kenya

- Lake Basin Development Authority (LBDA), concerned with the Lake Victoria Basin

- Kerio Valley Development Authority, which deals with parts of the western and Rift Valley drainage areas

Urban land-use planning or physical planning concentrates on the design, growth, and management of the urban sector. The major concerns of urban land-use planning are

- to provide a planned spatial framework of development within which a balanced program of social and economic development can be carried out

- to provide a legislative mechanism for control and implementation of devised plans

The main factors controlling urban land-use planning include population needs, land availability and ownership, environmental conservation, and cost effectiveness.

Individual

Individual land-use planning is concerned essentially with the capabilities of land resources at the farm level. The primary consideration is the size of the resource and its constituent qualities such as rainfall, soil fertility, slope of the land, water resources, social values, and proximity to the market. The land-owner who is the end user of the plan is mainly concerned with the productivity of the land unit.

CONCLUSION

Land-use planning has been used in Kenya for a number of years, though the emphasis has been on the specific area of urban or town planning. However, the three categories of land-use planning have been applied by a number of planning agencies, but records of implementation or application of the resulting plans have been poor.

DISTRICT-BASED LAND-USE PLANNING MODEL

District-based land-use planning is, in essence, the evaluation of resources within the confines of a district and the extent to which the resources can be used to meet existing and future human needs. The present and future population occupies a central position in this kind of evaluation.

The major components of district land-use planning are

- population
  a. present and projected population, including density, distribution, and family size
  b. demand for basic needs such as food, water, education, health facilities, and communication

- land resources
  a. categories of land capabilities
  b. ecological classification of land
  c. land-use patterns; for example, for agriculture, livestock, forests, etc.

- infrastructure
  a. schools
  b. health care
  c. roads and other communication facilities
  d. electricity
  e. industries

- other resources
  a. minerals
  b. wildlife and game reserves

- current use of land, water, and infrastructure

- levels at which the existing resources are meeting the current demands

- demand/supply gaps
- development proposals to meet supply/demand gaps for present and future needs
- implementation and monitoring

Some of the information prepared for the Kitui District land-use plan is given as a case study following this paper.

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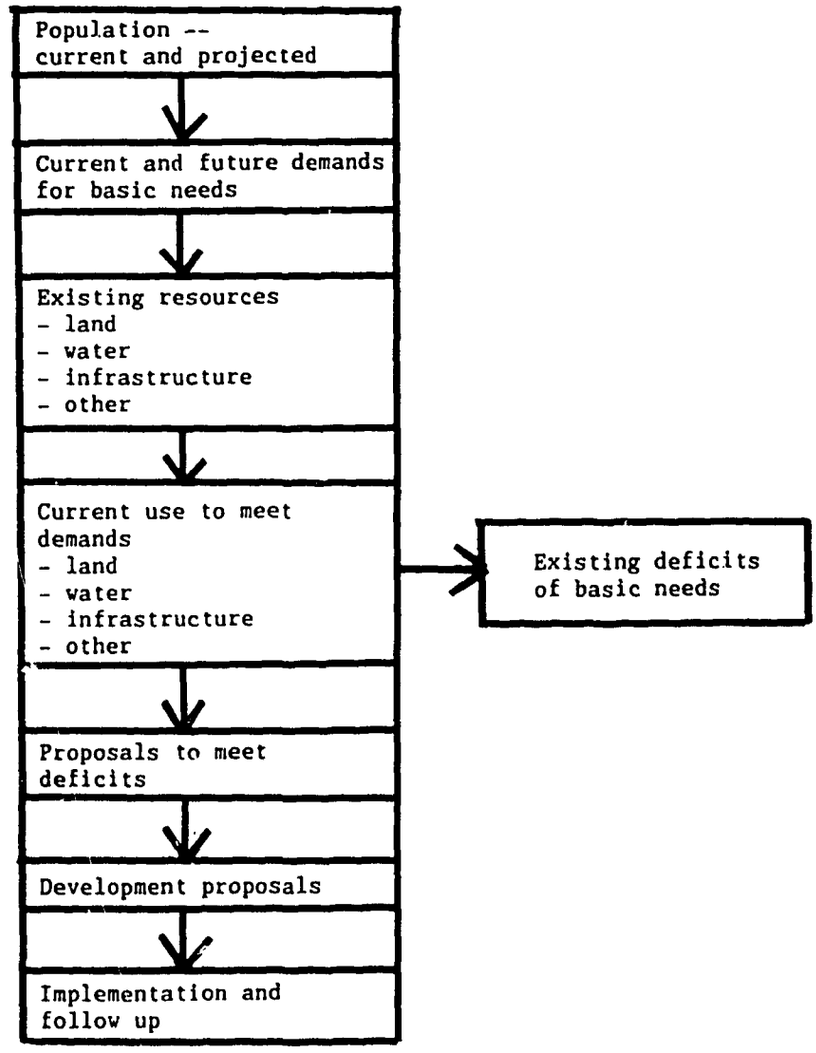


Figure 1. District-based land-use planning model.

LAND-USE PLANNING CASE STUDY -- KITUI DISTRICT

Development Objectives

a. Identify natural resources and review current development against the e natural-resource potentials.

b. Consider industrial and semiprocessing commercial sectors that are constrained by inadequate financing and lack of power.

c. Make the district self-sufficient in food production, and raise its economy's capacity to absorb local labor.

Basic Surveys (Data Collection)

a. Position, size, and topography.
   - Area is approximately 31,000 km^2.
   - The topography of the district is divided centrally into upland and lowland areas. To the east is featureless plain that drops from 600 m to 400 m above sea level. The upland areas to the west of the ridge range in elevation from 1,000 m to 1,763 m.

b. Climate. The rain falls in two peak seasons: April to May and November to December. June to October is a long dry period. Rainfall ranges from 1,190 mm to 300 mm. The highest rainfall is recorded in the central hilly area, then it falls to the east. Variation in mean annual rainfall is between 30% and 70%.

c. Minerals. Garnet, limestone, sillimanite, magnesite, coal, graphite, asbestos, and vermiculite are said to exist in the district.

d. Soils. A soil map with the legend was provided.

e. Ecological zones.
   - Ecological zone III, with rainfall between 760 mm and 1,190 mm, covers about 2% of the district.
   - Ecological zone IV, with rainfall between 450 mm and 800 mm, covers 37% of the district has a carrying capacity of 4 to 6 su/a.
   - Ecological zone V, with rainfall between 300 mm and 450 mm, covers about 60% of the district and has a carrying capacity of not less than 6 su/year.

f. Water. There are two permanent rivers, Tana and Athi, that form external boundaries. Other rivers, like Thua, hold water during rainy season.

g. Human population. The population of the district was 464,283 in 1979. The population growth rate in Kenya has been 3.5%. Urban population growth is at 7%.

h. Livestock numbers in 1983:

cattle	220,800
goats	298,000
sheep	80,800

i. Wildlife:

Year	Total Figures
1977	11,760
1978	12,850
1979	17,000

j. Honey production. In 1981, 94,000 beehives produced 216,270 kg of honey.

k. Poultry. In 1983, there were about 415,000 local birds and 8,000 improved ones.

l. Forest. In 1983, afforestation work had started on seven gazetted hills.

m. Ranches. In 1983, there were 12 existing ranches, and 12 more had been proposed.

n. Crop production. Production of major crops like maize fluctuate from year to year. Area under maize fluctuated from 25,500 ha to 65,900 ha between 1977 and 1983. Tobacco and cotton are the major cash crops in the district.

Land Evaluation

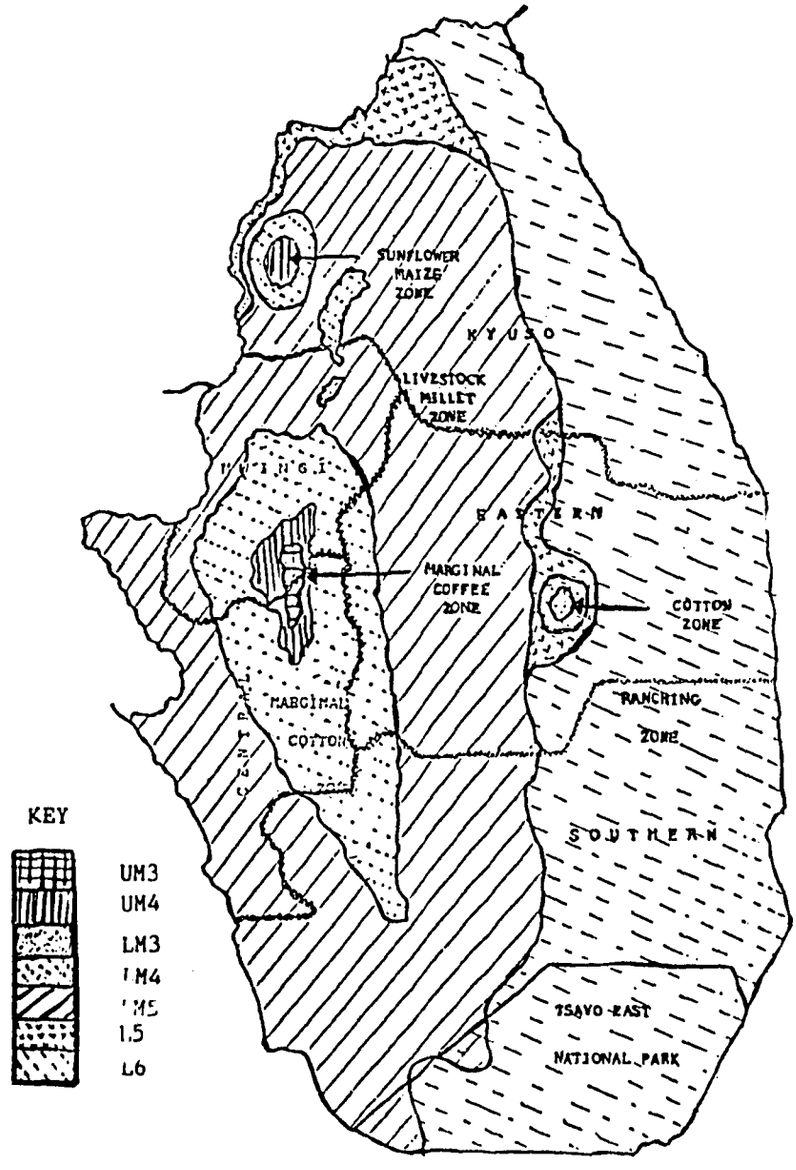
To assess agricultural potential, it was necessary to look at the agro-ecological zones of the district. The district is divided into seven agroecological zones based on altitude and rainfall as follows (figure 2):

Table 1. Agroecological zones.

Zone	Area (ha)	Altitude (m)	Annual rainfall (mm)
UM_{3-4} Transitional coffee zone	69,000	1,340-1,620	900-1,050
UM_4 Sunflower-maize zone	275,000	1,180-1,550	850-1,000
LM_3 Cotton zone	25,000	1,050-1,400	800-1,000
LM_4 Marginal cotton zone	2,533,000	760-1,280	720-1,000
LM_5 Livestock-millet zone	9,380,000	760-910	550-790
L_5 Lowland livestock millet zone	786,000	550-760	450-700

Table 1. Agroecological zones (continued).

Zone	Area (ha)	Altitude (m)	Annual rainfall (mm)
L6 Lowland ranching zone	6,996,000	No rainfed agriculture possible.	



DIVISIONAL BOUNDARIES

Figure 2. Agroecological zones.

a. Crop production. The district being semiarid and arid, it is marginal for agriculture. Crop failures are common due to lack of moisture since four out of eight seasons get less than 300 mm of rain a year. Rain falls for a short period, and this makes land preparation critical -- it must be done quickly. The ox is the main power source in land preparation.

b. Ranching. Most of the existing 12 and proposed 12 ranches are in LM_4 and LM_5. Land ownership and water availability are the main constraints in L_6. Most of the existing ranches are either company or cooperative. Yatta B_2 is the best-run ranch in the district.

c. Wildlife. The district has about seven species of wildlife occupying mostly the northern end of the district, the south, and a few in the eastern stateland. Elephants, giraffes, and oryx were the dominant species.

d. Woodfuel. The demand for woodfuel in Kenya by the year 2000 will increase by 12 million tons, while in Kitui it will increase by about 385,000 tons of woodfuel equivalent.

e. Honey. The marketing of honey is not well organized, and farmers are being exploited by middlemen.

Development Decisions (Land-use Planning)

It was observed that, while human population increases at 4%, food production increases at 2% in the district. The large difference between the two rates makes it very difficult to close the gap in food deficiency. At the moment, farm families are able to meet only half of their annual requirements for maize and beans. To increase food production, output per acre and output per worker must be increased. The farm model recommended a food-production plan that will create food surpluses in cassava, sweet potatoes, and sorghum that can be stored for drought years or used as feed.

a. Livestock development. Some of the existing ranching methods such as individual, company, and cooperative should be discouraged. Individual ranches are good, but there is not enough land; company and cooperative ranches offer little to individual members. Members prefer ranching organizations like grazing schemes in which they own cattle that they can milk or market. Members also can have some land for cultivation. Such schemes are recommended for L_5 and LM_5 while grazing blocks are recommended for L_6.

b. Honey production. Kenya Top Bar Hives should be increased since they produce about five times as much honey as the local hives. A cooperative society could be formed to market honey in the district.

c. Poultry. The number of improved hens must increase so egg production can increase from 90,000 to 270,000.

d. Minerals. Some minerals, such as coal, have been given priority for further investigation. Phosphate is important in the manufacture of fertilizer and, therefore, should be given priority.

Table 2. Food situation in Kitui District by year 2000 at 2% production increase rate.

	Present production level (tons)					Proposed production by the year 2000 (tons)				
Division	Maize	Beans	Sorghum	Millets	Cowpeas	Maize	Beans	Sorghum	Millets	Cowpeas
Central	16,236	3,450	324	135	2,168	21,837	4,640	435	181	4,260
Eastern	6,435	990	1,980	2,362	1,454	8,655	1,331	2,663	3,176	1,955
Southern	10,444	495	2,645	4,050	5,040	14,047	665	3,557	5,447	6,778
Northern	15,840	8,415	5,940	270	4,896	21,304	11,318	7,989	363	6,585
Far North	4,000	594	7,525	6,750	3,945	5,380	798	10,119	9,078	5,306
Production	52,955	13,944	17,413	13,567	18,503	71,223	18,572	24,763	18,245	24,884
Demand	109,223	22,776	3,809	16,950	9,352	196,599	40,995	6,855	61,921	16,833
Surplus or Deficit	(-)56,268	(-)8,832	14,604	(-)3,383	9,151	(-)125,376	(-)22,243	17,908	(-)43,676	8,051

Sources: Present production is derived from District Agricultural Office annual report for 1984. Projected production by the year 2000 is based on observed CBS production growth rate between 1972 and 1982.

Table 3. Household food requirements in Kitui District, 1985 and 2000.

	No. of Households Year		Demand 1985 (tons)					Demand 2000 (tons)				
Division	1985	2000	Maize	Beans	Sorghum	Millets	Cowpeas	Maize	Beans	Sorghum	Millets	Cowpeas
Central	31,021	55,837	39,127	8,158	1,365	6,000	3,350	70,428	14,684	2,457	10,800	6,030
Eastern	9,843	17,717	12,412	2,588	433	1,939	1,063	22,341	4,658	779	34,902	1,913
Southern	13,987	25,072	17,638	3,678	615	2,755	1,510	31,748	6,620	1,107	4,959	2,718
Northern	18,928	34,072	23,869	4,978	832	3,729	2,044	42,964	8,960	1,497	6,712	3,679
Far North	12,829	23,216	16,177	3,374	564	2,527	1,385	29,118	6,073	1,015	4,548	2,493
Totals	86,609	155,914	109,223	22,776	3,809	16,590	9,352	196,559	40,995	6,855	61,921	16,833

Source: The demand for 1985 is based on 1983 household survey by Central Bureau of Statistics as presented in Farm-Management Handbook of Kenya, Vol. II, part C, for Eastern and Coast Provinces. The demand for the year 2000 is calculated on the 1985 base year at 4% annual increase in the number of households.

Table 4. Food situation in Kitui District after adoption of recommended farm by the year 2000.

Division	Maize	Beans	Millets	Cowpeas	Cassava[a]	Sweet potatoes[a]	Cotton[a]	Sorghum
Central	72,364	16,583	17,086	18,091	55,837	111,674	4,467	106,090
Eastern	22,961	5,262	5,241	5,740	17,717	35,434	1,417	35,256
Southern	32,518	7,446	7,672	8,123	15,072	50,144	2,006	47,636
Northern	44,157	101,119	10,426	11,039	34,072	68,144	2,726	64,736
Far North	30,087	6,895	7,104	5,014	23,216	46,432	1,857	44,110
Total	202,087	46,305	47,709	48,007	155,914	311,848	12,473	297,828
Surplus on Deficit	5,528	5,310	(14,212)	31,174	144,569	311,472	8,533	290,973

[a]These crops have been declining in production. Future trends are roughly interpolated from these declines.

Source: A composite derivative of Agricultural Farm Plans projected from 1985 into the year 2000 using a 4% population growth rate over the same period.

Table 5. Proposed grazing schemes and grazing blocks.

		Central	Mwingi	Kyuso	Eastern	Southern
IL_5 and LM_5	Area (ha)	90,675	59,400	307,500	218,900	290,100
	Grazing schemes	13	8	43	33	41
	No. of cattle	25,187	16,500	85,417	60,805	80,583
	No. of families	1,950	1,200	6,450	4,950	6,150
IL_6	Area	-	-	263,500	169,500	266,600
	Grazing block	-	-	2	1	2
	Cattle	-	-	73,195	47,083	74,055
	Families	-	-	3,110	2,004	3,152

Herd Projection

It is projected that the number of cattle in UM3-4 and LM3-4 be reduced from 53,000 to 40,000. At the moment, not all families in these zones own cattle. This may be due to poverty or lack of land. The idea of reducing the number of cattle is to give more room for improved dairy cows and cultivated crops. Cattle in IL_5, LM_5, and IL_6 will increase as shown below by the year 2000.

IL_5 and LM_5	to	268,492
IL_6	to	194,333
Total		462,825

By the year 2000, the district is planned to have 504,800 head of cattle.

Recommendations

a. Bulking sites for seeds and cuttings, which already are in short supply, should be started immediately in chosen places close to the farmers. Certain farmers can be identified to do the bulking of planting material for sale to neighbors. The planting materials required are:

- certified cassava cuttings
- sweet potato vines
- serere sorghum
- katumani composite
- bana grass
- improved millet varieties.

b. The integration of the district into an economic system depends on the transportation and communication systems and ease of access. Every effort should be made to ensure that all market centers are fully accessible by road at all times to facilitate the distribution of crop and livestock inputs and help make market centers and other rural centers the nuclei of growth for the rural communities.

   Crop inputs should be available to farmers on a timely basis and by the types required annually. To assist in the coordination of input supply, the Ministries of Cooperative Development and Agriculture must submit to the main suppliers of inputs, such as KGGCU, the ranges and amounts of inputs required by the stockers and wholesalers in Kitui District. The two ministries also should coordinate the exercise of selecting and establishing input stockers in strategy market centers in Kitui.

c. Farmers should be encouraged and assisted to have more oxen because the use of the oxen plow should be intensified in this remote district. Tractors still can be used in areas near urban centers where diesel fuel can be purchased and mechanics can be reached for repairs. The rest of the district will rely on the oxen plow for some time.

d. Land consolidation and demarcation should be speeded up so that landowners can get title deeds, which they can use to secure loans.

e. Further formation of company and cooperative ranches should be reviewed because it deprives many people of land.

f. Potential storage-dam sites should be investigated and the feasibility of promising sites (including potential for irrigation) should be studied.

g. Feasibility studies for exploitation of certain resources are recommended in the following areas:
   - mining
   - rural tannery project
   - manufacture of animal feeds from surplus sorghum, millets, sunflower, and cotton seeds

   Appraisals can be commissioned through the DDCs, and the national government, county councils, and cooperatives can secure loans and run the projects.

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HISTORY OF RANGE MANAGEMENT IN KENYA

Julius H.N. Mwangata

ABSTRACT

The huge scope of range management in Kenya was recognized late in the last century with the construction of the Kenya/Uganda railway. Before then, the extensive open hinterland was inaccessible and used only by the nomadic pastoralists. It soon became obvious that, to maintain the railway line, agricultural production had to be stepped up. The immediate answer to this was to settle immigrant soldiers of the two World Wars. This decision shifted most land ownership to the Europeans. In fact, by the Kenya (Annexation) Order-in-Council of 1920, all land assumed the status of Crown Land. Land was then issued on leases for 99 years and 999 years or was sold on easy terms. Soon the traditional landowners resented the way land was being administered. Subsequent rules and orders set limits to the boundaries of the African reserves and established the White Highlands (scheduled areas). The demand of the war led to great leaps in agricultural production. After initial failures, commercial ranching flourished in Nakuru, Laikipia, and Machakos. Meanwhile, population increases in the African areas were causing serious overgrazing, denuding, and soil erosion. In 1946, a ten-year Development Plan (1946-1955) was adopted to effect an agrarian change in the pastoral areas. Assisted by the Colonial and Welfare Fund, ALDEV implemented the development plan and the Swynnerton Plan (1954 to 1959) through schemes of grazing management. The Range Management Division took over the function from ALDEV as an instrument of change in the pastoral economy, a responsibility it has been holding since independence.

INTRODUCTION

The history of range management in Kenya dates back to the 1940s when the colonial administration recognized the importance of increased agricultural production in the pastoral areas. Enormous problems were encountered that were inherent in pastoral development, including traditional land tenure, entrenched social and cultural attitudes controlling lifestyles of the pastoral communities, extensive denuding and erosion of soil, overstocking, badly distributed and scarce water supplies, and poor infrastructure. Further, there was a lack of an appropriate organization and funds to carry out the program.

It was necessary, therefore, to introduce suitable rules and regulations to effect the changes necessary to enable the program to succeed. Further, it was necessary to carry out research and training and draw out appropriate long-term plans. But it was the creation of the implementing organization, and especially the provision of funds, that made possible the drawing out of long-term plans and their implementation with assurances of success in terms of support and continuity.

LAND TENURE AND LAND-USE POLICY

Late in the nineteenth century, it was recognized that Kenya was blessed with extensive areas that were unsuitable for cultivation but that could be used for the development of pastoral industries. Thus, land is a central factor when considering the history of range management and pastoral development in Kenya. At the beginning of European settlement,

the colonial administrators gave priority to ownership of land by Europeans.

Orders and rules were formulated to implement the settlement scheme. In particular, the Crown Lands ordinances of 1902 and 1915 were used to grant land on lease for periods of 99 years and 999 years and to sell land on easy terms to the settlers. The Kenya (Annex) Order-in-Council of 1920 gave all land the legal status of Crown Land. This caused problems with the traditional land occupants. Subsequent orders delimited and affirmed the boundaries of African land reserves (later, in the 1940s, called Native Land Units). Then the White Highlands, also known as "scheduled areas," were created. The first successful ranching was recorded in the scheduled areas, with Nakuru, Laikipia, and Machakos producing high-quality meat.

At independence, therefore, the country inherited three categories of land:

- private land
- state land
- trust land

RANGE MANAGEMENT AND PASTORAL DEVELOPMENT

The urgency and necessity of producing more to feed the war led to great leaps in agricultural production in both the European and African areas. But even after World War II, the African sector's production did not approach the European sector's. For the first time, however, the urgency and gravity of the situation in the African reserves were recognized officially at the highest level of the colonial administration, which took strong interest in the complex and recalcitrant agrarian problems of the African lands. The problem presented, therefore, was the extent to which government should endeavor to control, divert, and assist in this problem of agrarian change as part of its responsibility for seeing that the land was not reduced to desert as a result of overpopulation by people and livestock.

THE STRATEGY OF PASTORAL DEVELOPMENT

Having recognized the importance of increasing production in the African areas, the next step was to develop a strategy for achieving that objective. Two developments that played major roles in bringing about basic changes in African agriculture during this period were the African Land Development Organization (ALDEV) and the Swynnerton Plan.

AFRICAN LAND DEVELOPMENT ORGANIZATION

A development committee was appointed in 1945, and its report was adopted as the 10-year development plan for 1946 to 1955. This plan was to be financed partly by Kenya's own funds and partly by the Colonial Development and Welfare Fund. ALDEV was created and charged with the responsibility of carrying out the plan. In fact, it became the postwar key of government administration of the earlier policy to develop the African sector along with the European sector in the dual economic development of Kenya. Created basically to recondition and plan better use of African areas, it was destined to be a vital part of the machinery to develop the African agricultural economy. ALDEV evolved over a period of years, changing titles in the process to suit changing

circumstances. Despite the changes of title, ALDEV played an essential, consistent role during the 16 years leading up to independence.

Problems faced by ALDEV during the board's operation were complex and involved many different factors, including:

- excess livestock, usually of low quality
- widespread denuding and erosion of soil
- badly distributed and scarce water supplies
- lack of roads
- lack of knowledge of about how to use areas available for settlement but difficult or unattractive because of such factors as low rainfall, lack of surface water, and infestation by tsetse flies
- how to persuade the peasants and pastoralists, who lived a traditional way of life in their own lands and usually were indifferent or hostile, to cooperate in official plans

Joint meetings and discussions from the district level to the headquarters were essential for a coordinated plan. In the process, the board gathered a wealth of experience and created new observations and guidelines for future effort.

GRAZING SCHEMES

It was recognized early that the main objective in the management of the rangelands was to keep the herds and flocks in better condition by mitigating, so far as possible, the hard conditions of their lives. This objective was to be achieved through schemes of grazing control or management. The schemes ranged from technically simple to complex. In particular, the schemes consisted of measures such as

- limitation of stock to the carrying capacity of land
- controlled rotational grazing
- extension of available grazing and facilities of rotational grazing by developing water supplies and eradicating tsetse flies

ALDEV planned and implemented the grazing schemes, which eventually covered about 25,000 km^2 of range, and stocked the area with over 500,000 head of cattle. The organization also established African District Council ranches at which immatures were fattened.

NECESSITY TO FINANCE PASTORAL DEVELOPMENT

Rural indebtedness is a danger closely identified with traditional land ownership; nevertheless, in newly developing economies, contracting debt is a necessary means of securing capital for agricultural investment and development. This is especially true if rapid development has to be fostered for political or other reasons but low-cost methods of capital creation cannot be employed fully. This recognition spurred the development of the rural areas. By Act of Parliament, the British government established the Colonial Development and Welfare Fund in 1940. This, along with Kenya funds, was used by ALDEV (1946 to 1962) to

implement the development plan (1946 to 1955) and the Swynnerton Plan (1954 to 1959).

At independence in 1963, the first development plan stressed the importance of agriculture to the economy of the country. Apart from the several reasons advanced in support of the government stand, it was emphasized in strong and clear terms that "since we have to develop through import substitution, local incomes have to increase rapidly and it is through agriculture that we can most easily raise the incomes of our local people. Moreover, it is worth noticing that private foreign capital is unlikely to go into agriculture, pointing to the special responsibility of government in this sector." Armed with this policy, the government established the Range Management Division in the Ministry of Agriculture in 1963 and charged it with the task of rangeland development, assisted by international donor finance.

DEVELOPMENT PROJECTS

Rangeland has been developed through a series of projects since independence:

UNDP/FAO SF Range Management Project

On October 1, 1964, the government of Kenya and FAO (as the executive agency of the United Nations Special Fund), set up a plan of operation to strengthen and expand the Range Management Division to promote the pastoral development of the vast Kenyan range areas. The objectives of the project were

- to carry out land-use surveys as a basis for detailed range-development planning
- to provide training for extension officers and an extension service for range farmers and pastoralists
- to intensify applied research on specific problems of range development and productivity

National Range and Ranch Development Project (USAID)

The objective of the National Range and Ranch Development Project has been to develop, increase, stabilize, and manage forage- and water-storage potentials to increase livestock production to the optimum practical level in the Madogashe/Kalalut areas of Garissa District. The area (also known as the pilot project) covers about 715.0 ha divided into three grazing-management blocks. Total project cost was U.S. $3.8 million.

Kenya Livestock Development Project

IDA (129 KE) Livestock Development Project, Phase I. The first IDA credit for livestock development was extended in 1968, with a total project cost of about Ksh. 81,396,000 over a 5-year period. Of this amount, Ksh. 43 million was ranch loans. The principal objectives of the project were to increase beef production by providing credit to group and commercial ranches and to provide facilities and services for livestock marketing, water development on communal land, and disease control. Under this project, credit was extended for the first time to pastoralists to assist them in the transition from a subsistence to a

market-oriented economy. At the conclusion of the phase, 108 ranches had been developed instead of the 60 ranches originally envisaged. This cost a total of Ksh. 52.20 million instead of Ksh. 43.0 million.

Phase II (1974 to 1980). Phase II of the IDA Kenya Livestock Development Project was started in 1974 with the aims of

- Establishing 60 group ranches, 100 commercial ranches, 21 company/cooperative ranches, and 3 feedlots.

- Improving an additional 2.8 million ha of communal grazing land in the North-Eastern Province and 1.2 million ha in Isiolo through the provision of water facilities, access roads, and grazing systems.

- Developing three wildlife areas and establishing a census and ecological monitoring unit. Total project cost was to be Ksh. 350.5 million, out of which credit to ranches was to be Ksh. 206.5 million. After a 2-year extension to December 1982, the project terminated without having attained its full targets.

REMARKS

While Phase I of the Kenya Livestock Development Project was considered successful, Phase II was marred by a lot of problems. In 1976, the recommendations of a review mission resulted in appreciable changes in the project targets and cost. In particular, the ranch-development component was reduced to 1.5 million ha from 1.9 million ha. This, in turn, reduced projects cost from U.S. $21.5 million to U.S. $15 million. The project suffered such substantial modifications that the documents produced, from the proposal (1972) to the report of the supervision mission (1980), looked like different project documents in themselves. Although these modifications were unavoidable, given unforeseeable circumstances, they made it difficult to evaluate properly the impact of the project. The people in charge of implementing the various components in the field, for example, might not have been aware of the modifications.

Despite that, the range-development program can boast of major achievements, including:

- opening an increased market outlet for immatures from the North-Eastern Province

- opening the coastal hinterland for beef production

- assisting commercial ranches, previously owned by foreigners, to be Kenyanized

- developing, experimenting, and gaining experience with organizational structures that now can be adapted to meet different social requirements

- developing, experimenting, and gaining experience in the institutional set up for project implementation

While it is encouraging to note that many issues of rangeland development have been resolved, the major issue not yet resolved is how the institutions of rangeland development can work together under unified leadership with the objective of serving a common goal. One other very

important issue that is probably of immediate concern is the termination of finances to the rangeland development effort by international donors, temporary or not and for whatever reason. Although the going has not been easy, a lot of groundwork has been laid. Experiences gained from ALDEV schemes indicates that halting or stagnating the effort is likely to lead to management breakdown with disastrous consequences. Rangeland development is a long-term exercise and, as has been stated earlier, operates on long-term plans for which implementation requires assurances of success in terms of support and continuity. Adequate financing should be sought as a matter of priority.

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RANCH AND LIVESTOCK MANAGEMENT

CHEMICAL COMPOSITION AND IN VITRO DRY-MATTER DIGESTIBILITY OF HERBAGE*

S. Tessema

Herbage from a typical, natural-pasture grazing land was collected monthly for four years (1980 to 1985) using a number of enclosure cages, and the composite samples were used to determine dry-matter yields and nutrient contents. Species separations also were carried out monthly for one year to identify major species of grasses, broadleafed weeds, shrubs, and trees. Esophageal-fistulated cows were used to determine the degree of selection by grazing animals. Nutritional investigations have been based on the new detergent system of fiber analysis (Goering and van Soest, 1970), which fractionated the plan components into identifiable chemical entities; for example, NDF (total fiber), cellulose, lignin, and hemicellulose. The two-stage in vitro system was used to determine true digestibility.

The natural vegetation of these semiarid areas in the Eastern Province of Kenya contained a wealth of good grazing grass and browse species. Nutritional investigations, however, showed that these plant species not only have high proportions of structural carbohydrates but also that these components are deposited in the plant tissues at an earlier vegetational stage. From the age of 4 to 24 weeks, the percentage NDF (total fiber) ranged from 67 to 76, the percentage ADF ranged from 42 to 54, the percentage of cellulose from 33 to 40, the percentage of hemicellulose from 18 to 24, and the percentage of lignin from 6 to 9.

An important fact that was revealed from these investigations was that the time of high nutritional value of the vegetation of these grasslands is limited to short periods of rapid growth that last not more than 2 months during each season. Although crude-protein content can be as high as 11% when plants are young, this fraction showed the greatest change per unit of time, becoming as low as 4% at 24 weeks old. considering the minimum level of 7% to 8% required in forages before intake and digestibility are affected, this level was reached between 8 and 12 weeks of age. Of the fiber fractions, cellulose had the most negative ($r = -.86^{**}$) relationship with digestibility, exceeding lignin ($r = -.78^{**}$). As expected, the relationship between crude protein and digestibility was significantly high ($r = .89$) and, therefore, crude protein was a better predictor of digestibility than any of the fibers.

Using esophageal-fistulated cows, it was found that the herbage consumed by the grazing animal had a composition diverging widely from that of the clipped herbage collected. The herbage consumed by the grazing cow contained up to 5% more crude protein and was up to 12% more digestible than the herbage clipped from the same pasture.

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*From Tessema, S. 1985. Natural pasture grazing lands of semiarid areas (Katumani, Machakos). Paper presented at Range Development and Research Workshop organized by the National Range Research Station, Kiboko, Kenya, April 2-4, 1985.

Table 1. Monthly rainfall amounts, dry-matter production (kg/ha), and percentage dry matter of the herbage from natural grazing lands; Katumani, 1984-85.

Months	Rainfall amounts (mm)	Dry-matter production (kg/ha)	Dry matter (%)
November	154	292	40
December	80	318	40
January	56	191	35
February	43	134	63
March	73	191	58
April	115	109	45
May	64	298	48
June	11	287	59
July	4	156	59
August	4	188	70
September	7	171	73
Total	611	2,335	

Table 2. Species composition of natural pasture herbage and percentage appearance of each species at different cutting dates, 1984-85.

	CUTTING DATES										
Species Names	11/21/84	12/5/84	1/7/85	2/5/85	3/5/85	4/4/85	5/6/85	5/20/85	7/5/85	8/5/85	9/5/85
GRASSES											
Themeda triandra	49.69	50.75	15.5	-	16.49	13.41	31.59	14.48	22.23	32.01	34.09
Sporobolus fimbriatus	6.32	-	-	-	6.72	8.14	0.37	-	-	-	-
Cenchrus ciliaris	15.72	6.41	-	5.47	4.38	-	0.64	2.08	1.82	2.22	2.66
Digitaria milanjiana	9.21	20.97	3.3	40.41	0.92	-	3.89	-	-	-	-
Digitaria abyssinica	0.33	1.42	-	-	1.80	16.03	2.25	0.70	8.45	-	3.45
Eragrostis superba	-	0.86	0.8	-	-	4.21	1.18	-	-	-	1.73
Eragrostis cilianensis	-	-	-	-	-	-	1.08	5.11	-	-	-
Eustachyus paspaloides	0.94	1.02	-	-	-	-	-	-	-	-	-
Aristida adcensionia	0.56	1.25	3.2	-	1.23	-	-	-	-	-	-
Aristida kenyensis	-	-	-	3.86	22.69	44.78	36.84	32.17	43.51	61.79	58.05
Panicum maximum	-	-	8.9	9.60	-	-	4.17	-	-	-	-
Cynodon spp.	-	1.22	-	14.24	-	-	-	0.61	-	-	-
Bothriochloa insculapta	-	0.71	-	0.63	-	-	-	-	-	-	-
Heteropogon contortus	-	-	3.1	19.99	-	9.61	6.51	9.58	6.48	1.64	-
BROADLEAF WEEDS											
Solanum incanum	-	-	1.3	-	3.53	3.09	-	8.92	-	-	-
Polygala sphenoptera	-	-	2.2	-	15.13	-	0.80	1.04	2.91	-	-
Umbelliferae	3.18	3.12	-	-	-	-	-	-	-	-	-
Pspilionaceae	-	10.08	2.2	-	4.03	-	-	6.40	-	-	-
Commelina	0.35	-	16.7	5.76	-	0.69	0.93	0.67	1.81	-	-
INDETERMINABLE SPECIMEN	13.68	3.38	30.5	-	23.0	-	6.51	18.0	13.0	2.0	-

Table 3. Chemical composition and in vitro dry-matter digestibilities of natural pasture herbage during the various seasons and months of the year; Katumani, Machakos, 1980-85.

		CHEMICAL COMPOSITION															
Month	Season	% ASH		% CP		% NDF		% ADF		% ADL		% CELL		% HEM		% IVDDM	
Nov.	Wet	8.46	(1.61)*	7.26	(3.83)	75.54	(13.92)	53.70	(6.92)	7.20	(1.20)	39.22	(7.49)	23.33	(4.85)	39.95	(11.55)
Dec.	Wet	8.38	(0.81)	9.05	(1.66)	73.67	(3.02)	46.60	(4.57)	6.11	(0.83)	36.23	(4.52)	27.17	(2.35)	47.25	(9.41)
Jan.	Wet	8.11	(1.13)	6.49	(1.62)	72.16	(6.19)	47.47	(3.99)	6.80	(2.29)	36.63	(2.40)	24.69	(7.70)	47.47	(8.94)
Feb.	Wet/Dry	7.62	(0.55)	5.49	(1.98)	71.39	(2.47)	45.38	(4.81)	6.50	(1.07)	34.93	(3.49)	26.01	(4.94)	46.03	(8.24)
Mar.	Dry/Wet	9.40	(1.11)	10.53	(5.21)	67.51	(2.58)	42.66	(6.11)	5.94	(0.95)	33.08	(4.96)	24.86	(3.55)	54.80	(13.07)
Apr.	Wet	9.08	(1.83)	9.60	(4.68)	70.86	(3.52)	45.08	(5.16)	5.32	(1.00)	35.94	(4.42)	25.78	(2.34)	51.70	(12.56)
May	Wet	8.40	(1.15)	9.80	(4.01)	73.47	(3.96)	48.27	(3.45)	6.17	(0.90)	37.97	(2.29)	25.20	(3.45)	46.05	(5.31)
June	Wet/Dry	7.82	(1.05)	6.59	(0.72)	71.34	(3.92)	49.22	(1.32)	6.24	(0.53)	36.97	(1.52)	26.89	(2.14)	41.89	(2.32)
July	Dry	8.12	(1.45)	4.46	(1.12)	74.09	(3.44)	50.04	(0.66)	6.41	(0.25)	39.42	(1.08)	24.71	(4.98)	43.33	(7.15)
Aug.	Dry	8.74	(1.60)	4.59	(0.66)	75.75	(4.75)	51.59	(1.60)	7.29	(0.30)	39.20	(1.89)	24.14	(4.39)	37.93	(4.57)
Sept.	Dry	7.66	(1.72)	5.10	(0.28)	76.88	(5.30)	54.82	(1.10)	8.37	(1.08)	40.67	(2.21)	22.06	(4.58)	33.04	(4.47)
Oct.	Dry/Wet	8.94	(-)	4.72	(-)	72.82	(-)	53.98	(-)	7.79	(-)	39.22	(-)	18.84	(-)	38.20	(-)

*Figures within brackets show standard deviations from means.

Table 4. Chemical composition and in vitro dry-matter digestibilities of the major grass species found among herbage of natural grassland; Katumani, Machakos.

		CHEMICAL COMPOSITION							
Species name	Cutting date	% ASH	% CP	% NDF	% ADF	% ADL	% CELL	% HEM	% IVDDM
Cenchrus ciliaris	11/21/84	9.86	10.40	67.28	43.63	4.74	36.02	23.65	59.71
Digitaria milanjiana	11/21/84	8.45	8.48	69.81	49.21	5.41	40.81	30.89	41.77
Sporobolus fimbriatus	11/21/84	6.02	6.57	74.56	45.92	4.84	39.01	28.64	41.69
Heteropogon contortus	1/7/85	6.22	9.75	79.16	54.25	6.27	43.90	24.91	38.18
Cynodon spp.	2/5/85	12.35	7.50	65.53	45.98	5.28	34.88	19.55	49.53
Aristida Kenyensis	5/6/85	8.90	6.31	78.68	54.80	5.90	41.54	23.88	35.66
Eragrolis superba	5/6/85	7.50	7.38	75.65	52.97	6.12	43.77	22.68	44.75
Themeda triandra	11/21/84	8.98	8.90	67.10	44.17	4.32	36.08	22.93	56.08

Table 5. Simple correlation coefficients observed between various plant dry-matter components of the natural pasture herbage.

	CP	NDF	ADF	ADL	CELL	HEMCELL	IVDMS
CP	1.00						
NDF	-.48	1.00					
ADF	-.68	.53	1.00				
ADL	-.58	.50	.77	1.00			
CELL	-.68	.65	.87	.58	1.00		
HEMCELL	.19	.51	-.44	-.21	-.21	1.00	
IVDMS	.89	-.57	-.91	-.78	-.86	.31	1.00

Table 6. Percentage crude protein and percentage in vitro dry-matter digestibilities (IVDDM) of natural pasture herbage samples collected from esophageal-fistulated cows as compared to hand-clipped samples from the same pasture; Katumani, Machakos, 1984-85.

	% crude protein		% IVDDM	
Sampling month	Fistula sample	Clipped sample	Fistula sample	Clipped sample
Dec.	10.72	9.13	60.07	43.62
Jan.	8.77	8.06	56.07	57.11
Feb.	6.36	7.31	55.78	50.33
March	-	7.56	-	49.23
April	12.40	6.94	51.54	43.06
May	11.98	6.50	51.32	40.20
June	10.14	7.25	51.84	39.67
July	7.26	4.13	49.20	38.49
Aug.	5.35	3.25	39.47	31.27
Sept.	4.38	3.69	35.67	30.31

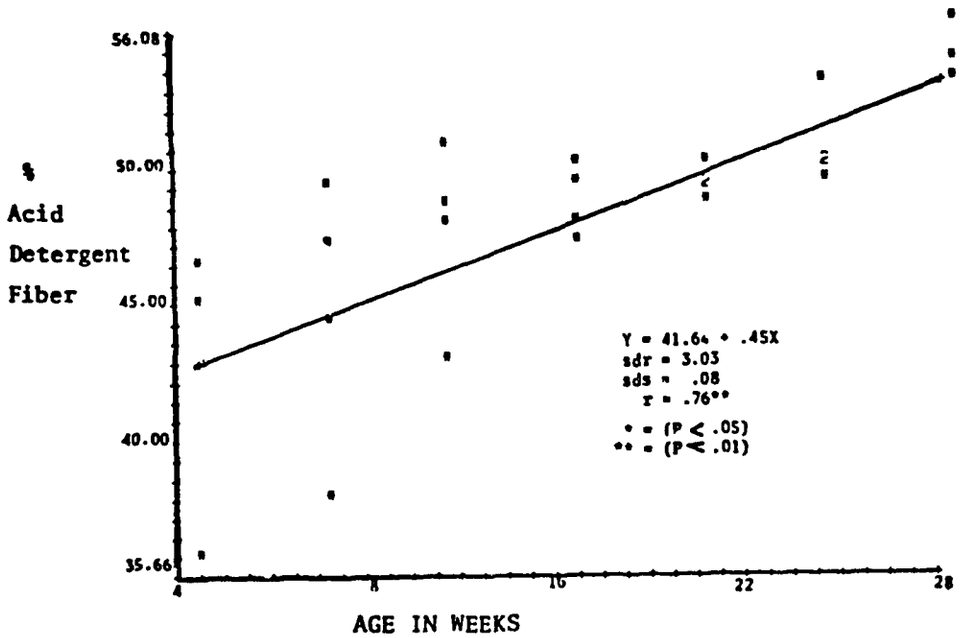

Figure 1. Relationship between age of plant (in weeks) and percentage Acid Detergent Fiber; natural pasture herbage; Katumani, Machakos, 1980-85.

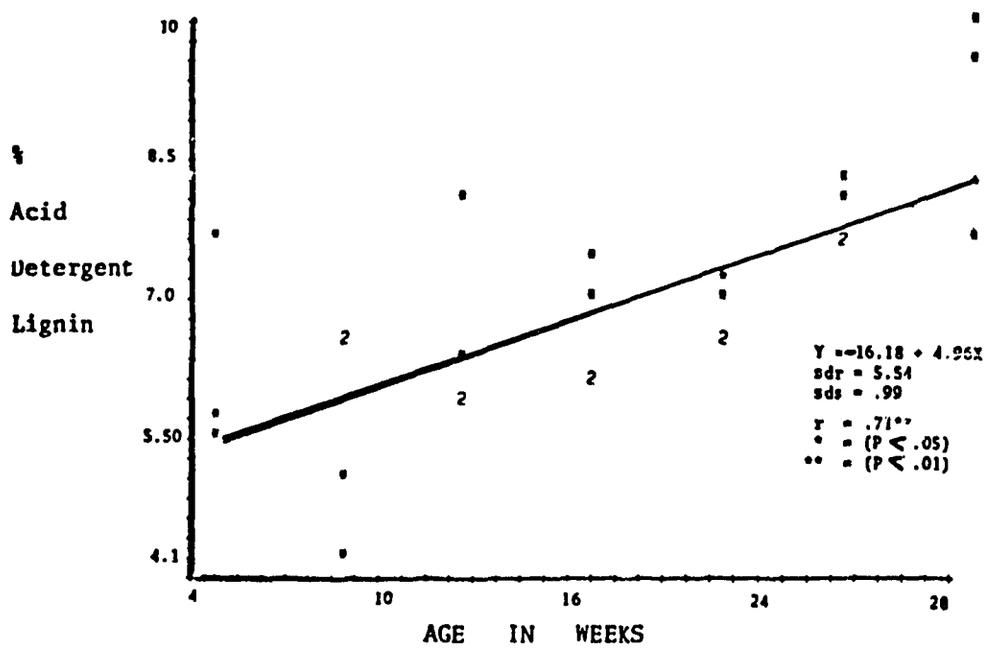

Figure 2. Relationship between age of plant (in weeks) and percentage Acid Detergent Lignin; natural pasture herbage; Katumani, Machakos, 1980-85.

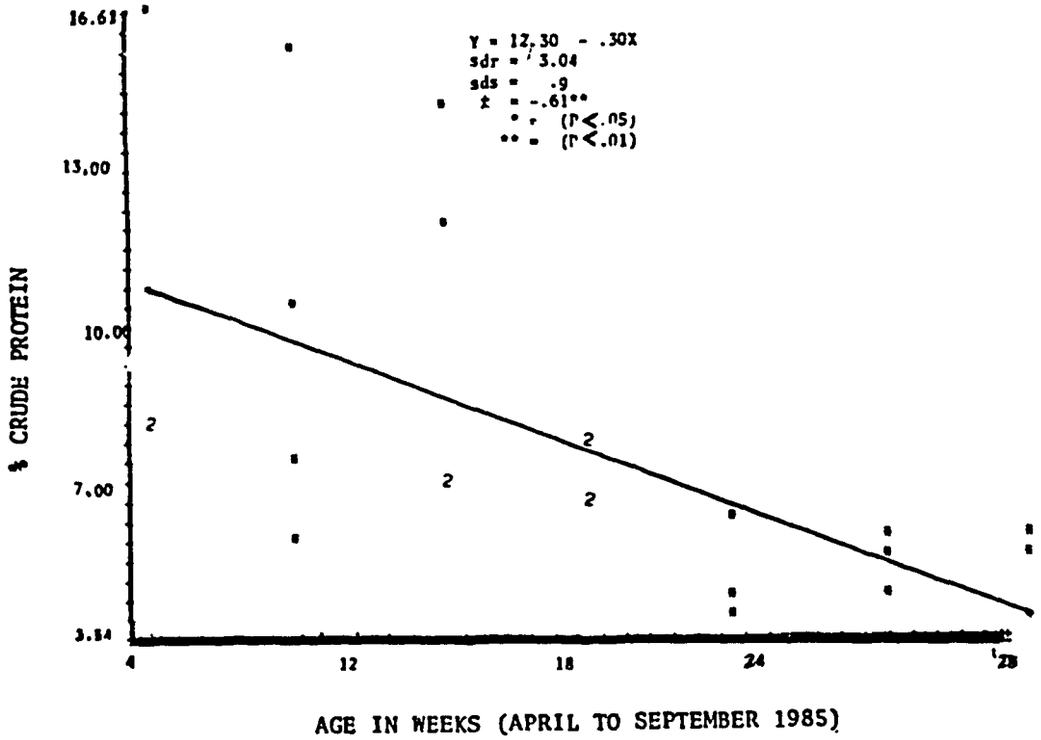

Figure 3. Relationship between age of plant (in weeks) and percentage crude protein; natural pasture herbage; Katumani, Machakos, 1980-85.

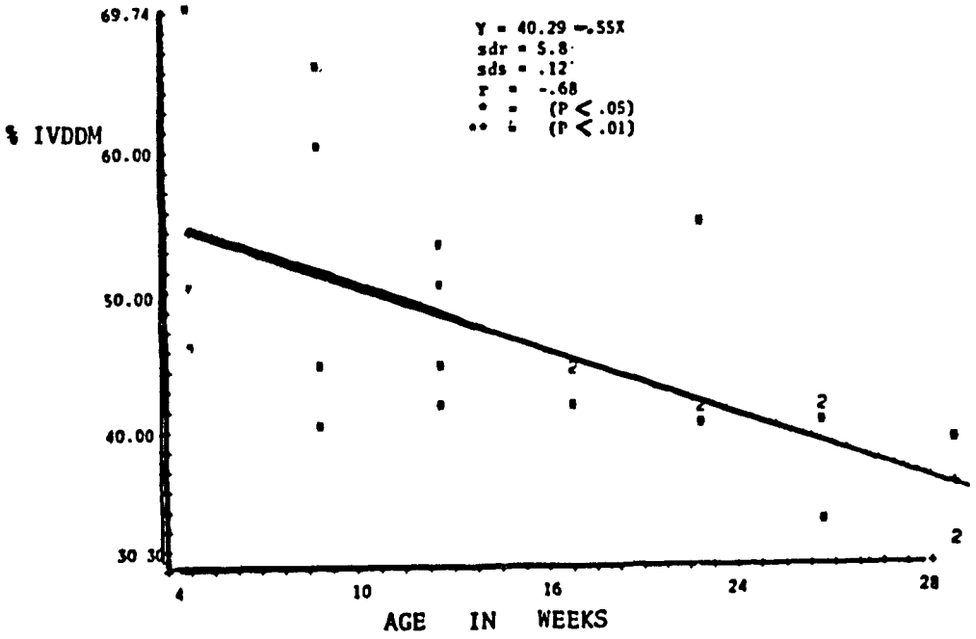

Figure 4. Relationship between age of plant (in weeks) and percentage in vitro dry-matter digestibility; natural pasture herbage; Katumani, Machakos, 1980-85.

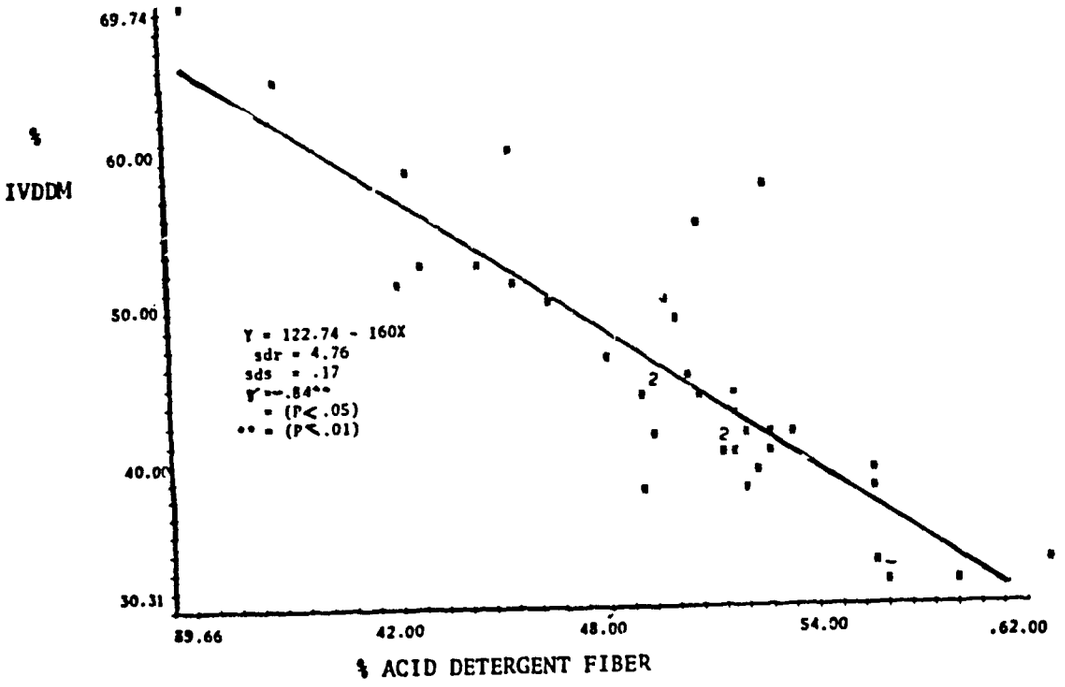

Figure 5. Relationship between the percentage acid detergent fiber and percentage in vitro dry-matter digestibility; natural pasture herbage; Katumani, Machakos, 1980-85.

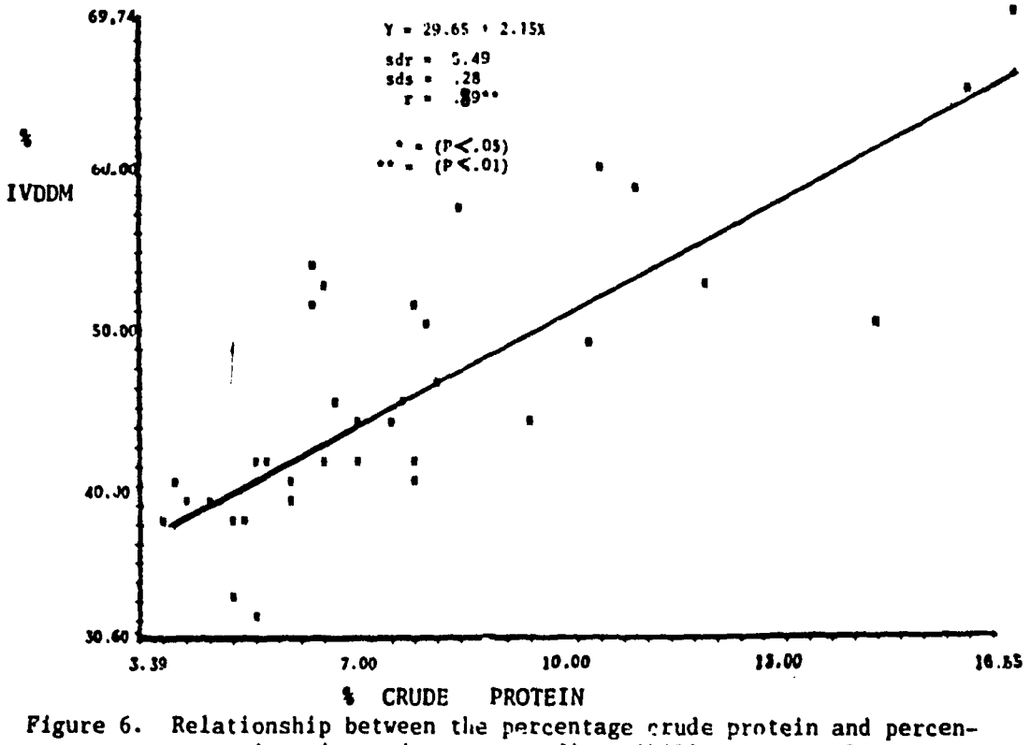

Figure 6. Relationship between the percentage crude protein and percentage in vitro dry-matter digestibility; natural pasture herbage; Katumani, Machakos, 1980-85.

BOTANICAL COMPOSITION AND SELECTION OF DIETS BY RANGE CATTLE

Philip F.K. Kibet

ABSTRACT

Botanical composition of cattle diets may vary considerably within or among seasons. Grasses usually are the most important constituent of cattle diets unless grass availability is extremely limited. However, some studies show that cattle prefer both forbs and browse.

Composition of forage on range is not a good indicator of the botanical composition of cattle diets because animals graze selectively. Area and species preference and plant-part selectivity influence cattle's diet selection. Cattle often selectively graze plant parts or plant species higher in protein content than the principal species available. Leafy parts consistently dominate dietary components of cattle that graze native range.

The nutritive value of cattle's range diets can be highly variable. As seasons progress and plants mature, nutritive value of range forages generally declines. This decrease often is associated with a decrease in crude protein (CP), phosphorus, and dry-matter digestibility, and an increase in crude fiber (CF) and lignin.

Attributes influencing animal preference and plant palatability affect range cattle's diet selection. Palatability factors may stimulate a selective response by animals or may prevent the plant from being grazed. Physiological stimuli, feeding habits, and environment influence food acceptance by grazing animals.

Knowledge of the botanical and chemical composition of diets consumed by grazing animals is needed to improve range management and range-animal nutrition. Also, an understanding of diet selection would assist in range use and planning and proper care of range resources.

INTRODUCTION

Most of the rangelands of Kenya are devoted to livestock production, irrespective of their diversity in feed resources and environmental conditions. During some times of the year, feed resources available to animals become too low in quality and quantity. Recurrent droughts in range areas exaggerate such problems. Unlike highlands, range areas receive too little rainfall to support rainfed cropping systems; so rangelands are reserved predominantly for pastoral industry, wildlife use, or recreation.

The present high population rate in the high-potential areas of the country exert pressure on semiarid rangelands to produce food. Therefore, animal production is facing direct competition with crops for the land in the highlands. Such competition has resulted in livestock production being redirected to arid and semiarid ranges. With the introduction of a national food policy, rangeland improvement and productivity has received added emphasis to produce animal-related food for local consumption and probably for export.

To produce food from range regions, range managers and other range-associated technicians ought to understand range-animal nutrition principles and concepts and related technological knowledge. Such tools could be useful in planning and directing rangeland projects that aim at proper use of range resources.

Thorough knowledge of the botanical and chemical composition of diets ingested by animals must be attained to improve range productivity through enhancement of range-animal nutrition. Another field of equal importance is diet selection by grazing animals. Therefore, the following review is intended to provide some planning aids that may be useful to range professionals and other related workers.

BOTANICAL COMPOSITION OF CATTLE DIETS

Methods of Collecting Diet Samples

Procedures used for obtaining dietary samples for subsequent analysis of their botanical and chemical compositions were reviewed by Theurer (1976). These included:

- field observations of grazing animals and hand-picking forage selected by such animals (Eldlefsen, Cook, and Blake, 1960; Halls, 1954)

- before-and-after method whereby samples are collected by hand-picking (Cook, Harris, and Stoddart, 1948)

- esophageal-fistula method (Torrel, 1954; later developed by Lesperance, Bohman, and Marble, 1960)

- bite-count procedure (Reppert, 1970)

- fecal collection for microhistological analysis

Of all these procedures, the use of fistulated animals appears to be the best method for obtaining representative samples of the grazing animals' diet, even though species identification of masticated forage samples is tedious and time consuming and animals vary considerably in dietary preferences.

Methods of Analyzing Botanical Contents of Diets

Theurer (1976) and Ward (1970) prepared methods for determining botanical composition of grazing animals' diets. These methods are grouped broadly into the following categories:

- Visual appraisal in which botanical components of diets collected by fistulated animals are visually appraised. Cook et al. (1958) analyzed extrusa and found that browse could be identified by texture and color differences, whereas herbaceous plants were too masticated for visual identification.

- Manual separation in which botanical components are separated and identified based on morphological characteristics such as color, texture, veination, and hairy or glabrous surface (Hoehne, Streeter, and Clanton, 1965; Obioha, 1967).

- Microhistological technique in which samples are dried, ground through a 1 mm screen, and analyzed by examining mounted slides under compound binocular microscope (Free, Hansen, and Sims, 1970; Vavra, Rice, and Hansen, 1970).

- Microfragment technique in which diet fragments are dried, separated, and analyzed under dissecting microscope (Kibet, 1984; Kothmann, 1968).

- Microscopic-point technique developed by Heady and Torrel (1959) and illustrated by Harber, Torrel, and Van Dyne (1964).

Among these techniques, the most promising ones appear to be the microhistological, microfragment, and microscope-point techniques.

Species Composition in Diets

Botanical composition of forage ingested by grazing animals differs in composition from forage available in pasture (Arnold, 1960; Hardison et al., 1954). These differences exist because grazing animals prefer some plants and certain parts of plants to others (Theurer et al., 1976). Kibet (1984) noted that heifer diets contained a great diversity of plant species when forages were green but were limited to what was available when species were mature during the dry season. He also found that 96.8% of the heifer diets were composed of grass and grasslike plants, 1.0% of forbs, and 2.2% of browse (table 1).

DIET SELECTION

Each herbivore selects a daily ration from available plants. Grazing includes elements of choice ranging from preference for a single plant species or genus to little preference for any species. The plants preferred are said to be "palatable."

Palatability and preference concepts are inseparable in determining forage selectivity. Preference refers to the animal's reaction and palatability to the plant's characteristics. Forage selectivity is the grazing of certain plants or parts to the exclusion of others. This results from a highly complex interaction among three sets of variables operating over time: the plant being eaten, the animal doing the grazing, and the environment of both (Heady, 1975). Animal selectivity is influenced by many factors, such as the following.

Selectivity for Major Plant Groups

Grasses are the most important components of cattle diets as reported by several investigators (Cook, Blake, and Call, 1963; Kirby and Stuth, 1982; Van Dyne and Heady, 1965). Cattle's selection of grass over browse has been very specific in Nevada studies (Lesperance et al., 1970). In Acacia-digitaria grasslands of eastern Kenya, Kibet (1984) showed that cattle preferred grass to either forbs or browse. Ansotequi et al. (1972) found that rumen-fistulated cattle selected over 95% grass from May through September on mountain ranges in northeastern Nevada.

Selectivity for Plant Parts

Observation indicates that cattle selectively graze succulent or tender parts of plants -- mostly leaves. In two studies, leaves composed the majority of plant parts identified in rumen-fistula samples collected

from steers grazing desert grassland range (Galt et al., 1969; Galt, 1972). The two studies also showed that seasonality influences selectivity; for example, stems comprised 23% of observed dietary samples in winter but only 5% in summer. Studies at Kiboko range show that cattle diets comprised 66.4% leafy and 33.6% stem portions (table 2) (Kibet, 1984). However, Van Dyne and Heady (1965) reported that stems predominated in cattle and sheep diets on an annual grassland range.

Selectivity Among and Within Seasons

Botanical composition of diets varies greatly from season to season within the same range (figure 1). Bohman and Lesperance (1967) reported that average botanical composition of rumen-fistula forage samples on a Nevada range varied from 68% to 93% for grass, 4% to 17% for forbs, and 0% to 24% for browse during the same period. These yearly changes in diet composition were primarily influenced by availability of grass, which was largely dependent on precipitation.

Cattle sometimes supplement their diet with browse or forbs even though grass species are abundant. For example, cattle showed a high preference for green Talinum kafrum forb, even though plenty of grass was growing beside the forb (Kibet, 1984). In Arizona studies, cattle consumed up to 15% prickly pear cactus during December (Calt et al., 1969).

Dietary botanical composition commonly shifts with season. Buchanan et al. (1972) found grasses and forbs to increase in early- and late-season diets on a forb range in Montana. Allison and Kothman (1979) reported a decrease in cool-season grasses and an increase in warm-season grasses in diet from spring through fall.

FACTORS INFLUENCING DIET SELECTION

It is well understood that, under almost all circumstances, herbivores graze selectively on the range. Both animal and forage attributes affect diet selection. Animal factors determine preference whereas plant attributes determine palatability.

Palatability Factors

Palatability factors are the attributes of plants that affect their acceptability to grazing animals. They may stimulate a selective response from animals or prevent the plant from being grazed (Heady, 1964). The following factors influence palatability.

Chemical Composition (Nutrient Content)

It is commonly accepted that forages that are high in crude protein are highly palatable to cattle and sheep (Harrison et al., 1954; Cook, 1959; Blaser et al., 1960). Forages high in sugars, fats, or ether extracts usually correlate with high palatability (Hardison et al., 1954; Price, 1952). Livestock accept the grass cultivars that are highest in phosphorus and potassium before plants that have low contents of these minerals (Leigh, 1961). The percentages of lignin and crude fiber increase when crude protein, simple carbohydrates, and fats decrease, resulting in a negative relationship between palatability and lignin and crude fiber (Heady, 1964).

Proportion of Plant Parts

The proportions of plant parts influence the palatability of forages. Grasses and forb leaves contain greater proportions of fat, crude protein, and simple sugars and less lignin and crude fiber than do stems. Fruits and seeds usually have relatively high contents of crude protein, fats, and carbohydrates; therefore, leaves, flowers, and seeds are more palatable than stems. However, during the dry season grazing animals select leaves over stems and green material over dry or dead material (Heady, 1975; Kibet, 1984).

Growth Stage

As plants mature, they decrease in palatability and nutrient value. The whole plant becomes high in fiber, and the leaf-stem-fruit ratio changes toward a high proportion of stems than in young material (McIlvaine, 1942; Cook and Harris, 1950). Pidgen (1952) showed that position and extent of lignification in each grass species characterized advancing maturity, curing quality, and palatability.

External Plant Form

Usually presence of awns, spininess, stickiness, coarseness of texture, and unfavorable odor reduce palatability, whereas glabrousness and succulence enhance it (Heady, 1975).

Associated Feed Elements

Associated feeds alter palatability of any other food in the diet. Normally, as availability of forage decreases so does selectivity. Cowlishaw and Alder (1960) found that the presence of highly unpalatable species decreased the selection of palatable species. The availability or proportional botanical composition of a species in the vegetation influences its acceptability.

Preference Factors

Preference factors are attributes associated with the grazing animal that control food acceptability. Animals' reactions that regulate food acceptance have been classified into three interrelated systems (Young, 1948): stimuli within animal body, development of evolutionary feeding habits, and animal environment.

Internal animal factors. An animal's preference for food is stimulated by its senses of sight, smell, taste, and perhaps hearing (Heady, 1975). Arnold (1966) compared sheep's sight, smell, taste, and touch separately and in combinations and concluded that sight allowed sheep to recognize food items and orient themselves with their surroundings, while smell, taste, and touch of the leaves each were important in determining the acceptability of some forage species. Changing conditions of breeding, pregnancy, lactation, fatness, fear, excitement, gut fill, and hunger influence animal behavior, grazing time, and amount of forage intake (Arnold, 1964).

Learned and evolved behavior. Grazing animals have instincts -- hereditary nutritional wisdom -- for selecting food they can use. This selection process seems to be a self-regulating mechanism whereby materials that are accepted readily along the digestive tract are not

accepted in the mouth (Heady, 1975). However, previous grazing experience influences animals' food preferences (Arnold, 1964).

Environmental influence. Grazing animals change their behavior, including food preferences, with differences in weather (Castle and Halley, 1953) and with wetness of forage (Taylor, 1953). Topography and soil characteristics affect plants' palatability and animals' preferences for food (Cook, 1959).

Fertilization and burning change palatability and preference. Animals prefer to graze in fertilized and burned areas (Heady, 1975).

CONCLUSIONS

Detailed knowledge of botanical composition and nutrients of animal diets and of diet selection are prerequisites for proper use of range resources. Such knowledge could also contribute to better understanding of dietary interrelationships of range animals. These ingredients could enhance multiple use of ranges while sustaining their resources. Consequently, higher range-use efficiency could be obtained in the long run.

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Table 1. Selection for forage classes by heifers grazing *Acacia-Digitaria* grassland.

	Months						
Forage class	June	July	Aug.	Sept.	Oct.	Nov.	Mean
Grass/Grass-like plants	93.3	97.8	99.0	98.2	94.8	97.8	96.8
Forbs	2.4	T′	T′	T	2.1	T	1.0
Browse	4.3	2.2	1.0	1.8	3.0	1.2	2.2

T′ = selection less than 0.5%. NS = within months were not significantly different at 95% level of probability.
Source: adapted from Kibet, 1984.

Table 2. Selectivity for plant portions of cattle diets grazing Kiboko range.

	Months						
Plant portions	June	July	Aug.	Sept.	Oct.	Nov.	Means
Leaves	72.4	69.6	58.3	61.5	60.7	76.0	66.4
Stems	27.6	30.4	30.4	38.5	39.3	24.0	33.6
Leaf:stem ratio	2.6	2.3	2.3	1.6	1.5	3.2	2.0

Source: adapted from Kibet, 1984.

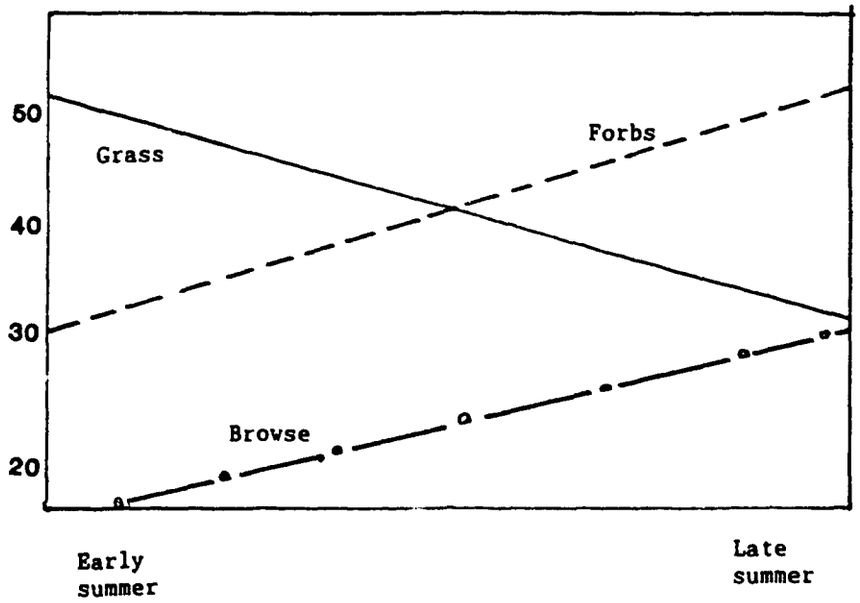

Figure 1. The composition of diets for cattle by forage classes from early to late summer on a typical range in northern Utah.

EFFECTS OF AVAILABLE FORAGE ON GOAT DIETARY SELECTION AND NUTRITION

Peter Njenga Kamau

INTRODUCTION

Goats are browsers and grazers and have a tendency to change their diets with changing seasons. A goat has a prehensile upper lip that allows it to be very discrete in selecting plants and plant parts that are palatable. Goats select a diet that maximizes energy intake, but the magnitude of selectivity is determined by feed abundance (Emlen, 1966; Hanley, 1980).

Bush encroachment is a problem on 25 million acres of grazing land in Kenya (Heady, 1960). Early studies indicate that goats would effectively suppress understory in this area and kill some trees (Woods, 1903). Goats would open up vegetation, thereby increasing the accessibility of other livestock classes to more nutritious forage.

Goats feed readily on most available plants including leaves, stems, fruits, inflorescence of grasses, bark, and roots. Further, goats have a higher threshold for bitter tastes than cattle (French, 1970). These qualities enable goats to consume a wider array of vegetation than cattle. The ability of the goats to use browse is probably an important factor contributing to their survival, especially in areas where feed is of low quality. Goats digest forage, especially the fiber fraction, more efficiently than other domestic animals (Ademosum, 1970; Gihad, 1976; Devendra, 1977; Sharma and Rajora, 1977), and this efficiency enables these animals to adapt better to poor environments where they convert low-quality materials into other products needed for human use.

Eighty percent of Kenya is classified as rangeland. This semiarid region supports 60% of the country's estimated 9 million beef cattle and more than 70% of the estimated 8.5 million sheep and goats, 1 million camels, and a considerable number of wildlife (Pratt and Gwynne, 1977; Ayuko, 1978; Bernsten and Jacobs, 1983). The livestock and wildlife in this area depend on natural vegetation for their nutritional requirements and production (Pratt and Gwynne, 1977).

The savannas of southcentral Kenya exhibit a wide array of bush conditions that have been created, in part, by overgrazing by the general herbivores and suppression of fire. However, knowledge of goats' browsing preferences in this region would be useful for assessing their potential as biological bush-suppressing agents. Presently, very little information exists as to the role bush plays in the diets of goats in this region, particularly during the most stressful period -- the long, dry season extending from June through October. Although the goat has been domesticated for up to 10,000 years and has been encountered over a wider geographical area than any other farm animal (French, 1970), its feeding habits in eastern Africa continue to be a subject of some controversy since the goat exhibits great plasticity in food habits.

PROCEDURE

Experimental Paddocks

Three bush conditions, twice replicated, were identified in the field based on total canopy cover. The study site was generally a wooded,

bushed grassland. Areas with bush cover less than 15%, 15% to 35%, and greater than 35% were designated light, moderate, and heavy, respectively. Each replicated treatment paddock was 2.25 ha in size.

Experimental Animals

One esophageally fistulated Galla goat with two esophageally fistulated small East African goats were allowed to graze each treatment paddock each morning for two consecutive days until enough extrusa was collected. These animals made up part of the herd that was going to be used for applying the necessary grazing pressure on a one-day graze, 28- to 30-day cycle beginning in June and ending in November, 1982.

Vegetation Measurement

Available browse and herbaceous standing crop in each treatment paddock were determined within 7 days of each grazing event, beginning June 9 and ending November 16, 1982. A modification of the line-intercept/belt-transect technique was employed. A shrub odumn grazing depth technique (GDT), similar to that used by Lopes and Stuth (1984), was employed to compute browse production.

Diet Measurements

Dietary samples were collected in rectangular sacks of nylon parachute cloth. They were dried approximately two days in a rack with a nylon-wire-screen bottom. Each sample was divided into halves. One half was analyzed for dietary fragments (macrohistology), and the other half was subjected to chemical analysis. The Micro-Kjedahl technique was used to determine crude protein (CP) (AOAC, 1975). In vitro organic matter digestibility (IVOMD) was determined by the fermentation stage of Tilley and Terry (1963) followed by neutral detergent extraction (Van Soest and Wine, 1967).

RESULTS AND DISCUSSION

Graminoids were high in the goat diets in June and July when more grass and grasslike herbage was available since the woody plant species were more or less in a dormant stage with their leaves shed (table 1). Browse, particularly Acacia senegal pods, increased in diets during the months of August and September while graminoids decreased. Forb consumption increased in the early wet season, thus reducing grass, grasslike species, and browse in the diets. This season was the most important factor creating substitutive relationships between grass/grasslike species, browse, and forbs in goats' diet composition throughout the study period.

Digitaria macroblephara was the dominant grass and contributed the highest species composition across treatment paddocks throughout the period of study. Cenchrus ciliaris, Sporobolus pellucides, Eragrostis caespitosa, and Chloris roxburghiana played important roles in diet composition at the beginning of the dry season and during the wet season. Solanum incanum, Grewia bicolor, Acacia mellifera, Acacia senegal, and Commiphora africana were the most-preferred woody species during the early dry and late dry seasons that contributed substantially to diet composition. Talinum portulacifolium was the most dominant forb found in goat diets during October, the beginning of wet season.

Selection for plant parts by foraging animals varied with seasons. Leafy materials dominated goat diets at the beginning and at the end of the study period. However, stems and fruits contributed to the goat diets during the dry season (table 2).

Crude protein was generally high in the diets from moderate- and heavy-bushed conditions, which offer higher levels of CP than do grasses (Rector and Huston, 1976; Lopes and Stuth, 1984).

Organic matter digestibility was high in the diets at the beginning of the dry season but decreased by the middle of the dry season followed by a steady increase until the end of the study period. This trend followed a decrease in graminoids in the goats' diets and an increase in forbs, immature browse, and grass as the available moisture increased. Digestible energy increased as forbs, grass, and immature browse increased in the diets in response to increased precipitation.

MANAGEMENT IMPLICATIONS

The study indicated that there is no deficiency in nutritive value of forage during the most stressful period -- June through November. Grass, grasslike forbs, and browse are necessary to contribute the nutrients needed in the diets of goats. Any management strategy that is aimed at increasing goat production should consider forage availability rather than the nutritive value of the forage. Acacia senegal pods provide a useful source of crude protein during August and September when most other vegetation material is unavailable to the grazing animal. Solanum incanum fruits play a very important role in the diets of goats during the early wet season. Such pods and fruits should be considered in the management of goats in similar areas falling in ecological zone V.

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Table 1. Botanical composition (%) of goat diets selected by month (on weight basis) for various categories of bush conditions in an Acacia senegal savanna at Kiboko, Kenya, 1982.

	June			July			August			September			October			November		
Forage class/ species	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Grass/ Grasslike	20.8	67.6	83.8	85.2	27.5	88.8	92.4	30.1	77.6	79.4	33.1	20.0	57.2	29.7	0.1	42.1	36.5	12.6
Forbs	T	T	T	T	T	T	T	T	T	T	T	T	43.1	14.2	18.9	T	17.6	27.9
Browse	78.5	19.9	14.3	14.0	72.5	10.2	7.6	69.9	92.4	20.6	66.8	80.0	2.1	56.1	81.3	57.8	45.5	59.4

L = Light
M = Medium
H = Heavy
T = Trace

Table 2. Plant part composition (%) of goat diets selected from light, moderate, and heavy bush-cover paddocks in Acacia senegal savanna at Kiboko, Kenya, 1982.

	June			July			August			September			October			November		
Plant part	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Leaf	65	37	67	18	52	25	42	22	13	33	31	35	84	89	99	72	80	58
Stem	32	46	31	78	26	50	55	33	17	52	41	32	16	11	1	20	12	15
Fruit[a]	3	13	2	4	22	25	3	45	69	15	28	33	T	T	T	8	8	17

[a]Includes pods and seeds.

Table 3. Mean dietary nutrient of esophageally fistulated goats grazing on Acacia senegal savanna of varying bush conditions throughout the dry season and early wet season at Kiboko, Kenya, 1982.

Mean Nutrient	Month					
	June	July	August	September	October	November
Crude protein	12.3	11.8	12.7	14.0	26.6	16.2
Organic matter digestibility	63.0	60.9	52.3	55.1	69.4	71.7
Digestible energy	2424.9	2436.9	2091.0	2204.3	2776.1	2867.5

Crude protein of 9.3% was found to be the lowest in the light-treatment paddock in the month of August. IVOMD and energy were lowest during the same month.

ENVIRONMENTAL FACTORS INFLUENCING PRODUCTIVITY OF SAHIWAL CATTLE AT NAIVASHA

B.A.J. Mwandotto

ABSTRACT

Pedigree Sahiwal data kept at the National Animal Husbandry Research Station from 1964 through 1983 were analyzed using least-squares procedures to identify and characterize environmental factors affecting birth weight, growth rate to 27 months of age (females), mature weight, and lactation yield of the Naivasha herd.

Sire and birth year influenced all the characters analyzed, while parity affected only birth weight and lactation yield ($P<.001$). Sex of calf also had significant influence on birth weight ($P<.001$). While season had only marginal effects on birth weight ($P<.05$), birth year x season interaction influenced all the characters in varying degrees, being least for mature weight. Previous calving interval affected birth weight and lactation yield both linearly and quadratically, while lactation length affected lactation yield only quadratically ($P<.001$). Cow weight at calving did not influence either calf growth or lactation yield ($P>.05$).

Male calves were 2.0 kg heavier than females. Average lactation yield and growth rate had linear declines of -23.3 $\pm$ 7.9 kg and -4.4 $\pm$ 2.2 g/day per year respectively over the study period. Years with average or more-than-average rainfall tended to produce cows with smaller mature weight. Linear and quadratic partial regression coefficients of birth weight on mean preceding calving interval were 0.0061 $\pm$ 0.0023 kg/day and -0.0000054 $\pm$ 0.0000021 kg/day^2 respectively. The respective coefficients for milk yield were 2.47 $\pm$ 0.43 and -0.002 $\pm$ 0.0004, and the respective coefficients for milk yield on mean lactation length were -0.68 $\pm$ 0.52 kg/day and 0.02 $\pm$ 0.0013 kg/day^2.

INTRODUCTION

Naivasha station has been a central breeding station for Sahiwals (original breed of Pakistan and India) from 1964. The station, located in the Rift Valley Province of Kenya, is in a semiarid ecozone IV as described by Pratt et al. (1966) with a mean annual temperature of 18°C and a mean annual rainfall of 620 mm. The central breeding program was designed to produce a dual-purpose animal with slightly more emphasis on milk yield for the range areas (figure 1). The initial stock of upgraded Sahiwals from the indigenous, small East African Shorthorn Zebu foundation has been maintained with the specific objectives of producing progeny-tested bulls for the national artificial insemination program, producing animals of high merit for pastoralists and ranchers, and ensuring continuous improvement of the breed. Details of this program have been described by Mason (1965), Meyn and Wilkins (1974), and Kimenye (1978). Production data of the Naivasha herd have been kept consistently from the inception of the breeding program. This paper reports some of the results from this database aimed at identifying some of the environmental trends in the productivity of the Sahiwal herd. Management implications thereof are discussed.

MATERIALS AND METHODS

Herd Management

A deliberate effort was made to keep the management of the herd as consistent as possible. The herd was kept as a commercial unit of about 400 milking cows to simulate the conditions under which the potential buyers would keep cattle. At parturition, calves were removed from their dams. Both the dam and calf were weighed, and the calf was tattooed in the ear with a serial identification number. Calves were bucketfed with whole milk up to 55 kg, and their weights were taken weekly, after which they were introduced to commercial pellets until they attained 125 kg. Colostrum was fed the first 3 days. Dehorning was done at 6 weeks. After achieving a weight of 125 kg, bull and heifer calves were managed in separate herds on natural pasture without supplementary feeding. Bulls were weighed monthly, but heifers were weighed at 27 months of age when they were first bred.

All animals were regularly treated for internal parasites and dipped once a week against ectoparasites. They also were inoculated against foot and mouth, black quarter, anthrax, brucellosis (heifers), and Rift Valley diseases. The herd was 100% artificially inseminated by trained heat detectors and inseminators. Herdsmen attended the animals at all times to protect them against theft and predators and detect animals that were in heat or sick. All herds, except very young calves, grazed for 24 hours a day with free access to water and mineral licks at the grazing paddocks. Cows were hand-milked twice a day. Ground hay mixed with dairy meal was fed at milking to ensure good milking temperament and easy milk let-down. Cows producing 5 kg/day from natural pasture were fed at the estimated rate of 1 kg concentrate for every 3 kg of milk produced. This practice stopped in 1971, and every cow was given about 5 kg of the concentrate mixed with ground hay every day.

The natural grazing consisted mainly of kikuyugrass (*Pennisetum clandestinum*) and common stargrass (*Cynodon dactylon*). Leleshwa and fever trees (*Tarchomanthus camphorates* and *Acacia xanthophloea*, respectively) were the common bush trees on the grazing paddocks. Low-lying bushes of *Solunum panduriforms* and *Psaidia arabica* occurred. The pasture was managed according to ecological principles. A mature animal was allowed about 10 acres of grazing per year. Rotational grazing, based on physical appraisal of standing crops, ensured a good spread of manure on the paddocks and recovery of the pasture after grazing. Dry herds followed the milking herd in the rotation. Bush encroachment was manually but not consistently controlled. There was very active competition for grazing resources between the experimental herd and herds of zebras, gazelles, hippopotamuses, buffalo, and sometimes giraffes. Estimated nutrient composition of the feed and forage consumed by the herd is shown in table 1.

Data Classification

All live-weight, milk-yield, pedigree, veterinary, service, calving, and disposal records were collected continuously from the field and stored at a central office. Records for this paper were confined to animals of accurate pedigrees that were not consistently sick and that had at least birth-weight or first-lactation records. About 10% of the records were deleted on this basis. Variables extracted directly from the certified data were animal's pedigree, parity, date of birth, birth weight (BW),

live weight at different stages of growth, lactation yield (LACY), lactation length, and previous calving interval. Derived variables were season of birth or parturition, average growth rate from birth to 27 months of age for females (ADG 27), and mature weight (MW).

Season was classified on the basis of temperature-humidity index (THI) and mean monthly rainfall (table 2) following Kiwuwa (1973) and Kimenye (1978). The THI was developed by the United States Weather Bureau (1959) as: THI = td - (0.55 RH) x (td - 58), where td = dry bulb temperature in ^{o}F and RH = relative humidity. Using the index, Kimenye (1978) identified four 3-month seasons that span the months of January through March, April through June, July through September, and October through December to be suitable seasons for Naivasha. This classification was adapted for this study. Parity was classified from 1 through 8, the later including higher parities. Parity represented age-of-cow effects due to high correlations between cow age parity (Mosi, 1980). ADG27 and MW were derived according to Fitzhugh and Taylor (1971). ADG27 was defined as weight at 27 months of age minus BW divided by 813 (813 was mean age at 27 months in days). Preliminary analyses revealed that cow weights reached their peak at parity 7 (Mwandotto, 1985). In obtaining MW, least-squares additive adjustment factors for parities 1, 2, 3, 4, 5, and 6 of 66, 38, 24, 12, 4, and 3 kg respectively were used, which were developed from the same data. Means were taken for cows that had two or more of these mature equivalent weights. This definition of MW did not take into account the animal's body condition.

Statistical Analyses

Initial editing and checking for the data structure was executed using the SORT, MEAN, and FREQUENCY procedures of the Statistical Analyses System (SAS, 1979). This provided for raw means, maximum, minimum, and frequency tables for individual characters. Estimates of these values were required for the final analyses using the Least Squares and Maximum Likelihood (LSML76) program of Harvey (1982). This program allowed for mixed-model analyses, with sire and error terms entering the models as random variables. The error means squares were used as the test of significance criteria. Data were sorted according to apriori postulation of the sources of variation affecting the respective characters.

Sums of squares for sires were computed in two steps. First, the sires were ignored, and reduction sums of squares were calculated. In the second round, the sires were included, and their sums of squares were computed as the difference in the reduction sums of squares in the two runs. Variance component for sire was therefore estimable. Previous calving interval and lactation length were analyzed as covariates. Individual models for characteristics studied are shown in table 3.

RESULTS AND DISCUSSION

Results of the analyses of variance for the four characters studied are summarized in table 3. The results show that all the factors tested had significant effect ($P<.05$) on birth weight. However, the environmental effects of season and dam parity did not influence the growth of Sahiwal calves to maturity ($P>.05$). Previous calving interval of dam also did not affect the growth of calves after birth. All the factors tested had significant influence on cow lactation yields ($P<.001$) except parturition season and linear effects of lactation length when quadratic effects of the latter was in the model. Preliminary analyses showed

that dam and cow weight at birth had no influence on birth weight and milk yield respectively (P>.05). Though seasonal effects were important only for birth weight, the effect of year x season interaction influenced all the characters studied, the effect being only marginal for mature weight. Only environmental factors will be discussed further, even though sire effects also were important, implying significant genetic effects.

Least-squares constants for year effects in all the analysis models and for parity effects in the birth weight and lactation yield are presented in table 4. There was no systematic year trend affecting birth weight. A 6.8% difference between birth weights in 1975 (heaviest) and 1965 (lightest) is smaller than the one reported by Harricharan et al. (1976) for Sahiwal cattle. There was, however, a definite negative trend in the other traits as years progressed from the start of the breeding program. Linear regression coefficient of the least-squares mean of ADG27 on years was -4.2 ± .9 g/day/year (P<.05), which compared well with a similar coefficient of -4.4 ± 2.2 for growth to 24 months for Ndama cattle (Touchberry, 1967).

Linear regression coefficient of the mean for milk yield on years was -23.3 ± 7.9 kg/year (P<.05). Such drastic decrease in yield has been reported recently by Schneeberger et al. (1984) in the Jamaica Hope breed, and they attributed it to decline in feeding and cow-culling management. There was also a continuous decrease in mature weight of the Naivasha Sahiwal cattle over the study period. Decline in these important characters could be a reflection of adaptation of the animals to an increasingly difficult production environment in terms of frequency of droughts that impart nutritional stress to animals. Linear regression of total annual rainfall for Naivasha on years was not significant (P>.05) and reflects independence of the decline in the herd performance of annual rainfall amounts received. The nutritional stress could be operating through other management practices such as decreased grazable land due to bush encroachment, increased number of wild game in grazing paddocks resulting in lack of standing hay for drought-feeding management, and increased frequency of outbreaks of diseases such as foot and mouth. Quarantines imposed during outbreaks restrict regular animal disposals, thus causing depletion of grazing and eventual permanent deterioration of the land's carrying capacity. The decline in milk yield was attributed mostly to decline in lactation length, which was similarly affected by the same factors influencing milk yield and which had high correlation with milk yield (r = 0.7).

Sex of calf and maternal effects expressed through dam parity and previous calving interval were only important at birth of calf. Male calves were 2 kg (9.5%) heavier than female calves at birth. The recorded mean birth weight of 22.9 ± 0.01 kg and the weight difference between male and female calves agree with the weights recorded by the International Livestock Centre for Africa (ILCA, 1981) and Harricharan et al. (1976) for Sahiwal calves. Parity effects showed maximum birth weight and milk yield to be expressed at parity 7, and a decline sets in for both characters at subsequent parities. This decline is associated with the onset of the aging process of the dam (Fitzhugh, 1976). Tonn (1974) did not find any dam age effects on birth weight of Boran calves, and he attributed this to the harshness of the environment of his study. Linear and quadratic partial regression coefficients of birth weight on the mean preceeding calving interval of 0.0061 ± 0.0023 kg/day and -0.0000054 ± 0.0000021 kg/day^2 respectively were obtained in the study, indicating an advantage in resting the cows sufficiently before

rebreeding; but the advantage diminishes at exceedingly long resting periods. Harricharan et al. (1976) did not find significant influence of calving interval on birth weight of Sahiwal calves. Calving interval seems to be part of maternal effects whose expression depends on the environment pertaining to a particular herd. In the Naivasha herd, prenatal effects disappear soon after birth of calves, probably due to the bucket-feeding practice.

Parity effects on lactation yield showed similar trends to birth weight. The continuous production increase of Sahiwal cows up to about 11 years of age shows good adaptation of the Sahiwal to the Naivasha environment. Decline in production of Boran cows at 4 years of age has been recorded by Tonn (1974) and by Ruvuna et al. (1984) for Sahiwal cows. Calving interval effects on milk yield also showed an increase of lactation yields to a maximum, followed by a decline as preceding calving interval increased. Linear and quadratic partial regression coefficients of milk yield on mean preceding interval of 2.47 $\pm$ 0.43 kg/day and -0.0002 $\pm$ 0.0004 kg/day respectively were found in this study. The effect of calving interval also has been shown to influence milk yield of Sahiwals in India by Ruvuna et al. (1984). Milk yield also increased in a quadratic manner in this study, as in the study of Ruvuna et al. (1984), as lactation length increased. Linear and quadratic partial regression coefficients of milk yield on mean lactation length of -0.68 $\pm$ 0.52 kg/day and 0.02 $\pm$ 0.0013 kg/day^2 were obtained in the present study. These compare with the respective coefficients of -0.40 and 0.02 from Ruvuna et al. (1984). In the present study, the effect of the linear term ceased to be significant when the quadratic term was included in the model.

Preliminary investigation into the effect of dam and cow weights at birth on weight or growth and milk yield, respectively, had shown cow weight not to have any influence in these characters ($P>.05$). Lack of relationship between cow weights and weight performance of their calves or milk yield could have been due to the ability of Sahiwal cows to maintain their body condition during dry seasons as evidenced by high fertility rates of the cows during the dry seasons in this study. Cow weight loss during dry seasons lowers fertility (Thorpe et al., 1981). Seasonal changes of cow weights were not investigated in the present study. Late first breeding of Sahiwal heifers at Naivasha at 27 months of age also could have diminished the potential relationship between these characters, especially the growth of the calves since the relationship normally is larger in the early part of the cow's lifetime (Fitzhugh, 1965). Kimenye (1978) found an increase in milk yield as weights of cows increased in the Naivasha herd. Lack of this relationship in the current study could be due to exclusion of first calves in the model; thus, the cows dealt with are slightly more mature and have more stable weights than the animals in Kimenye's study. Further research in this area is warranted.

Season had marginal importance only at birth, but the effect of year x season interaction was persistent up to the maturity of animals. Lack of seasonal effects in most of the characters reported could be due to the low repeatability of the defined seasons across years as shown by the year x season interaction. Other bases of seasonal classification have been attempted successfully before. Kimenye (1978) found individual months could be defined as independent seasons. For data sets spanning long time intervals, this takes many degrees of freedom, and management implications are difficult to apply. Carles and Riley (1984) defined seasons on the basis of soil-water budgets, considering residual

moisture the month previous to the month of birth and the additional moisture the following month. Mwandotto, Carles, and Cartwright (unpublished) considered the yearly distribution of rainfall to define season and analyzed individual months in the seasons as nested within season. Total rainfall in the season was then included as an independent covariate. Both of these yielded useful results for seasonal effects. Kimenye (1978) advanced the possibility of seasonal breeding for the Naivasha herd. This practice is not supported by the current results that came from data covering a wider period than the one reported by Kimenye (1978). The requirement air continuous milk supply and maintenance of productive labor in the dairy industry also would not support seasonal breeding for the dual-purpose herd in Naivasha. The importance of year x season interaction as it affects milk yield is demonstrated in figure 2. The least-squares constants show that cows calving in seasons 2 and 3 are less variable about mean milk yield than those calving in seasons 1 and 4. Milk yield tends to vary from season to season in a manner that is not predictable from year to year. Small seasonal variations exhibited in years 1970, 1974, and 1976 could not be explained in terms of rainfall figures, though 1976 was a drought year in eastern Africa. There was a tendency, however, for cows born in years with average or more rainfall to end up with smaller mature weights than those born in the years having the least rainfall. Such long-term stunting effects could be associated with build up of internal worms, ticks, and other ectoparasites, poisonous plants, wildlife-species populations, and bush encroachment, which may affect the growing calf in a pattern that is not offset by compensatory growth. Monitoring of all these effects has not been incorporated into the routine observations at Naivasha. Most of these factors tend to have seasonal effects; for example, infective stages of worms, levels of toxins in plants, and seasonal migrations of wildlife.

SUMMARY AND CONCLUSION

Pedigree Sahiwal data kept at the National Animal Husbandry Research Station, Naivasha, from 1964 through 1983 were used for the study. Final analyses of the data were executed using SAS (1979) and the Least Squares and Maximum Likelihood program of Harvey (1982) to identify and characterize environmental factors affecting birth weight, growth rate to 27 months of age for females, mature weight, and lactation yield of the Naivasha herd. The respective means for these characters were 22.9 $\pm$ .1 kg, 320.5 $\pm$ 1.5 g/day, 423.5 $\pm$ 1.9, and 1507.3 $\pm$ 19.8 kg.

Sire, birth year, and year x season interaction affected all the characters studied. Birth season, previous calving interval, and parity affected only birth weight; but parity, calving interval, and lactation length all affected lactation yields significantly. While the effect of calving interval was both linear and quadratic, the effect of lactation length was only quadratic. Male calves were 2.0 kg heavier than females at birth.

Maternal effects of parity and calving interval on growth of calves ceased to exist at about 3 months of age, indicating that potential breeding animals can be selected early in their life after compensatory growth. Our current practice of selecting breeding bulls at 24 to 30 months of age should be reviewed so that they are evaluated as early as 18 months of age. Cows, however, continue to grow and increase in milk yield up to parity 7, showing maximum productivity of Sahiwal cows at about 11 years of age. This shows suitable management of the animals at Naivasha and(or) the adaptation of the breed to Naivasha environment.

Continuous decline in the herd's production characters except birth weight is an indication of deterioration in management and environment at Naivasha across years. Feed supplementation policies for the dry season and drought years should be worked out and incorporated into routine management, which also should include monitoring of the land's carrying capacity. Since the annual decline in production is conditioned by seasons, more research is warranted in seasonal profiles of poisonous plants, worm burden, wildlife numbers, and interactions and weight changes of cows. This knowledge is important for developing policies for managing the herd. No suitable breeding season could be recommended for this herd. Continuous breeding seems the only way to optimize fertility, calf viability, growth, milk yield, and the use of labor on the farm.

The mean birth and mature weights, milk yield, and calving interval (432.4 $\pm$ 96.0 days) established for the herd make the Sahiwal fit the characteristics of the dam line described by Cartwright (1970), especially for pasture regimes (Long et al., 1975) or for cow-calf operations (Cartwright, 1979), with desirable qualities of relatively small size, appreciable milk yield, freedom from dystocia, high fertility, and general adaptability. The Sahiwal and Boran have been shown to be the best breeds as foundation stock for Kenya ranches (Tonn, 1974; Mwandotto, 1978; Trail and Gregory, 1981) in terms of their potential for individual growth and as base for crossbreeding with Bos taurus breeds. Sahiwal cows tend to be more productive than Boran cows when credited for their superior milk yields and shorter calving intervals (Trail and Gregory, 1981). On this basis, the Naivasha herd will continue to play a key role as a nucleus herd, generating seed stock for meeting superior purebreed requirements both at home and overseas and for crossbreeding. Management of the herd, therefore, should be stepped up to reverse the declining production trends.

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Table 1. Annual and seasonal rainfall (mm) for the study period at Naivasha.[a]

	Seasons[b]				
Year	1	2	3	4	Total
1966	100.2	291.4	124.9	130.4	646.9
1967	100.2	282.0	117.3	166.8	666.3
1968	239.8	320.8	51.0	201.7	813.3
1969	221.0	139.8	96.2	124.3	581.3
1970	235.4	192.1	122.9	96.1	646.5
1971	110.5	227.2	197.4	151.0	692.1
1972	145.0	179.1	89.2	179.8	593.1
1973	137.0	197.9	167.8	111.4	614.1
1974	69.1	360.2	175.6	107.5	712.4
1975	115.1	182.9	217.0	111.2	626.2
1976	64.3	229.2	138.5	66.7	498.7
1977	107.9	361.4	135.5	253.5	858.3
1978	296.4	237.2	230.8	217.7	982.1
1979	328.2	219.3	131.7	111.5	790.7
1980	104.7	281.1	33.9	139.9	559.6
1981	185.3	287.1	145.1	167.2	784.7
1982	65.4	270.0	163.2	333.7	832.3
1983	78.0	272.9	109.2	236.2	696.3
Mean	150.2	249.3	135.0	161.8	699.7

[a]Mean annual rainfall for Naivasha = 620 mm.
[b]1 = Jan-Mar, 2 = Apr-June, 3 = July-Sept, 4 = Oct-Dec.

Table 2. Chemical composition (%) of feed and grasses used by the Sahiwal Stud.[a]

Description	Dry matter	Crude protein	Crude fiber	Total ash	Nitrogen-free extract	Number of samples
Compound feeds						
Dairy meal	88.96	15.68	9.45	5.94	68.93	41
Early-weaner pellets	89.73	18.89	5.15	5.89	70.07	5
Grasses						
Kikuyugrass	28.94	11.56	25.66	11.06	51.72	5
Naivasha stargrass	31.60	20.20	25.30	12.90	41.60	5
Rhodesgrass (hay)	91.43	5.78	42.16	9.82	40.45	10

[a]Percentage of nutrients calculated on dry-matter basis.

Source: adapted from K.R.G. Irungu and J.P. Nduyu (unpublished report).

Table 3. Degrees of freedom (DF) and tests of significance (TS) for the mean squares of factors affecting birth weight (BW), average growth rate to 27 months of age (ADG27), mature weight (MW), and milk yield (LACY).

Source	BW		ADG27		MW		LACY	
	DF	TS	DF	TS	DF	TS	DF	TS
Sire	204	xxx	175	xxx	129	xxx	168	xxx
Birth year (Y)[a]	19	xxx	16	xxx	13	xxx	19	xxx
Birth season (S)[a]	3	x	3	NS	3	NS	3	NS
Sex	1	xxx	-	-	-	-	-	-
Parity	6	xxx	6	NS	7	NS	6	xxx
Y x S	57	xx	44	xxx	37	x	57	xxx
Calving interval								
Linear	1	xx	1	NS	-	-	1	xxx
Quadratic	1	x	1	NS	-	-	1	xxx
Lactation length								
Linear	-	-	-	-	-	-	1	NS
Quadratic	-	-	-	-	-	-	1	xxx

x = P<.05
xx = P<.01
xxx = P<.001
NS = Not significant
[a]Parturition year and season for LACY.

Table 4. Number of animals (N), least-squares constant + standard error of year and parity effects for birth weight (BW), average growth rate to 27 months of age (ADG27), mature weight (MW), and lactation yield (LACY).

	N	BW (kg)	N	ADG27 (g/d)	N	MW (kg)	N	LACY (kg)
Over-all Mean	6022	22.9 ± .1	2579	320.5 ± 1.5	1108	423.5 ± 1.9	5429	1507.3 ± 19.8
Birth year[a]								
1964	246	0.2 ± .6	227	53.0 ± 5.1			229	127.2 ± 34.5
1965	334	-1.0 ± .3	233	75.3 ± 4.2	17	21.3 ± 15.0	309	-16.2 ± 30.3
1966	415	-0.5 ± .2	237	38.2 ± 3.9	92	12.2 ± 7.3	388	-5.6 ± 27.6
1967	455	0.1 ± .2	287	6.5 ± 3.5	127	13.6 ± 5.3	422	36.1 ± 25.8
1968	371	-0.1 ± .3	224	10.4 ± 4.9	108	5.8 ± 7.7	295	95.0 ± 28.8
1969	262	0.4 ± .2	112	4.5 ± 5.0	70	23.4 ± 8.2	228	200.7 ± 30.7
1970	229	0.0 ± .2	116	13.6 ± 4.8	72	7.3 ± 6.1	202	258.4 ± 31.4
1971	277	0.4 ± .2	149	-8.2 ± 3.8	127	7.9 ± 4.8	244	283.3 ± 28.8
1972	258	0.3 ± .2	92	12.8 ± 4.3	84	2.7 ± 5.2	233	300.7 ± 30.2
1973	292	0.1 ± .2	127	4.8 ± 3.6	93	-21.3 ± 5.2	258	167.1 ± 27.9
1974	316	0.3 ± .2	111	-53.6 ± 4.1	67	6.5 ± 6.3	276	64.2 ± 27.1
1975	351	0.5 ± .5	77	-24.2 ± 5.4	57	-11.2 ± 8.9	319	13.9 ± 75.5
1976	285	0.0 ± .2	105	-5.8 ± 6.7	76	-10.6 ± 8.0	261	-194.4 ± 29.8
1977	308	-0.1 ± .2	130	-15.3 ± 5.3	75	-27.6 ± 8.7	284	-120.1 ± 27.7
1978	271	0.1 ± .2	112	-18.0 ± 5.4	43	-18.6 ± 10.6	251	-102.7 ± 29.4
1979	316	0.2 ± .3	78	-58.4 ± 6.8			246	-39.1 ± 30.6
1980	286	0.1 ± .3	162	-36.1 ± 5.7			275	-198.1 ± 29.5
1981	283	-0.4 ± .3					269	-299.9 ± 31.1
1982	302	-0.9 ± .3					295	-245.7 ± 31.4
1983	165	0.1 ± .3					144	-258.2 ± 41.7
Parity								
2	1912	-0.2 ± .1					1717	-69.6 ± 12.5
3	1239	0.0 ± .1					1116	-13.9 ± 13.4
4	895	0.2 ± .1					810	45.0 ± 14.8
5	675	0.1 ± .1					609	-0.8 ± 16.5
6	474	0.2 ± .1					442	-1.4 ± 18.9
7	324	0.0 ± .1					291	57.5 ± 22.9
8	503	-0.4 ± .1					444	-17.8 ± 19.7

[a]Parturition year for LACY.

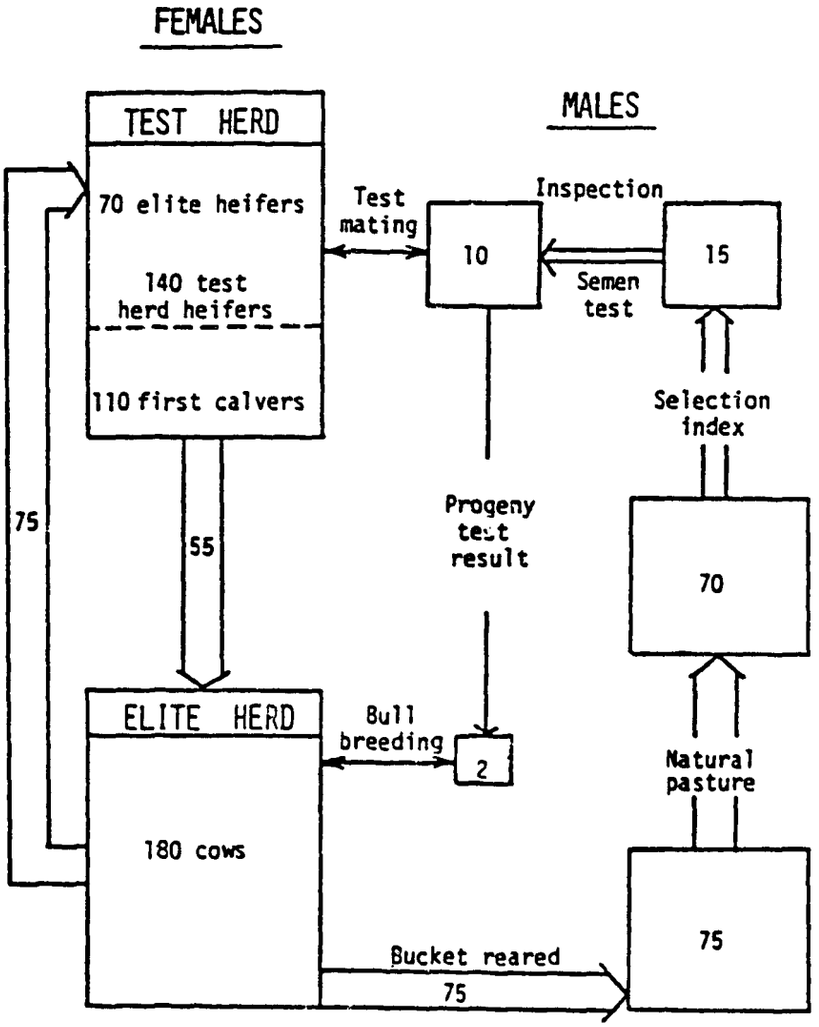

Figure 1. Breeding plan at the National Sahiwal Stud, Naivasha.

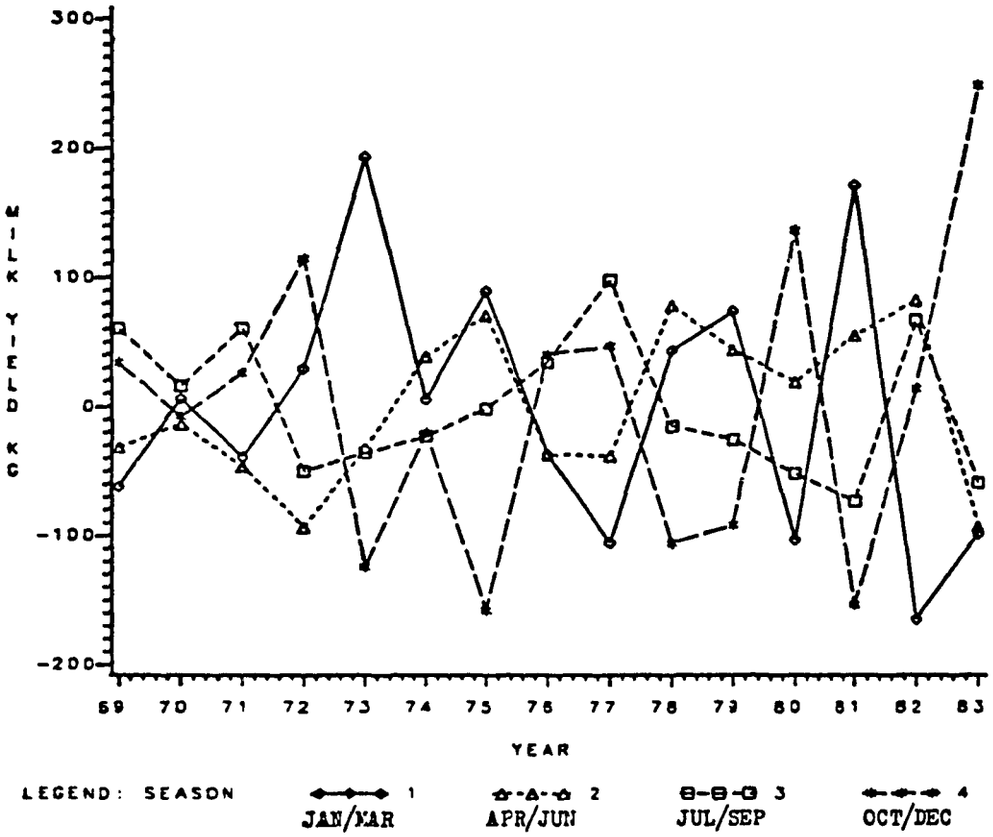

Figure 2. Season least-squares constants computed across years for mean milk yield.

EFFECTS OF BURNING ON SOIL- AND PLANT-WATER RELATIONS IN A BUSHED GRASSLAND IN KENYA

A.R. Ali, F.E. Smeins, and M.J. Trlica

ABSTRACT

Seasonal xylem tensions, transpiration rates, and diffusive resistances of two grass and two shrub species, and seasonal data on soil-water potential were collected on burned bushed grassland areas in Kenya. Burning did not affect soil and plant water throughout the growing season, but it did affect plant-water status on some dates. Xylem tension of plants was predominantly influenced by seasonality of soil-water availability. Transpiration rates were primarily affected by vapor pressure deficits when soil-water potential was not limiting. Xylem tension of Acacia mellifera was usually more negative than for other species. The two grasses were intermediate, and Commiphora riparia had values always less negative than -2.0 MPa. The shrubs transpired at higher rates than the grasses. These plant species had various drought-avoidance mechanisms to cope with seasonal drought stress. Differences in rooting characteristics and leaf morphological features were observed that allowed these plants to coexist in a seasonally variable soil-water environment.

INTRODUCTION

About 80% of Kenya is rangeland that is characterized by low rainfall, high temperatures, and soils that are shallow, stony, or high in salts (Heady, 1960). Therefore, the land is suitable for maintaining livestock and wild ungulates; however, sound range-management practices must be applied to sustain optimum animal production and conserve soil, water, and vegetation resources. Several tools have been used for management of range resources, including prescribed burning. It was reported that a decrease of frequency and intensity of fire and an increase in livestock grazing pressure has resulted in bush encroachment in Kenya (Heady, 1960; Skovlin, 1971). Heavy bush thickets reduce herbaceous-forage production, and most forage that is produced in dense thickets is inaccessible to livestock (Thomas and Pratt, 1967). Kinyamario (1982) found that the woody canopy and height of shrubs were effectively reduced and stem mortality increased by burning during the dry season. Prescribed burning has been shown to have positive effects on the quality of forages, and plants on burned sites often are species that are preferred by herbivores (Vogl and Beck, 1970; Daubenmire, 1968; Klett et al., 1971). Big game are known to prefer new growth on burned sites because of its higher palatability. Furthermore, burning reduces old growth and may reduce the populations of ticks, mites, and biting flies (Van Rensburg, 1971).

Reaction to fire varies with grassland type, fuels, soils, moisture conditions, frequency and intensity of burning, and biotic factors (Vogl, 1974). Thus, these factors interact to affect plant composition, grass production, watersheds, and plant-water relations.

Burning of vegetation produces differential responses by favoring some plant species more than others. Productivity of Panicum maximum, Heteropogon contortus, and Themeda triandra were found to be increased with burning, while Latipes senegalensis and Chloris roxburghiana decreased (Pratt, 1966; Thomas and Pratt, 1967). Trlica and Schuster

(1969) reported that fall, spring, and summer burning significantly reduced total forage production of a Texas High Plains grassland but caused a decrease in vigor of less-desirable grasses. Prescribed burning also has been found to influence soils and hydrologic characteristics of rangelands. Cheruiyot (1984) found that burning before a long rain during February resulted in lower infiltration rates and higher sediment production in burned areas compared to unburned areas. However, results were reversed during October. The area burned in October received lower grazing pressure from wild animals than the area burned in February because the former comprised a much larger area than the latter.

Burning results in exposure of more bare ground that may result in increased erosion. Infiltration rate was higher and sediment production was lower on vegetated areas of a bushed grassland in Kenya than on bare ground (Mbakaya, 1985). Infiltration rates, then, influence the amount of soil-water storage and consequently affect the amount of soil water available for plant growth. In an evaluation of plant- and soil-water potentials, Maranga et al. (1985) found that leaf-water potentials for Digitaria macroblephara and Panicum maximum were quite similar and were correlated with soil-water potential.

Little is known of the effects of burning on soil- and plant-water relations in Kenya. Reduction in vegetation cover caused by burning should result in changes in microclimate. The factors associated with microclimate, such as solar radiation, wind, ambient temperature, and relative humidity, undoubtedly will be affected, which in turn will affect soil- and plant-water relationships. Specifically, this study was designed to determine the effects of burning on seasonal dynamics of xylem tension, transpiration rate, and diffusive resistance of Acacia mellifera, Commiphora riparia, Chloris roxburghiana, and Digitaria macroblephara.

PROCEDURES

The study was conducted at National Range Research Station, Kiboko, Kenya, which is about 160 km southeast of Nairobi (figure 1). The station covers 30,000 ha and ranges in altitude from 900 m to 1,000 m. Long-term annual rainfall since 1904 is 600 mm, with a long rainy season from March through May and a short rainy season from November through December. This usually results in two distinct growing seasons interrupted by dry periods. Mean annual temperature and evaporation are 23°C and 2,000 mm, respectively. Rainfall data was collected on each study site at 10-day intervals during the duration of the study from November 8, 1982, to February 28, 1983. Vegetation of the research area station is bushed grassland (Michieka and Van der Pouw, 1977). The dominant woody species occupying the area are Commiphora riparia, Acacia mellifera, Acacia senegal, Acacia tortilis, Grewia villosa, Cordia ovalis, and Balanites aegyptiaca. Associated dominant grass species are Digitaria macroblephara, Chloris roxburghiana, Eragrostis caespitosa, Brachiaria insculpta, and Cenchrus ciliaris.

Two specific sites were chosen for this study. These were the Mwailu and Boma-8 sites, which were located about 1.5 km and 8 km southeast of the station headquarters, respectively. Soils of the two study sites are acri-rhodic ferralsols, and the vegetation is dominated by Acacia senegal, Acacia mellifera, Commiphora riparia, Grewia villosa, Chloris roxburghiana, Digitaria macroblephara, and Eragrostis caespitosa. Four 100-m x 100-m plots, arranged in a row, were selected at Mwailu site.

Two plots were selected randomly to be burned in February 1982. The other two plots were left as unburned controls. Four other experimental plots about 100 m apart were identified at the Boma-8 site. Two of these plots were burned in October 1982, while the other two plots were treated as unburned controls.

A sample of four leaves per plant of the four plant species of Acacia mellifera, Commiphora riparia, Digitaria macroblephara, and Chloris roxburghiana were evaluated for plant-water status. Xylem tensions of plant species were measured using a pressure bomb as described by Scholander (1964). Leaf temperatures, transpiration rates, and diffusive resistances were measured with a Licon 1600 steady-state porometer. Microclimatic variables such as ambient temperature, relative humidity, and quantum flux also were measured with the steady-state porometer. Vapor-pressure-deficit values were generated using a relationship that used air temperature and relative humidity (Rosenberg, 1974). Soil-water potential at 10-cm, 30-cm, and 120-cm soil depths were measured at one location within each plot on each sampling day, using a single-junction stainless-steel-screen soil psychrometer.

Soil- and plant-water status were measured on 18 dates throughout a growing season. Data were collected at Mwailu site between 1000 and 1200 hours and at Boma-8 between 1215 and 1415 hours.

The experiment used a randomized-block design with split-split plot arrangement of four species and 18 dates, having two replications of the burning treatments (burned and unburned). Samples of four plants each with four leaves on each plant were taken on each treated plot per day for the total period of 18 dates. An analysis of covariance, using air temperature as the covariate, was used to test differences between the two study sites for plant-water relation. Analysis of variance was used to test the effects of burning on soil- and plant-water status variables.

Root-distribution data for Acacia mellifera, Commiphora riparia, Digitaria macroblephara, and Chloris roxburghiana were collected from an area adjacent to the Mwailu plots. Data were collected during July 1982 before actual data collection for the soil- and plant-water variables. Two replications about 400 m apart were selected. On each replicate, four trenches 3 m long, 1 m wide, and 1.5 m deep were excavated. In each trench, one of the large walls, which contained a plant whose central axis ran through the middle of the wall, was vertically flattened. Soil blocks of 15 cm x 15 cm x 15 cm were removed on one-half of the wall section. Soil was washed from the plant roots over a 1-mm sieve, and the roots were dried and weighed for determination of root biomass. On the other half of the wall, the plant roots were exposed using a sharp-pointed instrument. Photographs showing root distributions of the four study species were taken.

RESULTS

Rainfall patterns of both study sites appeared similar except during October, when rainfall was well distributed throughout the month at Boma-8 but occurred only during the first 10 days at Mwailu (figure 2). Factors associated with microclimate, such as air temperature, relative humidity, quantum flux, and vapor-pressure deficit, were significantly different ($P<.05$) among sampling dates in a season (figure 2). Values for ambient temperature and vapor-pressure deficit initially decreased

to minimum values on November 28, then increased to maximum on January 26, after which values showed great variations with increasing cloud cover. The seasonal patterns of relative humidity showed an opposite trend. Generally, the relative humidity was higher and ambient temperature and vapor pressure deficit were lower at Mwailu than Boma-8 because measurements were taken at different times of day. Initially, quantum flux did not show rapid seasonal changes; but it changed greatly toward the end of the season, probably because of cloud cover.

Seasonal soil-water-potential patterns of the two sites were similar (figure 3), but Mwailu had higher soil-water potential than Boma-8. At both sites, soil-water potential at 10-cm and 30-cm depths initially increased very rapidly after rains in November. Soil water potential at 120-cm depth showed a delay and, compared with the other two depths later in the season, the delay was more pronounced at Mwailu. Toward the end of the dry period, variations of soil-water potential were high, resulting from few rainfall events during January and February.

Covariance analysis indicated that the Mwailu and Boma-8 sites were significantly different ($P<0.05$) in all plant-water-status variables. Thus, the two sites were analyzed separately. Results indicated that, overall, burning did not significantly affect xylem tension, transpiration rate, and diffusive resistance of the four plant species ($P<0.05$) (figure 4). There were significant differences ($P<0.05$) for the plant variables on some dates; however, significant differences were numerically small.

There were significant differences ($P<0.05$) in xylem tension among the four plant species throughout the growing season. Acacia mellifera maintained and attained the most negative xylem tension value (-5.2 MPa) of all plant species, while Commiphora riparia was never more negative than -1.3 MPa. Digitaria macroblephara and Chloris roxburghiana were more similar in xylem tension, and both grasses had values somewhat less negative than Acacia mellifera. Although the plant species differed in xylem tension, the seasonal patterns were found to be similar for all species. Commiphora riparia had relatively small changes in xylem tension values across all sample dates, ranging from -1.1 MPa to -0.5 MPa (figure 5).

Transpiration rates among the four plant species from burned and unburned areas were significantly different ($P<0.05$). Acacia mellifera had the greatest transpiration rates, whereas the two grasses had the lowest transpiration rates. The seasonal patterns of transpiration rates were more similar between burned and unburned plots within a site than between the two study sites (figure 6). Transpiration rates between sites were different because measurements were taken at different times of day. Results indicated that high diffusive-resistance values often were associated with low values for transpiration rates.

The results showed that the root biomass within 1.5-m x 1.5-m x 1.5-m sections of a pit wall, among the plant species, were different; but the two grasses were more similar than the two shrub species. The total root biomass of Acacia mellifera, with an average height of 1.5 m, was 221.3 g. This plant had long laterals and a deep taproot system that penetrated beyond 1.5-m soil depth. Commiphora riparia had a total biomass of 317 g, and 82% of this weight was distributed within the top 30 cm of soil depth. This plant had a well-developed lateral root system. Its taproot was short, terminating about 1.0 m from the surface. Root biomass of Digitaria macroblephara and Chloris roxburghiana

were 99 g and 135 g, respectively. Seventy-two percent of the total root biomass of Chloris roxburghiana was distributed at the top 30 cm of soil depth. Only 58% of the total root biomass of Digitaria macroblephara was distributed at the top 30 cm of soil depth. Both grasses had extensive root systems.

DISCUSSION AND CONCLUSION

Burning did not significantly affect plant-water status throughout the growing season, but there were significant changes in plant-water status variables through time. Most differences among previously burned and unburned plants that were observed were small and were felt not to be of biological importance. It was observed that both old and newly emerged leaves were present on unburned plants, while only newly emerged leaves were found on burned plants. Differential use of plant leaves of various sizes, ages, and stomatal densities during sampling may explain, perhaps, some small differences in burning-treatment effects. Hairy and fully expanded mature leaves, generally, have a thick boundary layers and high diffusive resistances. Leaves with high diffusive resistances have low transpiration rates, and vice versa (Larcher, 1975). A study by Fisher (1978) showed that the volumetric water potentials of two tropical pasture species for unburned plants was -1.8 MPa to -1.4 MPa and for burned plants was -1.1 MPa and -0.9 MPa. Fisher pointed out that the stomata of the unburned plants were closed and no growth occurred, whereas the stomata of the burned plants were open and there was growth.

Results indicated that seasonal changes in xylem tension were controlled predominantly by the seasonality of soil-water potential (figures 4 and 5). However, all plants except Commiphora riparia showed large seasonal variations in xylem tension in response to seasonal fluctuations of soil-water potential. This suggested that these plants had different strategies of controlling movement of water. Seasonal evaluation patterns indicated that Chloris roxburghiana attained more negative xylem tension value than Digitaria macroblephara at the end of dry season. Observation indicated that, where these two grasses coexist, Chloris roxburghiana remained green longer than Digitaria macroblephara during the dry season.

On the other hand, transpiration rate appeared to be affected predominantly by vapor-pressure deficits, when soil-water potential was not limiting. The seasonal transpiration patterns indicated that the transpiration rate of Acacia mellifera was higher than Commiphora riparia throughout wet and dry seasons (figure 6). Fenner (1981) also has observed that the transpiration rate of Acacia mellifera (20.9 mg dm^{-2} min^{-1}) was much higher than Commiphora africana (14.5 mg dm^{-2} min^{-1}).

Although the four plant species were growing in similar environments, they differed in xylem tension and transpiration rates (figures 5 and 6). Plants allocated and partitioned water resources through various drought-avoidance mechanisms. Commiphora riparia, which had an extensive, shallow root system, absorbed large quantities of water during wet periods. This plant maintained a few succulent leaves even in dry periods. As conditions became dry, Commiphora riparia shed leaves and thus reduced transpiring surfaces. Acacia mellifera absorbed water through lateral as well as deep tap-root systems. This plant had small, pinate leaves, which reduced water loss to the atmosphere. The shallow, fibrous root systems of the two grasses absorbed a great deal of water

during wet periods; however, the grasses had leaf dry back as shallow sources of soil water declined.

Results indicated that the prescribed burning, overall, did not affect xylem tension, transpiration rate, and diffusive resistance of the four plant species studied. Therefore, prescribed burning might be used to reduce bush encroachment and increase the quality of Digitaria macroblephara, Chloris roxburghiana, and other desirable grasses in bushed-grassland community. Little differences in soil- and plant-water dynamics as affected by burning might be expected. Where prescribed burning increases resprouts of Acacia mellifera, Commiphora riparia, and other undesirable bush species, fire should be repeated at regular intervals.

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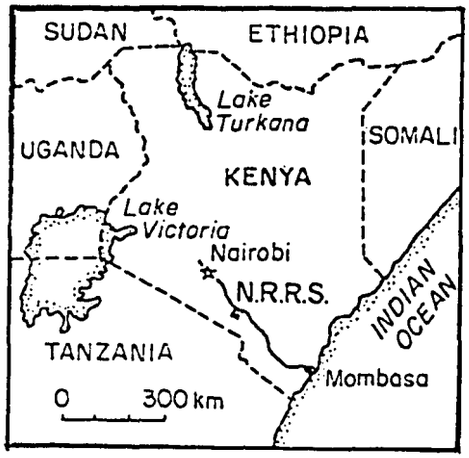

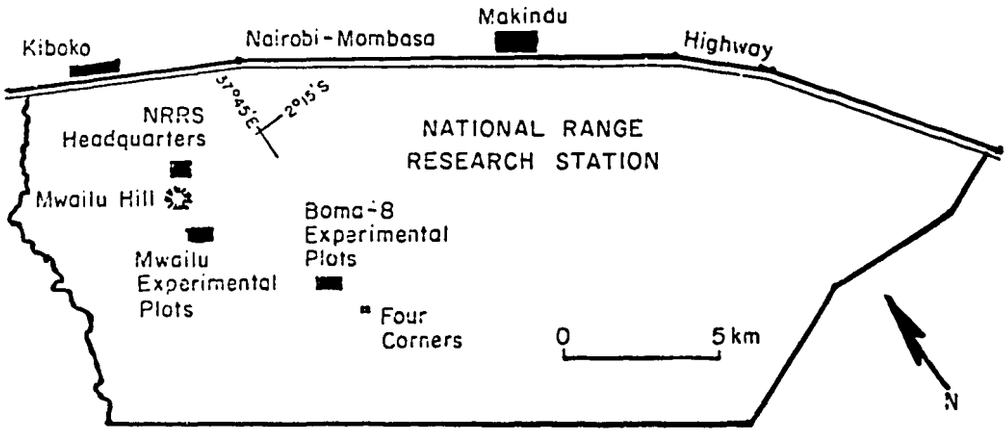

Figure 1. Location of the National Range Research Station, Kiboko, and the Boma-8 and Mwailu experimental plots.

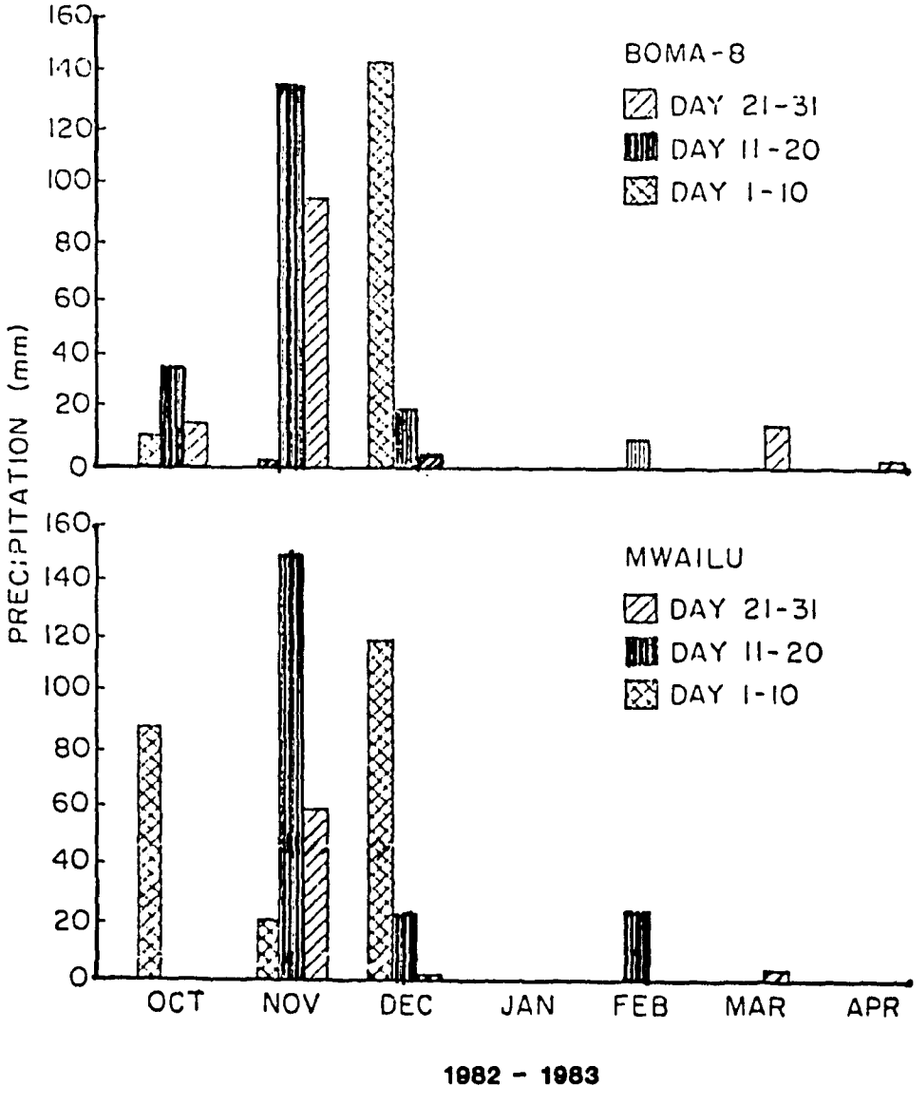

Figure 2. Rainfall distributions for the two experimental locations, Mwailu and Boma-8, at the National Range Research Station, Kiboko, Kenya.

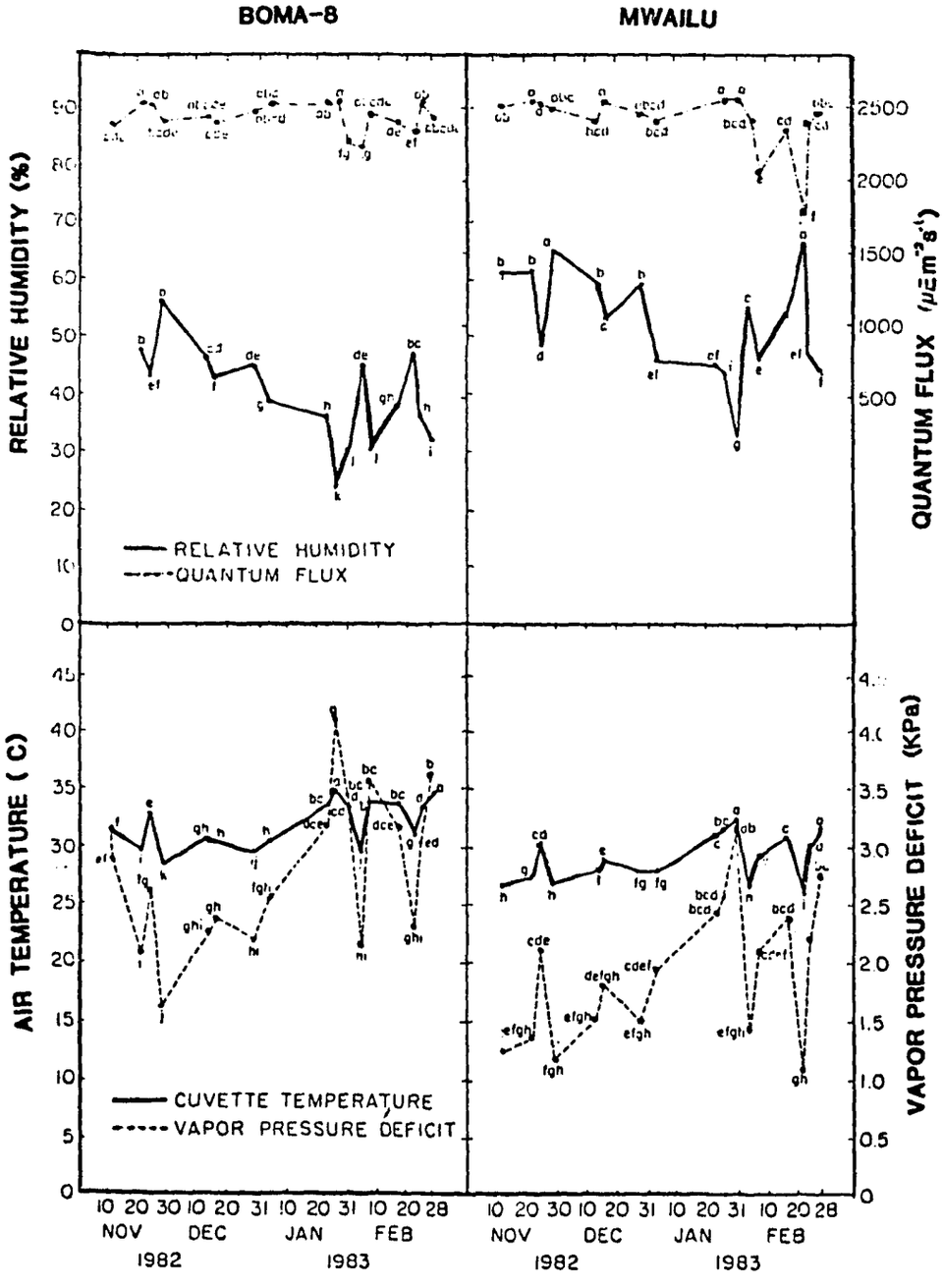

Figure 3. Seasonal variation of relative humidity (%), quantum flux (E m-2 s-1), air temperature (oC), and vapor-pressure deficit (kpa) at Mwailu and Boma-8 sites, 1982-83.

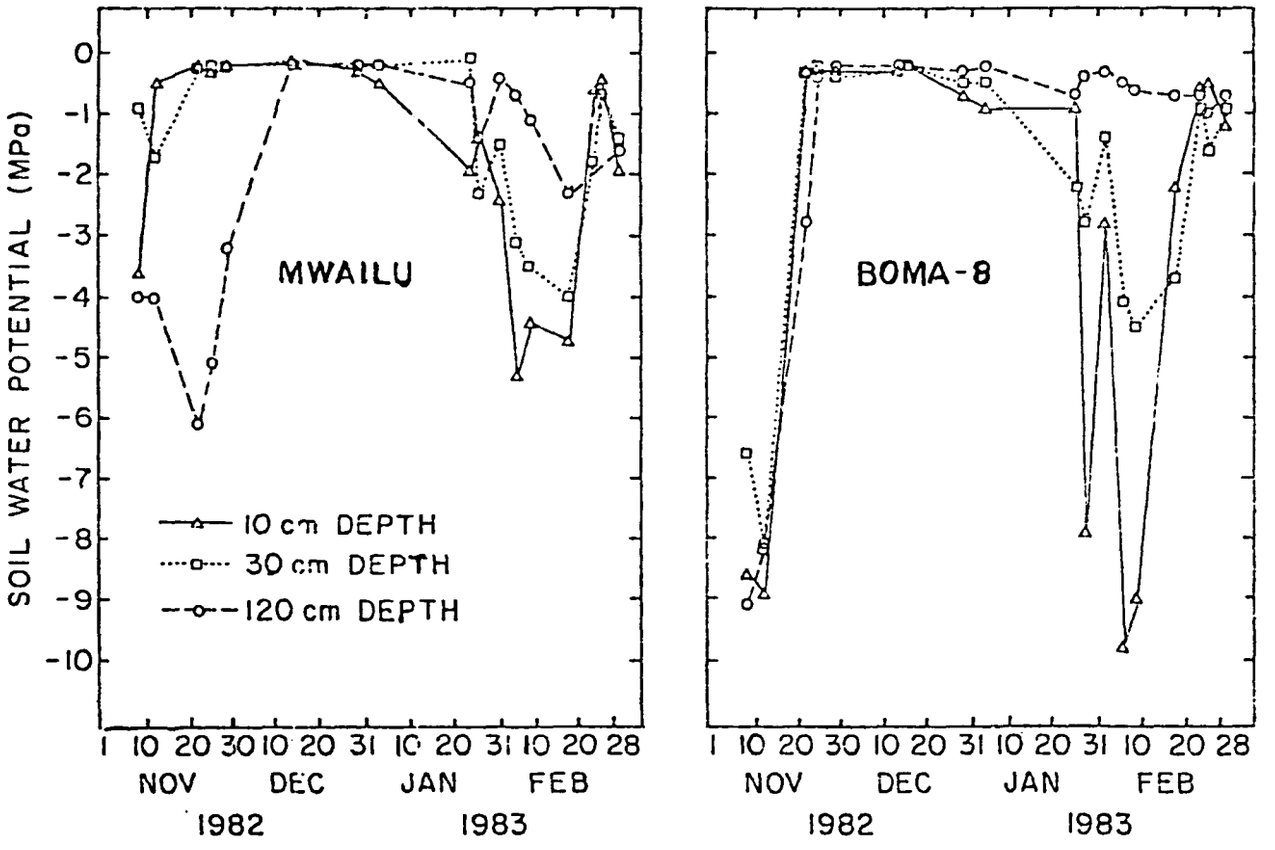

Figure 4. Seasonal variation of soil-water potential (MPa) for three soil depths (10 cm, 30 cm, and 120 cm) based on average of burned and unburned plots at Mwailu and Boma-8 sites, 1982-83.

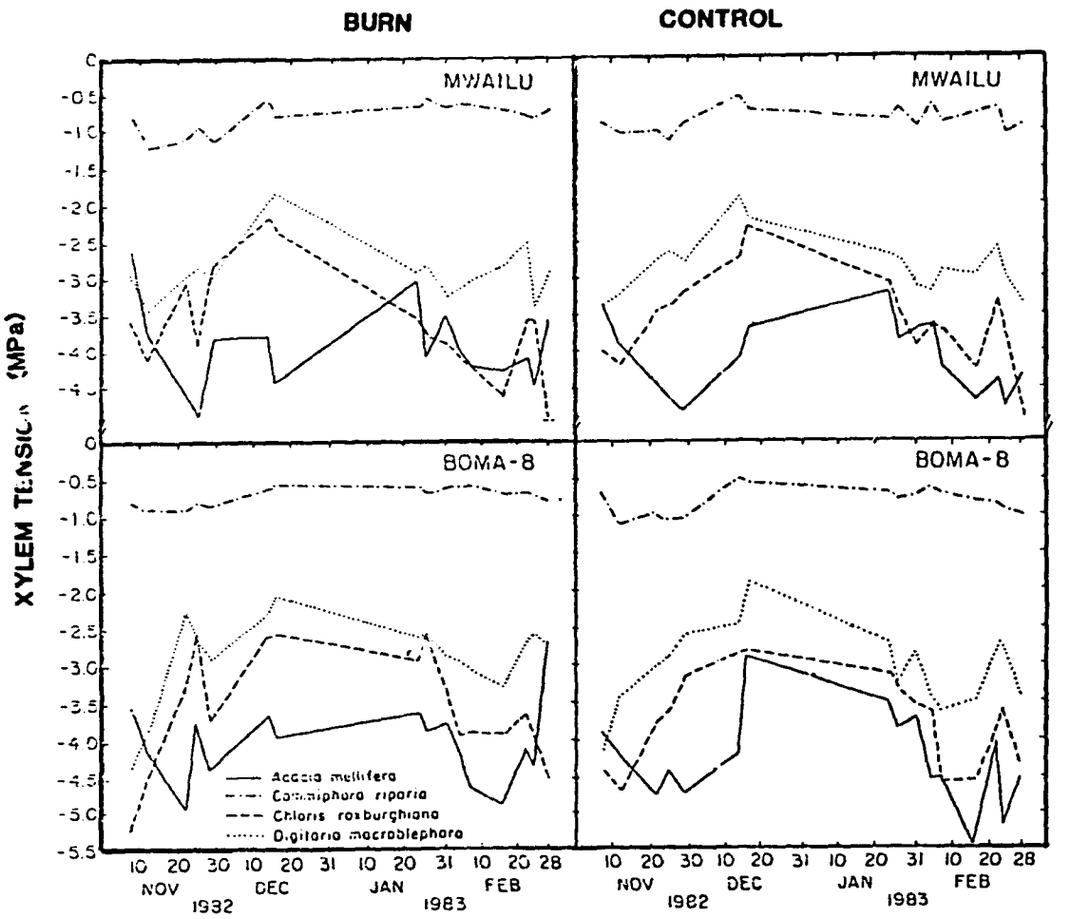

Figure 5. Seasonal variation of xylem tension (MPa) of four plant species by site and treatment (burned and unburned), 1982-83.

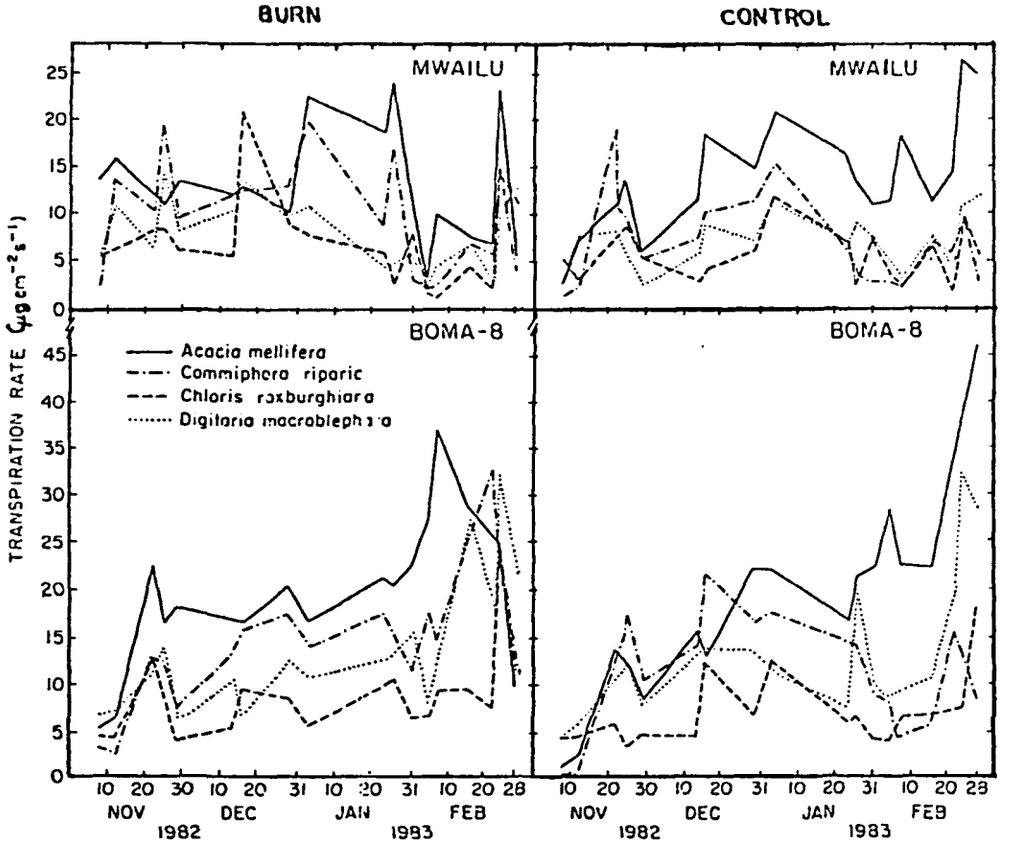

Figure 6. Seasonal variation of transpiration rates (mg cm^{-2} s^{-1}) of four plant species by site and treatment (burned and unburned), 1982-83.

EFFECTS OF PRESCRIBED BURNING ON CATTLE AND GOAT DIETS

Moses K. Mbui and Jerry Wayne Stuth

INTRODUCTION

Dense stands of bush severely reduce herbaceous production of rangelands, and much of the browse forage may not be easily accessible to the grazing livestock (Thomas and Pratt, 1967), hence reducing forage production of rangelands. Afoloyan (1970) observed that certain grass species are maintained in the habitat by burning and grazing, while complete protection from burning and grazing enhances the growth of unpalatable grasses and shrubs.

Fire has been a recurrent phenomenon in the development and maintenance of grazing lands in eastern Africa. Under the traditional agricultural and animal-husbandry patterns of the tribes of eastern Africa, most of the intentional burning was carried out during the dry periods. The goal was to extend grass growth into the dry season, encourage seed germination, remove dead herbage, and check woody species (Lemon, 1968; Ndawulu-Seyimba, 1972; Harrington and Ross, 1974; Kinyamario, 1982). Grass burning is practiced by pastoralists to suppress bush encroachment and to take advantage of early regrowth, among other benefits.

Seasonal distribution of rainfall in the range areas of Kenya is erratic. Rangeland herbage is generally of high quality, if not adequate quantity, during and immediately following the rains. As the vegetation matures into the dry season, quality and quantity (particularly of protein) decline rapidly. The use of fire to improve diet quality has been reported. Apart from influencing botanical composition and accessibility of the available forage, burning enhances dietary crude protein (CP) and organic-matter digestibility (OMD) of forage for varying lengths of time (Lemon, 1968; McKay, 1970; Angell, 1983; McGinty et al., 1983). The dietary benefits of prescribed burning are short-lived, typically lasting through the rapid growth periods following the burn (Hilmon and Hughes, 1965; McAtee et al., 1979; Angell, 1983; McGinty et al., 1983).

The objective of this study was to evaluate the effects of prescribed burning on the seasonal dietary CP and OMD of cattle and goats during the first year of the burn.

SITE AND METHODS

The study was conducted at the National Range Research Station, Kiboko, in an area that had not been used regularly by station livestock or burned since 1972. The study site is located within the basement-system plain of the volcanic-basement complex and the floodplains of the station soils (Michieka and Van der Pouw, 1977).

The climate of Kiboko and the general area fall under the influence of the intertropical convergency zone (Whyte, 1968), characterized by a bimodal rainfall distribution, with rainy seasons from the end of March to mid-May and from the end of October to mid-December (Michieka and Van der Pouw, 1977). The months of January and February are characterized by a short dry period, while the period from June to October is usually extremely dry. A 45-year weather data record from the general area

indicates long-term annual average rainfall, evaporation, and temperature to be 600 mm, 2,000 mm, and 23°C, respectively (Michieka and Van der Pouw, 1977). Based on the monthly rainfall distribution, May and October could be counted as dry months since they average about 30 mm or less.

The study site vegetation is dominated in the tree layer by Acacia senegal, while Hermania alhensis dominates the shrub layer. Other tall, woody species include Acacia spp., Grewia spp., Commiphora spp., Cordia spp., and Balanites aegyptiaca. Solanum incanum, Hibiscus spp., Lantana spp., and Sida ovata are the major subordinates of the shrub layer. Digitaria macroblephara dominates the herbaceous layer, with Bathriochloa insculpta, Chloris roxburghiana, Bothriochloa glabra, Microchloa kunthii, Sporobolus spp., and Panicum maximum as subordinate grass species. Talinum portulacifolium dominates the forb layer.

Two adjacent paddocks were selected based on ocular-similarity rating of the vegetation. The herbaceous-vegetation-similarity index (Sorensen, 1948) as cited by Mueller-Dombois and Ellenburg (1974) for transects in these paddocks ranged from 80% to 94%. These paddocks had not been used regularly by the station livestock or burned since 1972, but they were under infrequent use by livestock and wildlife. One of the paddocks was burned on February 25, 1982, when the prevailing air temperature, relative humidity, and wind speed were 33°C, 40%, and 8.5 km/hr, respectively. Diet-sample collections from these two paddocks started in March after active vegetation regrowth.

Four esophageally fistulated heifers and two esophageally fistulated goats were used to collect diet samples from the two treatment paddocks for two consecutive days per sampling interval. The sampling intervals were twice monthly during the months of active vegetation growth (except in November and December) and once monthly at other periods for one year's duration. The sampling animals were fasted overnight to avoid extrusa contamination. They grazed alternately in the burned and unburned paddocks after the heifers were fitted with extrusa-collection bags (Cook, 1964; Van Dyne and Torell, 1964) and the goats were fitted with rectangular collection sacks (Kamau, 1984). Four heifer-extrusa samples and two goat-extrusa samples per paddock per sampling day were obtained. The diet samples (per collection day) from each animal were air dried separately on wire-screen-bottom racks for two days and later oven dried at 60°C for 24 hours. The samples then were ground in a Wiley mill to pass a 0.5 mm screen, and the subsamples of the ground samples were subjected to chemical analysis. Special note should be made that, since the whole sample was not completely ground, quality estimates represent the most digestible components of the diet.

The dry matter of each diet sample was estimated by oven drying approximately 0.5 g for 12 hours at 120°C. The organic matter (OM) content of each diet sample was estimated by ignition of 0.5 g of the sample in a muffle furnace at 500°C for 4 hours. All the estimates of the dietary components were computed on an organic-matter basis.

Nitrogen (%N) was determined by the micro-Kjeldahl technique (AOAC, 1975). Percent crude protein (CP) was estimated on an OM basis by multiplying percent nitrogen by a constant of 6.25.

In vitro organic-matter digestibility (IVOMD) was determined by using the fermentation stage of Tilley and Terry (1963) and then the neutral-

detergent phase of Van Soest and Wine (1967). Standards of known in vivo OMD were run with the diet samples to correct for variations in laboratory procedures and rumen inoculum to apparent digestibility.

For statistical analysis, the year was divided into six seasons in relation to the rainfall patterns, and the treatment mean effect was burning. A t-test was used to analyze the diet quality data by treatments (burned and unburned) and season to detect differences between treatments at 95% confidence level.

RESULTS AND DISCUSSION

Nutritive Value of Cattle Diets

The nutritional data for the diets were aggregated into six distinct seasons based on rainfall patterns, and the nutritional parameters were analyzed within seasons (table 1).

Higher diet-quality values occurred during the wet seasons. These were periods of active plant growth when the grazing animals would have been actively selecting for leafy, green plant material. Kibet (1984) reported the highest percentage of green leaves in the diets of cattle in November, rather than during the months of June to September, from an adjacent pasture to this study site during the same period. The dry season corresponded with the lowest levels of nutritional quality of cattle diets. Periods of advanced plant maturity have been documented as periods of low CP and OMD (Cook and Harris, 1950; Pritchard et al., 1963; Terry and Tilley, 1964; Cook and Harris, 1968; Kothman, 1968; Burzlaff, 1971; Haggar and Ahmed, 1971; Sims et al., 1971; Houston et al., 1981; Heitschmidt et al., 1982). These periods coincide with seasons when plants shed most of their dead and senescent leaves. The grazing animals' diets have high stem-to-leaf ratios (Kibet, 1984), and the low levels of dietary quality during the dry periods were indicators of reduced live-plant material in the diets.

Burning enhanced dietary CP of cattle throughout the long wet season and into the early long dry season. The positive effect of burning on dietary CP was lost during the late long dry season, picking up again for 1 month after the October rains. The dietary CP values during the dry season were similar for both burned and unburned paddocks. This was an indication of lack of selectivity for green leaves and stems by the grazing animals due to herbage maturity and plant dormancy. Short-lived, high dietary CP lasting through the rapid growth period following burning has been reported (Holman and Hughes, 1965; McAtee et al., 1979; McGinty et al., 1983). However, cattle selected diets of slightly higher CP from the burned paddock than from the unburned paddock.

Burning had positive effects on the dietary OMD during the long wet season and the early short wet seasons; it had no detectable effect ($P<0.05$) during other seasons. Thus, burning enhanced OMD insignificantly.

Nutritive Value of Goat Diets

The nutritional quality of goat diets followed a similar seasonal trend as that of cattle except that the variation from one season to the next was not as dramatic (table 2).

Burning had a significant positive effect ($P<0.05$) on dietary CP in the early short wet season. There was no apparent positive effect of burning during other seasons. However, it is probable that a positive effect would have been detected during the long wet season had samples for the April flush of growth been included in the analyses. Diets from the burned paddock maintained higher trends of CP levels than diets from the unburned paddock in almost all seasons of the study period. Is also apparent that burning increased seasonal variation in the dietary CP in the burned paddock compared to the unburned paddock.

Although goats prefer browse (Harrington, 1982; Rector, 1983; Kamau, 1984), they are not obliged browsers (Harrington, 1982; McDonell and Woodward, 1982). Thus, goats graze according to the availability and quality of herbage. The abilities of goats to select and consume plant parts of high quality and shift their diets with season are demonstrated by the high quality of their diets in all seasons. The seasonal variation within the burn treatment may have been due to the increase in forb availability, especially Talinum spp. and Hibiscus spp., whose leaves and fruits are relished by goats.

Even though dietary OMD content appeared to be higher in diets from the burned paddock during most of the year, differences could be detected only during the late short wet season ($P = 0.024$), when the dietary OMD content was higher in the diet from the unburned paddock. During the other seasons, OMD of the diets was apparently similar (P = range of 0.1005 to 0.74). It is apparent that burning did not provide goats with a significantly greater opportunity for selecting more digestible forage due to the fact that goats are able to select the nutrient-rich parts of grasses and browse of higher digestibility from the available forage (Arnold, 1960; Malechek and Leinweber, 1972; Harrington, 1982; McDonell and Woodward, 1982).

SUMMARY

The effect of prescribed burning on the seasonal quality of cattle and goat diets was investigated. Burning enhanced the CP content of cattle diets during the wet seasons and into the early part of the dry seasons. The positive effects of burning were detectable only during the early part of the wet seasons. Detectable positive effects of burning on the OMD of cattle diets lasted for shorter periods than the effects of burning on CP. Burning had detectable positive effects on dietary CP and OMD of goat diets only during the early part of the wet seasons.

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Table 1. Mean seasonal dietary crude protein (%) and organic-matter digestibility (%) of fistulated heifers grazing burned and unburned *Acacia senegal* savanna pastures at Kiboko, Kenya.

		Burned			Unburned			
Season	Period	n[a]	Mean	SE[b]	n	Mean	SE	α
				Crude protein (%)				
Long wet	Mid-March to late May[c]	28	15.6	0.62	36	12.3	0.57	0.0003
Early long dry	Early June to late July	22	11.1	0.17	22	10.0	0.20	0.0001
Late long dry	Early Aug. to mid-Oct.	15	8.6	0.26	16	8.5	0.16	0.86
Early short wet	Mid-Oct. to mid-Nov.	16	20.7	0.82	16	17.4	0.55	0.002
Late short wet	Mid-Nov. to mid-Jan.	16	13.7	0.31	16	13.1	0.35	0.22
Short dry	Mid-Jan. to mid-March	22	8.7	0.25	22	8.9	0.18	0.46
				Organic-matter digestibility (%)				
Long wet	Mid-March to late May[c]	28	74	0.51	36	71	0.74	0.001
Early long dry	Early June to late July	22	70	0.85	22	68	0.60	0.085
Late long dry	Early Aug. to mid-Oct.	15	63	0.62	16	63	0.40	0.83
Early short wet	Mid-Oct. to mid-Nov.	16	76	0.37	16	72	0.22	0.0001
Late short wet	Mid-Nov. to mid-Jan.	16	71	1.12	16	70	1.76	0.65
Short dry	Mid-Jan. to mid-March	22	68	0.69	22	69	0.95	0.295

[a]Number of samples analyzed.
[b]Standard error of the mean.
[c]No March samples for the burn treatment due to lack of regrowth after the burn.

Table 2. Mean seasonal dietary crude protein (%) and organic-matter digestibility (%) of fistulated goats grazing burned and unburned *Acacia senegal* savanna pastures at Kiboko, Kenya.

		Burned			Unburned			
Season	Period	n[a]	Mean	SE[b]	n	Mean	SE	α
				Crude protein (%)				
Long wet	Mid-March to mid-May[c]	4	17.4	0.71	4	18.1	0.38	0.44
Early long dry	Early June to late July	7	16.6	0.55	7	14.8	1.16	0.19
Late long dry	Early Aug. to mid-Oct.	8	15.3	0.83	8	13.9	0.77	0.23
Early short wet	Mid-Oct. to mid-Nov.	8	23.3	0.84	8	21.1	0.65	0.0481
Late short wet	Mid-Nov. to mid-Jan.	8	19.2	0.62	8	18.4	0.90	0.44
Short dry	Mid-Jan. to mid-March	12	16.4	0.58	12	16.7	0.48	0.74
				Organic-matter digestibility (%)				
Long wet	Mid-March to late May[c]	4	73	0.98	4	72	0.72	0.49
Early long dry	Early June to late July	7	68	1.56	7	66	1.77	0.31
Late long dry	Early Aug. to mid-Oct.	8	63	2.60	8	59	1.55	0.15
Early short wet	Mid-Oct. to mid-Nov.	8	79	1.45	8	75	1.78	0.1005
Late short wet	Mid-Nov. to mid-Jan.	8	71	0.67	8	73	0.63	0.024
Short dry	Mid-Jan. to mid-March	12	62	1.35	12	61	1.29	0.74

[a]Number of samples analyzed.
[b]Standard error of the mean.
[c]No sampling done in March and April. Values are for May only.

DIET QUALITY AND INTAKE OF STEERS UNDER RANGE CONDITIONS

William Ngoyawu Mnene and Jerry W. Stuth

ABSTRACT

A study was conducted during the long dry season and beginning of short rains of 1983 at the National Range Research Station, Kiboko, Kenya, to determine the effects of site, herbage allowance, and season on diet quality and nutritive intake of steers. Percentage composition of plant species and fragments in the diet samples collected by esophageally fistulated heifers was affected most by herbage allowance and season. During the dry season, a combination of less bush and less herbage resulted in selection of diets very low in crude protein. Diets selected during the wet season had twice as much crude protein as those selected during the dry season. In vitro organic-matter digestibility of the diets declined with reduced herbage allowance but remained constant between sites and seasons. Animals achieved greater organic-matter intake under low-bush/high-herbage conditions and during the dry season. Crude protein intake was least under less-bush/less-herbage conditions during the dry season and was affected by season only under high-bush conditions. Highest energy intake was from low-bush/high-herbage conditions, while the least was during the wet season.

INTRODUCTION

Rangelands are mostly either arid or semiarid; that is, rain is scanty and unreliable. The plant communities vary extensively in the tree, shrub, and grass components (Heady, 1960; Pratt, 1966). For rangeland economics, animal production under extensive systems is the mainstay.

Without due regard for sustained resources, efforts to maximize immediate production without proper grazing management results in depleted range (Ayuko, 1978; Bernstein and Jacobs, 1983). Grass and forb (herbage) availability becomes limiting, and the selection patterns of the livestock are inadvertently altered. Presumably, a traditional grazer consumes more and more woody vegetation in a bid to achieve gutfill. For instance, in northern Kenya, Lusigi et al. (1984) observed that browse could be a major part of the cattle diet, with a single woody species constituting up to 8% of the selected diet.

Since different plant species have different vegetative-parts composition, and availability is sometimes reduced, selected diets might differ in leaf:stem ratios. Milford and Minson (1965) and Wallace et al. (1972) reported direct influences of leaf:stem ratio on the nutritive value of the herbage consumed.

Further, reduced herbage resulting from intense forage use leads to selection of diets low in digestibility and crude protein (Hodgson et al., 1977; Heady, 1964). Increasing maturity of forage, similar to that during dry seasons, has been reported to depress mean voluntary intake (Dougal and Bogdan, 1958; Pieper et al., 1959; Poppi et al., 1980). When availability is not limiting, intake increases until it reaches a critical herbage allowance where the animal is at or near maximum intake, at which point herbage digestibility becomes the governing factor (Jamieson and Hodgson, 1979; Minson, 1981).

Since a significant linear relationship between fecal output and organic matter is an established fact, then by using diet digestibility data and indigestible markers, voluntary intake can be quantified (McCullough, 1959; Tilley and Terry, 1963; Ellis et al., 1982; Van Soest et al., 1983). Rare earths with large molecular size and reduced displacement by hydrogen have been recommended (Uden et al., 1980). These can be recovered completely in the feces (Ellis and Huston, 1968) because of their high binding capacity with feeds of high fiber content (Teeter et al., 1984) and because they are relatively easy to detect with atomic absorption spectrophotometry (Ellis et al., 1982).

PROCEDURES

Location and Climate

The study was conducted at the National Range Research Station, Kiboko, Kenya, in 1983. Kiboko is situated in ecoclimatic zone V. The year 1983 was particularly dry -- an unusual five months of drought between the rains and a dry January. Consequently, the wet-season trial referred to henceforth is based on long-term rainfall regimes. Otherwise, it was actually a transition period between a prolonged dry season and the beginning of the short rains (figure 1).

Two vegetation sites were used: a wooded grassland with a 70% canopy cover, and an adjacent open grassland with a 30% canopy cover resulting from hand grubbing of all major woody stands in 1977. Both sites had received intermittent use by cattle since the clearing operation.

Treatment Paddocks

Four paddocks of approximately 5 ha each were delineated -- two in each vegetation site to represent four treatments: high bush/high herbage, low bush/low herbage, high canopy/low herbage, and low canopy/high herbage. To achieve low-herbage treatments, one paddock in each site was grazed down to about 50% of the herbaceous standing crop in the other paddocks before sampling.

Vegetation Sampling

The line and belt transect technique (NRC, 1962) was used to estimate available herbage, canopy cover, and density of woody species. Clipped material was separated into live-dead and leaf-stem-other fractions. Browse volume and available weight were determined by a technique similar to that used by Lopez and Stuth (1984).

Animals

Four esophageally fistulated heifers were used to provide estimates of the quality and composition of selected diets. Sixteen noncannulated steers also were used (eight per site) for fecal-output estimation. The animals averaged 300 kg live weight.

Diet Collection and Analysis

A technique similar to that of Canfield (1941) and Campbell et al. (1968) was used. Fistulated heifers were corralled from 1800 to 0800 hours before collection of extrusa at 0800. Two subsamples were collected per heifer per collection day for 20 to 30 minutes using screen-bottomed bags. Three collections were done every 2 days.

Established procedures were used to analyze the dietary macrohistology dry matter (Hacket et al., 1964), ash percent nitrogen (AOAC, 1970), organic-matter digestibility (Tilley and Terry, 1963), neutral detergent extract (Van Soest and Wine, 1967), and crude protein (micro-Kjeldhal process).

Fecal Sampling and Analysis

The indigestible external marker erbium acetate was used in a technique similar to that of Ellis et al. (1982) to quantify daily fecal output, which was used to derive the organic-matter intake of the steers.

Statistical Analysis

The data was analyzed as a nested-split-plot design system using Statistical Analysis System (SAS) software (Barr et al., 1976). General Linear Models (GLM) were used to determine the analysis of variance. Error terms were derived by pooling factor interactions in each analysis. Duncan's new multiple-range test was performed for variables in the model at $\alpha \leq 0.05$, which yielded the significant differences to be referred in the discussion unless otherwise specified.

RESULTS AND DISCUSSION

Bush Density and Canopy

The shrub layer comprised more than 96% of the total woody vegetation density in all paddocks (table 1). There was no difference between the two bush levels in shrub density; rather, low-herbage paddocks had more shrubs than high-herbage paddocks. Commiphora africana and C. riperia were the major trees, which made up to 100% of the tree density in some paddocks. These trees were practically absent in the low-bush site, where only one or two tree forms of Balanites aegyptiaca occurred.

Shrub canopy was similar in all paddocks except the high-bush/high-herbage paddock. However, tree canopy was very different between the sites: high-bush paddocks had more trees than low-bush sites. There was also a difference in tree canopy between the two high-bush paddocks due to differences in tree species.

Density was unaffected by season, while a 10% increase in canopy-cover increment was realized from the tree layer only.

Standing-crop and Diet Composition

Percentage composition of available standing crops varied with herbage allowance, bush level, and season (table 2). The herbage allowance effect, however, was evident only between the paddocks in the low-bush site, suggesting a possible interaction between reduced herbage or canopy cover to yield such an effect. While bush level alone did not affect the percentage composition of grasses during the dry season, forbs were more abundant in the low-bush than in the high-bush site. Owing to regrowth just before and soon after the first rains and a drastic reduction in herbaceous standing crop, the percentage browse composition increased twofold, particularly in the high-bush site.

In dietary species composition, grasses dominated the diets throughout the study, varying from 78% to 94% and 58% to 65% in the dry and wet seasons, respectively (table 2). Bush level did not affect the amount

of grass in the cattle diets, regardless of season. Grass in the diets selected from within herbage levels also were similar; however, reduced herbage allowance in the dry season decreased grass consumption. In all cases, browse replaced grasses where grass composition declined in the cattle diets. Much less grass was selected during the wet season than in all other cases.

Woody species were the second-most-dominant category of plants in the diets, with major differences between seasons and herbage-allowance treatments. Browse consumption by cattle in the low-herbage paddocks was similar and significantly higher than in the high-herbage paddocks during the dry season. Therefore, bush level difference did not influence browsing; instead, the shortage of herbaceous forage forced cattle to browse more. Browsing intensified during the wet season, accounting for nearly a third of the selected diet composition. This sharp increase was attributed to the reduced herbaceous standing crop and increased availability of browse following regrowth.

Available and Dietary Plant-parts Composition

Available forage was predominantly leafy and dead in all treatments during the dry season (table 3). The wet season forage was different between bush level in leaf composition, and less than that of dry season. Reduction of available herbage decreased the percentage leaf composition but had little effect in percentage live component. Stems dominated the available forage during the wet season, constituting almost twice as much of the forage as leaves in the low-bush site. Most of the live material in any paddock was the stem fraction.

Leaf fractions dominated the diets selected, irrespective of herbage allowance, bush level, or season. Plant parts were not always selected according to availability. For example, while bush level affected availability of the leaf component during the dry season, it did not affect leaf consumption in either season. Also, since most available live material was stems, animals selected little of this and more of the mostly dead leaves.

Lack of direct relationship between availability and selection of plant parts in most of the treatments was further complicated by the presence of fragments other than leaf or stem. These fragments were classified as "other" and were composed of flowers, fruits, roots, and even barks. The "other" fragments were consumed mainly during the dry season, particularly under low herbage allowance.

Dietary Crude Protein

There was a great seasonal difference in dietary crude protein (CP) and much less difference between herbage-allowance levels (table 4). Diets selected during the wet season had nearly twice as much CP as diets selected during the dry season. This related well with high-dicot live and leaf-fragment contents of diets.

The effect of herbage allowance on dietary CP was negligible under high-bush conditions but was significant in low-bush paddocks. This was indicative of a possible shading effect on the quality of available forage combined with low live:dead and leaf:stem ratios. Although animals in the low-bush/low-herbage paddock also consumed high amounts of dicot, they were observed selecting them from dead leaves lodged in bunch grasses or actually licking them off the ground. Such fragments

no doubt were of poor quality and could not contribute much to the dietary CP.

In Vitro Organic-matter Digestibility

Diets selected from low-herbage paddocks had less in vitro organic-matter digestibility (IVOMD) than diets from high-herbage paddocks in both bush levels. Less herbage implied reduced selectivity, with subsequent diets containing greater amounts of dead and stem components.

Although diets selected from high-bush/high-herbage paddocks contained more green leaves and overall higher live:dead and leaf:stem ratios, the bush effect on IVOMD was not significant. A compensatory role could have been played by the more browse consumed in the low-bush paddocks.

However, the compensatory role was lacking in low-herbage paddocks where, despite high browse consumption, the IVOMD of the diets were depressed. Either high amounts of browse in the diets have negative effects on IVOMD, or the diets selected (including browse) from low-herbage paddocks generally were of poor quality.

The relationship between dietary CP and IVOMD was positive for low-bush paddocks, where diets lower in CP had less OMD. Lack of similar results for high-bush paddocks, despite equal dietary CP, could have been due to the higher browse component in the diets from low-herbage paddock, yielding greater amounts of digestion depressants.

Organic-matter Intake

Herbage allowance and season had significant effects on organic-matter intake (OMI). Bush level had little influence on OMI during the dry season and none during the wet season. Animals on high herbage allowance achieved greater OMI than those on low herbage allowance. Highest and lowest intakes were observed in animals in low-bush/high-herbage and high-bush/low-herbage paddocks, respectively. Overall, animals had better OMI under low-bush conditions regardless of herbage allowance, particularly during the dry season.

Lower OMI in the wet season could have been due to a number of factors:

- Animals had a significant loss in body weight (up to 22 kg) between seasons.

- Diets selected during the wet season had higher water content than diets selected during the dry season. High dietary water content may lead to gutfill but low OMI. Mugerwa et al. (1975) reported increased intake with increased dry-matter content of the forage.

- Most browses are known to contain high amounts of digestibility depressants such as lignin and tannins. Therefore, high levels of browse in the diets could have depressed OM intake.

The effect of herbage allowance on IVOMD did not translate directly to level of intake, especially under high-bush conditions where OMI was similar for animals on high and low herbage. Whereas IVOMD for diets selected from these paddocks were significantly different, the difference was not sufficient to limit intake.

Consequently, the significant difference in OMI for animals in low-bush paddocks could not be explained by a difference in IVOMD alone. Rather, the existence of significant difference in dietary CPI, alone or together with IVOMD, could have effected a significant reduction in intake.

Crude-protein Intake

Crude-protein intake (CPI) was not influenced by a single factor but by an interaction of two or more factors. During the dry season, CPI was affected by herbage allowance under low-bush conditions but not under high-bush conditions. Animals in the low-bush/low-herbage paddock consumed significantly less crude protein. Lack of herbage-allowance effect on CPI under high-bush conditions implies that low CPI was a result of both less herbage and less bush.

Similarly, the CPI during the wet season showed no difference between the bush levels. CPI under low-bush conditions was identical for animals in the high-herbage paddock in both dry and wet seasons. On the other hand, animals achieved higher CPI during the wet season in high-bush paddocks. Enhancement of an animal's consumption of CP was more likely a result of higher-quality forages, particularly browse and green-leaf fractions in the diets selected from the heavy-bush condition. Despite a doubling in dietary CP during the wet season, the CPI did not double due to reduced IVOMD, animal weights, and OM intakes.

Energy Intake

Total-digestible-energy (TDE) intake was affected mainly by herbage allowance and season. Animals under low herbage levels consumed less TDE than those under high herbage levels. Increased bush depressed TDE intake, especially during the dry season, just as animals consumed diets 50% to 60% lower in energy during the wet season.

Drastic reduction in TDE intake was related to the equally increased browse content in the selected diets during the wet season. Browse species are known to have low energy contents. In effect, low dietary-energy levels lead to reduced organic-matter intake, as was the case during the wet season.

CONCLUSIONS

Season was the single most effective factor in determining the available herbage, browse, leaf, and live components of the forage. Subsequently, season influenced the composition and nutritive quality of the diets selected.

Selection of more leaf and live fragments by the animals during the wet season did not affect diet digestibility, mainly because of high consumption of browse, which contains digestibility depressants. Therefore, while wet-season diets may be nutritionally superior, the presence of high amounts of browse could hinder availability of the nutrients to the animal.

Despite high dietary-CP content during the wet season, energy was low, resulting in reduced OM intake. A balance is required between nutrients for a diet to have good value.

The site factor was not important, particularly during the stressful dry season. The site difference was only pronounced in forage composition during the wet season when browse availability increased sharply in the high-bush paddocks. Also an interaction of site and herbage-allowance factors yielded significant differences. So, site alone was not much of a factor influencing diet selection, quality, or intake in this study.

Herbage allowance was effective in influencing selected diet composition, quality, and intake. The effect was not uniform, though; and in some cases it required another factor to produce significant differences. Overall, animals were on a better nutritional plane under low-bush/high-herbage conditions and during the dry-season trial.

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Table 1. Bush density (plants/ha) and canopy cover (%) of the shrub and tree layers in the high-bush/high-herbage, high-bush/low-herbage, low-bush/high-herbage, and low-bush/low-herbage paddocks during the dry and wet seasons, 1983.

		DRY SEASON								WET SEASON			
		High bush				Low bush				High bush		Low bush	
		High herb[2]		Low herb		High herb		Low herb		High herb		High herb	
	N[1]	Dens[3]	Can[4]	Dens[4]	Can	Dens	Can	Dens	Can	Dens	Can	Dens	Can
Shrub layer	15	5160[a5]	52.4[b]	6440[b]	35.3[a]	4960[a]	27.8[a]	6946[b]	30.3[a]	5737[a]	53.3[b]	6133[a]	26.4[a]
Tree layer	15	160[c]	16.5[b]	160[b]	34.9[a]	54[ab]	2.7[a]	13[a]	1.7[c]	120[abc]	26.1[b]	26[a]	5.7[a]
Total	15	5320[a]	68.9[b]	6600[a]	70.2[b]	5013[a]	30.5[a]	6960[a]	32.0[a]	5746[a]	81.4[c]	6159[a]	32.1[a]

[1] N = number of transects sampled
[2] herb = herbage
[3] Dens = density
[4] Can = canopy
[5] Means with same letter for density or canopy are not significantly different ($\alpha = 0.05$).

Table 2. Composition (%) of grass, forbs, and browse standing crop and selected diets in the high-bush/high-herbage, high-bush/low-herbage, low-bush/high-herbage, and low-bush/low-herbage paddocks during the dry and wet seasons, 1983.

	DRY SEASON								WET SEASON			
		High bush			Low bush				High bush		Low bush	
	High herb[1]		Low herb		High herb		Low herb		High herb		High herb	
	SC[2]	Select[3]	SC	Select	SC	Select	SC	Select	SC	Select	SC	Select
Grass	78.2[c4]	94.3[b]	77.6[c]	78.1[a]	71.6[b]	89.0[b]	76.0[c]	80.4[a]	60.5[a]	65.1[c]	69.5[b]	58.3[c]
Forbs	0.4[a]	1.9[a]	1.6[b]	5.8[bc]	6.0[c]	3.6[ab]	4.8[c]	4.7[abc]	0.0[a]	3.3[ab]	0.0[a]	8.2[c]
Browse	21.2[a]	3.8[a]	20.7[a]	16.1[b]	22.4[a]	7.4[a]	19.3[a]	15.0[b]	39.1[c]	31.6[c]	30.5[b]	33.5[c]

[1] herb = herbage
[2] SC = standing crop
[3] Select = selected diet
[4] Means with same letter for standing crop or selected diet are not significantly different ($\alpha = 0.05$).

Table 3. Morphology of available forage and selected diets as leaf (%), stem (%), other (%), leaf:stem ratio, live (%), dead (%), and live:dead ratio in the high-bush/high-herbage, high-bush/low-herbage, low-bush/high-herbage, and low-bush/low-herbage paddocks during the dry and wet seasons, 1983.

	DRY SEASON								WET SEASON			
	High bush				Low bush				High bush		Low bush	
	High herb[1]		Low herb		High herb		Low herb		High herb		High herb	
	Avail[2]	Select[3]	Avail	Select	Avail	Select	Avail	Select	Avail	Select	Avail	Select
Leaf	66.8[c4]	74.9[b]	56.2[b]	65.8[a]	52.4[b]	72.0[b]	LD	65.6[a]	45.3[a]	86.0[c]	34.6[a]	87.6[c]
Stem	33.2[a]	25.1[b]	43.8[b]	30.7[bc]	47.6[b]	28.4[b]	LD	34.1[c]	54.7[bc]	11.0[a]	66.4[c]	12.7[a]
Other	-	0.7[a]	-	3.8[c]	-	0.2[a]	-	1.0[ab]	-	2.5[c]	-	0.9[ab]
Leaf:stem	2.0[c]	3.2[b]	1.3[b]	2.2[a]	1.1[b]	2.7[b]	LD	1.9[a]	0.8[ab]	10.5[c]	0.5[a]	8.4[c]
Live	28.3[c]	27.8[c]	24.9[bc]	16.8[a]	45.1	22.7[abc]	LD	20.1[ab]	18.6[ab]	75.0[d]	10.6[a]	78.4[d]
Dead	71.7[b]	72.8[b]	75.1[b]	83.5[c]	54.9[a]	78.0[bc]	LD	80.2[c]	82.2[c]	25.4[a]	90.4[d]	22.3[a]
Live:dead	0.4[bc]	0.7[b]	0.3[bc]	0.2[a]	0.8[c]	0.3[a]	LD	0.2[a]	0.2[ab]	4.2[c]	0.1[a]	4.2[c]

[1] herb = herbage
[2] Avail = available forage
[3] Select = selected diet
[4] Means with same letter for available forage or selected diets are not significantly different ($\alpha = 0.05$).

Table 4. Dietary crude protein (CP), in vitro organic-matter digestibility (IVOMD), animal weight (ANIMWT), fecal organic-matter output (FOMOUT), organic-matter intake (OMI), body weight (BW), crude-protein intake (CPI), and total-digestible-energy intake (TDEI) of steers grazing in *Commiphora* savanna high-bush/high-herbage, high-bush/low-herbage, low-bush/high-herbage, and low-bush/low-herbage paddocks during the dry and wet seasons, 1983.

	CP (%)		IVOMD (%)	ANIMWT (kg)		FOMOUT (kg)		OMI (kg)	BW (%)	CPI (kg)	TDEI (Mcal)
	N	Mean SE	Mean SE	N	Mean SE	N	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE
DRY SEASON											
High-bush/high-herb	20	6.5 ± 0.2[a1]	67.5 ± 1.2[a]	8	303.4 ± 2.9[a]	39	2.1 ± 0.1[a]	6.5 ± 0.3[a]	2.1 ± 0.1[a]	0.4 ± 0.02[abc]	19.3 ± 0.8[b]
High-bush/low-herb	11	6.6 ± 0.1[a]	59.1 ± 1.6[b]	8	304.7 ± 2.7[a]	34	2.4 ± 0.1[a]	6.0 ± 0.3[a]	2.0 ± 0.1[a]	0.4 ± 0.02[abc]	15.6 ± 0.8[c]
Low-bush/high-herb	22	6.6 ± 0.3[a]	67.0 ± 1.6[a]	8	305.2 ± 4.0[a]	36	2.6 ± 0.1[a]	7.9 ± 0.3[b]	2.6 ± 0.1[b]	0.5 ± 0.02[cd]	23.3 ± 1.0[a]
Low-bush/low-herb	20	5.1 ± 0.2[b]	61.2 ± 1.0[b]	8	302.0 ± 3.7[a]	32	2.6 ± 0.1[a]	6.7 ± 0.3[a]	2.2 ± 0.1[a]	0.3 ± 0.01[a]	18.0 ± 0.7[b]
WET SEASON											
High-bush/high-herb	13	12.4 ± 0.5[c]	66.0 ± 2.2[a]	8	281.0 ± 2.6[b]	33	1.[illegible] ± 0.2[b]	4.2 ± 0.4[c]	1.5 ± 0.1[c]	0.6 ± 0.1[d]	11.9 ± 1.1[d]
Low-bush/high-herb	17	12.7 ± 0.4[c]	65.4 ± 1.0[a]	8	283.1 ± 3.2[b]	31	1.5 ± 0.1[b]	4.2 ± 0.2[c]	1.5 ± 0.1[c]	0.5 ± 0.02[cd]	12.0 ± 0.5[d]

[1] Means across paddocks with same letter were not significantly different ($\alpha = 0.05$).

USE OF FECAL NITROGEN INDEXES TO PREDICT CATTLE DIET QUALITY

Salim B. Shaabani, J.W. Stuth, and R.M. Hansen

ABSTRACT

The study was conducted at the National Range Research Station, Kiboko, Kenya, to determine the predictive relationship between fecal-nitrogen indexes and dietary quality.

Two sites were chosen for the study that represented the lowest extreme in forage availability and two extremes in bush cover. The available forage ranged from less than 400 kg/ha to more than 800 kg/ha, while the bush cover ranged from 30% to 70%. The experiment began from August to September 1983, the dry-period part of the study, during which the animals were supposed to be experiencing high nutritional stress. The second part, from September 1983 to January 1984, covered a period when forage quality was starting to improve.

Fecal samples were collected from 16 steers, and dietary samples were collected from four esophageally fistulated cows. The samples were analyzed for total nitrogen and cell-wall-bound nitrogen (NDFN). Fecal samples were analyzed further for tannins. Diet samples were analyzed further for in vitro and in vivo digestibility. Samples were pooled across days, fecal samples were matched with diet samples, and regression equations were developed to test for predictive relationships between fecal and dietary parameters.

Neutral-detergent-fiber nitrogen (NDFN) gave the best relationship to percent dietary crude protein using the following equation: $Y = 1.79 + 8.37$ (NDFN), $R_2 = 0.88$, $P<0.005$. Neutral-detergent-fiber nitrogen gave the best relationship to organic-matter intake (kg) by the following equation: $Y = 8.56 - 3.58$ (NDFN), $R_2 = 0.57$, $P<0.005$. Digestibility, both in vivo and in vitro, was poorly related to fecal-nitrogen indexes.

INTRODUCTION

Feed intake and feed quality are two major controlling factors in livestock production because they determine live weight gain and reproductive success of the animal. Many studies conducted in the tropics show that livestock gain weight rapidly in the wet season and lose weight rapidly in the dry season (Hutchison, 1959; Stobbs, 1969; Norman and Phillips, 1970; Young, 1972; Romero and Siebert, 1980). In the wet season, tropical grasses produce large amounts of dry matter of relatively high nutritional quality (Wilson and Hydock, 1971; Wilson et al., 1976; Rees and Little, 1980). In the dry season, the amount of forage available to grazing animals is reduced (Maloiy and Heady, 1965; Pratt et al., 1966), and the quality of forage declines with advancing maturity (Harris and Fawler, 1975; Ford, 1978; Ford et al., 1979; Simonson et al., 1982). The combination of low forage quality and low availability makes the dry season the most stressful nutritional period.

Problems associated with sampling vegetation to determine forage quality and availability have led to the development of many indirect techniques for estimating feed quality and forage intake (Raymond, 1948; Lancaster, 1949; Holechek et al., 1982a). Indirect methods of vegetation sampling are important for rangelands because, since these lands support diverse plant communities and have rugged terrain, the accuracy and precision of

nutrition measurements are a problem (Holechek et al., 1982a, 1982b). Holechek et al. (1982a) reviews many indirect techniques used to determine the nutritive quality of range ruminants' diets. The greatest advantage of the fecal-nitrogen techniques over other indirect techniques is that vegetation sampling is not needed. The animals can be left to graze undisturbed in the field -- they do not have to be penned, surgically fistulated, or sacrificed (Erasmus et al., 1978). The technique is quick, simple, inexpensive, and reasonably reliable (Holechek et al., 1981).

METHODS AND MATERIALS

The study was carried out at the National Range Research Station, Kiboko, Kenya, between August 1983 and January 1984; therefore, it spanned the dry period and the transition period between dry and wet seasons.

Two sites were chosen for the study, based on the bush cover. One site had a high bush cover dominated by Commiphora spp., Grewia spp., and Hermania alhiensis; the other site had low bush cover. The two sites had the same types of grasses dominated by Chloris roxburghiana, Cymbopogon spp., Digitaria macroblephara, and Bothriochloa spp. For details of vegetation and soils, see Shaabani (1985).

Two 5-ha paddocks were delineated with fire breaks on each vegetation type. One paddock in each vegetation type was severely grazed before each grazing period to create a low herbage level while the other was left undisturbed to allow a normal level of herbage.

Sixteen 2-year-old steers weighing between 250 kg and 300 kg were used for the study. The steers were of the most common breeds in Kenya including Sahiwal, Boran, Sahiwal x Zebu, and Boran x Zebu. They were divided into two groups, paired according to similar breed, size, and weight. Each group of eight animals was assigned to a particular site.

The two herds were managed by traditional methods. The animals were herded to the grazing area in the morning and back to the central area to be corralled in the evening. The herders made sure that the animals grazed only in their assigned paddocks. Water and salts were provided ad libitum at the corrals. The animals were given no supplementary feed, and night grazing was not allowed.

The steers were drenched with a broad-spectrum anthelmintic drug at the start of the experiment, and they were dipped once per week to control ticks. There were no incidences of major disease throughout the experiment.

The experiment was started by grazing the two herds in high-herbage-allowance paddocks in both the bushed and open-grassland sites. The steers grazed these paddocks for 10 consecutive days and then rotated to the low-herbage paddocks.

Diet Samples

Diet samples were collected from four esophageally fistulated cows for estimation of the nutritional quality of the forage available to the experimental animals. Sampling was done only in the paddocks that were being grazed at a particular time, and each paddock was sampled for 2 days. Two samples were collected per animal per day.

Samples were collected between 0800 hours and 1000 hours to prevent them from being contaminated by regurgitation (Bredon et al., 1967; Marshall et al., 1967). If a sample was contaminated by ruminal contents, it was discarded and a fresh sample was collected. The samples were collected in wire-bottomed sample bags.

Fecal Samples

Fecal samples were collected starting on the sixth day after the animals moved into the experimental plots. This allowed enough time for the animals to pass all forage eaten in the previous paddock. Samples were collected via rectal aeration or immediately after a defecation. Each sample was put in a plastic bag, making sure that it was not contaminated by other fecal materials or by any other material that could alter its nitrogen content.

LABORATORY ANALYSIS

Feed and fecal samples were air dried for 48 hours and then dried for 12 hours in a forced-air oven at 60°C. Both diet and fecal samples were ground in a Wiley laboratory mill to pass through 2-mm mesh, and dry-matter and ash contents were determined by AOAC (1975) methods. Both types of samples were analyzed for total nitrogen using the micro-Kjeldhal procedure (AOAC, 1975). Neutral-detergent fiber (proportion cell wall) and bound nitrogen (NDFN) were determined using the procedure of Goering and Van Soest (1970). In NDFN analysis, 0.5 gm sodium sulfite was added to the samples to facilitate filtration.

All diet samples were analyzed for in vitro digestibility using the fermentation-stage method of Tilley and Terry (1963) followed by neutral-detergent analysis (Van Soest and Wine, 1967). Standards of known in vivo digestibility were run with the samples to correct for variations in the laboratory procedures and rumen inoculum.

In vivo digestion of the diet samples was done using three cows fitted with permanent rumen cannulae. These samples were analyzed in triplicate, and standards of known in vivo digestibility were run to correct for variations in the rumen inoculum and laboratory procedures. The cows grazed on the same type of vegetation the experimental animals were grazing.

Organic-matter intake and fecal output were determined using rare-earth markers in a cooperative study. (For details of this procedure, see Mnene, 1985).

Fecal condensed tannins were analyzed by the procedure used at the Texas Agricultural Experimental Station at Uvalde, Texas. (For details of the procedure, see Shaabani, 1985).

The data was subjected to analysis of variance by sites, herbage levels, paddocks, breeds, and seasons. Significant differences among treatments were separated by Duncan's multiple-range test (Steel and Torrie, 1980). Significant differences were determined at 95% significant level.

Regression equations were developed using the General Linear Models Procedure (SAS, 1982) to evaluate predictive relationships between dietary parameters and fecal parameters.

RESULTS AND DISCUSSION

Dietary Profile

Dietary crude protein varied from 5% to 12% during the dry and transition periods, respectively (table 1 and 2). The doubling of crude protein in the transition period was due to the new, lush growth in both herbaceous and browse species that was available to the steers (Ford, 1974; Gohl, 1981). Dietary cell-wall-bound nitrogen (NDFN) followed the same pattern as the crude protein. Percent NDFN in the transition period was more than double that of the dry period. There was significant difference ($\alpha = 0.05$) in dietary crude protein between the seasons and between herbage levels, but there was no difference between sites.

In vitro organic-matter digestibility averaged approximately 63% and 64% in the transition and dry periods, respectively, showing that the steers selected more digestible forage even in the dry period. In vivo dry-matter digestibility was lower than in vitro organic-matter digestibility by 5.8 digestibility points across seasons and treatments. There were no significant differences in digestibility between seasons, sites, or herbage allowance at $\alpha = 0.05$. This is consistent with the work of Hansen (1986), which showed that there was no significant difference in digestibility of cattle diets between the dry and wet seasons.

Organic-matter intake was higher in the dry period compared to the transitional period. Mean organic-matter intake was 7 kg/day in dry periods and 4 kg/day in the transitional period (tables 1 and 2).

The low organic-matter intake could be the result of low forage availability in the transitional period, or it could be due to the combined effects of low forage availability, higher tannin levels in the forage, and low forage organic-matter content. Tannins have been shown to depress organic-matter intake (Barry and Duncan, 1984; McLeod, 1974).

Organic-matter intake was higher in high-herbage-allowance paddocks compared to low-herbage-allowance paddocks. There were significant differences in organic-matter intake between bush levels at $\alpha = 0.05$. Crude-protein intake was below maintenance requirements for steers (Kearl, 1982; NRC, 1984) in the dry season in all treatments except the high-herbage grassland paddocks.

Fecal Profile

Total fecal nitrogen was 1.1% in the dry period, compared to 1.6% in the transition period (tables 3 and 4). Fecal bound nitrogen (NDFN fecal) also was lower in the dry period. This was because the diet was higher in crude protein during the transition period and because the diet during this period contained appreciable amounts of browse, which is known to contain higher levels of condensed tannins (Reed, 1984). Tannins bind with protein to form complexes that are indigestible by ruminal microbes (Barry and Duncan, 1984; McLeod, 1974). This would lead to higher fecal nitrogen.

There was a significant difference in total fecal nitrogen between the study periods and herbage levels, but no significant difference was detected between bush levels at $\alpha = 0.05$. Fecal bound nitrogen (NDFN) was significantly different between seasons but not between bush and herbage levels.

RELATIONSHIP BETWEEN FECAL AND DIETARY PARAMETERS

Organic-matter Intake

Total fecal nitrogen was poorly correlated with organic-matter intake: $Y = 9.59 - 2.99$ (Fecal N) ($R^2 = 0.23$). Poor correlation of fecal nitrogen to organic-matter intake has been reported in various studies (Wofford et al., 1985). However, nonfiber fecal nitrogen (total nitrogen % - neutral-detergent-fiber nitrogen %) had a higher association with organic-matter intake ($Y = 3.61 + 4.41$ (fecal non-NDFN) $R^2 = 0.36$, $P<0.005$) than with total fecal nitrogen. This is opposite of the finding of the study by Wofford et al. (1985).

Percent fecal neutral-detergent-fiber nitrogen had a better correlation with organic-matter intake: $Y = 8.57 - 3.58$ (NDFN) with $R^2 = 0.57$ and $P<0.005$. (See figure 1.)

This study indicates that total fecal nitrogen is an unsuitable predictor for ruminant forage intake, but fecal non-NDF nitrogen can be used to give satisfactory predictions for organic-matter intake.

Crude Protein

Percent fecal neutral-detergent-fiber nitrogen gave the highest prediction for dietary crude protein: $Y = 1.79 + 8.37$ (NDFN) $R^2 = 0.88$, $P<0.001$. Percent total fecal nitrogen gave a good prediction with $Y = -2.59 + 8.56$ (fecal nitrogen %), with $R^2 = 0.54$ and $P<0.005$ (figure 2).

Percent total fecal nitrogen is affected by the dietary nitrogen concentration; an increase in dietary nitrogen leads to an increase in fecal-nitrogen concentration (Arman et al., 1975). Fecal-nitrogen concentration of less than 1.2% indicates that the animals are in crude-protein deficiency. This is in agreement with the study of Squires and Siebert (1983), which showed that cattle on an Australian ranch started losing weight when fecal-nitrogen concentration was between 1.3% and 1.4%. Winks et al. (1976), as quoted by Squires and Siebert, reported that cattle started responding to nonprotein-nitrogen concentration of between 1.3% and 1.4%.

This study is consistent with other studies done in various places on fecal nitrogen in showing that fecal-nitrogen concentration can provide a reasonable indication of trends in ruminant-diet nitrogen concentration.

Digestibility

The relationship of fecal nitrogen to dietary digestibility was very low to indicate any predictive relationship for both in vivo and in vitro digestibilities. Fecal non-cell-wall-bound nitrogen had an R^2 value of 0.32, $P<0.05$, for in vivo dry-matter digestibility: $Y = 55.32 + 4.75$ (fecal non-NDFN). In vitro organic-matter digestibility had the least relationship with fecal nitrogen. The use of non-cell-wall-bound nitrogen in the equation $Y = 57.04 + 12.47$ (non-NDFN) had an R^2 value of 0.29, $P<0.05$.

This study and other studies (Wofford et al, 1985; Holloway et al., 1982; Wilson et al., 1971) are consistent in showing that fecal nitrogen is a poor predictor of dietary digestibility; but Scales et al. (1974)

found that fecal nitrogen was superior to others in predicting in vivo digestion.

SUMMARY AND CONCLUSION

This study is consistent with other studies (Arnold and Dudzinski, 1963; Erasmus et al., 1978; Holechek et al., 1981; Lamborne and Reardon, 1982; Wofford et al., 1985) in showing that fecal nitrogen is a good indicator of organic-matter intake and dietary crude protein and that fecal nitrogen does not have a strong predictive relationship to either in vivo or in vitro digestibility (Wofford et al., 1985; Holechek, 1981; Holloway et al., 1982; Wilson et al., 1971); however, Scales et al. (1974) found fecal nitrogen indexes to be superior to others in predicting in vivo digestion.

High concentrations of dietary and fecal tannins and other phenolics have been shown to alter the predictive nature of the fecal nitrogen indexes; therefore, the technique must be studied further so units can be established above which tannin concentrations will be suspected, and the technique should not be used for predictive purposes.

MANAGEMENT IMPLICATIONS

Fecal-nitrogen index is potentially an important tool for livestock management in pastoral areas where other techniques of determining feed quality are unavailable or too expensive for routine use. The pastoralists can collect fecal samples routinely from their herds and take them to any laboratory for nitrogen analysis. From the analysis, they can have an idea of their herds' nutritional statuses, which will allow them to correct for nutritional deficiencies before the obvious symptoms (which, in most cases, are irreversible) set in.

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Table 1. Dietary mean ± (standard error) for total N (%), CP (%), NDFN (%), non-NDFN (%), OM intake (kg), CP intake (gm), in vivo (%) dry-matter, and in vitro (%) organic-matter digestibility during the dry period.

	Open grass site		Bushed site	
	High herbage	Low herbage	High herbage	Low herbage
Total N	1.0 (0.03)a	0.08 (0.03)b	1.0 (0.03)a	1.2 (0.08)a
CP	6.5 (0.14)a	5.1 (0.21)a	6.5 (0.18)a	7.3 (0.51)c
NDFN	0.5 (0.02)a	0.4 (0.04)c	0.4 (0.03)a	0.5 (0.03)c
Non-NDFN	0.6 (0.02)a	0.4 (0.04)b	0.6 (0.04)a	0.7 (0.08)a
OM intake (kg)	8.1 (0.55)a	7.6 (0.27)b	6.2 (0.25)bc	5.9 (0.27)c
CP intake (gm)	0.58 (0.02)a	0.34 (0.03)b	0.41 (0.04)bc	0.43 (0.03)c
In vitro OM	65.9 (1.56)	62.5 (0.23)	67.7 (2.65)	59.5 (0.02)
In vivo DM	59.9 (0.06)	57.2 (0.01)	59.1 (0.8)	56.1 (0.01)

For means that are followed by the same letter between sites and herbage allowances, there is no significant difference at $\alpha = 0.05$.

Table 2. Dietary means ± (standard error) for total N %, CP %, NDFN %, OM intake (kg), CP intake (gm), in vitro and in vivo digestibility in the transitional period (high-herbage paddocks).

	Open grass site	Bushed site
Total N	2.0 (0.07)d	1.9 (0.06)
CP	12.3 (0.45)d	11.8 (0.38)d
NDFN	1.8 (0.09)d	1.5 (0.17)d
Non-NDFN	0.2 (0.08)d	0.4 (1.18)d
OM intake	4.1 (0.18)d	4.4 (0.44)d
CP intake	0.5 (0.07)d	0.5 (0.06)d
In vitro digestibility (OM)	62.9 (0.83)	63.1 (0.67)
In vivo digestibility (DM)	56.7 (0.01)	58.0 (0.36)

For means that are followed by the same letter between sites, there is no significant difference at $\alpha = 0.05$.

Table 3. Fecal mean ± (standard error) for total N (%), NDFN (%), non-NDFN (%), tannins (mg/g) during the dry period.

	Open grass site				Bushed site			
	High herbage		Low herbage		High herbage		Low herbage	
Total N	1.3	(0.03)a	1.0	(0.06)	1.3	(0.03)a	1.0	(0.01)b
NDFN	0.6	(0.06)a	0.6	(0.02)a	0.5	(0.09)a	0.6	(0.01)a
Non-NDFN	0.7	(0.03)a	0.4	(0.02)b	0.7	(0.03)a	0.4	(0.01)c
Tannins	0.068	(0.002)a	0.067	(0.004)a	0.065	(0.005)a	0.068	(0.004)a

For means that are followed by the same setter between sites and herbage allowances, there is no significant difference at $\alpha = 0.05$.

Table 4. Fecal mean ± (standard error) for total N (%), NDFN (%), non-NDFN (%), tannins (mg/g) in the high-herbage paddocks during the transition period.

	Open grass site		Bushed site	
Total N	1.7	(0.19)c	1.5	(0.02)d
NDFN	1.3	(0.04)b	1.2	(0.04)b
Non-NDFN	0.4	(0.05)c	0.3	(0.009)b
Tannins	0.08	(0.002)b	0.08	(0.009)b

For means that are followed by the same letter, there is no significant difference at $\alpha = 0.05$.

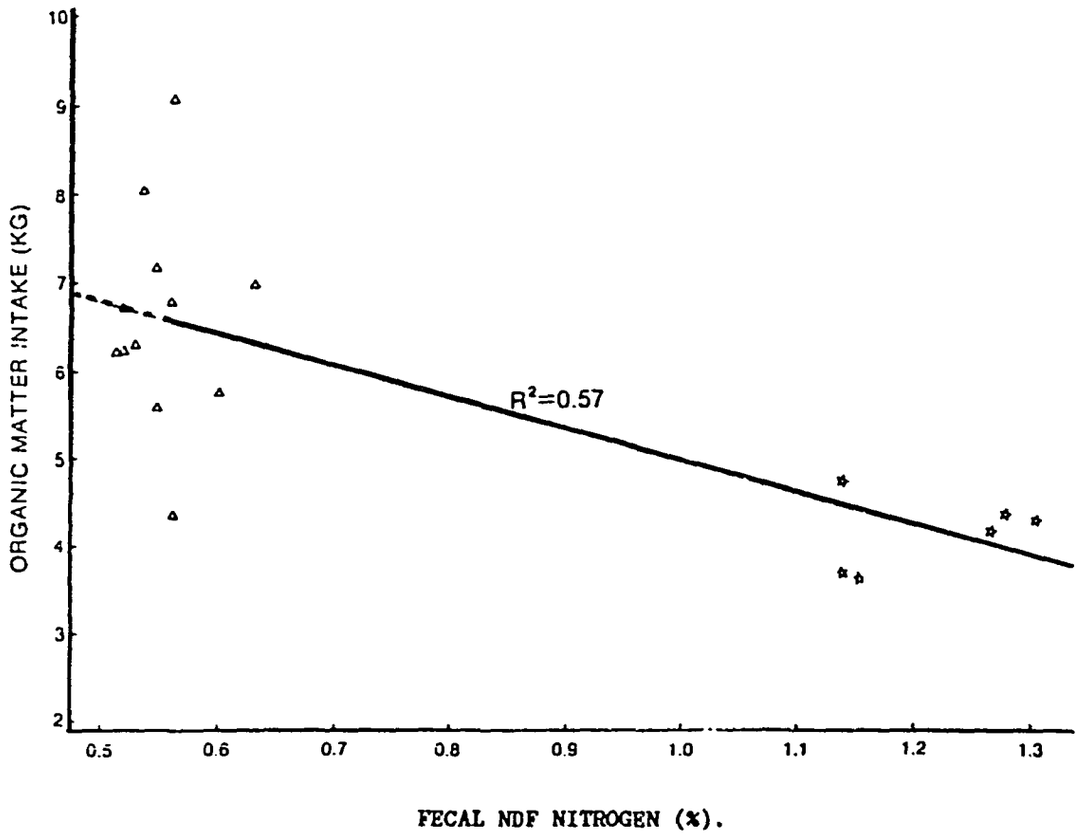

Figure 1. Relationship of organic-matter intake to fecal NDF nitrogen.

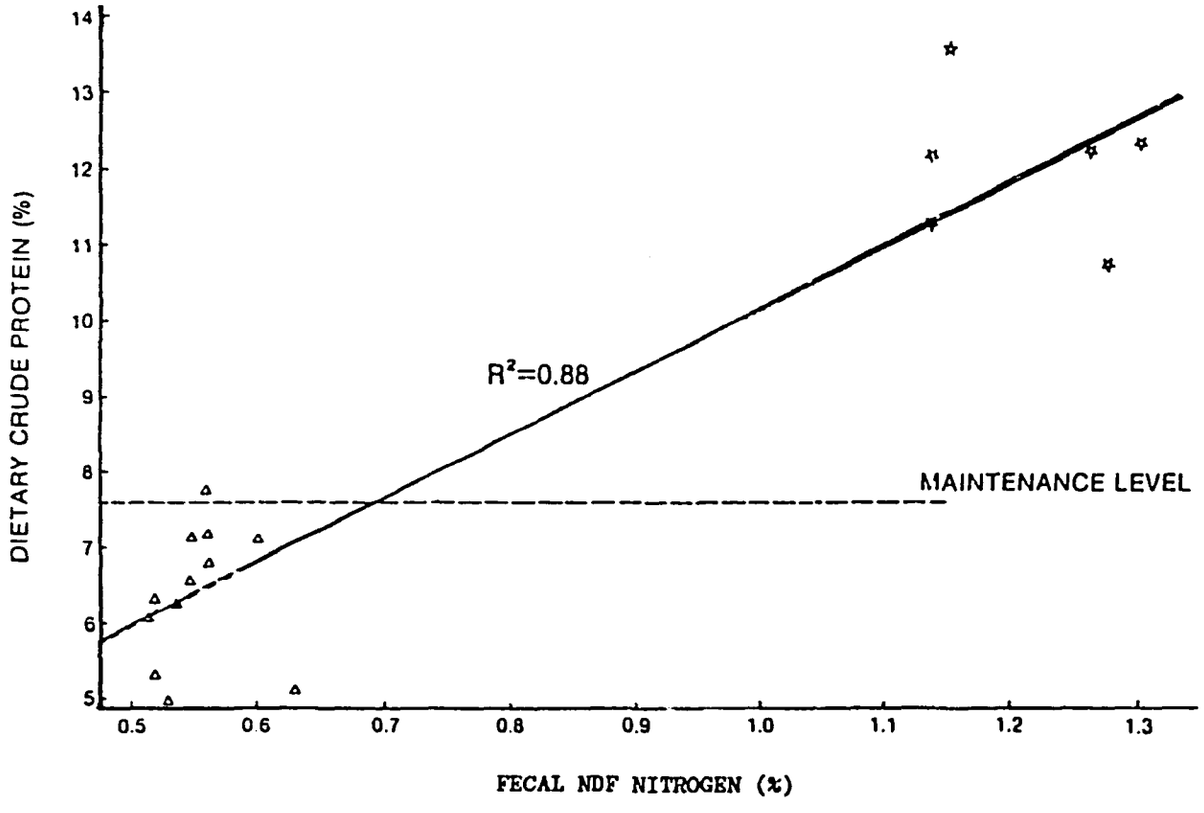

Figure 2. Relationship of percent dietary crude protein to fecal NDF nitrogen.

DIGESTIVE CAPABILITIES OF SHEEP, GOATS, CATTLE, AND CAMELS

W.E. Migongo-Bake, R.D. Child, and D.L. Whittington

ABSTRACT

It has been suggested by several authors that the type of basal diet affects the digestive power of the rumen through its influence on the rumen's microbial population. Rumen digestive capabilities of camels, cattle, sheep, and goats grazing free in an open range were compared in both a green season and a dry season, when basal diet was assumed to vary most, using the nylon-bag technique. Three forage species (two grasses, Pennisetum clandestinum and Cynodon dactylon, and one forb, Chrysanthemum cinerariaefolium) were used in the trials. Rumen digestive efficiency in the green season was significantly higher ($P<0.01$) than in the dry season for all livestock species. Correlation coefficients (r^2) between the rumen digestive efficiencies of sheep, goats, and camels relative to steers were 0.95, 0.97, and .096 respectively. The relative ranking of rumen digestive power was steer followed by goat, sheep, and camel.

INTRODUCTION

Animal husbandry has been the most productive use of semiarid and arid areas of the world. An extensive area of eastern Africa is rangeland and, although there are marginal areas that can be used for crop production through irrigation, most of it has no alternative for food production other than grazing. In Kenya, more than half of the rangeland area is arid to semiarid, receiving less than 370 mm of rain annually. These areas are used mainly by seminomadic tribes that keep sheep and goats with cattle, camels, or both. To be able to make sound decisions on the management of such delicate ecosystems, it is important to know not only the resource allocation to different herbivore species but also how well these species use the given forage resources.

That the basal diet influences microbial populations of the rumen and, hence, the digestive capability of a herbivore for a given feedstuff has been suggested by several authors (Van Keuren and Heinmann, 1962; Hopson et al., 1963; Uden et al., 1974; Lindberg, 1981; Weakley et al., 1983). In this study, it was assumed that the different livestock species with their different food habits should show differences in rumen digestive capability for given forage species. It also was assumed that, for a given livestock species, the basal diet and hence the rumen digestive power would be most different between the green and the dry seasons. It was the objective of this study to verify these assumptions by rumen digesting two grasses (Pennisetum clandestinum and Cynodon dactylon) and the forb (Chrysanthemum cinerariaefolium) using the nylon-bag technique (Van Dyne, 1964) during a green season and a dry season.

MATERIALS AND METHODS

The study was conducted in the semiarid lowland region occupied by Rendille pastoralists in Southwestern Marsabit District of Kenya. The major tree, forb, and grass genera in the region are Acacia, Indigofera, and [illegible], respectively (Herlocker, 1979). The rainfall is bimodal, with the long rains falling from March to May and the short rains from October to November. However, rainfall is very unpredictable in occurrence, amount, and duration, and droughts are relatively frequent.

A mature steer (Bos indicus), sheep (Ovis aries), goat (Capra hircus), and camel (Camelus dromedarius) were fitted with rumen fistulas and used for digestion trials using the nylon-bag technique (Sparks and Malachek, 1968). The above-ground parts of three forages -- two grasses (Pennisetum clandestinum and Cynodon dactylon) and one forb (Chrysanthemum cinearaefolium) -- were dried in a forced-air oven at 65°C for 3 days and then ground in a Wiley mill using a 1.0 mm screen.

One type of nylon cloth was used for the bags. Openings between the threads could not be seen using 400x magnification. A cloth without discernible pores was chosen to prevent solid particles from moving in and out of the bags. The mesh was 50/cm. Each nylon bag was oven-dried and weighed to the nearest 0.01 g before the trial. Ten bags of each forage with 2 g of forage per bag were digested for 48 hours in the rumen of each animal in both the green season and the dry season. After removal from the rumen, the samples were rinsed with tap water in a bucket until no color was seen in the wash water. The samples were then left standing in the water for about one-half hour and rinsed again. This was repeated about three times until no color was seen in the rinse water after one-half hour's soaking. The bags plus their residues were then dried until no further weight loss before weighing to the nearest 0.01 g. Percent dry-matter disappearance (DMD) was calculated using the following formula:

$$DMD = 100 \times \frac{R-B}{S-B}$$

Where B = weight of nylon bag, R = weight of nylon bag plus residue after rumen digestion, and S = weight of nylon bag and sample before digestion.

RESULTS

A significantly higher percentage ($P<.01$) of dry weight was digested from each forage by each ruminant during the wet season than in the dry season (table 1). Rumen dry-matter disappearance was significantly greater ($P<.05$) from the steer than from the camel for the plant species tested in both the wet and dry seasons. Both the sheep and goat digested Pennisetum and Cynodon more effectively ($P<.01$) in the wet season than did the camel. Except for Pennisetum in the dry and wet seasons ($P<.01$ and $P<.001$ respectively) and Cynodon in the wet season ($P<.001$), the goat digestibilities were not significantly different ($P>.05$) from those of the camel. The steer digested Pennisetum more completely ($P<.01$) than the goat or sheep in the dry season. There was no difference ($P<.05$) between the steer, sheep, and goat in the digestion of Cynodon or Chrysanthemum cinearaefolium in the dry season. The steer digested more of all forages ($P<.05$) than did the sheep in the wet season. Differences in digestion between the steer and the goat were not significant for all forages in the wet season. The digestion of Cynodon by the goat was better ($P<.001$) than by the sheep in the dry season. Both Pennisetum and Cynodon were digested in greater amounts by the goat ($P<.01$) than by the sheep in the wet season.

DISCUSSION

The results showed that the seasonal change in basal diet has an influence on the rumen digestive power of livestock species grazing freely in an open range. All livestock species digested the offered forages

significantly better in the green season than in the dry season ($P<0.01$). The quality for forages and, hence, the availability of nitrogen for microbial-population growth in the rumen were highest in the green season and lowest in the dry season (Migongo, 1984). Hansen (1986), however, found contradictory results, where the rumen digestive capability of three Zebu steers grazing freely in a natural range was not significantly different between green and dry seasons.

The results here also indicate that cattle are better digesters of forages than the other three species. Linear correlation coefficients were calculated between the rumen digestibility of sheep, goats, and camels relative to cattle (figure 1). Correlation coefficients (r) were 0.95, 0.97, and 0.96 for the sheep, goat, and camel respectively. The line for the sheep and goat are parallel, indicating that the goat is a more efficient digester of the forages tested, regardless of the digestibility of the forage. This supports work conducted by Davendra (1978) that showed that goats had a higher digestibility of fiber than sheep. Therefore, for sheep to have an equal or higher plane of nutrition they must browse on grasses that have a higher nutritive content.

The data for the sheep and goats supports observations by Van Soest (1982) that the smaller animal is at a disadvantage in digesting fiber, and even more so at a lower quality. The rumen digestive power of the camel was exceptionally and significantly lower than that of the other three species. This exceptional difference also has been observed in another study (Migongo, 1984). Maloiy (1972) reported that the outflow rate of fluid from the stomach to the intestines was far greater in the camel than in the Zebu, suggesting a higher passage rate in the camel. This may account for the greater digestibility efficiency of cattle observed in this study. This observation also suggests that the camel has to consume large quantities of forage over time and, in this way, compensates for the low dry-matter digestive efficiency. Camels in the area of study have been observed to continue grazing even in the hottest part of the day when other animals are resting under the shade (Migongo, personal observation). According to Cloudley-Thompson (1969), a factor that seems to favor this behavior is the concentration of body fat in the hump, leaving the subcutaneous tissue virtually fat-free and thus allowing a lower internal temperature. Merton (1983) found research information that states that camels are able to survive on low-quality feed due to their ability to adapt to low-protein diets through urea recycling. This mechanism also may compensate for the high passage rate observed in camels.

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Table 1. Dry- and green-season rumen digestibility (X+SE) of three forages in four domestic ruminants.

Species	Season	*Pennisetum clandestinum*	*Cynodon dactylon*	*Chrysanthemum cinearaefolium*
Bos indicus	Dry	50 ± 1.1	47 ± 1.8	69 ± 1.7
	Green	65 ± 1.9	68 ± 1.7	80 ± 1.6
Sheep	Dry	44 ± 1.1	43 ± 1.3	69 ± 1.5
	Green	56 ± 0.9	61 ± 1.1	76 ± 1.2
Goat	Dry	45 ± 1.4	48 ± 0.9	70 ± 1.1
	Green	63 ± 0.6	66 ± 0.7	77 ± 0.8
Camel	Dry	33 ± 2.0	33 ± 2.5	65 ± 2.7
	Green	51 ± 1.5	55 ± 1.3	74 ± 1.7

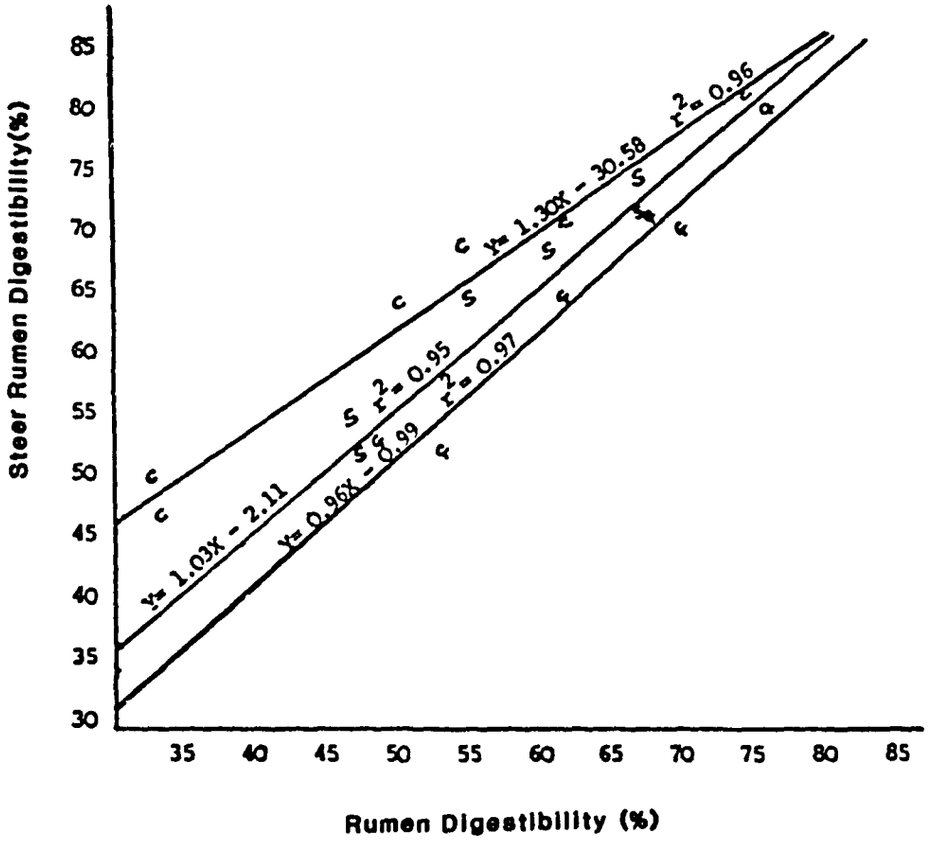

Figure 1. Relationship of rumen digestibilities of sheep (s), goat (g), and camel (c) to steer.

ECOLOGY AND ENVIRONMENT

THE SEASONAL CLIMATE OF RANGELANDS

D.K. Musembi

ABSTRACT

The most important climatic factor limiting agricultural productivity in the rangelands is rain. The rainfall is low, erratic, and highly variable in amount and occurrence. The rainfall comes in two seasons: the long rains (March to May) and the short rains (October to December).

Rangelands are naturally suited to livestock production, but lately increasing population pressure in the high-potential areas has caused people to migrate into the drylands and start mixed farming. To maximize output of both crops and livestock, the nature of the two rainy seasons must be understood by farmers.

The last 79 years' monthly rainfall data for Makindu Meteorological Station were analyzed to show the amount of rainfall in each of the seasons. The data were then related to historical information about years of drought and food crises.

The results show that the short rains are the most critical for food production and livestock management. Most famines are caused by failure of rains in this season, and the data show that there has been a change in the rainfall pattern dating back to early in the present century.

INTRODUCTION

Since Kenya lacks mineral resources, its economy is based on agriculture. However, only 20% of the land has medium to high agricultural potential. The rest has a marginal climate with mean annual rainfall below 500 mm (Griffiths, 1972; Cocheme, 1966). In these dry areas the rangelands are found. Temperature, radiation, and evaporation are high throughout the year; maximum values are experienced just before the start of the rains, while minimum values are experienced during the cold weather of June to August (Todorov and Pali-Shikhulu, 1973).

This area is unsuitable for crop production; however, population pressure in the high-potential areas has forced people to migrate into the rangelands, bringing with them the tradition of mixed farming. The introduction of crops in these lands is continuously reducing the area available for livestock production and is a threat to the protein source nationally.

Soil fertility is a limiting factor to agricultural productivity due to low organic matter and phosphorus contents (Konijn, 1985); but the single most important limiting factor is rainfall. The rainfall is low, variable, unreliable, and poorly distributed. It comes in association with the overhead sun in March to May (the long rains) and October to December (the short rains). January to February is the short dry season, which often receives rainfall of significant agricultural importance (Musembi, 1984); whereas June to September (the long dry season) is practically dry. The cold weather of June to July normally delays the harsh effects of the long dry season. In spite of its close association with the Intertropical Convergence Zone (ITCZ), the rainfall is hard to predict (Johnson, 1962), and the farmer finds it hard to plan ahead.

The two rainy seasons greatly increase the rangeland's productivity, but the variability of rainfall causes large fluctuations in herbage and crop productivity (Allan, 1973; Potter, 1985; de Leeuw, 1982). Feed quality is related to the presence of rain, whereas feed quantity is related to the total amount of rainfall (Allan, 1965). Rehm, Krause, and Sorensen (1975) found that drought-damaged corn has higher protein and digestibility than normal corn silage, but nitrate concentration approaches lethal levels in some parts of the corn. Phillipson (1975) found that elephants in the Tsavo National Park died of starvation in spite of large quantities of brown vegetable found in their stomachs.

The Katumani maize composite B, commonly grown in the dry areas, grows in 120 days and requires at least 200 mm of rainfall. Stewart and Wang'ati (1980) have found that severe water shortages during the fertilization and grain-filling stages of this maize result in marked reduction in yield.

Representing rainfall data in the form of mean monthly and annual totals is misleading for areas of high rainfall variability -- it does not indicate the rainfall's effectiveness since the excess is lost as runoff (Sombroek, Braun, and Van der Pouw, 1980). Which then is the best way to present rainfall data so that they can be of maximum use agriculturally? Griffiths (1972) suggests that, in areas of high variability, rainfall data should be presented in probability form. Pratt and Gwynne (1977) have stated that weekly totals are useful for irrigated agriculture, but studies of drought and its distribution are more appropriate for ranching areas. Downing et al. (1985) have used autocorrelations to show that several droughts have occurred at the end of decades followed by very good years. The strongest common cycles have been found in the long rains. None have been found in the short rains. Musembi's (1984) soil-moisture analyses have shown the short-rains growing season to be better than the long-rains season.

This paper examines seasonal rainfall for two stations to understand its distribution and identify clues to mitigating the stressful effects of droughts and resultant animal-feed and human-food crises.

DATA ANALYSIS

The last 79 years' monthly rainfall data for Makindu Meteorological Station were obtained partly from the station and partly from the Kenya Meteorological Department, Nairobi. The period studied are 1904 to 1985, except for three years (1924, 1964, and 1967) whose data are missing (see table 1).

The data for each year are divided into four seasons: the short dry season (January to February), the long rains (March to May), the long dry season (June to September), and the short rains (October to December). Temperature, evaporation, relative humidity, and radiation data for the National Range Research Station at Kiboko are superimposed on the mean monthly data in figure 1. Kiboko is 14 km from Makindu Meteorological Station.

The seasonal data are presented in a time series (figure 2). They are then split into two periods, 1904 to 1912 and 1913 to 1985, which are analyzed separately to show the unique differences between them (tables 2 and 3).

Subsequently, the data are related to historical information of known crises arising from drought or famines. Each crisis year is tabulated with one year preceding and one year following it to determine which of the two rainy seasons precipitated the crisis and which alleviated it (table 4). The crisis years are then tabulated separately to show their seasonal rainfall patterns (table 5).

Nine years of monthly rainfall data for the National Range Research Station, Kiboko, covering the period 1977 to 1985, also are analyzed seasonally for comparison (table 6), and the number of rainy days in each season is computed to show the rainfall distribution (table 7).

RESULTS AND DISCUSSION

Figure 1 shows that radiation, temperature, and evaporation reach maximum just before the rains and remain high during the rainy seasons. They reach minimum during the cold weather of June and July; relative humidity follows a similar trend but is low all the time. Table 1 clearly indicates two distinct rainfall regimes: one in the period 1904 to 1912, and the other in 1913 to 1985. In the wetter period (1904 to 1912), the mean annual rainfall exceeded 1,000 mm (table 2), and the seasons did not exist as we know them today. The long rains lasted five months (March to July) with peak rainfall in May. August appears to have been a transition month, like the present short dry season. The short rains lasted three months (September to November). December through February was dry, corresponding to the present long dry season. This is most likely the period when the rainy seasons got their "long" and "short" names. The drier period, 1913 to 1985, has a mean annual rainfall slightly below 600 mm (table 3) and the rainfall pattern we know today.

Table 3 also shows that the mean seasonal rainfall during the short rains is 290 mm, or 49% of the mean annual total, whereas the long rains account for 225 mm, or 38% of the annual total. The rainfall during the short dry season is 12% of the total and is of significance to agriculture, especially to late-planted crops or when the two seasons merge. Rainfall during the long dry season is about 1% and is of no agricultural importance. When taken together, the rainfall during the short rains and the short dry season accounts for 61% of the annual total. The period from October to May, which receives 99% of the total rainfall, is the most productive agriculturally in the rangelands. Data for Kiboko show that the short rains supply over 58% (310 mm) of the rainfall compared to 28% (146 mm) during the long rains and 13% (70 mm) in the short dry season (table 6). The number of rainy days (table 7) also shows that the short rains are distributed better than the long rains -- an average of 24 rainy days in the former compared to 15 days in the latter.

Table 4 shows that drought crises have followed when the short rains have been 60% (175 mm) or less of the seasonal mean (290 mm). In 5 out of 8 crises (1984, 1975, 1965, 1960, 1943) -- 63% of the time -- the short rains were responsible for arresting the crises. The long rains saved the situation twice (1980 and 1927), or 25% of the time. Thus, most famines should be expected to last at least a year.

Table 5 indicates that, in a crisis year, the relative importance of the rainy seasons changes. The short rains supply 40% (154 mm) of the annual rainfall total of 386 mm, compared to 46% (179 mm) supplied during the long rains. The relative amount of rainfall during the short

dry season remains about the same (now 12%), but the actual amount is 60% of that received in normal years (table 3). The worst droughts have occurred when rainfall has failed in three consecutive seasons (for example, 1927 to 1928 and 1983 to 1984). The drought of 1974 is hard to explain; however, the period from 1973 to 1976 is characterized by low rainfall, and the effects of prolonged rainfall insufficiency (leading to depletion of animal feed and chronic crop failure) are implied by the name of the crisis, "Longosa."

The food crisis of 1980 cannot be explained by rainfall failure. The short rains of 1979 and the rains in the following short dry season were average (table 3). It appears that policy decisions might have been made that resulted in depletion of strategic food reserves before the nature of the long rains of 1980 was known. Apparently, those rains resulted in low grain yield, probably because the farmers failed to take advantage of the rainfall during the preceding short dry season; hence, the crisis. The famines of 1943 and 1960 seem to belong to this category, but care should be taken in making this conclusion because the maize variety in use at that time may not have been the Katumani variety.

Most famines lead to importation of expensive famine relief. The National Cereals Board estimates the strategic food reserve at 360,000 metric tons (Downing et al., 1985). This reserve should be accumulated with the short-rains crop because the long rains are more likely to fail. Even if the long rains are good, the grain output is likely to be lower than in the short rains since biennials (such as pigeonpeas) planted in the short rains are left as pure stands during the long rains, thus reducing the total land under grain cultivation. The misconception that the long rainy season is better than the short rainy season arises from the fact that there is more food variety at the end of the former than the latter due to harvesting of biennials such as pigeonpeas, cassava, pumpkins, and sweet potatoes. These crops are important in buffering famine. A failure in the short rains may cause all of these crops to fail and, thus, remove the famine buffer at the end of the long rains. Such famines are harshest, and the famine of 1984 falls in this category.

For livestock management, stocking rates should be reduced at the end of the short rains and before the start of the long rains (in March) so that any additional pasture from the long rains can carry the animals through the long dry season. Disposing of the animals at this time should also fetch maximum prices because they are healthy and the market is not flooded. Livestock breeding should aim at calving toward late November or early December so that the animals benefit from lush pasture in the short rains and have a longer period of high milk production to benefit the farmer.

CONCLUSIONS

The data for Makindu show that rainfall patterns changed around 1913. Between 1904 and 1912, mean annual rainfall was about twice what it was for the period of 1913 to 1985. The long rains in the wetter period lasted longer (5 months) and accounted for more rainfall (53% of the annual mean) compared to the short rains, which lasted 3 months and accounted for only 19% of the mean annual total. It is probably during this time that our rainy seasons got their present names.

The most critical season for the management of crops and livestock is the short rains; however, the importance of the long rains in increasing the area's agricultural potential cannot be overlooked. Famines have resulted mostly from failure of the short rains, and the short rains also have been responsible for arresting the food crises. When rainfall fails in three consecutive seasons, the worst drought/famine crises occur, as were the cases in 1943, 1974, and 1984.

The short rains are better than the long rains in rainfall amount and distribution. Strategic food reserves should be met with the yields of the short rains because the long rains are likely to fail. Intercropping of single-season crops with two-season crops is recommended to provide food diversity and famine buffer at the end of the long rains, and livestock management should be adjusted to take advantage of the superior short rains.

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Table 1. Monthly rainfall for Makindu Meteorological Station (1904-1985).

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1904	0.0	0.0	23.4	93.0	699.5	336.8	141.2	25.4	0.0	293.1	145.5	15.0	1772.9
1905	6.4	0.0	80.3	308.6	350.8	133.4	102.6	58.4	135.9	115.3	20.8	0.0	1312.5
1906	1.7	10.2	32.5	336.8	601.2	277.4	56.1	23.6	20.1	25.9	102.4	0.0	1497.9
1907	3.0	0.0	0.0	105.7	392.2	39.9	98.3	40.4	23.1	222.5	18.5	0.0	943.6
1908	0.0	0.0	0.0	262.1	528.6	53.8	105.7	66.3	38.6	406.4	11.4	2.5	1475.4
1909	2.5	0.0	12.7	268.5	224.5	161.3	150.9	44.7	102.9	4.6	99.1	91.2	1162.9
1910	10.9	0.0	2.0	51.8	376.7	78.5	123.2	58.7	19.2	10.2	40.6	11.7	783.5
1911	0.5	0.0	34.8	294.1	289.1	39.4	98.3	39.6	15.2	103.6	45.2	7.1	966.9
1912	0.0	23.1	47.2	173.0	14.7	29.7	47.0	39.9	19.3	48.3	110.7	62.0	614.9
1913	53.8	38.1	68.6	92.2	15.0	0.0	0.0	0.0	0.0	40.9	40.6	100.8	450.0
1914	169.2	0.0	0.0	55.9	21.6	0.0	0.0	0.0	0.0	10.7	92.2	108.5	458.1
1915	0.0	22.4	63.5	184.7	0.0	41.1	0.0	0.0	0.0	5.3	85.3	77.7	480.0
1916	189.2	56.4	28.4	305.8	87.9	0.0	0.0	0.0	5.1	37.3	436.4	603.3	1749.8
1917	135.1	5.8	147.6	93.5	62.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	444.7
1918	0.0	0.0	0.0	93.0	0.0	0.0	0.0	0.0	0.0	0.0	74.9	152.4	320.3
1919	0.0	7.6	650.2	203.2	0.0	0.0	0.0	0.0	0.0	19.1	38.1	0.0	918.2
1920	49.5	26.9	91.9	118.4	26.4	2.8	0.5	0.5	0.5	18.3	160.3	131.1	627.1
1921	213.9	0.0	0.0	10.2	19.1	0.0	0.0	0.0	0.0	3.6	515.1	169.1	931.0
1922	87.4	21.1	268.2	199.9	88.4	0.0	0.0	0.0	0.0	0.0	150.1	207.0	1022.1
1923	103.4	171.5	63.8	821.9	203.2	0.0	0.0	0.0	0.0	9.7	428.8	162.1	1964.4
1924													0.0
1925	57.3	37.3	0.0	0.0	34.8	2.5	0.3	0.3	0.5	30.0	215.6	142.7	521.3
1926	0.0	0.0	68.8	199.1	0.0	0.0	0.0	0.0	0.0	0.0	111.8	21.1	400.8
1927	43.2	14.0	247.1	77.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	381.8
1928	0.0	0.0	13.2	83.8	0.0	17.8	0.0	0.0	0.0	60.2	36.1	0.0	211.1
1929	30.2	19.1	159.3	250.4	199.4	0.0	8.4	0.0	0.0	2.5	202.7	134.9	1006.9
1930	30.2	19.1	159.3	250.4	199.4	0.0	8.4	0.0	0.0	2.5	202.7	134.9	1006.9
1931	0.0	110.7	40.4	112.0	0.0	1.0	0.0	0.3	2.8	0.0	71.9	69.3	408.4
1932	26.7	8.6	85.6	136.1	30.7	0.0	0.0	0.0	0.0	0.0	192.5	144.3	624.5
1933	169.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	158.8	174.0	509.6
1934	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	19.1	45.7	67.3
1935	0.0	116.8	7.6	43.2	0.0	5.1	0.0	0.0	0.0	0.0	137.2	67.1	377.0
1936	0.0	50.8	71.1	55.0	0.0	0.0	0.0	0.0	2.5	88.6	49.3	117.1	414.4
1937	0.0	15.5	181.1	188.0	45.7	0.0	0.0	0.0	0.3	40.9	75.4	132.6	679.5

Table 1. Monthly rainfall for Makindu Meteorological Station (1904-1985) (continued).

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1938	10.4	47.8	146.3	80.3	87.1	0.0	0.0	0.0	0.3	2.3	197.1	84.8	656.[illegible]
1939	14.2	4.1	84.8	145.3	12.7	0.0	1.0	0.5	0.8	0.3	68.3	12.1	[illegible]
1940	45.5	62.2	143.8	138.9	31.0	0.0	0.0	1.8	0.5	8.4	181.9	58.2	672.[illegible]
1941	0.8	0.8	101.9	93.2	13.7	1.8	0.0	0.0	0.8	3.0	250.4	197.4	663.8
1942	29.0	11.5	116.1	31.2	35.3	0.8	0.0	0.5	0.5	65.8	187.5	10.4	488.6
1943	12.2	5.5	71.4	233.7	23.9	1.0	4.6	0.5	0.0	0.8	47.8	112.3	513.7
1944	54.[illegible]	0.0	40.4	99.8	11.7	4.1	0.3	0.5	2.0	25.9	116.8	97.3	453.4
1945	17.0	22.9	11.2	32.5	13.2	0.8	0.0	0.5	4.6	0.5	256.1	45.0	406.3
1946	17.8	0.0	30.8	108.0	5.8	0.0	0.0	1.8	28.7	49.0	78.0	70.4	390.3
1947	67.3	0.0	139.2	202.4	40.9	1.0	0.0	0.0	1.3	3.6	91.4	183.[illegible]	730.[illegible]
1948	1.5	20.6	75.9	77.5	2.8	3.0	0.0	0.0	0.0	28.7	214.6	323.9	748.5
1949	3.0	0.0	2.5	110.5	6.6	0.0	2.3	0.0	0.6	0.5	50.5	155.7	333.0
1950	0.8	1.3	1[illegible].4	26.4	4.8	0.0	0.0	0.0	1.7	0.5	107.4	65.0	314.3
1951	1.0	0.0	130.8	141.5	108.5	0.5	1.8	0.8	0.0	118.6	136.4	158.0	797.9
1952	1.5	0.5	50.8	106.2	133.1	0.0	0.0	0.0	0.0	45.0	73.2	99.1	509.4
1953	46.0	0.3	69.9	41.7	17.5	0.3	1.0	3.0	3.3	1.8	290.3	88.1	563.2
1954	1.7	1.0	142.2	35.3	0.3	0.3	0.0	0.5	0.0	5.8	87.[illegible]	77.5	352.0
1955	5.3	105.[illegible]	13.5	54.6	10.7	1.5	0.0	0.0	0.0	10.4	45.0	120.7	367.4
1956	209.6	14.[illegible]	46.2	6.1	0.0	0.0	0.0	0.0	1.0	19.3	363.2	82.3	741.7
1957	60.7	4.6	66.3	81.5	74.9	0.5	2.0	0.0	2.3	40.4	153.4	136.1	622.7
1958	16.5	118.1	71.1	96.3	10.7	3.8	3.0	0.0	0.0	0.3	89.4	90.4	499.6
1959	75.2	14.0	81.3	41.1	14.0	0.0	0.0	3.3	1.0	0.3	173.7	58.4	462.3
1960	35.3	26.2	61.0	105.4	9.9	0.3	0.0	0.0	0.0	40.4	25.9	109.0	413.4
1961	2.5	16.3	27.2	57.4	29.5	0.5	0.3	0.3	14.2	221.7	478.3	130.3	978.5
1962	56.6	22.6	94.0	51.8	36.1	2.0	2.8	1.0	0.0	23.1	169.7	129.8	589.5
1963	57.8	58.7	127.9	69.9	16.6	4.8	0.0	0.0	3.8	6.3	450.6	326.9	1123.3
1964													0.0
1965	43.1	0.3	22.2	57.8	1.6	0.2	0.0	1.4	1.9	20.7	198.6	17.4	365.2
1966	36.3	56.8	135.5	140.5	6.5	0.3	0.0	0.0	0.0	5.8	44.3	47.9	473.9
1967													0.0
1968	0.0	134.8	205.1	291.6	14.0	6.2	0.0	0.0	0.0	16.6	431.2	0.0	1099.5
1969	105.1	61.3	95.3	24.4	3.4	0.0	0.0	0.0	0.0	6.8	204.5	25.1	525.9
1970	22.7	0.0	148.9	44.3	7.5	0.2	0.0	1.9	0.0	0.0	38.0	0.0	263.5

Table 1. Monthly rainfall for Makindu Meteorological Station (1904-1985) (continued).

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1971	24.6	5.0	14.8	6.2	4.2	2.3	0.6	4.0	0.9	2.2	171.4	67.6	303.8
1972	24.5	24.1	0.6	9.4	8.6	0.7	0.0	0.0	2.4	32.9	144.9	74.5	322.6
1973	58.4	70.9	1.1	94.9	33.8	0.0	0.0	0.0	1.5	9.5	135.9	3.0	409.0
1974	36.3	8.2	122.7	94.9	4.8	2.3	0.3	0.3	0.6	15.1	96.5	45.0	427.0
1975	10.1	12.1	9.9	123.8	9.9	0.0	5.2	0.0	1.4	4.3	83.3	42.7	302.7
1976	0.0	4.1	0.0	132.1	1.0	0.0	0.0	0.0	12.8	0.8	98.8	59.9	309.5
1977	16.0	34.3	41.0	140.4	98.2	14.6	0.0	6.2	3.2	3.4	170.6	157.6	685.5
1978	44.2	21.6	160.3	93.0	1.1	0.0	0.0	0.0	1.1	174.8	157.0	274.6	927.7
1979	233.2	92.7	18.5	127.0	63.1	4.6	5.5	0.0	2.2	19.5	148.5	117.3	832.1
1980	48.4	20.7	71.1	66.7	21.2	0.0	0.0	7.1	0.1	0.6	137.1	37.8	410.8
1981	0.0	0.0	104.9	288.2	80.4	0.0	0.0	0.4	2.4	42.9	45.2	98.5	662.9
1982	1.0	0.0	0.5	176.2	34.6	0.5	1.8	0.2	12.2	147.6	397.7	158.4	930.7
1983	0.5	36.9	3.0	40.8	12.0	0.1	0.5	0.0	2.3	0.3	15.8	147.2	259.4
1984	27.7	0.0	6.0	0.0	0.0	0.4	0.8	0.0	0.4	85.6	358.7	122.4	602.0
1985	5.3	83.1	34.1	81.9	13.8	0.0	1.6	0.0	1.6	67.4	125.6	87.3	501.7
Mo. Mean	37.67	25.32	74.05	123.68	71.93	16.23	12.36	5.50	6.34	37.54	147.84	97.37	656.42
Percentage	5.74	3.86	11.37	18.84	10.96	2.47	1.88	0.84	0.97	5.72	22.52	14.83	100.00

Table 2. Seasonal rainfall for Makindu Meteorological Station (1904-1912).

Year	S-Dry	L-Rains	L-Dry	S-Rains	Annual
1904	0.0	815.9	503.4	453.6	1772.9
1905	6.4	739.7	430.3	136.1	1312.5
1906	21.9	970.5	377.2	128.3	1497.9
1907	3.0	497.9	201.7	241.0	943.6
1908	0.0	790.7	264.4	420.3	1475.4
1909	2.5	505.7	459.8	194.9	1162.9
1910	10.9	430.5	279.6	62.5	783.5
1911	0.5	618.0	192.5	155.9	966.9
1912	23.1	234.9	135.9	221.0	614.9
Mo. Mean	7.59	622.64	316.09	223.73	1170.06
Percentage	.65	53.21	27.01	19.12	100.00

Table 3. Seasonal rainfall for Makindu Meteorological Station (1913-1985).

Year	S-Dry	L-Rains	L-Dry	S-Rains	Annual
1913	91.9	175.8	0.0	182.3	450.0
1914	169.2	77.5	0.0	211.4	458.1
1915	22.4	248.2	41.1	168.3	480.0
1916	245.6	422.1	5.1	1077.0	1749.8
1917	140.9	303.8	0.0	0.0	444.7
1918	0.0	93.0	0.0	227.3	320.3
1919	7.6	853.4	0.0	57.2	918.2
1920	76.4	236.7	4.3	309.7	627.1
1921	213.9	29.3	0.0	687.8	931.0
1922	108.5	556.5	0.0	357.1	1022.1
1923	274.9	1088.9	0.0	600.6	1964.4
1924	0.0	0.0	0.0	0.0	0.0
1925	94.6	34.8	3.6	388.3	521.3
1926	0.0	267.9	0.0	132.9	400.8
1927	57.2	324.6	0.0	0.0	381.8
1928	0.0	97.0	17.8	96.3	211.1
1929	49.3	609.1	8.4	340.1	1006.9
1930	49.3	609.1	8.4	340.1	1006.9
1931	110.7	152.4	4.1	141.2	408.4
1932	35.3	252.4	0.0	336.8	624.5
1933	169.9	0.0	0.0	339.7	509.6
1934	0.0	0.0	2.5	64.8	67.3
1935	116.8	50.8	5.1	204.3	377.0
1936	50.8	126.1	2.5	235.0	414.4
1937	15.5	414.8	.3	248.9	679.5
1938	58.2	313.7	.3	284.2	656.4

Table 3. Seasonal rainfall for Makindu Meteorological Station (1913-1985) (continued).

Year	S-Dry	L-Rains	L-Dry	S-Rains	Annual
1939	18.3	242.8	2.3	80.7	344.1
1940	107.7	313.7	2.3	248.5	672.2
1941	1.6	208.8	2.6	450.8	663.8
1942	40.5	182.6	1.8	263.7	488.6
1943	17.7	329.0	6.1	160.9	513.7
1944	54.6	151.9	6.9	240.0	453.4
1945	39.9	56.9	5.9	303.6	406.3
1946	17.8	144.6	30.5	197.4	390.3
1947	67.3	382.5	2.3	278.6	730.7
1948	22.1	156.2	3.0	567.2	748.5
1949	3.6	119.6	3.1	206.7	333.0
1950	2.1	137.6	1.7	172.9	314.3
1951	1.0	380.8	3.1	413.0	797.9
1952	2.0	290.1	0.0	217.3	509.4
1953	46.3	129.1	7.6	380.2	563.2
1954	2.7	177.8	.8	170.7	352.0
1955	111.0	78.8	1.5	176.1	367.4
1956	223.6	52.3	1.0	464.8	741.7
1957	65.3	222.7	4.8	329.9	622.7
1958	134.6	178.1	6.8	180.1	499.6
1959	89.2	136.4	4.3	232.4	462.3
1960	61.5	176.3	.3	175.3	413.4
1961	18.8	114.1	15.3	830.3	978.5
1962	79.2	181.9	5.8	322.6	589.5
1963	116.5	214.4	8.6	783.8	1123.3
1964	0.0	0.0	0.0	0.0	0.0
1965	43.4	81.6	3.5	236.7	365.2
1966	93.1	282.5	.3	98.0	473.9
1967	0.0	0.0	0.0	0.0	0.0
1968	134.8	510.7	6.2	447.8	1099.5
1969	166.4	123.1	0.0	236.4	525.9
1970	22.7	200.7	2.1	38.0	263.5
1971	29.6	25.2	7.8	241.2	303.8
1972	48.6	18.6	3.1	252.3	322.6
1973	129.3	129.8	1.5	148.4	409.0
1974	44.5	222.4	3.5	156.6	427.0
1975	22.2	143.6	6.6	130.3	302.7
1976	4.1	133.1	12.8	159.5	309.5
1977	50.3	279.6	24.0	331.6	685.5
1978	65.8	254.4	1.1	606.4	927.7
1979	325.9	208.6	12.3	285.3	832.1
1980	69.1	159.0	7.2	175.5	410.8
1981	0.0	473.5	2.8	186.6	662.9
1982	1.0	211.3	14.7	703.7	930.7
1983	37.4	55.8	2.9	163.3	259.4
1984	27.7	6.0	1.6	566.7	602.0
1985	88.4	129.8	3.2	280.3	501.7
Mo. Mean	70.12	224.95	4.99	290.33	590.38
Percentage	11.88	38.10	.84	49.18	100.00

Table 4. Rainfall data for Makindu Meteorological Station showing the crisis years and the years preceding and succeeding them.

Year	S-Dry	L-Rains	L-Dry	S-Rains	Annual	Famine Name
1926	0.0	267.9	0.0	132.9	400.8	
1927	57.2	324.6	0.0	0.0	381.8	Kakuti
1928	0.0	97.0	17.8	96.3	211.1	Nzalukangye
1929	49.3	609.1	8.4	340.1	1006.9	
1942	40.5	182.6	1.8	263.7	488.6	
1943	17.7	329.0	6.1	160.9	513.7	Mwolyo
1944	54.6	151.9	6.9	240.0	453.4	
1959	89.2	136.4	4.3	232.4	462.3	
1960	61.5	176.3	.3	175.3	413.4	Ndeke/Kilaiku
1961	18.8	114.1	15.3	830.3	978.5	
1964	0.0	0.0	0.0	0.0	0.0	
1965	43.4	81.6	3.5	236.7	365.2	Atta
1966	93.1	282.5	.3	98.0	473.9	
1967	0.0	0.0	0.0	0.0	0.0	Famine
1973	129.3	129.8	1.5	148.4	409.0	
1974	44.5	222.4	3.5	156.6	427.0	
1975	22.2	143.6	6.6	130.3	302.7	Longosa
1976	4.1	133.1	12.8	159.5	309.5	
1977	50.3	279.6	24.0	331.6	685.5	
1979	325.9	208.6	12.3	285.3	832.1	
1980	69.1	159.0	7.2	175.5	410.8	Nikwa Ngwete
1981	0.0	473.5	2.8	186.6	662.9	
1982	1.0	211.3	14.7	703.7	930.7	
1983	37.4	55.8	2.9	163.3	259.4	
1984	27.7	6.0	1.6	566.7	602.0	Ndukambikwatye
1985	88.4	129.8	3.2	280.3	501.7	
Mo, Mean	50.97	188.67	6.07	234.40	480.11	
Percentage	10.62	39.30	1.26	48.82	100.00	

Table 5. Rainfall for Makindu Meteorological Station showing the crisis years alone.

Year	S-Dry	L-Rains	L-Dry	S-Rains	Annual	Famine name
1926	0.0	267.9	0.0	132.9	400.8	
1927	57.2	324.6	0.0	0.0	381.8	Kakuti
1928	0.0	97.0	17.8	96.3	211.1	Nzalukangye
1943	17.7	329.0	6.1	160.9	513.7	Mwolyo
1944	54.6	151.9	6.9	240.0	453.4	
1959	89.2	136.4	4.3	232.4	462.3	
1960	61.5	176.3	.3	175.3	413.4	Ndeke/Kilaiku
1965	43.4	81.6	3.5	236.7	365.2	Atta
1966	93.1	282.5	.3	98.0	473.9	
1973	129.3	129.8	1.5	148.4	409.0	
1974	44.5	222.4	3.5	156.6	427.0	Drought
1975	22.2	143.6	6.6	130.3	302.7	Longosa
1976	4.1	133.1	12.8	159.5	309.5	
1980	69.1	159.0	7.2	175.5	410.8	Kikwa Ngwete
1983	37.4	55.8	2.9	163.3	259.4	
Mo. Mean	48.22	179.39	4.91	153.74	386.27	
Percentage	12.48	46.44	1.27	39.80	100.00	

Table 6. Monthly rainfall (A) and seasonal rainfall summary (B) for National Range Research Station, Kiboko.

(A) Year 1	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annua
1977	39.4	37.3	12.1	154.2	50.5	0.0	0.0	0.0	0.0	0.0	215.2	178.6	687.3
1978	85.5	7.5	124.7	19.0	8.3	0.0	0.0	0.0	0.0	132.7	161.3	205.8	744.8
1979	171.8	53.1	34.2	107.0	49.7	1.8	0.7	0.0	0.0	14.0	100.7	128.8	661.8
1980	31.5	4.5	74.2	34.7	6.7	0.0	0.0	0.0	0.0	0.0	155.6	47.1	354.3
1981	0.0	0.0	71.6	135.1	29.4	0.0	0.0	0.0	0.0	37.6	41.9	83.8	399.4
1982	0.0	0.0	0.0	92.9	20.6	0.0	13.5	0.0	9.5	86.5	197.4	142.2	562.6
1983	0.0	36.9	6.9	47.3	17.3	0.0	0.0	0.0	0.0	0.0	31.8	137.6	277.8
1984	17.5	0.0	35.0	72.9	0.0	0.0	0.0	0.0	0.0	75.6	245.6	113.6	560.2
1985	14.2	129.6	46.7	35.0	29.7	0.0	1.3	0.5	5.6	55.4	101.6	103.0	522.6
Mo. Mean	39.99	29.88	45.04	77.57	23.58	0.20	1.72	0.06	1.68	44.64	139.01	126.72	530.09

(B) Seasons Defined

Short dry season	Jan. - Feb.
Long rainy season	Mar. - May
Long dry season	June - Sept.
Short rainy season	Oct. - Dec.

Year	S dry	L rainy	L dry	S rainy	Annual
1977	76.7	216.8	0.0	393.8	687.3
1978	93.0	152.0	0.0	499.8	744.8
1979	224.9	190.9	2.5	243.5	661.8
1980	36.0	115.6	0.0	202.7	354.3
1981	0.0	236.1	0.0	163.3	399.4
1982	0.0	113.5	23.0	426.1	562.6
1983	36.9	71.5	0.0	169.4	277.8
1984	17.5	107.9	0.0	434.8	560.2
1985	143.8	111.4	7.4	260.0	522.6
Mean	69.87	146.19	3.66	310.38	530.09
Percentage	13.18	27.58	0.69	58.55	100.00

Table 7. Number of rainy days for National Range Research Station, Kiboko, summarized on monthly basis (A), and seasonal basis (B).

(A)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1977	5	2	3	14	6	0	0	0	0	0	19	21	70
1978	7	3	15	7	2	0	0	0	0	4	14	14	66
1979	20	2	3	3	6	1	1	0	0	4	11	11	62
1980	3	3	5	7	5	0	0	0	0	0	10	6	39
1981	0	0	6	11	3	0	0	0	0	3	6	3	32
1982	0	0	0	3	1	0	1	0	1	3	3	3	15
1983	0	3	2	5	3	0	0	0	0	0	4	12	29
1984	1	0	2	3	0	0	0	0	0	7	16	9	38
1985	3	11	4	8	5	0	2	1	12	6	13	10	65
Mo. Mean	4.33	2.67	4.44	6.78	3.44	.11	.44	.11	.33	3.00	10.67	9.89	46.22

(B)

Year	S-dry	L-rains	L-dry	S-rains	Annual
1977	7.0	23.0	0.0	40.0	70.0
1978	10.0	24.0	0.0	32.0	66.0
1979	22.0	12.0	2.0	26.0	62.0
1980	6.0	17.0	0.0	16.0	39.0
1981	0.0	20.0	0.0	12.0	32.0
1982	0.0	4.0	2.0	9.0	15.0*
1983	3.0	10.0	0.0	16.0	29.0
1984	1.0	5.0	0.0	32.0	38.0
1985	14.0	17.0	5.0	29.0	65.0
Mean	7.00	14.67	1.00	23.56	46.22
Percentage	15.14	31.73	2.16	50.96	100.00

* Rain given at 10-day intervals.

Key: R = Radiation
T = Temperature (maximum and minimum)
H = Relative Humidity (1500 hours lower; 0900 hours upper)
E = Evaporation

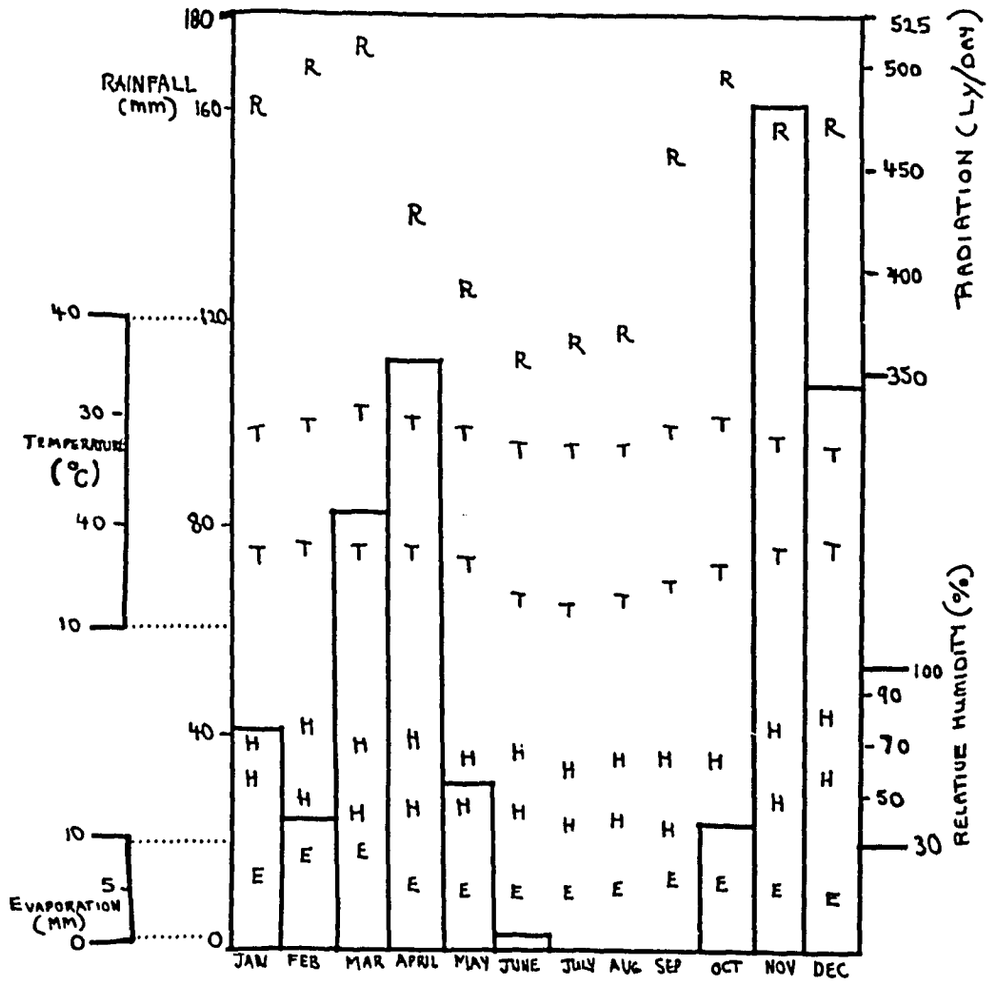

Figure 1. Mean monthly rainfall for Makindu Meteorological Station (1913-1985) with radiation (1984), temperature (1985), relative humidity (1985), and evaporation (1982) for the National Range Research Station, Kiboko, superimposed.

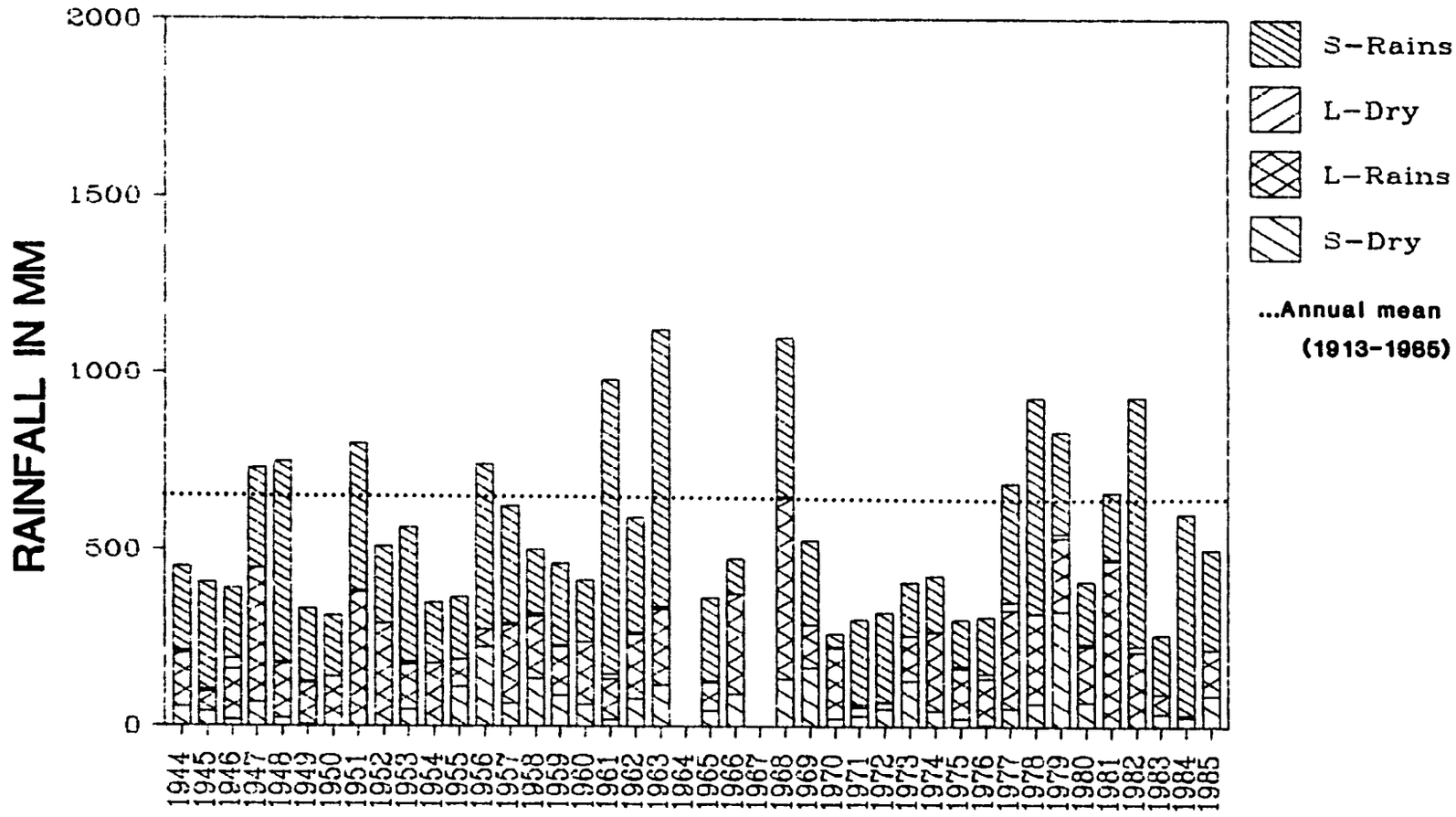

Figure 2. Rainfall for Makindu Meteorological Station, 1904-1985, seasonal summary (continued).

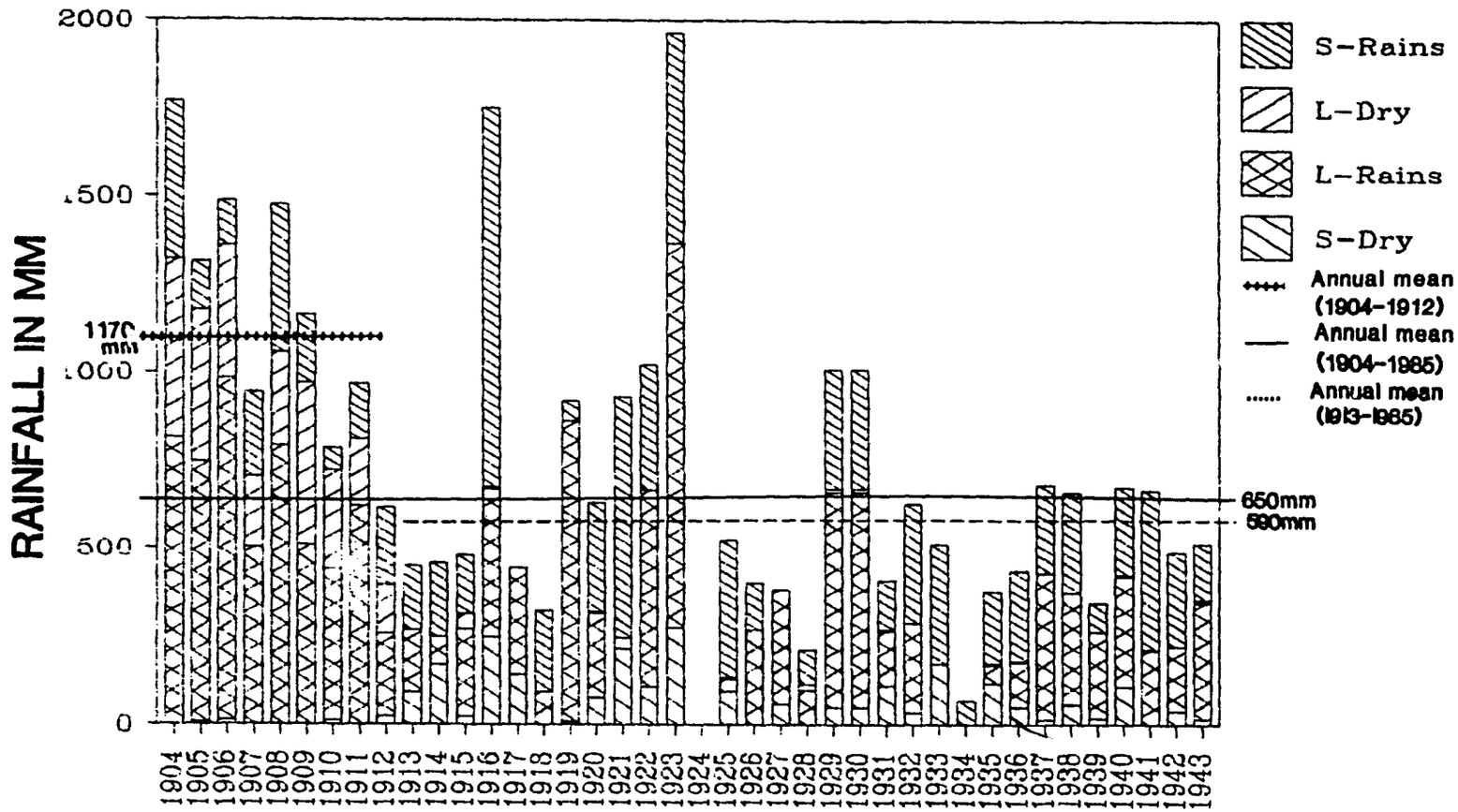

Figure 2. Rainfall for Makindu Meteorological Station, 1904-1985, seasonal summary.

EFFECTS OF PANICUM MAXIMUM AND DIGITARIA MACROBLEPHARA ON WATER INFILTRATION

Simeon Kibiegon Cheruiyot and Wilbert H. Blackburn

ABSTRACT

A drip-type rainfall simulator was used to assess the effect of different plant species on infiltration rates and sediment production on rangelands near Kiboko, Kenya. Two types of vegetation were studied: Panicum maximum growing underneath Acacia tortilis trees, and Digitaria macroblephara growing in the open. Infiltration rates were greater in P. maximum areas than in D. macroblephara areas. Sediment production was less from P. maximum areas than from D. macroblephara areas.

INTRODUCTION

Blackburn (1975) reported a positive correlation between infiltration rate and the amount of plant and litter cover. Infiltration rates were strongly negatively correlated with bare ground. Organic matter binds soil particles into aggregates, and the soil becomes less dense, thus increasing porosity and decreasing surface-crust formation. Infiltration rates are positively related to soil organic matter, except for sites where hydrophobic soils occur. Infiltration rates generally decrease as bulk density increases.

Vegetation cover and associated litter intercept rainfall kinetic energy and thereby decrease the mobilization of soil particles. Organic litter and shade stimulate microfaunal activity in the soil, improving soil aggregation and infiltration. It is generally agreed that soil erosion is extremely sensitive to the type and density of vegetation cover (Dunne et al., 1982). Dunne et al (1982) noted that the vegetation component that protects the soil most efficiently against erosion in the Kenya rangelands appears to be the ground cover or herb layer and the associated litter, rather than the bush-canopy cover. Many canopies are thin, especially early in the rainy season before leaves have developed and they allow raindrops to strike the ground surface directly. Many larger woodland canopies allow raindrops to fall 5 m to 8 m to the soil surface, which they reach with a considerable fraction of their original kinetic energy.

Work done at the National Range Research Station, Kiboko (Cheruiyot, 1984), showed that areas with Sporobolus fimbriatus and D. macroblephara had greater infiltration rates after 30 minutes of simulated rainfall than bare ground or Hermannia alhiensis areas. Sediment production was greater from bare-ground areas than from vegetated areas. The variables associated with vegetation (vegetation foliar cover, litter cover, standing crop, and litter accumulation) and aggregated stability were identified as being the most important variables in influencing infiltration rates and sediment production. Similar results were obtained by Mbakaya (1985).

Dunne (1977) wrote that the major factors that accelerate erosion in the semiarid regions of Kenya appear to be the reduction of ground vegetation cover and disturbance of the soil surface promoted by intense grazing, trampling, and cultivation without soil-conservation practices. Thomas and Barbar (1981) concluded that losses of soil and water vary greatly in different parts of Kenya's semiarid lands but often are

greater on grazing lands than on cropland. Where cover is lacking, losses can be very high; the loss of water being greatest where the surface seal is intact, and the loss of soil greatest where it is broken. Measures to break the surface seal and promote infiltration are essential to the restoration of cover, except where the surface is covered with quartzite. Moore et al. (1979) found that, near Machakos, Kenya, grass cover with heavy grazing does not increase infiltration rates significantly over bare soils, but ploughing and reseeding does. However, grass cover can reduce soil losses, with most reduction occurring at basal-cover densities from 0% to 20%, with little further reduction at higher basal covers. High intensity of rainfall 5 cm/hr to 10 cm/hr leads to high rates of runoff from both grass-covered and bare ground, particularly if the soil is already wet. At low intensity (2.5 cm/hr), a good grass cover can play a very significant role in reducing the percentage of rain that is lost as runoff.

Soil conservation practices such as terracing, managing crop residue, scarifying soil after removal of woodland or bush, and harvesting wood fuel in strips along contours may decrease soil loss (Dunne, 1979). Another set of land-use effects are associated with the extension, intensity of use, and maintenance of rural roads, which appear to be major sediment sources in some parts of Kenya. Dunne et al. (1982) noted that selective removal of trees for charcoal burning alone does not radically diminish the canopy at most production sites and, therefore, does not greatly increase the incidence of or intensity of erosion indicators, except where a thick bushland is opened up to grazing and trampling by livestock. They concluded that the practices that contribute greatly to soil erosion in Kenya include poorly regulated clear-cut deforestation, submarginal agriculture involving frequent slash and burn as in shifting cultivation, and excessive grazing pressure by stock and game.

STUDY AREA

The study area was located at the National Range Research Station, Kiboko, which is approximately 170 km southeast of Nairobi. The elevation of the station varies from 900 m to 1100 m (Michieka and Van der Pouw, 1977). The average annual rainfall, evaporation, and temperature are 600 mm, 2,000 mm, and 23°C respectively (Michieka and Van der Pouw, 1977). Rainfall distribution is limited, with rainy seasons from the end of March to mid-May and from the end of October to mid-December.

The study site was located in the Southern Ranch of the station (Muuni area). Soils of the experimental area were acri-rhodic ferralsol with an effective depth of 130 cm. The vegetation was bushed grassland, which consisted of the grasses *P. maximum*, *D. macroblephara*, and *Chloris roxburghiana*, and the woody species *A. tortilis* and *Commiphora riparia*. Virtually all the *P. maximum* occurred underneath the canopies of woody plant species.

METHODS

Six *A. tortilis* trees were selected to determine the influence of *P. maximum* growing underneath the trees and *D. macroblephara* growing in the open on infiltration rates and sediment production. Two 37-cm x 37-cm subplots of *P. maximum* were identified underneath each tree; and two *D. macroblephara* subplots, also 37 cm x 37 cm, were located outside the canopy of each tree. Data were collected in August and December 1982 to determine the effects of the two grass species over time. At each

sampling date, the subplots were prewetted 24 hours before simulated rainfall was applied. A total of 24 plots were sampled at each sampling date.

Water was applied to the subplots with a rainfall simulator similar to that described by Blackburn et al. (1974) at a rate of 14.4 cm/hr for 30 minutes. "Time to runoff" was the time that elapsed in minutes between the start of the simulated rainfall event and when runoff was collected. "Infiltration rate" was the difference between the amount of water applied and runoff. Runoff was determined by volume measurements taken at 5-minute intervals and converted to infiltration rate (cm/hr). Runoff from each plot was collected and thoroughly agitated, and a 0.5-liter subsample was taken. The sediment of each subsample was collected, oven dried at 105°C for 24 hours, weighed, and converted to sediment production in kg/ha, and was used as an index of sheet erosion.

Analysis

The data were analyzed using the Statistical Analysis Systems programs (Helwig and Council, 1979) on Texas A&M University's Amdahl 470/V6V8 computer. Treatment differences were separated using Duncan's multiple-range test (Steel and Torrie, 1980). Simple- and multiple-regression and correlation analyses were used to identify factors important to infiltration rates and sediment production (Draper and Smith, 1981). Forward-stepwise multiple-regression analysis (Draper and Smith, 1981) was used to determine the variables that influenced infiltration rates and sediment production the most.

RESULTS

The time to runoff was about 5.2 to 5.3 minutes in August and about 3.6 to 5.3 minutes in December (table 1). About 8.2 cm to 10.3 cm of water infiltrated the soil 30 minutes after wetting in areas with *D. macroblephara* (table 2). For *P. maximum* areas, the readings were 13.6 cm and 10.8 cm in August and December respectively.

Sediment production from *P. maximum* areas ranged from 31 kg/ha to 336 kg/ha in August and December respectively (table 3). From *D. macroblephara* areas, the sediment production means were 142 kg/ha and 393 kg/ha in August and December respectively. The aggregate stability was about 8.5 in *P. maximum* areas and about 7.5 in *D. macroblephara* areas. Organic carbon was between 2% and 2.4% in *P. maximum* and between 1.5% and 1.55% in *D. macroblephara*. The bulk density in areas with *P. maximum* ranged from 1.28 gm/cc to 1.54 gm/cc, while in areas with *D. macroblephara* it ranged from 1.49 gm/cc to 1.72 gm/cc.

DISCUSSION

Time to Runoff

Mean time to runoff was similar for both *P. maximum* and *D. macroblephara* areas in August and December sampling dates (table 1). Multiple-regression equations showed litter accumulation ($r = 0.357$), grass cover ($r = 0.439$), and organic carbon ($r = 0.456$) to be variables having an impact on time to runoff. These variables usually are influenced by the type of plant species growing in an area. According to Cheruiyot (1984) and Mbakaya (1985), time to runoff was influenced by litter accumulation, shrub and grass cover, aggregate stability, litter cover and antecedent soil water.

Infiltration

Mean infiltration rates after 30 minutes in soils with P. maximum were significantly higher than those in areas with D. macroblephara in August. There were no significant differences in December. However, the mean infiltration rates were generally higher in P. maximum than in D. macroblephara areas. Multiple-regression equations showed that bulk density, grass cover, and litter cover influenced infiltration rates after 10, 15, 20, 25, and 30 minutes. After 5 and 20 minutes, the infiltration rates were influenced by organic carbon and antecedent soil water. The correlation coefficients of the variables that influenced infiltration rates after 30 minutes were bulk density ($r = -0.483$), grass cover ($r = 0.471$), litter accumulation ($r = 0.406$), and organic carbon ($r = 0.436$). According to Cheruiyot (1984) and Mbakaya (1985), infiltration rates after 30 minutes were influenced by grass cover, standing crop, aggregate stability, litter accumulation, organic carbon, and litter cover. These variables are vegetation related and act as a protective cover for the soil surface. They increase infiltration by providing cover that acts as a barrier for surface concentration and flow, dissipates raindrop energy, and adds organic matter to the soil by means of mulch or root biomass (Mbakaya, 1985). P. maximum areas had a higher grass cover (71% in August and 78% in December) than D. macroblephara areas (66% in August and 73% in December).

Organic carbon was higher in the soils with P. maximum and bulk density was lower than in areas with D. macroblephara. Bulk density is inversely related to infiltration rates. Therefore, areas with a high bulk density have low infiltration rates. Areas with P. maximum and low bulk density (and, therefore, high soil porosity) had high infiltration rates. Soil organic matter not only binds soil particles in aggregates but lightens and expands the soil, thus increasing the porosity and decreasing crust formation.

Sediment Production

Mean sediment production from P. maximum areas was significantly lower than from D. macroblephara areas in August. There was no significant difference in sediment production in December. Multiple-regression equations identified litter accumulation ($r = -0.479$), grass cover ($r = -0.297$), litter cover ($r = -0.288$), soil-water content ($r = 0.137$), and organic carbon ($r = -0.236$) as the variables having an impact on sediment production and accounted for 66% of the variation.

Exposure of soil surface to raindrop impact results in a breakdown of soil aggregates, particle detachment, and transport by raindrop splash and runoff (Mbakaya, 1985). Detached soil particles may clog soil pores and result in reduced infiltration rates. A reduction in infiltration rates results in more water being available for sediment transport. Areas with high infiltration rates are usually areas with good protective cover, water-stable aggregates, and high organic carbon.

Infiltration rates are inversely related to runoff and soil loss. The factors that increased sediment production were antecedent soil water and bulk density. These two factors are negatively correlated with infiltration rates; therefore, they reduce infiltration and favor runoff that carries soil particles.

SUMMARY

Mean time to runoff was similar for areas with P. maximum and D. macroblephara. Infiltration rates were significantly greater in P. maximum areas than in D. macroblephara areas in August only. There were no significant differences in December. The grass cover in D. macroblephara areas increased from 66% in August to 73% in December, and this apparently resulted in increased interception of raindrops, giving the soil time to absorb water. Stepwise-regression analysis identified grass cover, litter accumulation, and organic carbon as variables having a positive correlation and bulk density as having a negative correlation with infiltration rates after 30 minutes.

Sediment production was significantly lower from P. maximum areas than from D. macroblephara areas in August because less water was available to carry soil particles in P. maximum areas due to high infiltration rates. The variables that influenced infiltration rates positively had a negative effect on sediment production, and vice versa.

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Table 1. Mean time to runoff (minutes) under different plant species by sample date, 1982, Kiboko, Kenya.

Treatment	Date of Evaluation	
	August	December
Panicum maximum	5.33 a[1]	5.27 a
Digitaria macroblephara	5.23 a	3.60 a

[1] Means within each date with the same letter are not significantly different at 0.05 level according to Duncan's multiple-range test.

Table 2. Mean infiltration rates (cm/hr) under different plant species by sample date, 1982, Kiboko, Kenya.

	Date of Evaluation			
	August		December	
Infiltration rates after	Panicum maximum	Digitaria macroblephara	Panicum maximum	Digitaria macroblephara
5 min.	14.28 a[1]	13.71 b	13.25 a	13.03 a
10 min.	14.00 a	11.80 b	11.67 a	10.32 a
15 min.	13.99 a	10.63 b	11.16 a	9.27 a
20 min.	13.89 a	10.70 b	10.88 a	8.83 a
25 min.	13.83 a	10.76 b	10.94 a	8.83 a
30 min.	13.64 a	10.35 b	10.85 a	8.77 a

[1] Means within each variable within each date with the same letter are not significantly different at 0.05 level according to Duncan's multiple-range test.

Table 3. Mean sediment production (kg/ha), bulk density (gm/cc), aggregate stability (no unit), organic carbon (%), and soil water (%) under different plant species by sample date, 1982, Kiboko, Kenya.

	Date of Evaluation			
	August		December	
Variable	Panicum maximum	Digitaria macroblephara	Panicum maximum	Digitaria macroblephara
Sediment production	31.0 b[1]	142.0 a	336.0 a	393.0 a
Bulk density	1.28 b	1.49 a	1.54 b	1.72 a
Aggregate stability	8.7 a	7.3 b	8.5 a	7.9 a
Organic carbon	2.08 a	1.50 b	2.43 a	1.55 b
Soil water	18.1 a	14.96 b	25.2 a	17.8 b

[1] Means within each variable within each date with the same letter are not significantly different at 0.05 level according to Duncan's multiple-range test.

INFILTRATION AND SOIL LOSS AS INFLUENCED BY VEGETATION AND COVER TYPES

David Siekisa Mbakaya

ABSTRACT

A drip-type rainfall simulator was used to evaluate effects of vegetation cover types on infiltration rates and soil loss at Buchuma Range Research Station, Kenya. Two types of vegetation (Chloris roxburghiana and Grewia bicolor) and bare ground (unvegetated) were evaluated.

Infiltration rates were greater in vegetated plots than in unvegetated plots. However, in the vegetated plots there was a significant difference between the two vegetation cover types. Infiltration rates were greater under Grewia bicolor than under Chloris roxburghiana. Soil loss was greater from unvegetated plots than from vegetated plots.

INTRODUCTION

Water, no doubt, is the key factor to full use of land resources, no matter what the land capabilities are for crops, pasture, or forest. These resources cannot be used as they should unless the water-supply problem is solved.

Some of the important consequences of inadequate soil water are seasonal variability of herbage growth, which makes it difficult to maintain live weight gains of grazing animals throughout the year; early maturity of grasses and herbs; and incomplete soil cover, which increases the danger of soil erosion (Unesco, 1979). The energy associated with raindrops striking bare soil causes disintegration of the soil aggregates, which then clog the soil pores and reduce infiltration. Infiltration rates depend on water movement between soil aggregates, root and faunal channels, and cracks in clay soils. Cheruiyot (1984) reported that infiltration rates were strongly negatively correlated with percent bare ground. Branson et al. (1970) established a positive relationship between bare soil and increased erosion. Organic matter in the soil is a major cause of aggregation. It not only binds soil particles into aggregates but also lightens and expands the soil, thus increasing the porosity and decreasing surface-crust formation. Infiltration rates are positively related to soil organic matter except for sites where hydrophobic soils occur.

Selective grazing and browsing change botanical composition, total nutritional yield, and future production of any range. When animals enter an area, they select the most palatable plants, leaving the less palatable plants. As the palatable plants disappear, the less-desirable plants proliferate; hence, species composition changes (Heady, 1981). Vegetation cover also may be damaged by cultivation, drought, rodents, fire, and wood harvesting for charcoal and timber -- conditions that expose the soil to wind and water erosion.

Vegetation cover and the associated litter intercept kinetic energy and thereby decrease the mobilization of soil particles. Excessive removal of vegetation litter for short or long periods may reduce the protective cover and thus

- increase the impact of raindrops and overland flow
- lower soil moisture

- decrease infiltration rates and increasing runoff and(or) erosion

Therefore, removing the protective cover leads to overall lower site potential (Blackburn 1983).

Vegetation cover may consist of one or more layers (for example, forbs, shrubs, bushes, and trees), of which the first three usually play a bigger role in reducing detachment of soil particles by raindrop impact. It is generally agreed that soil erosion is extremely sensitive to the type and density of vegetation cover (Dunne et al., 1981).

Dunne (1977), measuring infiltration rates in Kajiako, Kenya, found that the major controls of soil erosion were volume of runoff, vegetation cover, hillslope gradient, soil structure and texture, soil moisture, and animal trampling. The reduction of ground vegetation cover and disturbance of soil surface promoted by intense grazing, trampling, and cultivation without soil-conservation practices accelerated erosion in the semiarid regions of Kenya. Thomas and Barber (1981) concluded that losses of soil and water vary greatly in different parts of Kenya's semiarid lands but often are greater on grazing land than on cropland. The amount of erosion from bare ground appears to depend on the extent and nature of surface crust (Thomas and Barber, 1978).

Lal (1975) in Nigeria showed that

- Runoff is much less under natural vegetation than under cultivation.

- Crop production can be practiced without serious risk on slopes up to 15%, provided that zero or minimum tillage is used and crop and weed residues are maintained as mulch. Mulch conserves plant nutrients and reduces soil temperature, which in bare soils can be sufficiently high to inhibit germination and restrict early growth of some crops.

STUDY AREA

The study area was located at Buchuma Range Research Station in ecological zone V (Pratt et al., 1966). The station is approximately 98 km northwest of Mombasa in the Coast Province of Kenya. It covers about 800 ha with an average elevation of about 400 m above sea level. Long-term mean rainfall is 560 mm.

The study sites were 2 km south and southeast of the station headquarters. The natural vegetation is a Commiphora-Boswellia-Acacia association. The grass understory is composed of Chloris roxburghiana, Eragrostis caespitosa, Digitaria macroblephara, Enteropogon macrostachyus, Panicum maximum, Bothriochloa insculpta, and Cymbopogon excavatus. Shrubs consist mainly of Grewia spp. and Combretum spp. (Cassady, 1973).

MATERIALS AND METHODS

Seven 112-ha and two 2-ha blocks were used to determine the influence of vegetation cover (Chloris roxburghiana grass and Grewia bicolor shrub) and bare ground on infiltration rates and soil loss. Two 25-m x 25-m plots with nearly homogeneous vegetation and soil were identified in

each block, and sampling dates were assigned randomly. Data were collected in August (dry) and December (wet) 1983 to evaluate seasonal effects on vegetation and the resulting effects on infiltration and soil loss. At each sampling date, four 37-cm x 37-cm sample plots were randomly located in each vegetation-cover type and bare ground.

Simulated rainfall was applied with a drip-type rainfall simulator (Blackburn et al., 1974) at a rate of 11.8 cm/hr for 30 minutes on 37-cm x 37-cm plots that had been prewetted and drained to field capacity. Many variables were observed, including organic-matter content, bulk density, surface roughness, grass cover, litter cover and accumulation, and time to runoff. "Time to runoff" is the time that elapsed in minutes between the beginning of the rainfall simulation and collection of the first drop of runoff. Infiltration was determined by calculating the difference in simulated rainfall applied and runoff from each plot. Runoff from each plot was determined by volume measurements taken at 5-minute intervals for 30 minutes and converted to infiltration rates. Runoff from each plot was collected and, upon termination of a simulated rainfall event, was thoroughly agitated and a 0.46 liter subsample taken. The sediment of each subsample was collected, oven dried at 105°C for 36 hrs, weighed, and converted to sediment production in kg/ha, and was used as an index of sheet erosion.

ANALYSIS

All statistical analyses were performed using Statistical Analysis System programs (Heilwig and Council, 1979) on Texas A&M University's Amdahl 5850/470V8 computer. Data normality was evaluated through tests for skewness and kurtosis (Snedecor and Cochran, 1980). No variables were found to be highly skewed, making it unnecessary to perform common logarithmic transformation before conducting analysis of variance and regression analyses.

Differences between vegetation cover were determined by analysis of variance and means separated by Duncan's multiple-range test (Steel and Torrie, 1980). A 0.05 level of significance was used in both procedures. Multiple-regression and correlation analysis and forward-stepwise multiple-regression analysis were used to determine the degree of linear association of factors important to infiltration rates and soil loss and to identify the most important factors determining infiltration rates and soil loss (Draper and Smith, 1981).

RESULTS AND DISCUSSION

Vegetation Influences

The grass and forb standing crop in August was about two times larger than in December. This was probably due to the amount of rainfall from late May through August (120.8 mm) as opposed to the amount from September through December (77.7 mm). Litter accumulation was greater during August than during December; however, litter accumulation declined from August to December. The reduction could have been due to the insect, grazing, and climatic factors; however, there was no litter accumulation difference in either sample date on *Chloris roxburghiana* plots and under *Grewia bicolor*. Herbaceous foliar cover was greater on *Chloris roxburghiana* plots than for *Grewia bicolor* or bare ground for both sample date; however, percentages of grass, forbs, and litter cover generally decreased from August to December.

Soil Influences

Soil-moisture content was greater in Grewia bicolor plots than in Chloris roxburghiana or bare plots for both sample dates. There were significant differences in organic-matter content of Grewia bicolor, Chloris roxburghiana, and bare ground for both sample dates. Grewia bicolor had the greatest organic matter, followed by Chloris roxburghiana and bare ground. Aggregate stability is closely tied to the amount of organic matter in soil. The greater the organic matter in the soil, the greater the aggregation of the soil; thus, it is more porous and has lower bulk density.

Watershed Responses

During August and December, infiltration rates after 5, 10, 15, 20, 25, and 30 minutes were consistently greater in vegetated plots than in unvegetated plots (table 1). However, in the vegetated plots there was significant difference between the two vegetation types. Grewia bicolor plots had greater infiltration rates than Chloris roxburghiana plots. Greater infiltration in Grewia bicolor plots was associated to relatively greater litter accumulation, thus high organic matter and lower bulk density.

There was no significant difference in infiltration rates between August and December due to the small amount of poorly distributed rainfall during the wet season. The amount received in the wet season was the same as that received in the dry season; the only difference between seasons was distribution.

Variables showing fairly strong positive correlations with infiltration were vegetation related: litter cover, grass cover, grass and forb standing crop, and litter accumulation. These variables increased infiltration by providing cover that acted as a barrier for surface concentration and flow, dissipated raindrop energy, and added organic matter to the soil by means of mulch or root biomass. Exposure of surface soil to raindrop impact results in a breakdown of soil aggregates, particle detachment, and particle transport by raindrop splash and runoff.

Soil Loss

Sediment loss in August and December was consistently greater from bare-ground plots than from vegetated plots, which had cover that reduced the impact of raindrops. The type of vegetation cover had an influence on soil loss. Chloris roxburghiana plots had greater soil loss than Grewia bicolor plots (table 2). Grewia bicolor plots had higher organic matter and water-stable aggregates and lower bulk density than Chloris roxburghiana. Soil loss was negatively correlated with vegetation-related variables. These variables protected the soil surface from raindrop impact.

Time to Runoff

The time to runoff was significantly different among vegetation cover types. Grewia bicolor had the greatest time to runoff, followed by Chloris roxburghiana and bare ground (table 3). The greatest time to runoff was attributed to the amount of litter accumulation, litter cover, aggregate stability, organic matter, and bulk density. These variables promoted infiltration, thus there was less water to run off.

CONCLUSIONS

Infiltration rates were consistently greater and soil loss lower in Grewia bicolor plots than in Chloris roxburghiana and bare-ground plots. Associated with Grewia bicolor were greater litter cover, soil organic matter, aggregate stability, and lower bulk density than Chloris roxburghiana and bare ground. The vegetation-related variables that were positively correlated with infiltration rates protected the soil surface from raindrop impact.

Litter accumulation, aggregate stability, and grass cover were found to be important variables explaining infiltration rates. Soil-loss and infiltration-rate equations identified litter accumulation, aggregate stability, grass cover, and organic matter as being the most influential variables in predicting soil loss and infiltration rate. The only difference in the two sets of equations was that the variables were negatively correlated to soil loss whereas they were positively correlated to infiltration rates. Litter accumulation and cover were not important as variables that influenced time to runoff.

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Table 1. Mean infiltration rates (cm/hr) under different vegetation types and bare ground by sample dates, 1983, Buchuma, Kenya.

	Date of Evaluation					
	August			December		
Infiltration Rates	BAGR[1]	CHRO	GRBI	BAGR	CHRO	GRBI
After						
5 min	6.00b[2]	10.76a	11.25a	8.55c	10.93b	11.36a
10 min	3.86c	9.76b	10.80a	6.06c	10.38b	11.00a
15 min	2.89c	9.12b	10.50a	4.59c	9.95b	10.64a
20 min	2.32c	8.66b	10.23a	3.80c	9.01b	10.22a
25 min	1.89c	8.34b	10.01a	3.20c	9.26b	9.92a
30 min	1.58c	8.15b	9.81a	2.75c	9.03b	9.62a

[1] BAGR = Bare ground, CHRO = *Chloris roxburghiana*, GRBI = *Grewia bicolor*.

[2] Means with the same letter within each time interval within each sample date are not significantly different (α =.05) according to Duncan's multiple-range test.

Table 2. Mean sediment production (kg/ha) under different vegetation types and bare ground by sample dates, 1983, Buchuma, Kenya.

Vegetation	Date of Evaluation August	December
Bare ground	1703a	1146a
Chloris roxburghiana	342b	524b
Grewia bicolor	160c	278c

Sediment production means for each sample date with the same letter are not significantly different (α =.05) according to Duncan's multiple-range test.

Table 3. Mean time to runoff (minutes) under different vegetation types and bare ground by sample dates, 1983, Buchuma, Kenya.

Vegetation	Date of Evaluation August	December
Bare ground	1.71c	2.49c
Chloris roxburghiana	3.17b	3.92b
Grewia bicolor	5.00a	5.40a

Time to runoff means with the same letter within each date are not significantly different (α =.05) according to Duncan's multiple-range test.

THE ROLE OF RODENTS IN THE RANGELAND ECOSYSTEMS OF KENYA

G.H.G. Martin

INTRODUCTION

Few detailed ecological studies have been made of rodents in eastern African rangelands. In Tanzania, there has been very little work. Sinclair (1985) examined resource limitations in the Serengeti, and rodents formed part of this study. Senzota (1978) also in the Serengeti, has worked largely on Arvicanthis niloticus Desmarest. More recently, studies have been carried out on rodents as pests at Mgorogoro, but I have seen no publication relating to this work. The Queen Elizabeth National Park in Uganda has been the center of major studies on rodents by Delany and his coworkers (Delany, 1964a and 1964b; Delany and Neal, 1969; Cheeseman and Delany, 1979; Neal, 1968). In Kenya, the principal studies of rodents in grasslands include work by Delany and Roberts (1978), Field (1975), and Taylor and Green (1978), all of whom worked in the Rift Valley. Outside the Rift Valley, studies by Neal (1984) in Meru National Park and Martin (1986), Martin and Dickinson (1985), and Oguge (1985) on the Kenyatta University Nature Reserve complete the list of works in Kenyan grasslands.

This paper largely synthesizes the work carried out at Kenyatta University since 1980.

STUDY AREA

Work was carried out in the grassland area of Kenyatta University Nature Reserve about 25 km north of the center of Nairobi. Rainfall varies between 600 mm and 1,100 mm a year and falls mainly in two rainy seasons (figure 1).

Although the abundance of the various species of grasses have varied during the past six years Panicum maximum Jacq, Themeda triandra Forsk., Brachiaria brizantha (Rich.) stapt, and species of Hyparrhenia, Setaria, and Eragrostis have remained common. Rhynchelytrum repens (willd.) Hubbard has declined from being the most widespread grass (found at 60% of sample points in 1981) to a minor species (found at 11% of points in 1985). The cause of this decline is not known but may be associated with the drought years of 1983 and 1984 coupled with a burn in 1983.

Trees are represented by mature Erythrina abyssinica D.C. and small Acacia seyel Del.

Soils are a complex of ironstone and lithosols (Sombroek et al., 1982).

The only common larger mammals are reedbuck (Redunca redunca Pallas), bush duiker (Sylvicapra grimmia L.), aardvark (Orycteropus afer Pallas), and porcupine (Hystrix cristata L.). Fourteen species of rodents and four species of insectivore have been recorded from the area. The most common rodent species was Praomys natalensis Smith.

METHODS

Live traps were set in grid formation and were inspected twice a day, usually for 8 consecutive days a month. Specimens were individually

marked by toe-clipping, and a record was kept of species, sex, weight, reproductive condition, and location of capture.

Density and biomass estimates were made following the method described by Fleming (1971). Production estimates were calculated using the method employed by Cheeseman and Delany (1979).

RESULTS

Survival

Individuals of most species are likely to be at least one month old before becoming trappable, and no attempt was made to relate age to duration of residence on the grid. Therefore the data in figure 2 give only a measure of minimum survival time. Nevertheless, the results suggest that very few animals live to be one year old, and most live several months less than that.

Breeding

The most detailed information on breeding is for Praomys natalensis. It is clear that breeding starts at the end of the long rains and at the beginning of the short rains, with the main birth period occurring during the cool dry season, the short rains, and the short dry seasons (figure 3). Limited data for some other species suggest a similar pattern.

Densities, Biomass and Production

Examination of the mean monthly catch rate for the different species indicates populations generally reach their peaks during the rains (figure 4). On average, dry-season densities and biomass were half those of the rainy seasons (figure 5), although there was a tenfold difference between the highest and lowest estimates for dry and rainy seasons.

The average figure for net annual production derived from three 12-month periods was 6,387 g/ha^{-1} (table 1).

DISCUSSION

The results suggest groups of animals whose entire populations probably turn over every 6 to 9 months and whose breeding is closely associated with the rains. Individuals of many species are probably born during the early dry season, reproduce during the next rains, and die soon after. It is possible that some individuals of certain species such as Praomys natalensis can reproduce more than once during the course of any extended rainy season. Generally, the results are in agreement with other African rodent studies, especially those of the Ugandan work already cited.

The estimate for net annual production of 6,387 $g/ha^{-1}/yr^{-1}$ converts, using standard energetic values, to 3.5 k j m^{-2} yr^{-1}. Estimates from rodent studies elsewhere suggest that production is 1% to 3% of consumption and, therefore, consumption approximates to 6 g to 18 g (dry wt)/ m^{-2}/yr^{-1} based on grass having a value of about 19 kj/g.

In his study in the Serengeti, Sinclair (1975) derived equations describing the relationship between rainfall and primary production. Using

the equation for long grassland with rainfall figures for Kenyatta University, an estimate of 385 g(dry wt)/m^{-2}/yr^{-1} for primary production was made. Thus, consumption is 1.6% to 4.8% of primary production using Sinclair's equations.

Unfortunately, the estimates of primary production published in Sinclair (1975) appear to contain mathematical errors but, when recalculated, indicate a take-off of 25% of primary production by ungulates compared with 1.5% by rodents. Phillipson (1973), also in the Serengeti, had suggested a tentative figure 4.4% take-off by rodents. The proportion of primary production consumed by rodents in the present study is, therefore, similar to figures calculated for rodents in long grassland in the Serengeti. However, such figures from the studies elsewhere are known to vary widely (Ferns, 1980).

Work by Deshmukh and Baig (1983) suggests that estimates of primary production made using the conventional harvest method seriously underestimate primary production. Their estimates of primary production in Nairobi National Park were about double the conventional harvest method. If this factor proves to be general, then previous estimates of take-off percentages need to be halved; for example, 12.5% and 0.75% for ungulates and rodents respectively in the Serengeti, and 0.8% to 2.4% for rodents in the Kenyatta University Nature Reserve.

Both the calculations of Sinclair (1975) and those made during the present study of consumption assume that rodents are entirely herbivorous. This is not so. Several works, including recent studies on diets by Oguge (1985), have shown that most species are omnivorous to varying extents and that seeds form an important part of their diets. The percentage of primary production consumed by rodents will be lower than indicated earlier, probably by a factor that is between 10% and 20% for many grassland systems in Kenya.

In conclusion, it appears that the role of rodents as herbivores in most Kenyan rangelands is minor except during "outbreak" years. However, the significance of rodents as predators of seeds may be important in some circumstances and warrants further investigation.

SUMMARY

Rodents have been studied on the Kenyatta University Nature Reserve for 6 years.

Nearly 70% of individuals are caught only in one trapping period, and populations turn over every 6 to 9 months. Births occur mainly during the dry seasons, and peaks in population and standing-crop biomass occur during the rains. Net production averaged 6,387 g/ha^{-1}/yr^{-1}.

Speculative estimates suggest that consumption is not more than 2.5% of primary production and probably about 1%.

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Table 1. Average net annual production ($g/ha^{-1}/yr^{-1}$) of rodents in a Kenyan grassland.

Tatera robusta	596
Dendromus melanotis	57
Otomys irroratus	378
Praomys natalensis	3,197
Mus minutoides	220
Mus triton	276
Dasymys incomtus	786
Lemniscomys striatus	608
Arvicanthis niloticus	269
Total	6,387

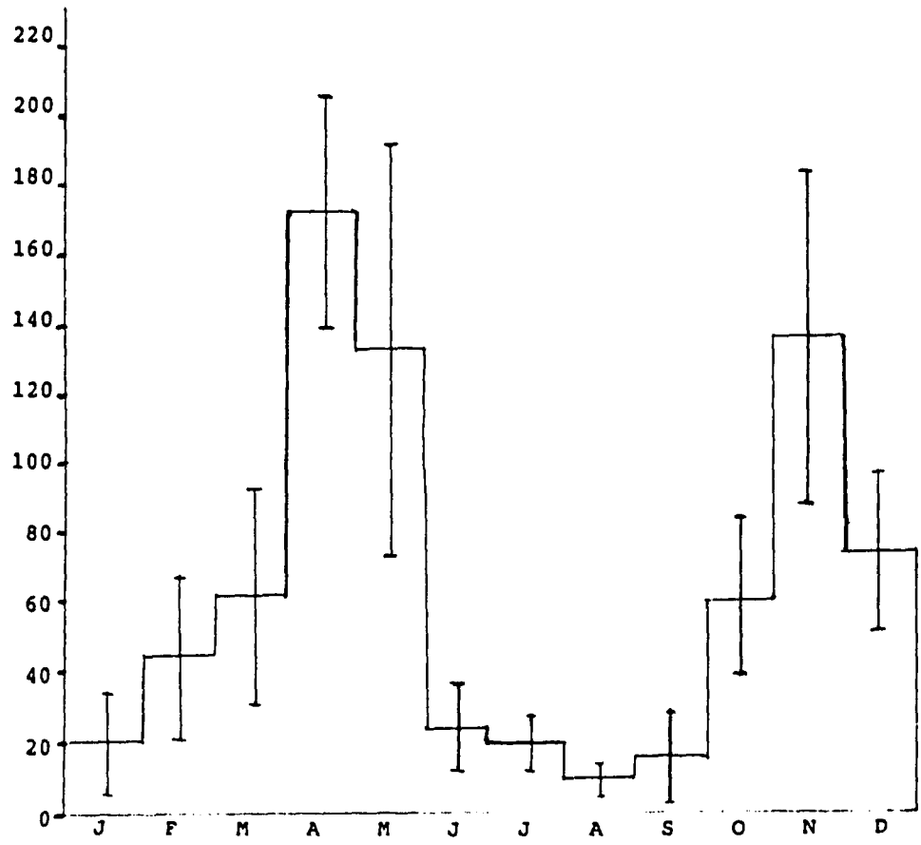

Figure 1. The mean monthly rainfall at Kenyatta University from October 1975 to April 1985.

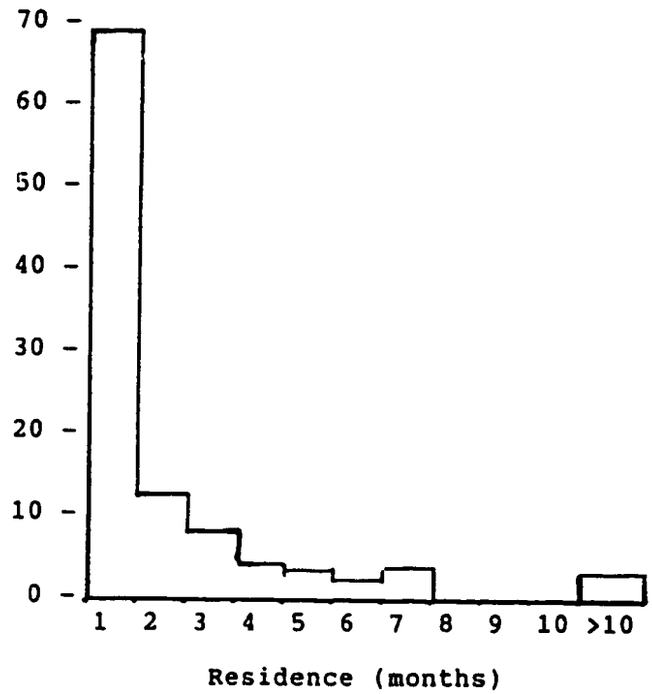

Figure 2. Duration of residence on trapping grids (% of total catch).

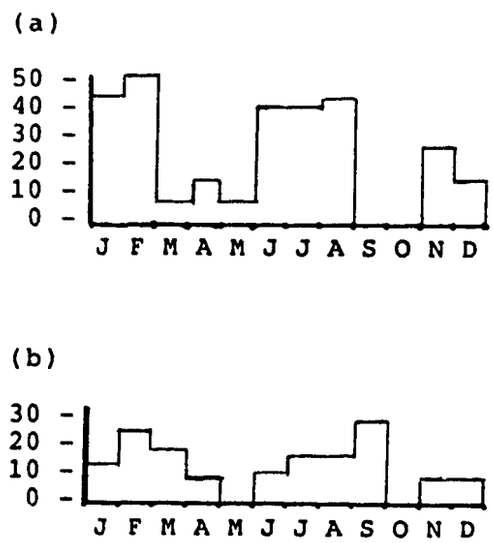

Figure 3. (a) Percentage of mature female Praomys pregnant or lactating. (b) Percentage newly weaned Praomys in the population.

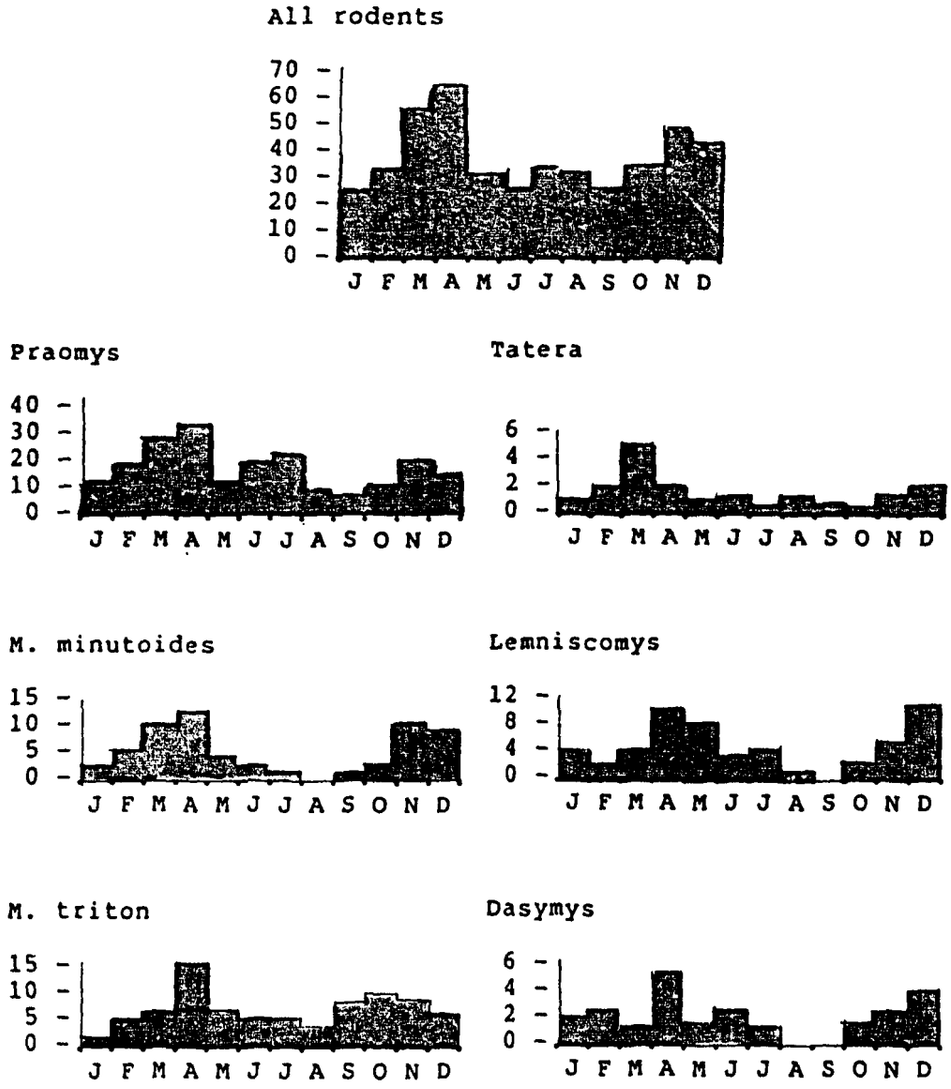

Figure 4. Number of individuals caught per 1,000 trap days.

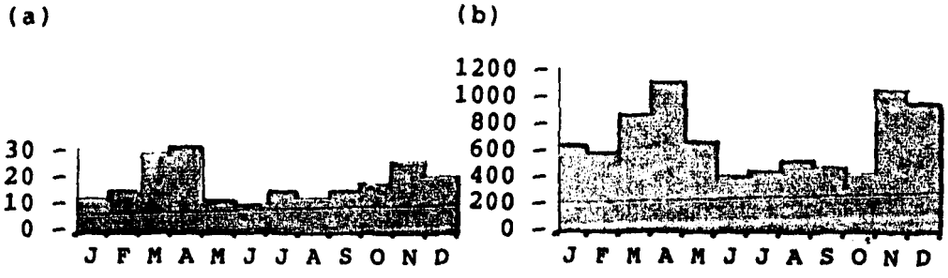

Figure 5. (a) Density (No./ha^{-1}). (b) Biomass (g/ha^{-1}).

DIETS OF RODENTS IN A DRY, SUBHUMID KENYAN GRASSLAND

N. Otienoh-Oguge and Graham H.G. Martin

INTRODUCTION

Rodents in grasslands, together with other grazers and fires, are essential factors for removing, through mineralization, large quantities of seasonally shed above-ground primary production. Without this mineralization factor, the regrowth of the new season's vegetation would be greatly impaired because of the accumulation of plant detritus (Fleming, 1974). In addition to serving as important links in the flow of energy and in mineral cycling, tropical mammals play important roles as seed predators and pollination and seed-dispersal agents.

Information about food habits of small African mammals is generally sparse (Neal, 1984). Food-habit studies are used for the evaluation of ecological relationships and for management decisions (Hansen, personal communication). Such information also is essential to any nutrition or competition study. Stomach analysis was used by Rudge (1965) and Pernetta (1976) in an investigation of the diet of shrews in relation to prey availability and by Taylor and Green (1976) and Neal (1984) to investigate food habits of small mammals in relation to reproduction and climate. The disadvantage of this method was the necessity of killing the small mammals to obtain samples. By histological analysis of fecal material, it is possible to obtain multiple samples from the same individual. Fecal analysis has proven useful in estimating monthly, seasonal, or annual diets and the foods being eaten by a species on an area basis, regardless of season (Hansen, personal communication). Antony and Smith (1974) reported 15 deer-pellet groups gave about the same amount of dietary data as did 50 rumen samples.

In the present study, determination of the diet based on fecal analysis and determination of food availability by independent estimates were carried out over a period of 8 months.

METHODS

A grid of 16 x 16 traps was constructed with 15 m intervals between trapping points and one trap at each point. Each of the trapping stations was marked by a peg, and a total of 256 traps were used each month.

Traps were set at 1600 hours on the first day of a trapping session and were checked between 0600 and 0800 hours and again at 1600. They were sprung but not removed from stations on the morning of the last day. Captured rodents were marked by toe clipping and released at the point of capture after the following information had been recorded: time and date of capture, grid point, species, identification number, sex, reproductive state (for example, testis scrotal or abdominal, or vagina open, closed, or gravid), body weight, and general condition (for example, if moribund). Fecal pellets then were collected from the traps, and the traps were thoroughly cleaned after each collection. Estimates of the monthly abundance of the small-mammal species were obtained by the number of animals captured per hectare.

Fecal samples collected were preserved in 10% neutral buffered formalin to stop microbial action before analysis. Seeds, other plant materials,

and arthropods were identified from each sample, and their frequency of occurrence was determined using the point method (Chamrad and Box, 1964), which involves dissolving the fecal material in water in a petri dish. A cross mark is then made at the bottom of the petri dish using a wax pencil. The dissolved material is thoroughly mixed and left to settle. The food particle nearest to or at the center of the cross mark is identified under the microscope at 20x magnification and recorded. Fifty points were examined for each fecal sample.

Surveys of vegetation were carried out on the study site in January and April 1985. At each of the 256 trapping stations, plant species occurring within a 5-m radius were identified and counted. The relative cover for each species and total percent cover also were noted. At the start of each trapping session, each of the common grass species were examined for phenological changes. The analysis was carried out along two permanent transects 50 m apart and running parallel to each other from the grassland to the riverine zone. At 5-m intervals, grass species occurring within a 5-m radius of the transect were identified and the stages of development of their inflorescence determined and recorded. The changes in phenology of the 10 grass species over the 8-month study period were then summarized in a histogram (figure 3).

Each month, macroarthropods were collected in sweep nets and pitfall traps. Sweep netting was carried out for one hour along a permanent transect that ran from the grassland to the riverine zone along the midpoint of the trapping grid. This was done on the third, fourth, and fifth days of the trapping session. Macroarthropods were placed in a killing jar and were later counted in the laboratory. The relative abundance of ground-dwelling macroarthropods was estimated with 150-mm x 150-mm plastic-can pitfall traps. Twenty traps were buried flush with the soil surface at 10-mm intervals along the permanent transect. The traps were opened every month for three consecutive nights; that is, on the third, fourth, and fifth days of each trapping session. The macroarthropods were collected and counted on each sampling date.

RESULTS

In the trapping program, 212 individual small mammals representing six species were marked and released (table 1). Erinacaus albiventris (the four-toed hedgehog) were common; however, they were not marked because this species was not of interest in the study. All of the rodents collected belonged to the families Cricetidae and Muridae -- two of the four families that compose the superfamily of the myomorph rodents. The Muridae are the dominant small, ground-dwelling rodents in the tropical zones of Africa (Cheeseman, 1975). Tatera robusta (black tuft-tailed gerbil) was the only member of the Cricetidae caught in the area. Lemniscomys striatus (punctated grass mouse), Mus minutoides (pigmy mouse), Mus triton (the larger pigmy mouse), and Praomys natalensis (multimammate rat) all belong to the Muridae. One Crocidura bicolor was the only shrew trapped. The nomenclature of the rodents follows that of Delany (1975). These species cover a considerable size range. The smallest C. bicolor weighed only 2 g, whereas the largest species, T. robusta, weighed an average of 83.5 g (table 1).

DIETARY STUDIES

During the 8-month study period, a total of 3,530 fecal pellets for P. natalensis, T. robusta, M. minutoides, M. triton, and L. striatus were collected and analyzed. An average of 10 fecal pellets constituted a

sample, and the range was between 8 and 12 fecal pellets. Only one capture of C. bicolor was made, and no fecal material was found in the trap. The proportions of different food materials in the diets of rodents were determined (table 2). Seeds formed the major foods of the five rodent species; however, arthropods also formed a regular part of the diet. Seeds averaged 84.7% of the diet of P. natalensis, 66.5% for T. robusta, 78.4% for M. minutoides, and 52.3% for M. triton. Only one fecal sample of L. striatus was available for analysis, and seeds formed 80% of the sample. Arthropods averaged 8.4%, 28.6%, 16.2%, 33.3%, and 16% respectively of the diets of P. natalensis, T. robusta, M. minutoides, M. triton, and L. striatus. All of the rodent species consumed other plant materials in small amounts throughout the study period. Proportions of different food items in the rodent diets varied considerable over the 8-month period; for example, seeds in the diet of T. robusta ranged between 35% and 88.8%, arthropods in the diet of P. natalensis ranged from 2.6% to 13.9%, and other plant materials in the diet of M. triton ranged from 0% to 40%. Information on the diets of M. minutoides and M. triton was based on small sample sizes and should be viewed with caution, and that of L. striatus was considered too limited to warrant inclusion in detailed statistical analysis.

The difference in overall mean seed consumption by P. natalensis and M. minutoides were not found to be significant (table 3) but were significantly different from those of T. robusta and M. triton. The differences in the proportion of arthropod consumption by T. robusta and M. triton were similarly found not to be significant but were significantly different from those of P. natalensis and M. minutoides. However, the differences in the mean consumption of plant materials other than seeds by the four rodent species (P. natalensis, T. robusta, M. minutoides, and M. triton) were not significant.

Comparison of table 2 and figure 3 suggests that the use of seed resources by P. natalensis, T. robusta, M. minutoides, and M. triton followed the phenological changes of the major grass species in the habitat. On the other hand, the consumption of arthropods by the rodent species (table 2) did not appear to follow the variation of arthropod estimates in the habitat (table 5), and there was no significant relationship between proportions of arthropods in the diets of the rodents and estimates of arthropod abundance in the habitat.

A correlation analysis showed a few positive relationships between numbers of captures of the two most common rodent species, P. natalensis and T. robusta, and cover values of grass species. Panicum maximum occurred in 56% of the 256 trapping stations and formed cover values of between 10% and 100% (table 6). Panicum maximum cover values had a highly significant positive association with P. natalensis captures. Themeda triandra was found in only 40% of the stations and never exceeded a cover value of 30%. However, T. triandra cover values had a highly significant positive association with T. robusta captures. Despite the significant positive correlations shown between the cover values of P. maximum and T. triandra and numbers of captures of P. natalensis and T. robusta, respectively, there was no significant correlation between the two rodent species and overall vegetation-cover value.

DISCUSSION

There is a positive, causal relationship between productivity and diversity (Hutchinson, 1959; Connell and Orias, 1964; MacArthur, 1972; Brown,

1973; Brown et al., 1979); however, climatic changes have major, long-lasting effects on the composition and diversity of biotas (Brown, 1981). In an earlier study in the same study area, Martin and Dickinson (1985) identified 18 species of small mammals in a 1-ha grid. The present study was carried out after prolonged drought followed by an accidental burn in the study area, and only seven species of small mammals were identified in a 5.0625-ha grid. This would suggest that there was a reduction in availability of food resources in the area. However, the duration of the present study was shorter (8 months) than that of the earlier study (27 months).

Resource-use differences exist between coexisting species (Brown and Lieberman, 1973; Price, 1973). Differences in diets could be a means of rodents' coexistence. In the study plot, although all the rodent species were omnivorous, there were differences between them in the use of seeds, other plant materials, and arthropods. Praomys natalensis and M. minutoides were mainly granivorous, with seeds forming over 75% of the diets and arthropods less than 20%. Tatera robusta and M. triton, on the other hand, were truly omnivorous, with seeds forming less than 70% and arthropods over 25% of their diets. Real interspecific differences in food-resource use by the rodents in the study area may be greater than the study suggests because the dietary data is based on a broad spectrum of food categories; for example, seeds, other plant materials, and arthropods would appear to be superficial categories and may not allow fine enough distinctions of rodents' food preferences. A similar situation is reported by Perrin (1980) in a study of ecological strategies of two coexisting rodents, Otomys irroratus and Rhabdomys pumilio, in the Fish River Valley bushveld in South Africa. He found that the food habits of the two rodent species were superficially similar but differed markedly in detail.

The omnivorous habits of M. minutoides, M. triton, P. natalensis, and T. robusta in this study are consistent with results reported by Cheeseman (1975), Cheeseman and Delany (1979), and Delany and Happold (1979); however, the granivorous habits of P. natalensis and M. minutoides in subhumid grasslands has not been reported previously.

Small mammals in a Chilean semiarid thorn-scrub community were reported to be opportunistic feeders during wet seasons (Meserve, 1981). In the study plot, there was no significant relationship between the temporal variation in relative arthropod abundance in the habitat and the proportions of arthropods in the diets of the rodents. It would appear, therefore, that the rodent species consumed arthropods irrespective of the abundance in the habitat, suggesting opportunistic tendencies.

It would be interesting to determine the precise nature of relationship between P. natalensis and cover values of P. maximum, and that of T. robusta and cover values of T. triandra -- more so because there was no relationship between P. natalensis and T. robusta and the general percentage of plant cover. Finer levels of food analysis are being carried out and may reveal significant differences in the rodents' food preferences.

SUMMARY

Food habits of four species of small mammals, live-trapped on a 5.0625-ha grid, were studied over an 8-month period.

All species were found to be omnivorous. However, two species, P. natalensis and M. minutoides, were found to be mainly granivorous. Seeds and arthropods formed the major foods of the rodents. Other plant materials, however, were consumed by all rodent species in small quantities.

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Table 1. Number of captures, including recaptures, on trapping grid from September 1984 to April 1985, and mean body weights (g) of six species of small mammals. Number of individuals shown in parentheses. SD = standard deviation.

Species	Number of captures Male	Female	T	Mean wt (g)	SD
P. natalensis	162 (98)	107 (59)	269 (157)	44.6	17.2
T. robusta	60 (27)	15 (7)	75 (34)	83.5	26.4
M. minutoides	6 (6)	6 (6)	12 (12)	6.3	0.80
M. triton	6 (3)	6 (3)	12 (6)	13.4	2.9
L. striatus	1	0	1	35.0	-
C. bicolor	1	0	1	2.0	-
E. albiventris	-	-	52	-	-

Table 2. Mean percentage of seeds (S), arthropods (A), and other plant materials (OPM) in the diet of *P. natalensis*, *T. robusta*, *M. triton*, and *L. striatus* captured in a dry, subhumid grassland in Kenya from September 1984 to April 1985 as estimated from fecal samples. Values shown are averages from 50 sample points per fecal sample and 95% confidence limits (in parentheses). N = number of fecal samples. Overall mean consumption is based on the total number of fecal samples analyzed.

Month	Food item	*Praomys natalensis*	*Tatera robusta*	*Mus minutoides*	*Mus triton*	*Lemniscomys striatus*
Sept. 1984	S	-	35.6%(±18.6)	-	20	-
	A	-	42.8%(±18)	-	40	-
	OPM	-	21.6%(±23.8)	-	40	-
	N	0	5	0	1	0
Oct. 1984	S	78.5%(±14.4)	60.8%(±15.9)	74%	57%(±28.1)	80%
	A	13.9%(±14.2)	34.6%(±18)	24%	40%(±31.4)	16%
	OPM	7.6%(±5)	46% (±5.2)	2%	3%(±1.2)	4%
	N	24	16	1	2	1
Nov. 1984	S	77.2%(±21.2)	66% (±9.7)	58%	-	-
	A	12.6%(±14.8)	33.4%(±9.2)	20%	-	-
	OPM	10.2%(±18.8)	0.6%(±0.9)	22%	-	-
	N	25	3	1	0	0
Dec. 1985	S	85.4%(±8.84)	-	100%	-	-
	A	6.9%(±6.5)	-	0	-	-
	OPM	7.7%(±6.4)	-	0	-	-
	N	14	0	1	0	0
Jan. 1985	S	79.7%(±16.4)	-	67%(±18.7)	-	-
	A	10.6%(±17.6)	-	31%(±18.6)	-	-
	OPM	9.7%(±7.1)	-	2%(±2)	-	-
	N	7	0	2	0	0
Feb. 1985	S	87.1%(±12.1)	76%	-	80%	-
	A	8.4%(±11.6)	24%	-	20%	-
	OPM	4.5%(±3.5)	0%	-	0	-
	N	56	1	0	1	0
Mar. 1985	S	90.6%(±8.5)	88.8%(±13.5)	83%(±6.9)	-	-
	A	4.1%(±6.3)	9% (±13.3)	12%(9.8)	-	-
	OPM	5.4%(±4.7)	2.2%(±2.9)	5%(±2.9)	-	-
	N	77	17	2	0	0
Apr. 1985	S	94.6%(±8.3)	71.6%(±18)	88.5%(±11.5)	-	-
	A	2.6%(±6.5)	27.6%(±17.5)	10% (±9.8)	-	-
	OPM	2.8%(±4.1)	0.8%(±1.5)	1.5%(±2.6)	-	-
	N	60	27	4	0	0
Overall mean consumption	S	84.7%(±11.9)	66.5%(±32)	78.4%(±27.2)	52.3%(±48.4)	80%
	A	8.4%(±7.7)	28.6%(±20.7)	16.2%(±19.8)	33.3%(±18.5)	16%
	OPM	6.9%(±5)	5.0%(±14.9)	5.4%(±14.8)	14.3%(±35.7)	4%
	N	263	69	11	4	1

Table 3. Multiple comparisons among mean percentages of seeds, arthropods, and other plant materials in the diets of *P. natalensis*, *T. robusta*, *M. minutoides*, and *M. triton* captured between September 1984 and April 1985 in a dry, subhumid grassland in Kenya. Values shown are overall mean consumption from all the fecal samples analyzed. The nonsignificant sets of means are indicated by double-headed arrows. The test is based on unequal sample sizes (a posteriori tests): the student-Newman-Keuls test (Sokal and Rohlf, 1969).

Food item	Seeds	Arthropods	Other plant materials
P. natalensis	84.7	8.4	6.9
T. robusta	66.5	28.6	5.0
M. minutoides	78.4	16.2	5.4
M. triton	52.3	33.3	14.3

Table 4. Correlation matrix of small-mammal captures with the cover values of different grass species, using data from all trapping points. Values shown are correlation coefficients. n = 256, ns = no significant correlation. Only species that showed at least one significant correlation and overall vegetation cover are presented.

	Praomys natalensis	*Tatera robusta*
Panicum maximum	.2853**	.0153 ns
Themeda triandra	.1398*	.178**
Brachiaria brizantha	.1295*	.1337*
Hyparrhenia spp.	.0013 ns	.1252*
Overall vegetation cover	.1124 ns	.0553 ns

Table 5. Numbers and proportions of captures of macroarthropods from September 1984 to April 1985 based upon combined data from pitfall traps and sweep netting.

Month	Captures Number	Proportion
1984		
September	54	.068
October	101	.128
November	94	.119
December	96	.122
1985		
January	97	.123
February	139	.176
March	107	.135
April	102	.129

Table 6. Distribution of the major grass species in the trapping grid. Values shown are proportions of stations at which species were recorded out of the 256 trapping stations.

Grass species	Proportional occurrence
P. maximum	0.56
Hyparrhenia spp.	0.53
Setaria spp.	0.51
B. brizantha	0.43
T. triandra	0.40
E. superba	0.24
H. contortus	0.22
D. abyssinica	0.12
R. repens	0.11
C. ciliaris	0.07

Table 7. Percentage cover of five most-common grass species in the study areas at 256 trapping stations. Values shown are frequencies at 10% interval scale.

Frequency	*P. maximum*	*Hyparrhenia* spp.	*B. brizantra*	*Setaria* spp.	*T. triandra*
<11%	167	155	205	209	233
11-20%	28	28	30	22	12
21-30%	17	32	8	17	11
31-40%	12	19	8	3	0
41-50%	8	10	3	3	0
51-60%	8	5	1	2	0
61-70%	4	7	1	0	0
71-80%	3	0	0	0	0
81-90%	6	0	0	0	0
91-100%	3	0	0	0	0

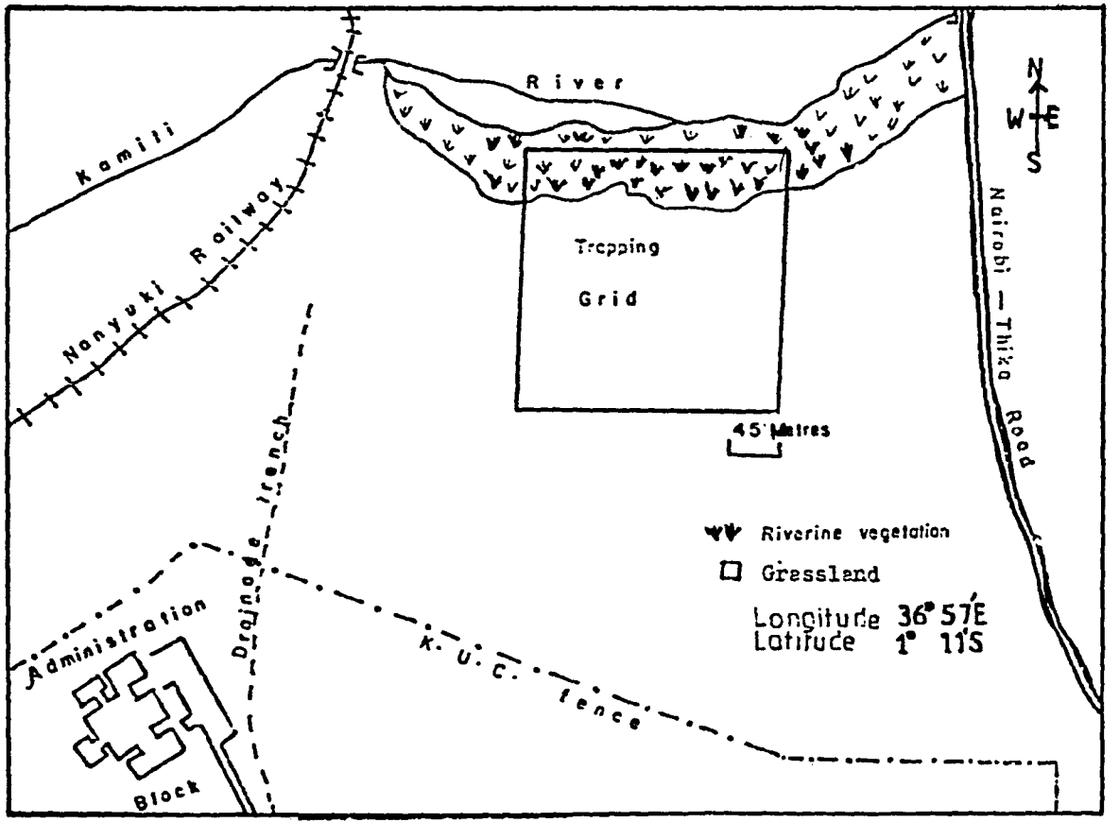

Figure 1. The position of the trapping grid within the Kenyatta University's Nature Reserve.

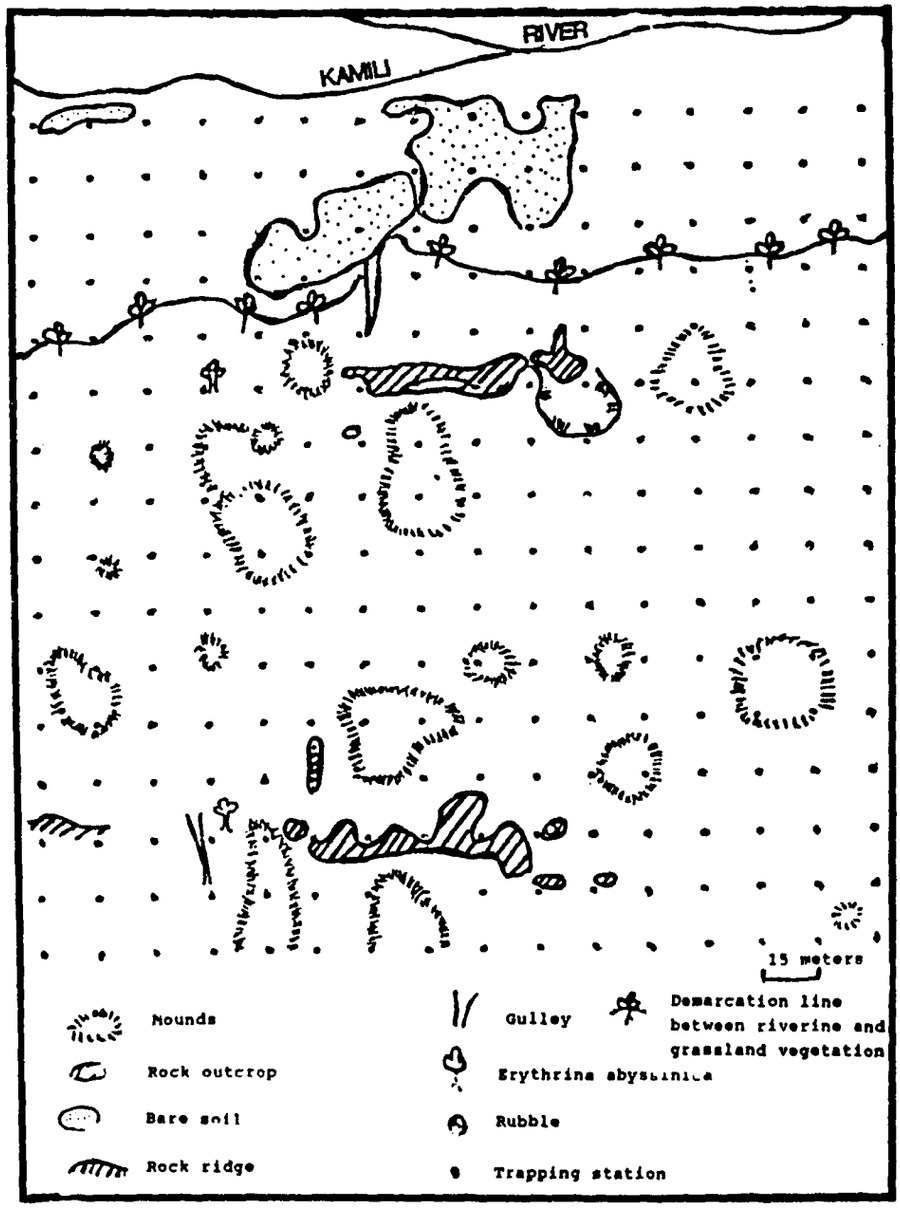

Figure 2. The positions of the trapping points and the dominant physical features of the study plot.

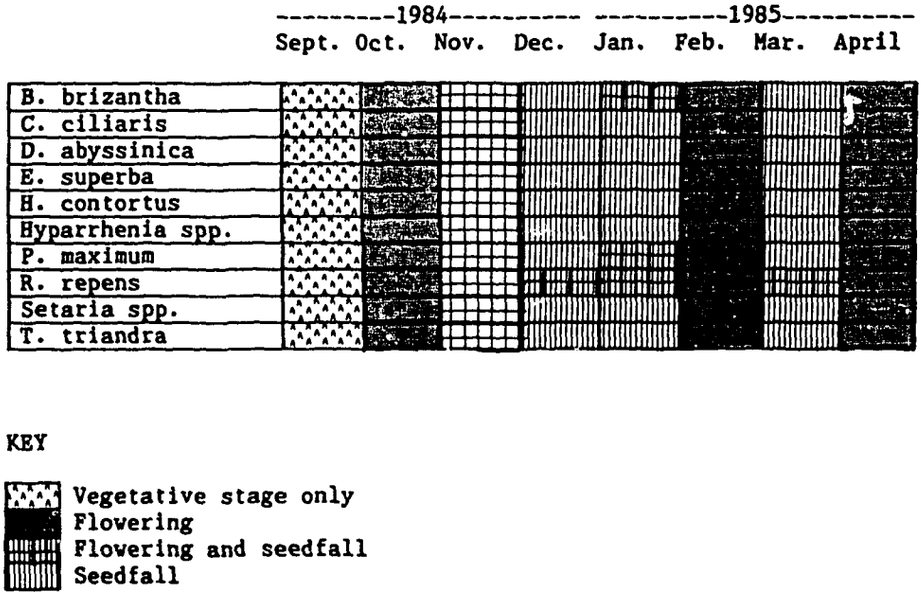

Figure 3. Summary of the phenological changes of the 10 most-common grass species in the trapping grid.

FORAGING PREFERENCES OF THE AFRICAN ARMYWORM (SPODOPTERA EXEMPTA WALK.)

J.I. Kinyamario and F.M. Muthuri

ABSTRACT

The African armyworm (Spodoptera exempta Walk.) is a general feeder but shows strong preferences for certain grass species. No defoliation was noted on dicot species; however, the degree of defoliation could not be correlated with the percentage frequency of plants on the study site. The worms feed almost entirely on leaves of plants and, therefore, are very destructive to preferred plant species. This presents a problem to range management due to reduction in leaf areas of the preferred grasses.

INTRODUCTION

The African armyworm is a larva of a moth called Spodoptera exempta Walk. It ranks next to the locust as the most troublesome insect pest on pasture and cereal crops (Odiyo, 1980). It is known to forage on wild grasses, sedges, and cereal crops.

Armyworms eat the leaves from the margin inwards and from upper to lower parts at all levels of the plant canopy (Odiyo, 1980). Degrees of preference of armyworms are known. Brown (1970) showed that Cynodon dactylon (L.) Pers. was the most preferred of the wild grasses. He noted that there was some age preference -- younger stages of growth are eaten more readily than the older, tougher plants.

Grazing animals, both domesticated and wild, are well-known selective feeders (Bredon and Marshall, 1962). By feeding selectively, animals compete for certain plant species. Therefore, this study addresses the foraging preferences of the armyworm with the goal of understanding how they may compete for food with grazing animals on our rangelands where armyworm outbreaks often occur when conditions are favorable (Brown, 1969).

METHODS

The experimental plot was located in the Nairobi National Park about 30 km southeast of Nairobi. The plant cover was dominated by grass species and some dicots and sedges. Grass species included Themeda triandra Forsk, Pennisetum mezianum Leeke, Pennisetum stramineum Peter, Cenchrus ciliaris L., Digitaria macroblephara (Hack.) Stapf, Eustachys paspaloides (Hack.) Lanza & Mattei, Cymbopogon caesius (Hochst.) Stapf ex Burtt Davy, and Sporobolus pellucidus Hoschst. The characteristic soil type is a black cotton vertisol, and the climate is hot and semiarid.

Armyworms were noticed on the experimental plot on December 18, 1984, following a widespread outbreak in Kenya. Sampling was carried out on December 23, 1984, after the worms had moved out of the plot. Twenty plants per species or plant category were randomly selected and clipped. All species that occurred on the plot were sampled. Sedge and dicot species were pooled as "all sedges" and "all dicots" plant categories, respectively.

All leaves on each plant were separated from the stems. Any defoliation on each leaf was noted, and the defoliation index for each plant stem was ranked on a scale of 0 to 100. Five stems for each plant were randomly sampled. The basis of ranking was as follows:

0	no leaf defoliation was noted
1 to 30	less than 30% of leaves defoliated
30 to 60	30% to less than 60% of leaves defoliated
60 to 90	60% to less than 90% of leaves defoliated, leaving the midribs
90 to 100	90% to 100% of leaves defoliated, with few or no midribs

Before sampling for defoliation index, plant-species frequency was estimated by the point-intercept method (Mueller-Dombois and Ellenberg, 1974). Ten 100-meter-long transects were located across the plot; at every one-meter interval a hit was taken, and the plant hit or nearest to the hit was noted. From these hits, a frequency table was constructed from which plant frequency was calculated. Correlation coefficient was calculated between the plant frequency on the study area and the mean defoliation index to determine the degree to which armyworm diet is influenced by plant frequency.

RESULTS

Table 1 shows that T. triandra, P. mezianum, and dicots were the most-abundant plant species or categories while S. pellucidus, E. paspaloides, and C. caesius were the least-abundant plant species.

S. pellucidus and P. stramenium were the most-preferred species on the plot (table 2). Although S. pellucidus was the least-abundant species, it was the most preferred. After the worms had moved from the plot, many stems of S. pellucidus and P. stramineum were left devoid of leaves.

C. caesius and P. mezianum were the next-most-preferred species. It is apparent that, although T. triandra was the most-abundant species, it was not highly preferred. Only an apparent 44% of its leaves were defoliated, compared to about 80%, 90%, and 97% of P. mezianum, P. stramineum, and S. pellucidus respectively. No evidence of defoliation was noted on any dicot species. Sedges were the least preferred of all plants.

When a correlation coefficient between the degree of defoliation and the frequency of plants on the study area was developed, no correlation could be established.

DISCUSSION

Plant frequency has been shown to determine type of diet for insects. Ueckert et al. (1972) found that, except for one grasshopper species, the frequency of plant species in the diet correlated with the frequency of plant species in the habitat. In this study, however, there was no correlation between armyworm plant-species-defoliation index and plant frequency on the study site.

The results show that grass species were most preferred by the armyworm while dicots were not. Similar observations have been reported by Brown (1970) and Odiyo (1980). Although armyworms appear to be general feeders, they showed strong feeding preferences to certain grass species. In this connection, damage was done entirely to the leaves.

Leaves of different plants differ relatively little in nutritional substances needed by insects. Substances of no nutritional value, such as glucosides, alkaloids, or tannins, act as olfactory chemical repellants that are effective at extraordinarily low concentrations (Dethier, 1954). Dicots are known to contain these chemical substances (Swain, 1966), which probably explains why dicots were not foraged by the armyworms.

The observation that these worms forage almost entirely on the leaves presents a vital problem for range management. Defoliation of leaves will greatly reduce the grazing capacity of a rangeland for the grazing animals. Through this defoliation, leaf surfaces important in the manufacture of chlorophyll are reduced. This will greatly reduce photosynthetic activity and biomass production of the defoliated plants (Jones et al., 1955). Consequently, this will lead to starvation of the range animals, especially if damage to the species of high-forage value to the grazing animals is severe.

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Table 1. Plant frequency at the study site.

Species/plant category	% frequency
T. triandra	38.2
P. mezianum	23.3
All dicots	10.1
P. stramineum	8.5
D. macroblephara	6.1
All sedges	5.0
C. caesius	3.0
E. paspaloides	2.4
C. ciliaris	2.1
S. pellucidus	1.3

Table 2. Degree of defoliation by African armyworms (n = 20; $\bar{x} \pm$ S.E.).

Species/plant category	% defoliation
T. triandra	44 (± 4.0)
P. mezianum	80 (± 4.6)
All dicots	0 (± 0.0)
P. stramineum	91 (± 4.4)
D. macroblephara	17 (± 5.8)
All sedges	8 (± 4.0)
C. caesius	82 (± 4.0)
E. paspaloides	18 (± 4.0)
C. ciliaris	63 (± 5.3)
S. pellucidus	97 (± 2.4)

AN ECOLOGICAL PERSPECTIVE OF THE PHYTOSOCIOLOGY OF WOODY-ACACIA/HERBACEOUS-UNDERSTORY COMPLEX

E.K. Maranga

ABSTRACT

The water relations of C_4 grasses occupying the understory strata of open acacia-wooded savannas in Kiboko, Kenya, were studied under field and growth-chamber conditions.

Precipitation and soil-water potentials were lower under the canopy of Acacia tortilis than in the open. Quantum flux varied from 537 $\mu Em^{-2}s^{-1}$ in the canopy to 1,069 $\mu Em^{-2}s^{-1}$ in the open. Transpiration and leaf-air temperature differentials for Panicum maximum under the canopy of Acacia tortilis were significantly lower ($\alpha = 0.05$) than for Digitaria macroblephara in the open.

Under moisture-stress treatment in the growth chamber, Panicum maximum experienced lower leaf-water potentials and reached wilting stage faster than Digitaria macroblephara. The ecological significance of these results in tree-grass interactions is briefly discussed.

INTRODUCTION

Acacia-wooded savannas comprise over half of the semiarid and arid ecosystems in Kenya. Savanna ecosystems provide an important forage resource for both livestock and wildlife. These savannas contain C_4 grasses that predominantly occupy the understory strata of Acacia spp. and other associated shrublands, mainly in ecological zones IV, V, and VI (Pratt et al., 1966).

The phytosociology of dryland plant communities remains poorly understood as well as the interplay of biotic and abiotic factors that may explain these phytosociological relationships. Sala et al. (1981) observed that associated or complementary relationships of herbaceous- and woody-plant communities in marginal-rainfall areas revolve centrally around the soil-water medium. Studies on the water-use economy of dryland communities in Kenya are scarce. Some of the very few studies of this kind have demonstrated, using simple field techniques, that much useful information on the water-use efficiency of semiarid plants can be obtained (Okali, 1971; Kerslake et al., 1978; Fenner, 1981). Survival of plant communities in water-stressed environments necessarily depends on the efficient use of available water (Cary, 1971; Daubenmire, 1972). The frequency and duration of water availability determines to a large extent the kinds and levels of forge production. An understanding of the internal regulations of the water-use economy of arid plants is central to the successful management of plants in the semiarid grazing lands.

This paper describes the water relations of Panicum maximum and Digitaria macroblephara occupying the understory strata of Acacia tortilis. Panicum maximum is a dominant species under the canopy of Acacia tortilis, whereas Digitaria macroblephara occupies the open areas. The study was conducted at the National Range Research Station, Kiboko, about 160 km southeast of Nairobi.

MATERIALS AND METHODS

Field studies were carried out on two experimental plots approximately 2 km apart on the National Range Research Station, Kiboko. A total of eight Acacia tortilis trees were selected -- four each in experimental plots 1 and 2 (figure 1). The trees that were selected varied in size but had well-developed canopies with dense understory matrixes of Panicum maximum and Digitaria macroblephara. Trees with adjoining canopies were not selected. A minimum distance of 30 m between canopies was kept for all trees. Two perpendicular transects to the tree trunks were established for each tree along the direction of maximum herbaceous-understory cover. Each transect was 26 m long and 4 m wide and extended well outside the canopy region of the trees.

Growth-chamber studies were carried out at Texas A&M University, U.S.A. Root crowns of Digitaria macroblephara and Panicum maximum were brought to the university from the National Range Research Station in September 1983. Study plants were grown from these crowns in a chamber that was programmed to simulate growth conditions typical of their tropical habitats. The conditions that were regulated included photoperiod (day length), temperature, wind speed, and vapor pressure. Fifty plants of each species were grown in 25 plastic pots containing sandy, loam soils at field capacity with free drainage of excess water. The soils were regularly watered with distilled water, and a complete nutrient solution was added to correct soil-mineral deficiencies. Physiological responses to environment were monitored under water-nonstress and water-stress conditions.

Transpiration, diffusive resistance, air temperature, and leaf temperature were measured by means of a portable Li-Cor LI 1600 steady-state porometer at equidistant points along the transects between 1000 hours and 1400 hours throughout the wet and dry phases of the growing season. Rainfall was measured by means of standard rainfall gauges. Leaf-water potentials were measured with a pressure chamber (Scholander et al., 1964). Soil-water potentials were monitored by means of thermocouple psychrometers and a Hewlett Packard Model 419 dew-point microvoltmeter.

RESULTS AND DISCUSSION

Rainfall Interception

Experimental plots 1 and 2 exhibited similar patterns of temporal distribution of rainfall. Greater rainfall amounts were received in areas occupied by Digitaria macroblephara than in the Panicum maximum community (figure 2). These differences in rainfall amounts under the canopy of Acacia tortilis and in the open may be attributed to canopy interception, which for locations 1 and 2 (figure 2) varied between 12% and 19% respectively. Differences in canopy-interception amounts may be due to differences in Acacia tortilis canopy continuity in the two sites.

Light Interception

Considerable variations in quantum flux (PAR) were recorded for areas under the canopy and in the open. Mean photosynthetically active radiation (PAR) for areas under the canopy was 537 $\mu Em^{-2}s^{-1}$. PAR in the open was 1,069 $\mu Em^{-2}s^{-1}$. Differences in PAR distribution in the open and under the canopy areas may be attributed to canopy interception. The differences in PAR were statistically significant ($\alpha = 0.05$).

Soil- and Leaf-water Potential

Leaf-water potential (Ψ_l) distributions for Panicum maximum and Digitaria macroblephara (figure 3) show that the first drying cycle progressed rapidly after cessation of soil-moisture recharge by mid-June. Soil-water potential declined from -1.0 MPa to -9.0 MPa at 10 cm.

Soil-moisture profiles in December, January, and February (figure 3) indicated that the difference in soil-moisture potential (Ψ_s) between Panicum maximum and Digitaria macroblephara microenvironments decreased in magnitude. These differences were statistically significant (α = 0.05) across experimental plots, months, trees, and transects.

The distribution of Ψ_l reflected a lower degree of variation in relation to Ψ_s (figure 3). It is believed that the effect of dew and short-lived, erratic showers may underly the small variation in Ψ_l.

Relatively low leaf-water potentials (-4.0 MPa in August 1981 and -7.0 MPa in the latter part of February 1982) correspond to periods of relatively high soil-water deficits (Ψ_s exceeded -9.0 MPa). The mean Ψ_l for Panicum maximum and Digitaria macroblephara were -2.9 MPa and 2.8 MPa respectively. These Ψ_l means were significantly different in the two experimental plots (α = 0.05); but the biological significance of the difference is debatable.

The drier soil environment under Panicum maximum may be linked to lower precipitation input due to canopy interception. Evidence obtained from growth-chamber studies on rooting patterns and water use of Panicum maximum (Maranga, 1984) suggested greater soil-moisture extraction rates by Panicum maximum due to greater root density than Digitaria macroblephara. This phenomon also is illustrated well in figure 4, which shows that with cessation of irrigation on January 5, 1984, Panicum maximum leaves exhibited Ψ_l difference of 0.7 MPa lower than Digitaria macroblephara after 9 days. After 22 days without irrigation, Panicum maximum was severely wilted (Ψ_l=-4.4 MPa), whereas Digitaria macroblephara showed a leaf-water potential of -1.2 MPa and appeared to be well hydrated with no signs of wilting.

Transpiration, Diffusive Resistance, and Leaf-to-air Temperature Differentials

Transpiration and leaf-to-air temperature differences were greater for Digitaria macroblephara than for Panicum maximum (figure 5). The highest transpiration rates were recorded for Digitaria macroblephara (25.0 $\mu gcm^{-2}S^{-1}$). Panicum maximum had a maximum value of 20.0 $\mu gcm^{-2}S^{-1}$. These differences were statistically significant (α = 0.05). Differences in transpiration between the two species may reflect the direct effect of quantum flux. Differences in quantum flux have been shown to bring about differences in transpiration and leaf-water potential (Papendick and Campbell, 1974; Davies and Kozlowski, 1974; Kaufmann, 1976).

In the absence of the influence of Acacia tortilis in the growth chamber, diffusive resistance (during the drying cycle) for Panicum maximum increased somewhat steeply. Digitaria macroblephara showed little change during the same period. Transpiration measurements suggested no great differences between the two species (figure 5).

At low leaf temperatures, differences in diffusive resistance between the two species remained small and increased with increasing temperatures. The slope of the leaf-temperature diffusive-resistance curve was steeper for Panicum maximum than for Digitaria macroblephara. This response pattern seems to suggest differences in bulk leaf-water status for the two species arising from either higher total transpiration rates or changes in abscisic acid induced by water stress (Maranga, 1984).

SUMMARY AND CONCLUSIONS

Panicum maximum seems to favor lower light intensities and lower evaporation rates, which tend to reduce heat loading and water losses through evapotranspiration. Transpiration, photosynthetically active radiation, and precipitation input are lower under the canopy than in the open. Diffusive resistance is higher and leaf temperatures are lower for Panicum maximum than for Digitaria macroblephara. Greater shoot biomass for Panicum maximum under the shade appears to be an adaptive response that maximizes the relatively lower light energy available for carbon assimilation, whereas greater root biomass favors rapid moisture translocation because of possible competition with Acacia tortilis. Digitaria macroblephara seems to cope with higher light intensities through increased transpirational cooling as reflected by higher transpirational values than Panicum maximum.

The results of this study provide useful information about the water-use ecophysiology of Panicum maximum and Digitaria macroblephara in their natural environments. This study also demonstrates the need to preserve the integrity of the ecological balance between woody-plant associations and perennial grasses. Management systems or perturbations such as felling of woody species for fuel are bound to cause shifts in ecological responses that may be reflected in net primary productivity.

ACKNOWLEDGEMENT

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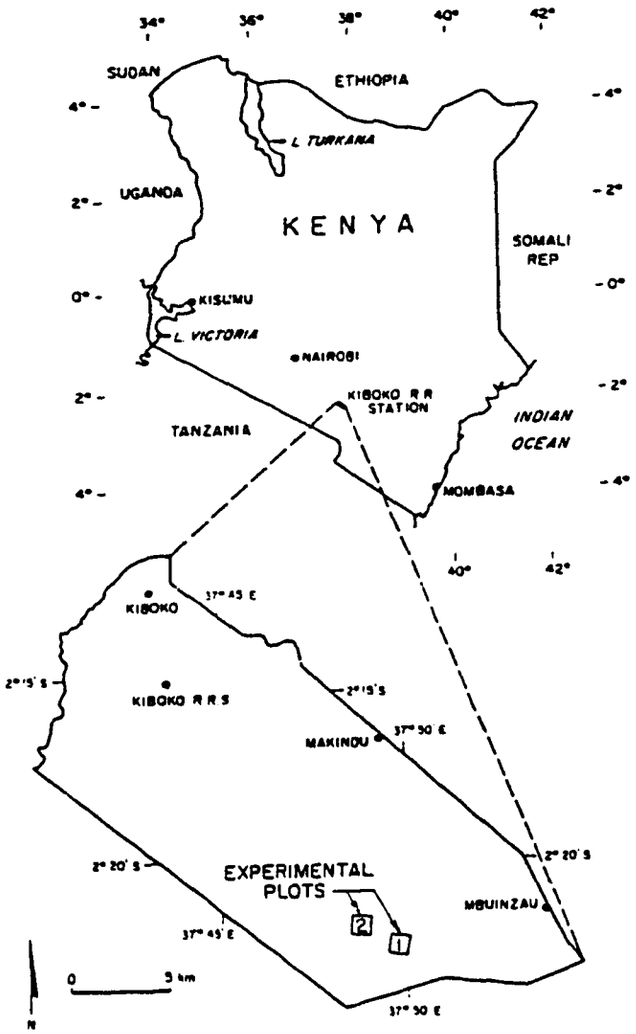

Figure 1. Location of the National Range Research Station, Kiboko, Kenya.

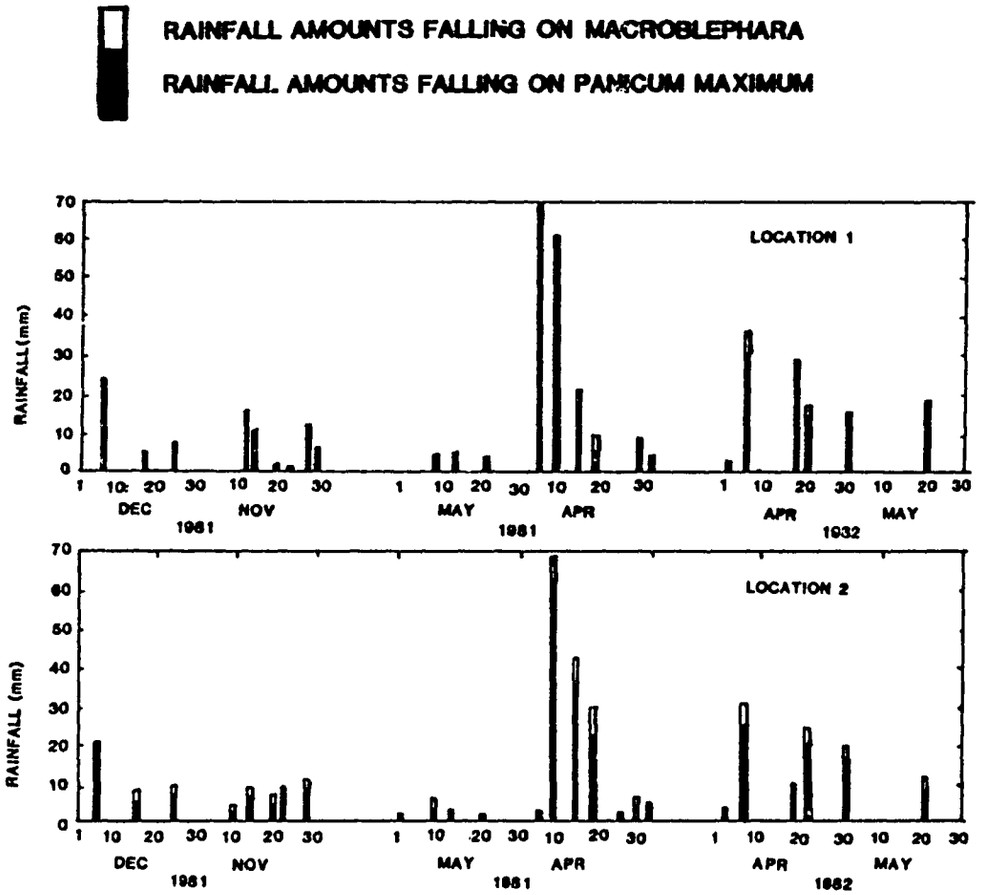

Figure 2. Seasonal distribution of rainfall during the 1981-1982 growing cycle for Panicum maximum and Digitaria macroblephara.

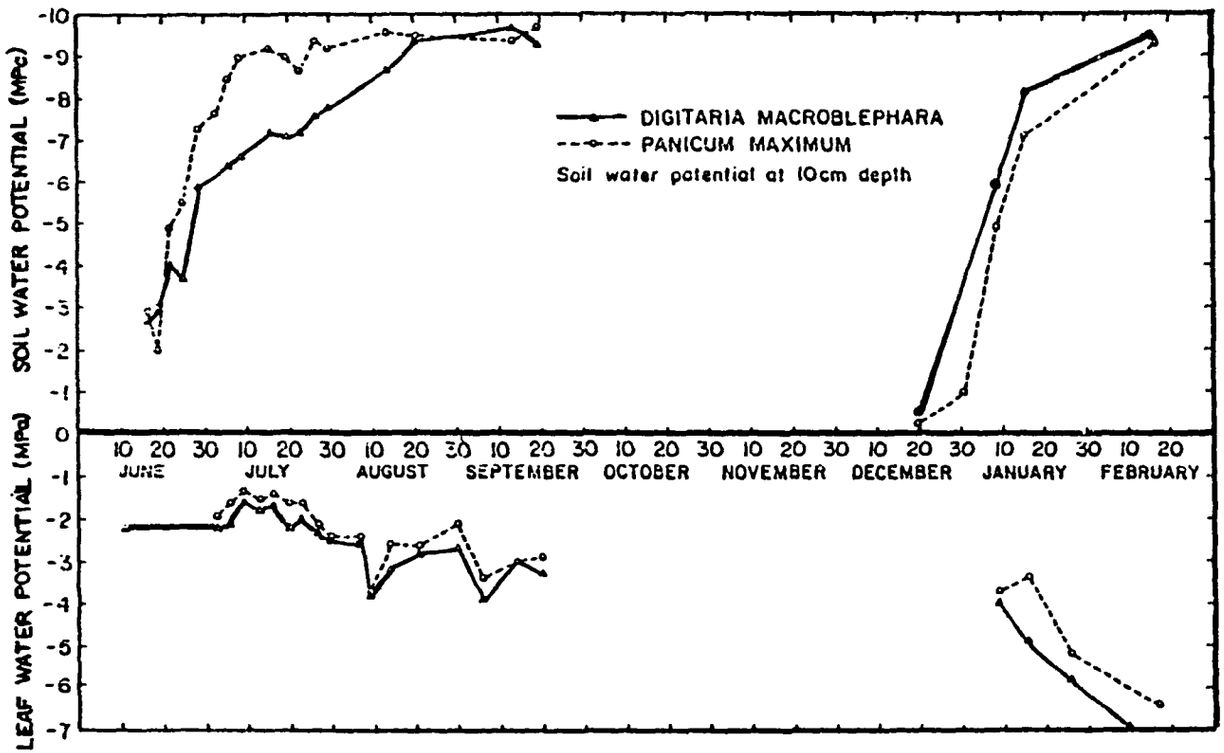

Figure 3. Temporal trends of leaf-water potential and soil-water potential for Panicum maximum and Digitaria macroblephera at Location 1, 10-cm depth.

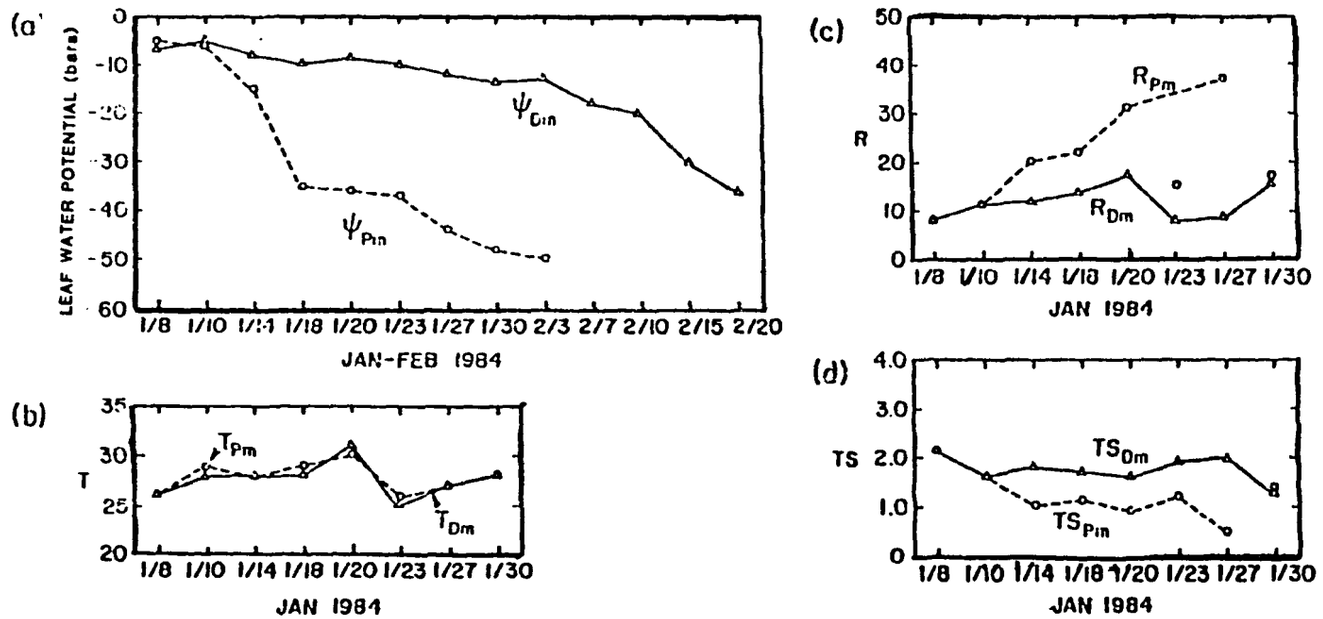

Figure 4. Relationship between time and leaf-water potential (Ψ), leaf temperature (T) in ^{o}C, diffusive resistance (R) in s cm^{-1}, and transpiration (TS) in $\mu g\ cm^{-2}s^{-1}$ for Panicum maximum (Pm) and Digitaria macroblephara (Dm).

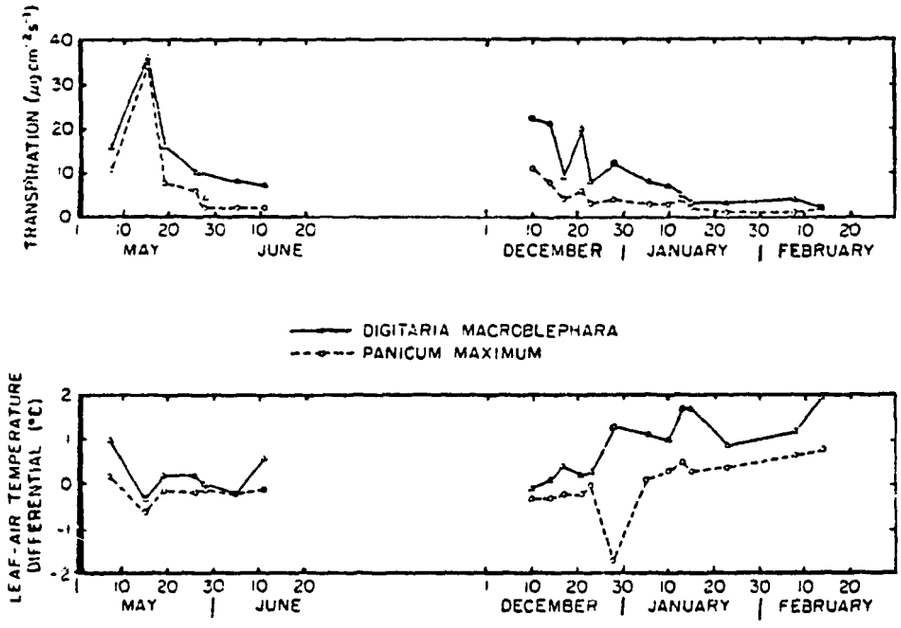

Figure 5. Seasonal trends of transpiration and leaf-to-air temperature differential for Panicum maximum and Digitaria macroblephara during the 1981-1982 growing season.

EFFECTS OF DEFOLIATION FREQUENCY AND INTENSITY ON PRODUCTION OF GRASSLAND COMMUNITIES

Daniel K. Too, F.E. Smeins, and R.D. Child

ABSTRACT

Herbage production of four grass communities was evaluated. Sites were located in ecological zone V, which showed contrast in topography, soils, and dominant grasses. Defoliation took place two to seven times a year at 5.0 cm and 12.5 cm. No significant community differences were observed, and fire had no effect on overall yields. Frequently defoliated plants gave more biomass than less-frequently defoliated plants, while intensity of clipping showed no significant effect on production. Caution should be used in evaluation of these data since results may be substantially different after several years of treatment. Frequent intensive defoliation ultimately may result in reduced vigor and correspondingly lowered production.

INTRODUCTION

Kenya's rangelands (over 80% of the country's land area) support 50% of nearly 10 million cattle, 70% of estimated 8.5 million sheep and goats, all camels and nearly all wildlife (Heady, 1960; Ayuko, 1978). The productive capacity of these rangelands has been declining, particularly in those areas occupied by pastoralists. The decline has been attributed to various factors such as

- overgrazing
- invasion of brush species
- encroachment of better grazing areas by cultivators and, hence, increased erosional hazards
- frequent droughts

According to the National Development Plan (1984 to 1988) of the government of Kenya, the country's objective is to produce enough red meat for the local population and a surplus for export. This goal can be met by increasing the productivity of ranges by devising grazing systems that permit maximum returns from the forage resources and perpetuate the forage's potential while remaining compatible with other resource values. Many studies have shown that the amount of damage caused by grazing depends upon intensity, frequency, and time of use.

A study was conducted to evaluate responses of plants to different frequencies and intensities of defoliation together with fire as a tool for improvement of range-forage quality and quantity.

STUDY AREA

The study was conducted at the National Range Research Station, Kiboko. The station is approximately 170 km southeast of Nairobi on the Nairobi-Mombasa Highway within latitudes 2°10′ and 2°25′ S and longitudes 37°40′ and 37°55′ E. It covers an area of 27,000 ha with an elevation that ranges between 915 m and 1,055 m above sea level (Michieka and Van der Pouw, 1977).

The primary range area consists of basement-system plains with flat and gently undulating topography. Soils are very deep, friable or firm sandy clay to clay texture with color varying from brown to dark red. The volcanic area comprises the volcanic cone, footslopes, and lava flows. Soils are shallow, black to very dark greyish brown, and stony to very rocky. Soils of the floodplains and bottomlands are well drained, moderately deep, very grey to black, and range from noncalcarious and nonsaline to extremely saline (Michieka and Van der Pouw, 1977).

Pratt et al. (1966) classified the area into ecological zones IV and V. It receives annual rainfall of 573 mm that occurs during two periods: the long rains from March through May and the short rains during November and December. Although the rainfall is bimodal in distribution, variability in annual or seasonal totals occur. In general, rainfall is erratic and unreliable. Temperatures do not vary much throughout the year. Monthly averages range between 26.5°C and 31.5°C. Evaporation usually is high (Michieka and Van der Pouw, 1977; Pratt and Gwynne, 1977; Bernstein and Jacobs, 1983).

Natural vegetation falls in the Acacia-Commiphora grassland type (Michieka and Van der Pouw, 1977). Dominant tree and shrub species include Acacia drepanolobium, A. mellifera, A. senegal, A. tortilis, Boscia spp., Commiphora africana, C. riparia, Grewia bicolor, G. similis, G. villosa, Hermania alhiensis, and Solanum incanum. Understory species include Chrysopogon aucheri, Cenchrus ciliaris, Chloris roxburghiana, Digitaria macroblephara, Enteropogon macrostachyus, Egragrostis caespitosa, Pennisetum mezianum, Sehima nervosum, Sporobolus pellucidus, and Themeda triandra (Kemei, 1982; Ndiang'ui, 1983).

MATERIALS AND METHODS

In late 1981, eight specific sites were selected for study. Within each site, a 30-m x 30-m fenced enclosure was erected to exclude livestock and wildlife. Two replications of four plant communities, dominated by combinations of five grasses, were included within these enclosures. The four communities are

- Chloris roxburghiana/Sporobolus pellucides
- Digitaria macroblephara/Themeda triandra
- Digitaria macroblephara
- Pennisetum mezianum

One-half of each enclosure was burned on March 8, 1982, near the end of the short dry season. Within each enclosure, 160 permanently marked 0.6-m^2 circular plots were established. Seven defoliation frequencies with five replications each were carried out. Defoliation was done at two intensities: 5 cm, which represented heavy defoliation; and 12.5 cm, which represented moderate defoliation. Defoliation frequencies and timing are shown in table 1.

The defoliation schedule was arranged so that treatments that took place following the rains started three weeks after the onset of rains. The cutting interval was maintained at 3 weeks, except during the dry season when clipping was carried out in mid-February and mid-September or early March.

Clipped material was weighed in the field. Randomly picked samples were oven dried at 65°C for 48 hours for moisture content determination. The

results were used to convert field weight to dry weight for the rest of the samples.

A soil profile in each enclosure was studied for identification of horizon depths, color changes, rockiness, and other soil characteristics. Samples were collected at two depths (0 cm to 15 cm, and 30 cm to 45 cm) and analyzed for texture using the hydrometer method (Bouyoucos, 1962). Organic matter in surface samples was determined using the Walkley-Black method (Walkley and Black, 1934). Bulk density was determined using the core method (Black et al., 1965).

ANALYSIS

Data were analyzed using a split-split plot design to test for treatment differences. Treatment means were separated using Duncan's new multiple-range test (Steele and Torrie, 1980). The .05 level of significance was used to test for significant experimental effect.

RESULTS

Yields for the four plant communities were not significantly different and varied between 376 kg/ha and 480 kg/ha across all dates and treatments, in spite of differences in soils and drainage regimes. Fire had no significant effect on overall yields (figure 1).

The following trend, for moderate intensity and treatments 1-7, was observed: 366, 328; 250, 300; 288, 304; 184, 216; 300, 316; 250, 232; 280, 320 g/1.0m^2 for the burn and control respectively.

Significant treatment differences were observed across all clipping dates (figure 1). The most frequently clipped plots gave the highest phytomass, while those that were clipped only during the long rains gave the least. This was contrary to earlier reports from temperate regions (Ehrenreich, 1959; Pond, 1961; Everson, 1966; Owensby et. al., 1974; Trlica, 1977), which indicated that frequent clipping decreased herbage yield by way of reduced photosynthetic surface and, hence, food depletion.

The heavy defoliation intensity (5 cm) gave consistently higher production than the moderate intensity (12.5 cm), though the differences were not significant. This may be attributed to more tiller production by low-spreading stoloniferous species. Also, more stem material is included in the heavy intensity. However, this result requires more study to confirm the widely reported earlier results that severe defoliation intensity decreases yield through reduction in leaf surface and root system and, hence, diminished food storage.

Seasonal yields indicated a significant burning effect early in the first year for both intensities (figure 2). Season 1 data was excluded. Season 2 clipping, however, excludes treatment 6 data in the analysis because it carried a lot of dead material since this was its first clipping (figure 4). Yields for treatments 1, 2, and 4, moderate intensity, were as follows: 50, 90; 44, 88; 28, 50 g/1.0m^2 for burn and control respectively. The low yield for the burned plots was attributed to the difference in levels from which growth started; that is, growth initiated from the soil surface in the burned plots, whereas regrowth started from either 5 cm or 12.5 cm in the unburned plots. These differences disappeared later in the year and also in the second year

(figures 2 and 3). Treatments 3, 5, and 6 had more yields during season 4 of the second year for moderate intensity, although these were not significant.

A significant treatment effect was noted during season 1 of 1983 (figure 3). Treatment 2 production was more than double that of treatments 1 and 5 for both the burn and control and both defoliation intensities. During season 2 of 1982, a trend was observed in which treatment 4 gave the lowest yield followed by 2, and treatment 1 yielded the highest phytomass for both burn and control. Season 4 of the same year indicated the lowest yield was obtained for treatment 6 for both intensities of defoliation and for both burn and control. An intensity effect was noted during season 2 of the first year in which the heavy intensity gave higher yields than moderate intensity for both burn and control. The rest of the seasons did not have any significant intensity differences.

DISCUSSION AND CONCLUSION

Moisture plays a key role in herbage production, especially in arid and semiarid environments. The rainfall pattern at Kiboko National Range Research Station is bimodal. During good rainfall years, March through May and October through December carry adequate moisture for plant growth. However, during the two years of study, rainfall fell short of the normal long-term average (figure 4). This condition adversely affected herbage yields, especially in the second year of study (figures 2 and 3). There was little regrowth during the dry seasons.

Time and interval between defoliation need critical consideration. Rate of growth can be interfered with by defoliating plants early in the growing season. Adequate residual leaves should be left after grazing or cutting. Young tillers have been shown to rely on older green leaves and storage organs for carbohydrates before they can manufacture their own. Severe intensity of defoliation may interfere with this source. A too-close defoliation interval does not allow tillers to develop and extend to points of removal. In the present study, the 3-week interval between defoliations may have contributed to the low yields. Woie (1984) reported that a 6-week interval was long enough to permit a large number of tillers to develop to the point that their removal did not reduce growth rate.

Frequent use delays maturity of herbage so that nutritive value remains high for longer periods. Although the present study showed that the most-frequently defoliated plots gave higher yields than the less-frequently defoliated, this could be misleading as it only considers a 2-year period. A further investigation is needed covering 5 or more years to study long-term effects. Continuous defoliation removes most of the photosynthetic area of the plant, which in turn affects the root growth. Such extended periods of use may result in permanent damage to pastures, especially those receiving close grazing.

This study did not simulate any particular grazing system, but results obtained from the low defoliation frequency indicated that early use in the wet season may not supply the bulk of herbage required to carry animals for an extended period. However, since quality usually is high at this stage, moderate use of pastures would ensure adequate nutrient supply and at the same time leave a reserve for dry-season use. Late-season use supplies the bulk needed, but quality may be low. Heavy use at this point may not hurt the plants since the storage organs have been

recharged. Seasonal use of pastures, therefore, may be appropriate; that is, pastures grazed during one growing season may be rested in the next season. This would supply the bulk of herbage for grazing while ensuring that the vigor of plants is maintained.

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Table 1. Frequencies and timing of defoliation.

Treatment (No. of defoliations/yr)	Time of defoliation
T_1 (7)	February, early April, late April, May, September, November, December
T_2 (4)	February, early April, late April, May
T_3 (3)	September, November, December
T_4 (3)	Early April, late April, May
T_5 (3)	February, November, December
T_6 (2)	Early April, November
T_7 (2)	May, December

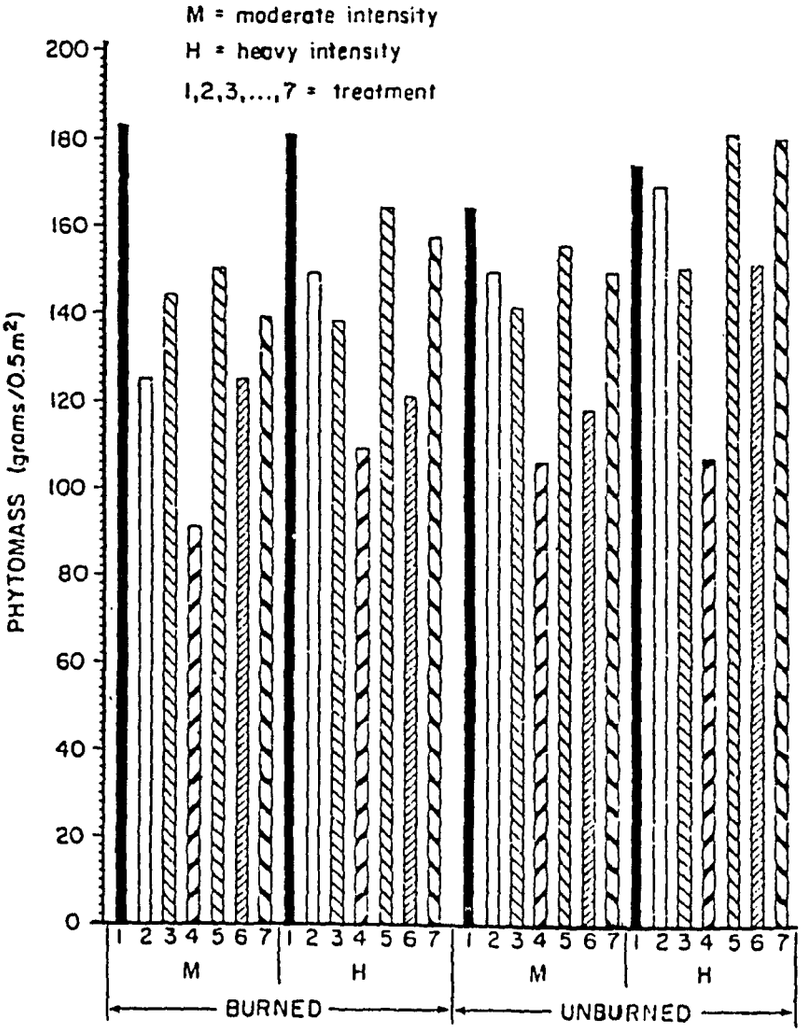

Figure 1. Phytomass (live + dead) across all seasons (1982-1983 minus first clippings of each treatment) and all communities by treatment and defoliation intensity within burned and unburned plots on the National Range Research Station, Kiboko, Kenya.

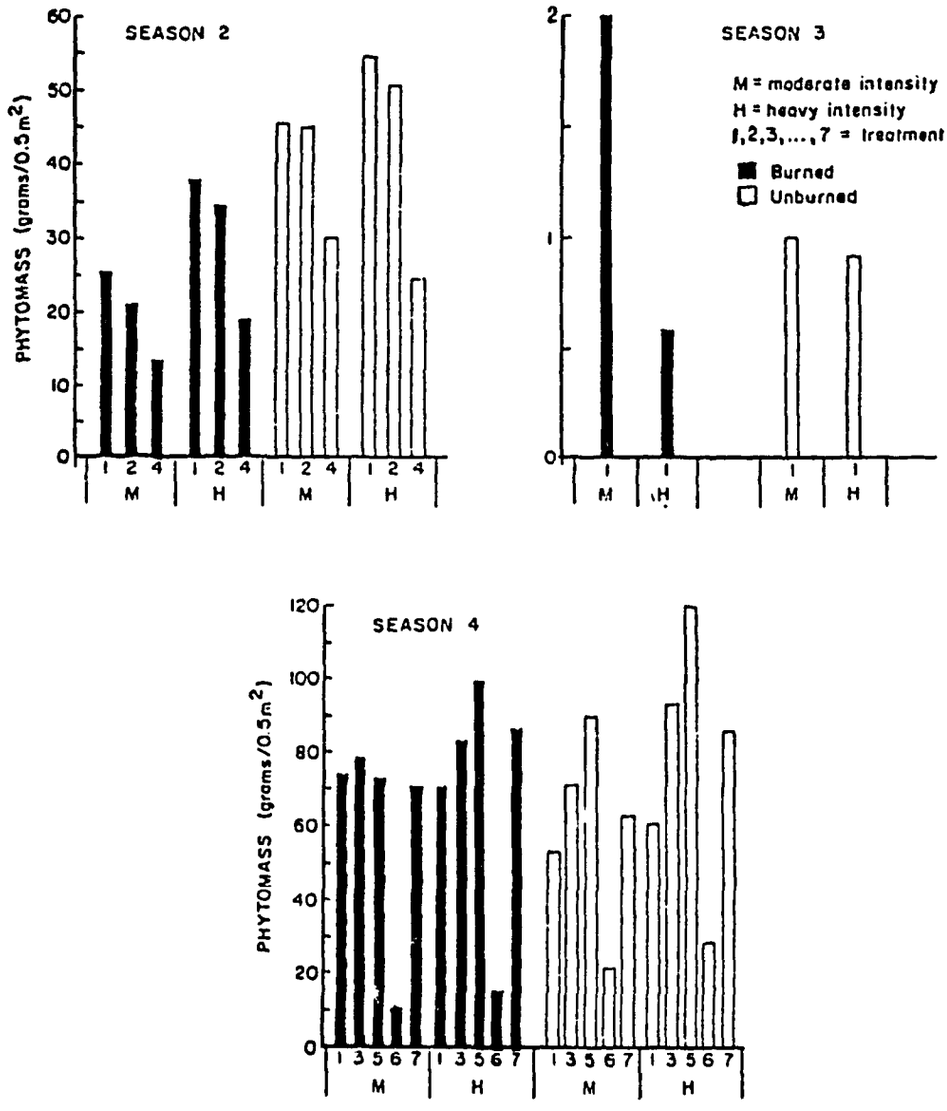

Figure 2. Phytomass (live + dead) across all communities by seasons (1982 minus first clippings of each treatment), treatment, and defoliation intensity within burned and unburned plots on the National Range Research Station, Kiboko, Kenya.

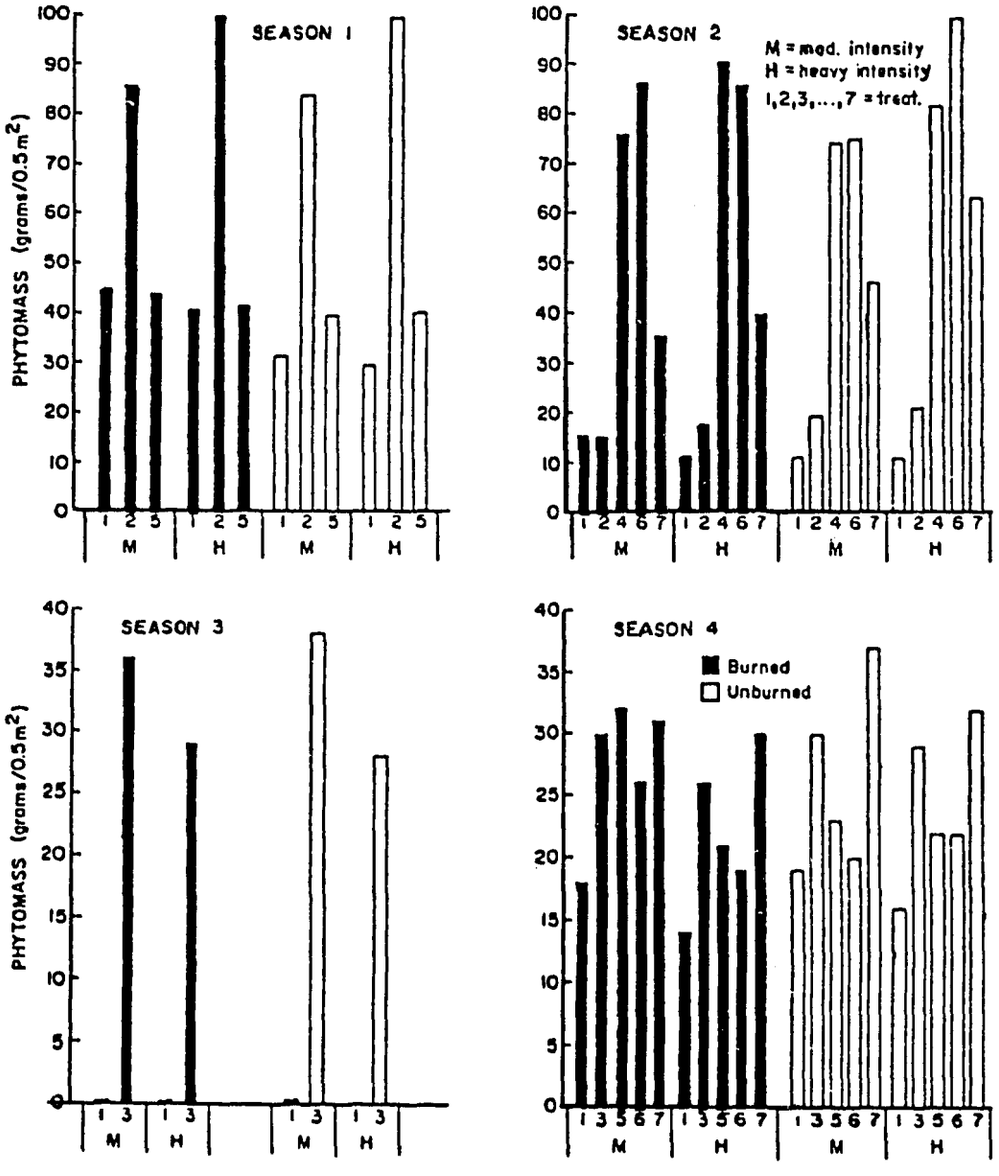

Figure 3. Phytomass (live + dead) across all communities by season (1983), treatment, and defoliation intensity within burned and unburned plots on the National Range Research Station, Kiboko, Kenya.

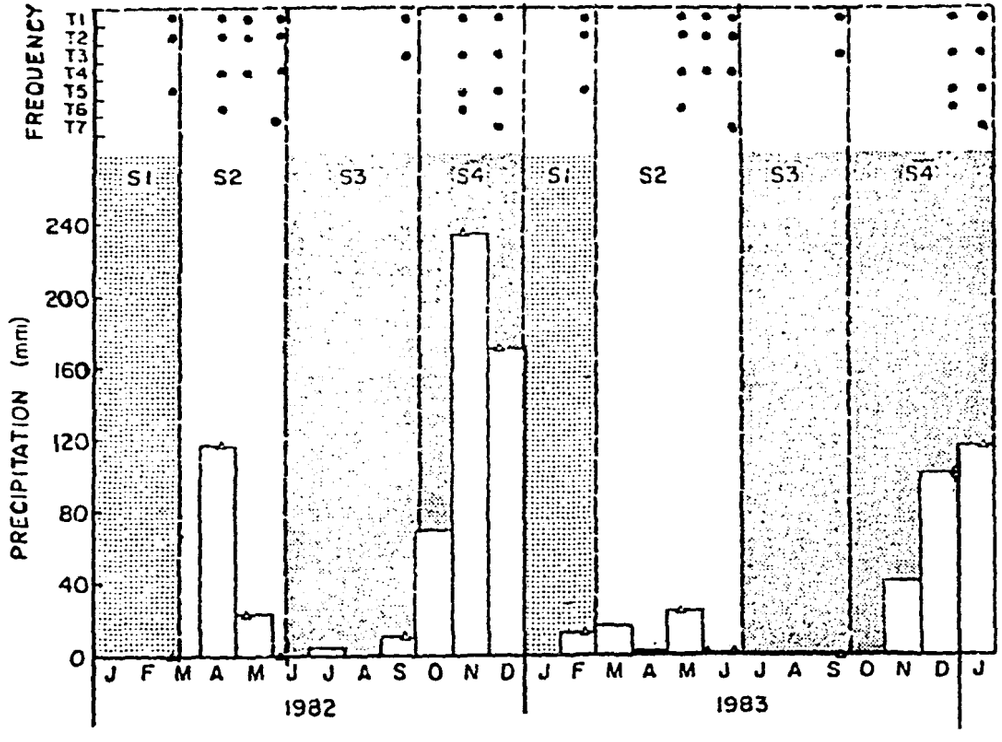

Figure 4. Seasonal (s) clipping dates (Δ) for each treatment (•) in relation to precipitation (bars).

EFFECTS OF DEFOLIATION ON RANGE GRASSES

B. M. Woie

ABSTRACT

Defoliation by grazing or cutting may be conducted primarily to harvest a maximum quantity of nutrients per unit area, produce a strong tillering response, improve forage quality for subsequent grazing, or manipulate botanical composition. Defoliation effects on persistence and productivity of range plants are concerned with frequency and intensity of defoliation and the stage of growth at the time of defoliation. It is obvious that the vigor of plants that are being grazed or cut can be reduced by too-early, too-frequent, or too-close use.

In general, grass species that elevate apical meristems within vegetative tillers are considered least tolerant of grazing or cutting and are most productive when grazed or cut periodically coincident with tiller maturity. Species that do not elevate apical meristems within vegetative tillers can be grazed or cut more frequently without reducing subsequent production.

In managing Kenya's arid and semiarid rangelands, grazing plans must allow for adequate residual plant material in the stubble during the growing season to support livestock maintenance during the dry season and to assure sufficient leaf tissue for subsequent regrowth. In formulating grazing plans, frequency and intensity of defoliation must be used to harmonize forage quantity and quality for improved livestock production.

INTRODUCTION

At present, extensive animal production in Kenya is confined almost entirely to the natural vegetation types, and most livestock and wild ungulates are supported by the natural vegetation of woodland or bushland and the dwarf-shrub grassland or bushed grassland types. In many of these plant communities, both herbaceous and woody plants are sources of feed for livestock and wildlife. Range plants and wild ungulates have a coevolutionary history in which competitive fitness was enhanced by natural rotational grazing due to seasonal rainfall patterns. The positive balance that evolved between plants and grazing animals is not maintained under continuous defoliation. Optimum production from the plant:grazing-animal system can be realized only from high leaf:stem and green:dead ratios in both the standing crop and animal diets. To realize optimum production, defoliation plans must control time of year, frequency, and duration of defoliation for individual plants and still permit high animal selectivity.

Defoliation may be conducted primarily to harvest a maximum quantity of nutrients per unit area, to improve forage quality for subsequent grazing, to produce a strong tillering response, and to manipulate botanical composition. However, the desired response from a given defoliation treatment or the potential to use the principles of plant growth and development to achieve any of these desired goals will depend largely on local opportunity and the degree of control over defoliation practices. The objective of this paper is to discuss the effects of grazing or cutting on those aspects of plant growth pertinent to vegetative management of range plants.

GRAZING VERSUS CLIPPING

The relative persistence and productivity of range plants when subjected to defoliation have been studied by use of various grazing systems and by imposing various defoliation frequencies and intensities by clipping. The ineffectiveness of most grazing systems can be attributed to the inability of the manager to control the extent of defoliation of individual plants (Anderson, 1981). Clipping removes all herbage above specified stubble heights, whereas grazing removes herbage at heights that vary from plant to plant and even within the same plant (White, 1973). Separation of the physical effects of animals from changes due to defoliation presents difficult problems, and results often are confounded in grazing studies. Although it is difficult to simulate a grazing situation in a clipping study, information obtained from clipping studies is used to suggest the periods of rest and defoliation that would have beneficial effects on range-plant growth (Heady, 1961).

BUNCHGRASS VERSUS SODGRASS

Monocots grow from intercalary meristems that are more protected from grazing than are the terminal meristems of dicots. Thus, most grass grows from an intercalary meristem located at the plant base (Hyder, 1972); however, there are some variations even within the grass family. The organization of tillers on a grass plant has given rise to two basic growth forms. On the one hand, the intravaginal axillary-bud expansion within the subtending leaf sheath contributes to the organization of tillers within close proximity and defines the caespitose (bunchgrass or tussock) growth form. On the other hand, the extravaginal axillary-bud expansion through the subtending leaf sheath contributes to a greater spatial arrangement among tillers and defines the creeping (sodgrass or spreading) growth form (Briske and Woie, 1984). Development of rhizomes and stolons (modified nonphototropic tillers) provides additional variation within the grass life form. The degree of internode elongation within these structures determines whether the caespitose or the creeping growth form will result.

DEFOLIATION TOLERANCE VERSUS DEFOLIATION AVOIDANCE

The ability of a grass to survive and maintain its abundance and productivity within a plant community subjected to herbivory is dependent on both avoidance and tolerance components of grazing or cutting resistance. Morphological characteristics confer grazing avoidance by reducing plant palatability and tissue accessibility. Growth following defoliation also is subject to morphological constraints and represents the tolerance component of grazing or cutting resistance (Briske and Woie, 1984).

Forage aspects that elevate apical meristems within vegetative tillers are considered least tolerant of defoliation and are most productive when grazed periodically, coincident with tiller maturity (Branson, 1953; Dahl and Hyder, 1977). Certain changes in structure induced by prolonged heavy grazing appeared to favor persistence of perennial grasses with the caespitose growth form. These changes included a relatively rapid regrowth after defoliation and a more prostrate growth that further facilitates escape from grazing. This results in more leafage being concentrated near the soil surface. Numerous branches, with enough of them decumbent to assure that some apical meristems escape removal by grazing animals, is therefore an important adaptation (Peterson, 1962; McNaughton, 1979). The range plants that are most

resistant to excessive defoliation, therefore, have apical meristems that are inaccessible to grazing animals; for example, they may have short vegetative shoots. All sod-forming grasses, such as bermudagrass (Cynodon dactylon), have short vegetative shoots. These plants can maintain a much higher proportion of photosynthetic tissue than species with long shoots whose entire leaf complement is elevated and vulnerable to removal by grazing (Peterson, 1962). A complementary trait of most species with short vegetative shoots is that they produce a high proportion of vegetative versus reproductive shoots. Reproductive shoots are adapted for seed production rather than for tolerance to grazing (Dahl and Hyder, 1977).

TILLERING

Langer (1963) reviewed tillering in the grass family and reported that a shoot required a certain number of leaves before it could produce a tiller. The tiller is defined as a unit of vegetation that develops from a specific axillary of basal bud prior to development of any roots from the node. Differences in tillering responses to defoliation are related to photosynthate supply and apical dominance. Defoliation to remove stem apexes stimulates tillering by removing the major source of auxin, which inhibits lateral bud development; but defoliation to remove only leaves retards tillering by reducing photosynthetically active tissue with a resulting reduction in carbon assimilation (Troughton, 1957; Peterson, 1962; McNaughton, 1979). Besides the additional growth of leaves that are not yet mature, regrowth following defoliation largely depends on the number, extent, and type of leaves remaining on intact tillers.

Although basal tillering occurs in tropical grasses, reproductive culms do not die after one growing season but continue to produce nodal tillers on primary, secondary, and tertiary branches that live for several seasons (Jewiss, 1972; Kinyamario et al., 1984). At Kiboko, Woie (1984) found that the 6-week harvest frequency resulted in significantly higher tiller numbers and regrowth heights than either the 3-week or the 9-week harvest frequencies (table 1). Wooly fingergrass (Digitaria macroblephara), guineagrass (Panicum maximum), and buffelgrass (Cenchrus ciliaris) were found to produce large numbers of tillers and sufficient leaf area to recover soon after 6-week defoliations because tillers reached a more mature stage that facilitated initiation of nodal tillers on older tillers, thereby enlarging the crown area (table 2). Effects of intensity of defoliation on tillering appeared to be more pronounced at the 3-week harvest frequency. For example, plants clipped at the 3-week harvest frequency with the 5-cm cutting height produced the lowest tiller numbers. As frequency of harvest decreased, intensity of defoliation appeared to have less influence on the performance of grasses studied.

Tillering is important in forage plants because of its effect on leaf-area production and dry-matter yield. A high rate of tillering would be beneficial in attaining high yields and maintaining a grass stand under defoliation.

DRY-MATTER PRODUCTION

Responses of plants to defoliation are influenced largely by the intensity and frequency of defoliation and the stage of growth at the time of defoliation. Provided that environmental factors are not limiting, defoliation according to any of these three factors or any combination

of them can cause a reduction in dry-matter yield, no obvious effects, or an increase in dry-matter production (Heady, 1975). Cassady (1973) found that close, repeated defoliation four to eight times during the first year produced yields equal to or higher than control plots; but when severe defoliation was continued for 2 and 3 years, yields were reduced 22% and 63%, and most of the grass stand was destroyed. In Tanzania, Voorthuizen (1972) reported that various intensities and frequencies of clipping induced varying responses from grasses. Guineagrass (Panicum maximum) yields, for example, were highest with close cutting (leaving 5-cm stubble heights) and with 8-week harvest frequencies. Buffelgrass (Cenchrus ciliaris) yields were highest with 4-week harvest frequencies and 10-cm stubble heights. Thatching grass (Hyparrhenia rufa) yields were highest with 6-week harvest frequencies and 20-cm stubble heights.

In the Athi River Plains of Kenya, Potter (1980) found that the grass stand, dominated by the red oatgrass (Themeda triandra) and bamboograss (Pennisetum mezianum), could withstand frequent severe defoliation, even at a 3-week harvest frequency with a 5-cm cutting height, provided that animal-associated physical damage to the grass stand was avoided. In southcentral Kenya, Woie (1984) studied the responses of six range grasses to various intensities and frequencies of clipping. In all grasses studied, dry-matter yield was highest at the 6-week harvest frequency (table 1). Under the most frequent (3-week harvest frequency) and intense (5-cm stubble height) defoliation, new tillers apparently never fully expanded. Less of each tiller was removed at the 3-week harvest frequency than either at the 6-week or the 9-week harvest frequencies. Furthermore, the more frequent defoliation removed mostly grass leaves and retarded tillering through a reduction of leaf tissue. Wooly fingergrass (Digitaria macroblephara), guineagrass (Panicum maximum), and buffelgrass (Cenchrus ciliaris) produced the highest dry matter, especially under the 6-week harvest frequency (table 2). Effects of intensity of defoliation on dry-matter production appeared to be more pronounced under the most frequent defoliation.

FORAGE QUALITY

Forage quality and quantity must be balanced because maximizing either component alone will render the other component unacceptable for sustained animal production. Forage quality is generally lowered as plant tissue ages and leaf:stem and green:dead ratios are reduced (Beaty et al., 1978). Immature forage is nutritionally important to the quality of animal diets because early growth corresponds to the lowest grass-stem content; that is, highest leaf:stem ratio (Brougham, 1957). Whereas mature forage is generally adequate to meet animals' maintenance requirements, green plant material, particularly leaves, is necessary for animal production (Kothmann, 1980). Nodal tillering, an important aspect of the morphology of many tropical grasses, increases forage nutritive value and available forage for grazing animals (Kinyamario et al., 1984).

Woie (1984) found that the most frequent (3-week) defoliation resulted in highest leaf:stem ratios, percentage of dry-matter digestibility, and percentage of crude protein (table 1). The digestibility of the leaf fraction exceeded the digestibility of the stem fraction by as many as 9 units in the horsetailgrass (Chloris roxburghiana); 14 units in guineagrass (Panicum maximum); 15 units in wooly fingergrass (Digitaria macroblephara), buffelgrass (Cenchrus ciliaris), and Masai lovegrass (Eragrostis superba); and 18 units in the red oatgrass (Themeda

triandra). These results indicated that the leaf fraction was more digestible than the stem fraction and that digestibility values declined as the interval between defoliations increased. Similarly, the crude-protein content of the leaf fraction exceeded the crude-protein content of the stem fraction by at least 3.5 units in all six range grasses. The crude protein content of both leaf and stem fractions declined as the interval between defoliations increased.

MANAGEMENT IMPLICATIONS

One of the most difficult features of managing arid and semiarid grazing lands is the variability in production from season to season. Under such conditions, a livestock producer who is trying to keep enough livestock to consume the total production of forage would in some years have less and in some years more forage production than was anticipated.

Because livestock need about the same quantity of feed each day for all 365 days of the year, grazing or cutting practices must be consistent with the need to permit adequate residual plant material in the stubble during the growing season to support livestock maintenance during the dry seasons and to assure sufficient leaf area for subsequent regrowth.

Improved livestock production from the arid and semiarid grazing lands can be realized only from high leaf:stem and green:dead ratios in the standing crop and animal diets. To realize improved production, grazing plans must control time of year, frequency, and intensity of defoliation for individual plants and still permit high animal selectivity.

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Table 1. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller numbers, regrowth height, and percentages of DDM and CP of six grasses harvested at three frequencies across experimental sites, intensities, and dates of clipping.

Grass	Frequency (weeks)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm/plant)	Tiller number	Regrowth height (cm)	Leaf (% DDM)	Stem (% DDM)	CP in leaves (%)	CP in stems (%)
C. ciliaris	3	128.2 c	5.1 a	10.5 b	20.2 b	17.8 c	76.6 a	61.7 a	13.1 a	6.8 a
	6	187.3 ab	4.3 ab	12.9 a	33.0 a	27.5 a	71.4 b	56.0 b	9.2 c	6.2 b
	9	198.1 a	3.4 b	11.5 ab	22.8 b	20.0 b	70.5 c	54.6 c	10.2 b	6.0 b
C. roxburghiana	3	92.0 a	6.2 a	10.0 a	14.9 a	21.5 a	69.8 a	63.5 a	13.6 a	8.1 a
	6	111.2 a	4.8 b	10.3 a	17.3 a	21.8 a	64.0 b	58.1 b	10.5 b	8.4 a
	9	93.1 a	3.9 c	7.3 b	9.3 a	12.6 b	63.2 b	47.2 c	10.2 b	6.5 b
D. macroblephara	3	134.6 b	6.7 a	10.1 b	40.5 b	23.3 b	80.3 a	50.0 b	15.8 a	9.3 a
	6	174.1 a	5.4 b	14.0 a	69.8 a	27.6 a	78.2 a	54.5 a	9.7 b	8.0 b
	9	175.4 a	4.4 c	11.3 c	70.5 a	25.4 ab	70.4 b	50.2 b	9.0 b	6.4 c
E. superba	3	125.1 c	4.9 a	7.3 a	13.6 a	15.4 c	74.8 a	55.8 b	13.0 a	8.7 a
	6	151.0 a	4.1 ab	7.0 a	15.2 a	19.8 a	71.7 b	58.6 a	9.8 b	7.5 b
	9	135.9 b	3.5 b	7.6 a	9.9 a	17.8 b	68.2 c	53.6 c	9.6 b	5.7 c
P. maximum	3	181.8 ab	8.1 ab	10.6 a	28.5 a	28.8 a	76.3 a	60.7 a	14.5 a	7.6 b
	6	196.2 a	8.5 a	10.5 a	31.6 a	23.9 b	72.1 b	60.3 a	11.2 b	5.8 ab
	9	170.7 b	7.2 b	9.9 a	31.8 a	21.1 c	71.1 b	57.3 b	9.7 c	6.6 c
T. triandra	3	36.0 b	5.1 a	6.5 a	10.5 a	18.8 b	71.5 b	53.8 b	10.4 a	6.0 a
	6	54.0 a	3.9 b	5.5 a	9.1 a	24.7 a	72.1 a	56.3 a	9.1 b	5.8 ab
	9	60.3 a	3.7 b	6.2 a	12.2 a	22.5 ab	68.1 b	48.0 c	8.8 b	5.4 b

Means for a given grass species for different frequencies of harvest followed by the same letter are not significantly different at the 0.5 level. Source: Voie, 1984.

Table 2. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller numbers, regrowth height, and percentages of DDM and CP of three frequencies and three intensities across grasses and experimental sites.

Frequency	Height of cutting (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm/plant)	Tiller number per plant	Regrowth height (cm)	Leaf (% DDM)	Stem (% DDM)	CP in leaves (%)	CP in stems (%)
3 weeks	0	-	-	10.6 a	31.2 a	33.9	-	-	-	-
	5	108.7 b	6.2 a	9.1 ab	14.7 b	11.8 c	74.9 a	60.1 a	13.7 a	7.5 a
	10	116.2 ab	5.6 b	8.9 ab	17.1 b	15.7 bc	75.5 a	57.8 ab	13.2 a	7.8 a
	15	124.1 a	6.2 a	8.1 b	22.5 ab	19.1 b	74.3 a	54.9 b	13.3 a	7.8 a
6 weeks	0	-	-	10.9 a	36.0 a	36.1 a	-	-	-	-
	5	151.9 a	5.9 a	9.8 a	23.6 a	17.4 b	73.8 a	57.6 a	10.2 a	7.3 a
	10	136.8 b	4.4 c	9.6 a	30.4 ab	21.4 b	69.7 b	58.5 a	9.7 a	7.4 a
	15	148.0 ab	5.2 b	9.8 a	27.3 ab	21.9 b	71.2 ab	55.9 a	9.8 a	7.4 a
9 weeks	0	-	-	9.1 a	25.4 ab	28.0 a	-	-	-	-
	5	136.4 a	3.7 b	8.2 a	22.1 b	17.0 b	68.7 ab	51.2 a	9.4 a	6.0 a
	10	137.0 a	4.6 a	8.9 a	32.5 a	17.1 b	67.8 b	51.4 a	9.6 a	6.0 a
	15	143.3 a	4.7 a	9.6 a	24.3 ab	17.6 b	69.2 a	52.8 a	9.7 a	6.3 a

Means for a given harvest frequency for different cutting heights followed by the same letter are not significantly different at the .05 level. Source: Woie, 1984.

RANGE RESEARCH AT CHEMERON

Frank W. Lusenaka

INTRODUCTION

Range research at Chemeron is important to the development of overused rangelands in Kenya. Studies of various components of the environment -- the soils, vegetation, and overall climatic influences on these factors -- can help make possible management for sustained agricultural production.

The approach to investigating problems within the ecosystem of Chemeron calls for integration of user departments of Egerton College. Research that uses a single-area approach cannot offer solutions to the almost permanently impaired land of Chemeron. Further, collaborative research between the Egerton College staff and other institutions would give replicable results.

This paper looks at some contributions that the Chemeron Field Station can offer in support of overall range research in Kenya. It first presents background information about the station. It then discusses the administration and structural developments that have been implemented. Priorities for the immediate use of the station after acquisition are indicated. This section is followed by a brief description of the programs at the field station and reasons why no research programs have been started. A list of research proposals by Egerton staff have been made and have been indicated as being not ready to be started.

The approach to establishment of Chemeron Field Station as a center for research and tuition programs has been pointed out in the discussion. Caution about duplication has been outlined with reference to the objectives of the field station viz. tuition, research, and extension. Recommendations for broad areas of study are suggested. Tangible and specific research proposals can be developed from these broad areas. In conclusion, lack of baseline data is suggested as being a major constraint to starting research programs at the field station. Data collection must be a cooperation effort among the college departments. For reliability of research results obtained at Chemeron, collaboration by Egerton College and other institutions in the country is encouraged.

BACKGROUND

Chemeron Field Station is about 133 km northwest of Egerton College and 13 km west of Marigat township toward Kabarnet in Baringo District. It covers 450 ha and receives average annual rainfall of 635 mm recorded at Marigat. The altitude is 1,200 m above sea level.

The soil is reddish-brown, sandy loam with many stones on the surface. Chemeron River, which flows seasonally, traverses the station from about west to east, and many gullies feed it. The ground has a gentle slope in some areas but is generally rough toward Chemeron River. Vegetation is mainly dense-bushed grassland dominated by *Acacia reficiens*, *A. mellifera*, *A. brevispica*, *Boscia angustifolia*, and *B. coriacea*. Other associated woody species include *Balanites aegyptiaca*, *Grewia bicolor*, and *Tamarindus indica* along sandy river banks and valleys. The field station is in ecoclimatic zone V (Pratt, Greenway, and Gwynne, 1966).

By 1972, Egerton College needed to acquire semiarid land for training range-management students in range ecology and management techniques. The Ministry of Agriculture, which used Chemeron as a research station, was willing to transfer the station to Egerton College. Eventually, the transfer was made through the county council of Baringo, and a leasehold status was agreed to by the two parties.

As early as the late 1950s, projects on reseeding denuded rangelands of Baringo had been started (Bogdan and Pratt, 1967). From 1965 to 1972, the Ministry of Agriculture (under a UNDP/FAO project) carried out trials on grass seeding/bush slashing at Chemeron on a 26-ha plot. The trials were concluded in 1973 (Ministry of Livestock Development, 1979).

At the time when Egerton College acquired the land at Chemeron, its immediate use was earmarked for the Range Management, Animal Science, and Agricultural Engineering departments. The emphasis was to start on programs that would be for tuition and staff research. The extension component was proposed for succeeding programs that would be of immediate use to the people living around the station or in the whole of Baringo. Today, Chemeron Field Station is open to all departments that are able to use the facility for the same objectives.

ADMINISTRATION AND DEVELOPMENT OF THE STATION

The Range Management Division oversees the running of Chemeron Field Station on behalf of the college administration. The officer in charge of the station, who is trained in range management, is responsible to the head of the Range Management Division.

The Chemeron Committee, appointed by the principal of Egerton College, is charged with the responsibilities of academic organization, identification of facilities for staff resident at the station, security, and general maintenance of the station. The research committee at Egerton College approves all staff research proposals for Chemeron Field Station.

Structural Developments

Egerton College's expansion program, funded by the U.S. Agency for International Development (USAID), included the Chemeron Field Station. A facility accommodating 28 male and 8 female students was made available. A general laboratory, a kitchen and dining hall, and visiting-staff quarters accommodating six members were constructed. Other facilities include a garage attached to a generator house, a borehole, resident-staff quarters, periphery barbed-wire fence, a goat shed with about 200 goats, and an all-weather road 3 km from the main Marigat-Kabarnet road.

PROPOSED RESEARCH PROGRAMS

There is no research program at Chemeron Field Station because the structural developments were completed just over 2 years ago and, more important, the officer in charge was recruited at the end of 1985. So far, what have existed at the field station are the indigenous small East African goats. No research on these goats has been made; however, Galla nannies and billies have been introduced for a simple cross-breeding program. A grass-reseeding demonstration plot of 5 ha has been established; but, so far, no studies of established grass species have

been proposed. The following proposals have been made by Egerton College departments, and some have been submitted to the research committee.

Ecology and Range Revegetation

Under the broad category of ecology and range revegetation, specific research proposals have been made for

- bush-control and management techniques relevant to Chemeron area
- plant revegetation -- grass seeding and woody-plant seedling establishment
- determination of nutritive value of some browse plants
- nutrient fluctuation in quantity and quality of major forage species at Chemeron
- influence of grazing cattle and goats on vegetation and soil

Livestock Management

- sheep and goats breeding program
- animal nutrients critical during various seasons at Chemeron

Soil and Water Management

Research proposals for soil and water management have been submitted to the College Research Committee and are pending approval. They cover wide areas and, hence, have been indicated for cooperation among the Agricultural Engineering, Range Management, Crop Science, and Forestry departments. Specific areas of study include

- runoff experiments using runoff plots
- sedimentation measures
- determination of dryland crop-water use, water harvesting, and irrigation
- effectiveness of different types of terraces on soil and water management
- reclamation and use of severely eroded lands
- design and construction of appropriate aerial water-harvesting system
- surface and subsurface water-storage structures -- design, construction, and performance
- identification, development, and use of appropriate forms of structures

Apiculture

- preliminary monitoring of productivity and habitation of bees during wet and dry seasons

DISCUSSION

To be able to institute any operation in range development, a survey is necessary. The inventory of existing resources and their conditions is required for planning the operation (Pratt and Gwynne, 1977). For Chemeron Field Station, Karanja (1984) presented an unpublished paper to the Chemeron Committee proposing a general-resource survey. It was accepted, but so far no survey has been done. To achieve a total land survey, cooperation among various departments has been proposed. The survey would give results presented in the context of ecological land units (Pratt and Gwynne, 1977).

The research proposals for ecology and range vegetation have been studied in the Chemeron area and elsewhere (Bogdan and Pratt, 1967; Ministry of Livestock Development, 1979). It may be necessary to find out which of those results can be used at Chemeron to rehabilitate the station. The purpose for doing a search is to avoid duplication -- research should be repeated only for demonstration for tuition. Results obtained at Chemeron on bush control and grass reseeding (Bogdan and Pratt, 1967) have value for both extension and tuition demonstrations.

Any research proposed for Chemeron should take into consideration the stage that denudation has reached. Efforts to rehabilitate Chemeron should look at establishing sustainable cover that would stabilize the soil, a proper range-production system for the delicate environmental conditions, soil and water structures that would be appropriate for such deteriorated land, and the kinds of livestock and nutrients required for maximum production.

CONCLUSION

The major constraint to range research at Chemeron lies in the fact there is little data available on soils, climate, vegetation, and sustainable land use. An inventory of all available resources must be made before any research is started. Data collected by general survey should be integrated from the start; and maps should be made available of ecological land units, water resources, vegetation and range conditions, and existing facilities and services (infrastructure). Collaborative research with other institutions in the country should be encouraged. The reliability of research results depends on replication in the same ecological zones.

ACKNOWLEDGMENTS

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KENYA ARID LANDS RESEARCH STATION

W. J. Lusigi

INTRODUCTION

More than half of the land surface of Kenya is arid or semiarid rangeland occupied by pastoralist societies and their livestock. Both the human and livestock populations of these regions are increasing, but the natural resources of the dry environment are very vulnerable to these increasing pressures. The problem has similarity and application elsewhere throughout northeastern Africa and parts of the Sudano-Sahelian zone. The spiral process of what is now commonly called desertification follows a familiar pattern: overexploitation, first of the herbaceous vegetation and then of trees and shrubs, leads to soil erosion, disturbed hydrologic patterns, further dessication, and a resulting decline in land productivity and its capacity to support the numbers of people living there.

Due to the little and very irregular rainfall in most parts of northern Kenya, rainfed agriculture is possible only in some of the few mountain ranges at altitudes that receive sufficient rainfall. Hence, the almost exclusive land-use activity is livestock herding by traditionally nomadic pastoralists (Rendille, Gabra, Boran, Turkana, etc.). The considerable increase in human and livestock population numbers have gone hand in hand with a decisive reduction of the grazing areas that are available to the herds of every ethnic group. Settlements and herds are moved less and less far.

Of even greater significance in the changes occurring in northern Kenya are the permanent settlements that have developed in the area due to provision of generally immobile facilities such as dispensaries, schools, and shops around a few permanent water sources, especially the boreholes that have been installed. Administration chiefs, police, and missions have settled there, too. Attracted by these amenities and by the double security of receiving famine-relief supplies, if necessary, and protection against intertribal raiding, the number of pastoralist households that settle permanently at these places is steadily increasing. Consequently, the extension and the rate of desertification in and around these areas of human and livestock concentration are still greater problems than elsewhere.

Since Kenya largely depends on primary production from its land resources, the full potential of the land must be developed by every means; but development must take the form most suited to the prevailing circumstances and the purposes to which an area is best adapted. Development of the range areas is as important as the development of any other organic natural resource and should be undertaken to the maximum extent consistent with its conservation.

Recognizing the importance of the range areas of Kenya (which cover over 80% of the total area of the country) and their potential for the production of goods and services needed by people, and recognizing also the dangers of erosion and desertification from indiscriminate use, the government has placed considerable emphasis on the proper development of these lands, based on the following principles:

- The people of the range areas must be allowed the opportunity for full social development in terms of the modern world and in accordance with the principles of human rights.

- Range areas should be developed, conserved, and managed in accordance with the ecological principles of proper land use.

- So far as other principles allow, the range areas should be developed to yield to the maximum benefit to the national economy.

Kenya's Development Plan for the years 1974 to 1978, in support of agriculture in general and of smallholders and the rural poor in particular, pointed out the need to pay greater attention to the development of the range areas. Even greater emphasis has been placed on the development of range areas in the current National Development Plan (1984 to 1988). This attention directed to range areas is in line with the broader goals for the national economy. These are clearly specified in the Development Plan and emphasize the importance of continued economic growth, a greater sharing of the benefits of growth by the poorer segments of society, full control over the country's economy, and broader participation by local organizations in governmental planning.

What are the common characteristics of the problems of arid-lands development in northern Kenya and elsewhere?

- The development of a single component (for example, water resources) of a land-use system may have detrimental effects on other components and therefore may destroy or reduce the long-term productivity of an area.

- The optimal output of a land-use system can be obtained only through its greatest possible adaption to the ecosystem and by ensuring the sustained functioning of the ecosystem.

- Efforts to transfer large-scale production systems founded on alien objectives and experience seldom have achieved their intended results.

Hence, this makes it essential

- to plan and implement development efforts in a comprehensive or integrated framework rather than by using a sectoral approach

- to understand fully the structure and functioning of arid and semiarid zones' ecosystems and how they are modified through land use

- to base development on the existing traditional land-management systems by using inputs closely linked to these traditional systems that offer the best prospects for making substantial impacts on local standards of living without this change being socioculturally and ecologically disruptive.

Though the need is great to set forth integrated approaches to management of natural resources, rural development, and regional-development planning in the arid and semiarid lands of Kenya or elsewhere, this tremendous task requires not only experts trained to follow this new approach, but also particular scientific knowledge. In this respect, the establishment of the Kenya Arid Lands Research Station (KALRES) --

aimed at providing the scientific basis for integrated management of arid and semiarid lands, monitoring changes and impacts, and training qualified personnel -- is a response to a great need felt in Kenya.

Background of the Project

Within the Marsabit District in northern Kenya, a Unesco pilot project of applied research, training, and demonstration started in 1976 with financial support from the United Nations Environment Program (UNEP) with a view to finding direct solutions to the most urgent environmental problems associated with desert encroachment and ecological degradation of arid lands and developing new strategies for pastoral-land management and regional development specific to this type of natural and human environment. The project, launched in the framework of Unesco's intergovernmental program on Man and the Biosphere (MAB), represents an effort to provide the scientific basis for a holistic and integrated approach to combat desertification and improve the living conditions of pastoral people.

The Integrated Project on Arid Lands (IPAL) in northern Kenya was conceived by Unesco at the same time as the United Nations Conference on Desertification, which in 1977 recommended concerted action in the fight against desert encroachment. With UNEP financial help, IPAL became an important part of MAB's fact-finding projects in the major desertifying regions of the world. In 1978, a Traditional Livestock Management Project (TLMP) was launched in association with IPAL, but funded through a funds-in-trust agreement between the Federal Republic of Germany and Unesco. The focus of this second project was on understanding and improving traditional livestock management of the Rendille tribe.

In line with the policy of UNEP to provide only catalytic or pump-priming support to field activities, the support of UNEP to IPAL came to an end in mid-1980. Prior to that, a special evaluation mission (January 28 to February 7, 1980) recommended that, to make the best possible use of the investments that already have been made in northern Kenya, the research, training, and demonstration activities should be reoriented and continued for a further 3-year period, starting July 1, 1980. The mission, which comprised representatives of the governments of the Federal Republic of Germany and Kenya and Unesco, also recommended that IPAL Phase III should integrate, within a single management and administrative unit, the research and other tasks that previously were handled under separate administrative and funding arrangements (that is, the UNEP-financed part of IPAL, and the funds-in-trust Traditional Livestock Management Project).

Based on these recommendations, tripartite agreements were set up between the governments of the Federal Republic of Germany and Kenya and Unesco for the implementation of IPAL Phase III, with Germany providing as funds-in-trust the financial resources needed for this project. In November 1982, all parties concerned agreed to extend IPAL III within its existing budget until December 1983. The performance and results of IPAL III were evaluated twice by tripartite review missions. The first one took place in November and December 1981, and the second one in February 1983. Both missions commended the progress made toward achieving the project goals following the reorientation, change of objectives, and reorganization of IPAL agreed upon for Phase III in 1980. The 1981 IPAL review mission recommended enlargement of the immediate project objective and, as an action-oriented output of its research, preparation of an integrated resource-management plan. On

this basis, the project submitted a draft management plan to the 1983 IPAL review mission. The mission report stated that "...a well prepared and comprehensive management plan has been elaborated covering almost every aspect of development in the area. The mission commends the efforts that were put into this."

The resource assessment and management plans for western Marsabit District, northern Kenya, were based upon 6 years of research, experiments, observation, and survey of the resources of the arid land ecosystems of northern Kenya. The background of knowledge gained by IPAL on the ecology and economy of western Marsabit District provides an information base for development that is unusually comprehensive and coordinated when seen in the context of a developing region in Africa. Effective management in the future, however, will depend upon reliable monitoring of the continuously changing ecology and economy of the region and repeated updating of the management measures.

Though the plan is the result of group effort by IPAL scientists who met for long periods in Marsabit to draft it, considerable time was spent discussing its contents with the Rendille people, government officials, and leaders in Marsabit District. Their views and feelings were then incorporated into the plan.

The plan is divided into two volumes. The first volume consists of detailed descriptions and assessments of the information about the area that is relevant to the management of its resources. This information is the summary of over 50 published and unpublished papers emanating from IPAL work. Only what is relevant for management is extracted, and detailed descriptions and methodologies are not included since they can be gotten from the relevant publications. The main components of this part of the plan are

I. Introduction

II. Background

III. Physical environment and resources
- a. Land resources
  1. Geographical location and area
  2. Major landforms and drainage
  3. Geology
  4. Soils
- b. Climate
  1. Livestock husbandry in arid and semiarid areas
  2. Rainfall
  3. Aridity and humidity
  4. Temperate regime
  5. Wind
  6. Evaporation
- c. Geomorphology
  1. Role of vegetation in morphodynamics
  2. Areas with high and very high erosion hazards
  3. Descriptions of different areas
- d. Water
  1. Surface water
  2. Subsurface water
  3. Water requirements of Rendille livestock

e. Range resources
    1. Range mapping
    2. Range type descriptions
    3. Primary production
    4. Range condition
    5. Carrying capacity
    6. Factors that determine final recommendations on stocking rates
    7. Description of range units
f. Woodland resources
    1. Resume of methods
    2. Woodland description and measurements
    3. Wood requirements of Rendille people
    4. Livestock fodder requirements
    5. Tree and large-shrub fodder production
g. Livestock resources
    1. Livestock numbers and distribution
    2. Livestock production
    3. Livestock nutrition
    4. Disease as a constraint to production
    5. Livestock and human interrelations
    6. Livestock offtake

IV. Socioeconomic and administration aspects
    a. Rendille camp size
    b. Social structure and settlement
    c. Geographical distribution of camps
    d. Population estimates
    e. Movement patterns
    f. Water management
    g. Leadership structures
    h. Change among pastoralists
    i. Administrative structures for development

V. Marketing and infrastructure
    a. Sales of livestock
    b. Organization of retail-goods marketing
    c. Potential offtake
    d. Constraints to improved commercial offtake
    e. Alternative industries

VI. Other land uses
    a. Forestry
    b. Agriculture
    c. Dairy farming
    d. Mineral resources

VII. Education, training, and extension
    a. Formal education
    b. Informal education
    c. Extension programs

Based on the above resource assessment, each section produced recommendations and advised how they could be incorporated in a management program for the Rendille grazing lands. These recommendations form part two of the plan. Its main topics are

I. Management policy

II. Resource-management objectives, proposals, and plans
   a. Introduction
   b. Management of water resources
   c. Management of range resources
   d. Management of woodlands and shrublands
   e. Management of livestock resources
   f. Human health
   g. Recommendations for the improvement of marketing and infrastructure
   h. Organization of western Marsabit range-development activities
   i. Forestry development
   j. Agricultural development
   k. Conservation of flora and fauna
   l. Education, training, and extension
   m. Conclusion

Acknowledging the valid results of IPAL, the 1983 mission recommended supporting the great interest expressed by the government of Kenya with a view

- to establishing a permanent institution for promoting, guiding, and monitoring integrated management of arid and semiarid lands in Kenya

- to starting development action in the Marsabit District based on the resource-management plan prepared by IPAL

The mission also recommended that, ideally, IPAL's integrated resource-management plan should be implemented in close collaboration with KALRES. Detailed proposals for such a Western Marsabit Integrated Development Project were included in the mission report, and the content and structure of this project were elaborated further in the final version of the IPAL resource-management plan (May 1984).

These recommendations were presented to the IPAL Steering Committee. The chairman of the steering committee assured the mission that

- The steering committee would be enlarged to include representatives from the Office of the President, Ministry of Water Development, Ministry of Environment and Natural Resources, Ministry of Health, Ministry of Regional Development, and Ministry of Science and Technology.

- The mission's recommendations were in line with his committee's own earlier wishes. He assured the mission that his committee would ensure that these projects got every support from the Kenyan government.

- As regards KALRES, the chairman welcomed Unesco's proposal to seek funds-in-trust from the Federal Republic of Germany.

Specific Considerations for the Establishment of KALRES

The successful implementation of IPAL had generated a number of specific assets that, in the view of the 1983 tripartite review mission, needed to be preserved by all means and further developed for the benefit of

the country. The best way to do this was the establishment of the Kenya Arid Lands Research Station (KALRES).

OBJECTIVES OF THE PROJECT

The primary objectives of the project shall be to help promote rational use of arid and semiarid lands in Kenya, which will improve the living standard of the people in these areas while halting desertification. So far as other principles allow, the range areas should be developed to yield the maximum benefit for the national economy.

The immediate aim of the project is to assist the government of Kenya in setting up and operating, during an initial 3-year phase, a Kenya Arid Lands Research Station (KALRES) that will afterward serve as a permanent institution of the Kenyan Ministry of Agriculture and Livestock Development. This 3-year project, focusing on the priority activities mentioned above, is laying the foundation for the full spectrum of activities to be carried out by KALRES on a permanent basis after international assistance has ceased. A summary of this spectrum of activities is as follows:

- The station will serve as a center where research information and practical knowledge gathered over the years from the IPAL study area will be refined continually and passed on to various user groups, in particular to pre-extension, extension, and development projects.

- The geographical coverage will be extended to adjacent areas of Marsabit, Samburu, and Turkana Districts and finally elsewhere in Kenya's arid zone.

- KALRES will try to fill gaps in knowledge through applied research aimed at integrated management of arid and semiarid lands, with due attention to all aspects of human ecology related to land degradation and rehabilitation and to the amelioration of the living conditions of the pastoral people.

- The research facility will provide a permanent multifunctional laboratory and permanent field stations with long-term observation areas such as enclosure plots, livestock-impact paddocks, and vegetation reserves. In these areas, studies can be made on long-term trends in vegetation recovery under controlled conditions, and the problem of long-term carrying capacity can be studied adequately. Range management in the arid zone and many related management activities that accompany it can be understood and correctly applied only if a body of knowledge is accumulated over a series of climatic fluctuations. Management based upon short-term observations tends to err on the side of overexploitation. Therefore, an establishment that provides the opportunity to undertake long-term research and monitoring of arid rangeland would be of great value, and the knowledge gained by it might prevent many mistakes in land exploitation in future years.

- Use of KALRES research workers to prepare, guide, and monitor resource-management plans that are founded on firm research data will help to overcome the present situation in many countries where the data and know-how that are available are not applied because the links between research scientists and resource managers are insufficient.

- The ecological monitoring facility will be established with a view to providing a permanent service, not only for Marsabit District, but also for the remainder of arid regions of Kenya. This service will maintain a continuing survey of the state of natural resources in the arid zone, with emphasis upon range, forest, woodland, and livestock. The monitoring facility will work in cooperation with KREMU but will undertake more intensive ground and aerial survey, with more attention to seasonal effects than KREMU is able to achieve owing to its need to cover the extensive semiarid and subhumid regions of the country.

- The station will maintain IPAL's meteorological network and extend it where appropriate.

- KALRES's training activities will focus mainly at two levels: postgraduates and technicians, including extension workers. The aim will be to promote an integrated approach to arid-lands development and to provide training tailored to the needs of different target groups concerned with environmental degradation, animal husbandry, range management, associated local industry, and social development.

- Accumulated information, including successful and failed development experiences, will be "translated" for use by a mobile service to schools and seminomadic communities throughout the region.

- Data and experience will be used for input into curricula designs and to prepare information and training materials at various levels in the forms of books, pamphlets, and audio-visual teaching aids.

- KALRES will organize an extended program of field demonstrations for different target groups.

- The station will build up a well-equipped library concerned with information transfer in arid-zone management that will be a repository for reference material including reports, publications, ground and aerial photography, and satellite imagery covering the arid lands of Kenya and in particular of northern Kenya.

- The station, being unique in its field, will (like IPAL) attract trainees and scholars from Kenya and elsewhere for whom it will provide a base for research and training.

PRESENT POSITION

KALRES's operation started formally on October 1, 1984, and the present funding arrangement will continue until September 30, 1987. The immediate transition from IPAL has gone smoothly.

The government has posted three research officers and seven technical assistants to the program. Two of the technical officers were sent abroad in October 1985 for further training. Two of the internationally recruited experts were replaced by locally recruited senior scientists in December 1985. KALRES also has extended its research activities to Turkana District on request from the Norwegian Agency for Development (NORAD). Here it is establishing a network of three research stations at Nadapal, Karokor, and Lorugum. It has already recruited a range ecologist for the program and started range and livestock investigations there. A livestock ecologist is to be deployed soon.

KALRES also has extended its monitoring work into Samburu District where, at the request of the German-funded Food Security Programme, its scientists carried out livestock censuses in 1984 and 1985 and gave advice on issues related to the development activities of that program.

In cooperation with the Food Security Programme Wamba, KALRES started the West Marsabit Integrated Development Pilot Project in January 1985. This is a small-scale project testing the management plan developed by IPAL in the southern part of the IPAL study area. It is headed by one of the scientists in the team that developed the plan, and it is yielding very encouraging results. KALRES presently is conducting negotiations with various other donors to start similar activities in Marsabit District.

KALRES AFTER 1987

The present funds-in-trust arrangement between the Kenyan government, the Federal Republic of Germany, and Unesco is due to expire in September 1987. To ensure that the KALRES operation does not come to a standstill, the above parties are looking for long-term funding from donors.

Since the activities of KALRES are not only beneficial to the arid lands of Kenya but also have wider applications in the Sudano-Sahelian zone, it is hoped that agencies, institutions, and governments concerned with problems of aridity and their amelioration will support this program.

VEGETATION-ENVIRONMENT RELATIONSHIPS AT THE NATIONAL RANGE RESEARCH STATION, KIBOKO, KENYA

I. K. Kemei

ABSTRACT

Vegetation of the National Range Research Station, Kiboko, is determined by the interaction between prevailing biotic and abiotic environmental factors. To determine and explain the relationships between the vegetation and environmental factors, relevant characteristics of sample stands were taken and analyzed. Forty-four vegetation stands were sampled for vegetation foliar-cover, frequency, soil, landscape, and disturbance (fire and grazing) properties. Reciprocal averaging ordination was used to describe vegetation relationships to environmental factors. Four major vegetation groups were identified. The vegetation of alluvial clayey soils was dominated by Pennisetum mezianum, Bothriochloa insculpta, Ischaemum brachyatherum, Acacia drepanolobium, and A. xanthophloea. The vegetation of the basement complex system with sandy clay loams was dominated by Chloris roxburghiana, Digitaria milanjiana (marcoblephara), Enteropogon macrostachyus, Eragrostis caespitosa, Commiphora riparia, C. Africana, Acacia tortilis, A. senegal, A. mellifera, and Duosperma kilimandscaricum. The vegetation of the lower volcanic area was dominated by Sehima nervosum, Heteropogon contortus, Combretum apiculatum, and Cordia gharaf. The upper volcanic cone was dominated by Chrysopogon aucheri, Tricholeana eighingeri, and Acacia hockii. In specialized wet areas, Themeda triandra, Andropogon distachyus, and Combretum apiculatum may be found. In denuded or heavily grazed areas, Microchloa kunthii, Aristida keniensis, and Eragrostis caespitosa were the increaser or invader plants. In a seasonally water-logged area in the basement complex system, Echinochloa haploclada was the dominant grass species and Acacia drepanolobium was at the edges of the stand.

INTRODUCTION

The Republic of Kenya consists of approximately 582,300 km^2, of which approximately 492,200 km^2 or 84% of the country is classified as rangeland. In these areas, the human population, composed mostly of pastoralists, is approximately 2 million people who own 50% of the nation's livestock. Range areas produce 60% of the nation's beef cattle, estimated at 9 million head, and more than 70% of the estimated 8.5 million sheep and goats (Pratt and Gwynne, 1977). The livestock and wildlife in range areas depend on natural vegetation for their nutritional requirements and production (Pratt and Gwynne, 1977).

The vegetation of a specific area is a function of species available and the environmental conditions that prevail. The environment includes both the physical environment and the modification of that environment by the associated biotic factors (Vesey-Fitzgerald, 1970). The physical environment includes: landform, physical and chemical characteristics of soil, climate, and fire. Biotic factors, such as herbivory, modify the environment by altering shading, transpiration, and circulation of nutrients. Consideration of past and present conditions is relevant because each plant community has a history of change, and the present vegetation represents a point along a temporal gradient (Lind and Morrison, 1974).

In Kenya, no comprehensive description exists of plant communities and species abundance along environmental gradients at the range-site level. To be able to understand and properly manage range-forage resources, it is imperative to investigate the environmental factors that influence distribution patterns of vegetation. The purpose of this study was to provide a quantitative analysis of the plant communities and associated environmental factors of climate, soils, topography, drainage, fire, animals, and human activities for the National Range Research Station at Kiboko.

STUDY AREA

The National Range Research Station consists of 27,000 ha in south-central Kenya. It is bounded by latitudes 2°10′ and 2°25′S and longitudes 37°40′ and 37°55′E. The larger part of the station lies between 915 m and 1,055 m (3,000 to 3,300 ft) above sea level. Geologically, the area is composed of areas underlain with basement-system rocks, lava flows, and alluvium (Saggerson, 1962). The soils of the study area are related to the geology of the area. The rainfall pattern is bimodal because the area falls under the influence of the intertropical convergence zone, which in this region is characterized by a bimodal regime of wet and dry seasons (Whyte, 1968).

The vegetation of the station is divided into three broad categories based on physiographic features (Michieka and Van der Pouw, 1977): the vegetations of the basement plains, the floodplains, and the bottomlands. The station is used for the grazing of cattle, sheep, goats, and wildlife. Evidence of overgrazing exists in most parts of the station, especially close to watering facilities and overnight bomas. Periodic unscheduled fires occur. Rarely are fires set to improve grazing or control tsetse flies.

METHODS

Vegetation Measurements

Extension reconnaissance of the National Range Research Station at Kiboko was made to locate various environmental conditions from which vegetation and environmental measurements were made. This was done with the assistance of the station's personnel. Forty-five samples were selected from areas surveyed for more detailed study based on the criteria of representativeness of various ecological conditions: vegetation, soil properties, topography, and fire and(or) grazing disturbance.

Homogeneous plant communities of sufficient size to avoid edge effect were selected for study. Stands ranged in size from approximately 0.25 ha to 200 ha. Within each stand, foliar cover and frequency of shrubs and trees were determined using 20 rectangular 4-m x 9-m quadrats. The Daubenmire (1968) method was used to estimate foliar cover in classes of 1% to 5%, 6% to 25%, 26% to 59%, 76% to 95%, and 96% to 100%. Foliar cover was determined by vertical projection of the canopy cover minus open areas in the canopy. Quadrats were located across each stand in a stratified random manner by locating several equidistant parallel lines across the stand and selecting quadrat position by use of a random-numbers table.

Foliar cover and frequency of herbaceous species was determined within four 1-m and 1-m contiguous quadrats located along the inside of one 4-m

side of the 4-m x 8-m quadrat. A total of 80 quadrats were thus sampled in each stand. The same percentage categories and procedures for estimating cover were followed as described for shrubs and trees.

Environmental Measurements

A topographic-position value was estimated for each stand. Five categories were established, and each stand was classified into one of the categories. The categories were:

1. slope between 0% and 3%; lowest portion of a local landscape; poorly drained; receives much moisture from runoff and either has a high water table or is flooded for periods of up to several weeks

2. slope between 2% and 7%; located at lower portion of long gradual slope but not the lowest portion of a local landscape; receives runoff from upslope; is moderately well drained

3. slope between 4% and 7%; at the upper mid-slope position of long gradual slope but not the lowest portion of a local landscape; receives runoff upslope; is moderately well drained

4. slope between 8% and 16%; lower portion of steep slope; receives as much runoff as it loses, but subsurface drainage is excessive due to porous soils

5. slopes generally greater than 16%; the highest position in a local landscape; loses much moisture to runoff; is excessively drained because of either slope position or porous soils

Slope, drainage, topographic position, parent material, and degree of rockiness were determined using procedures outlined in the FAO soil-description manual (1977).

Within each stand, several soil samples were obtained from 0-cm to 50-cm depth and pooled to form a composite sample for laboratory analysis. In the field, pH of the upper 10 cm was determined using a Hellige Truog Colorimeter kit, and an estimate of the hand-texture was made. This information was used to compare with laboratory analysis in case a low or high unexpected value was encountered.

Laboratory measurements for the 0-m to 50-m composite samples were made at the Kenya National Labortories at Nairobi. The specific measurements were:

- percentage of sand, silt, and clay, determined by hydrometer method

- pH in water and KCI; pH in KCI was measured using 1:25 soil-solution suspension

- electrical conductivity (EC), determined in a 1:25 soil-solution suspension

- cation-exchange capacity (CEC), determined by successive leaching of the soil with IN sodium acetate of pH 8.2; exchangeable bases were determined using the following procedure: the soil was leached using IN ammonium acetate buffered at pH 7.0, sodium and calcium were determined by EEL flame photometer with addition of lantranum for calcium, magnesium was measured by colorimetric

determination using Thiason yellow reagent, potassium was read on the flame photometer (Soil Conservation Service, 1972), saline soils were prewashed with 70% ethanol until free of CI and SO_4

- percentage $CaCO_3$, determined by gravimetric determination of loss of carbon dioxide (Richards, 1954); this was done only whenever pH was more than 7.3

- organic matter, determined using the Walkley-Black method (Black, 1965)

Each stand was evaluated as adequately as possible for past history of grazing and fire. Station personnel and available station records were consulted.

RESULTS

The vegetation of the National Range Research Station consists of grasslands, bushed grasslands, wooded grasslands, bushlands, dense bushlands, and bushed thickets. Chloris roxburghiana, Digitaria milanjiana, and Chrysopogon aucheri are the most visible annual-grass species at overgrazed areas. Acacia tortilis, A. senegal, Commiphora africana, C. riparia, Grewia bicolor, and Duosperma kilimandscaricum are the dominant shrubs and trees. The grass foliar cover varies from less than 3% to a maximum of 64% with an average of 21%. The woody-species foliar cover varies from 1% to a maximum of 88% with an average of 35%.

A total of 120 species were encountered in sampling the 44 stands. Most of the herbaceous species are of the Gramine family (43 species), and most of the woody species are of the Mimosaceae family (12 species). The genus Eragrostis had the most herbaceous species (5), while the Acacia genus had 8 species. However, the most visible herbaceous species is Chloris roxburghiana, while the most prominent woody species is Commiphora riparia. The most widely distributed grass is Digitaria milanjiana or D. macrophlephara. Also present are the species of the following herbaceous families: Compositae, 8 species; Amaranthaceae, 6 species; and Papilionaceae, 3 species. Other herbaceous families had two or one species. Among the woody families were Burseraceae, 3 species; Tiliaceae, 5 species; and Berbenaceae, 4 species.

Ordination Results

Ordination, based on absolute foliar cover values and reciprocal-averaging ordination procedure, arranged the stands in an array that placed vegetationally similar stands together and, depending on degree of similarity, grouped them into more or less tight clusters. A two-dimensional ordination was calculated, and each of the 44 stands was plotted within the ordination (figure 2).

Environmental/ordination Relationships

To determine how environmental factors related to the ordination, several variables were plotted against the stand locations within the two-axis system. Surface soil-texture class and topographic-position value related well to the stand arrangement. Stand position on axis 1 was strongly and positively correlated with sand percentage, topographic value, and organic matter (table 1). Silt percentage showed a weak positive relationship, while clay percentage showed a strong negative relationship to axis 1.

Axis 2 was positively correlated with CED, $CaCO_3$, EC, pH, and clay percentages and inversely correlated with sand percentage. CEC and sand percentages exhibited the highest correlations (table 1).

The ordination indicates that stand arrangement (axis 1) is related to increasing coarseness in soil texture and increasing topographic value, which is a function of increasing slope and increased surface and subsurface drainage. Thus, the left portion of axis 1 is represented by stands with soils of lower topographic position, poor internal drainage, and higher clay percentages than stands more to the right. At the extreme right, stands are characterized by high topographic position, excessive drainage, and sandy soil texture.

Axis 2 represents increasing clay percentages and is correlated with several factors that suggest increasing nutrient supply. Thus, near the origin of axis 2, stands have low clay and low fertility, while at the opposite extreme stands are more clayey and have a higher fertility status or may become saline.

When taken together, the stands can be divided into four general landscape units: alluvial, basement complex, lower volcanic cone, and upper volcanic cone (figures 1 and 2). These units exhibited internal characteristics that collectively distinguish them from each other (table 2).

Some soil factors also were related to each other. Cation exchange capacity (CEC) was positively related to percentages of silt, clay, pH, and organic matter and inversely related to percentages of sand. Organic matter was positively related to silt and pH and inversely related to topographic position. This indicates that when topographic-position value is low, the pH is high. This means lower areas or depressions may have high pH. $CaCO_3$ was positively related to pH and EC. This is a common relationship. Percentage of clay was inversely related to both topographic position and sand. This is also to be expected because clay is normally high in low-lying areas.

Means and ranges of physical and chemical soil characteristics for the four landscape units (table 2) were consistent with the ordination results. Textural fractions across stands ranged from 20% to 88% for sand, 4% to 28% for silt, and 4% to 64% for clay. The alluvial stands had the highest mean clay percentage, ranging from 42% in an inland waterlogged depression stand to 64% in a stand adjacent to Kiboko River. The lowest clay content was 4% in a volcanic-cone stand. The basement-complex areas had a broad range in clay content from 16% to 42%.

Organic-matter content ranged from 0.4% in a stand in the basement complex to 4.1% in an upper-volcanic cone. The low figure in the basement complex is expected in equatorial areas with an ustic soil-moisture regime in which decomposition processes and use of carbon by microorganisms are high (Sanchez, 1976); but the high organic-matter content in the alluvial soil could be because of incomplete oxidation or absence of appropriate microorganisms to use the organic matter. However, organic matter was exceptionally high only in a few stands. Soil samples from areas where recent dung decomposition took place also could increase the organic-matter content. This was observed in stand 27.

The pH of the volcanic areas was slightly basic in the upper volcanic cone with an average of 7.4 and a range of between 7.1 and 7.9. This is probably due to fibers of $CaCO_3$ and $MgCO_3$ salts found in the volcanic cone area (Michieka and van der Pouw, 1977). The lower volcanic cone

had an average pH of 7.1 and a range of 6.7 to 7.5. The pH of the basement complex was slightly acidic with an average of 6.5 and a range of between 5.6 and 7.1. This is about what to expect in an equatorial area with an ustic soil-moisture regime and basement-complex rocks of semicalcareous groups (Saggerson, 1962). The alluvial stands had the highest and lowest pH with an average of 7.5 and a range of 8.3 and 5.5. The highest was from a stand with saline soil and the lowest was from a seasonally waterlogged stand.

Electrically conductivity (EC) averaged 0.1 for the upper volcanic cone, 0.2 for the lower volcanic cone, 0.3 for the basement complex, and 0.8 for the alluvial stands.

The cation exchange capacity (CEC) ranged from 14.2 in a basement-complex stand to 41.0 in an alluvial stand. The averages were 20.3, 16.7, 14.8, and 31.8 in the upper volcanic cone, lower volcanic cone, basement complex, and alluvial study areas respectively. Cation-exchange capacities of the clay fraction were much higher for the soils of the volcanic-cone areas due to allophane dominance, and CEC:clay ratios were lowest for basement-complex soils due to higher oxide and kaolinite contents.

Plant-species/Ordination Relationships

To determine how species distribution was related to the soil characteristics and stand position on axes 1 and 2, correlation coefficients between these variables and corresponding species' absolute foliar cover were calculated across all 44 stands. Among the species with significant positive relationships to axis 1 were Chrysopogon aucheri, Tricholeana eighingeri, Tephrosia villosa, Rychelytrum roseum, Heteropogon contortus, Aristida mutabilis, Cordia gharaf, and Acacia brevispica. Species with significant positive relationships to axis 2 were Pennisetum mezianum, Sporobolus spicatus, Cyperus spp., and Acacia xanthophloea. This indicates that the species are influenced by the environmental factors associated with the two axes. Species positively related to axis 1 are related to high sand-percentage values and the topography of the volcanic cone, while the species positively related to axis 2 are influenced by the high clay-percentage values and associated soil-chemical properties.

Some species, however, had significant inverse relationships to both axes. Others had nonsignificant relationships with either axis. Among the species that had significant inverse relationships with both axes were Chloris roxburghiana, Digitaria milanjiana, Enteropogon macrostachyus, Acacia tortilis, A. senegal, A. mellifera, Commiphora riparia, C. africana, and Duosperma kilimandscaricum. All of these species were found primarily in the basement complex, which was close to the origin of both axes, indicating that these species are determined by medium characteristics determining axis 1 and axis 2. It already has been established that the axes are related to soil characteristics (increasing sand percentage, increasing clay percentage, and topographic position, respectively). This indicates that the soils of the volcanic areas and alluvial areas are determined by extreme edaphic characteristics while the vegetation of the basement complex is determined by medium soil characteristics. Correspondingly, this suggests that the species characteristic of the basement complex also are determined by medium soil and topographic characteristics. These are the modal environmental conditions expected in the areas. The species characteristic of the volcanic and alluvial areas are determined by extreme

soil conditions and therefore may be referred as edaphic vegetation because the limiting factors are edaphic.

To show individual species patterns with the ordination, the absolute foliar cover of several species was plotted within the axis 1 and axis 2 display of stand arrangement. Species were plotted to show contrast or similarity. Aristida keniensis, Microchloa kunthii, Eragrostis caespitosa, and Solanum incanum were invader species found primarily on overgrazed areas. Themeda triandra occurred in soils with relatively high moisture content from rainfall or runoff. Echnochloa haploclada occurred on soils that are seasonally waterlogged for up to 9 months per year.

To test the validity of the ordination, species not used in the ordination were examined to determine whether they showed logical patterns. The species plotted on the ordination were Eragrostis superba, which occurs primarily on basement-complex areas; Eustachyus paspaloides, which occurs primarily on wetter clayey alluvial areas; Grewia villosa, which occurs primarily on the basement-complex areas; and Maerua kirkii, which occurs primarily on lower volcanic cone. These species did show meaningful patterns within the ordination.

Interspecific competition was determined through calculation of correlation coefficients between absolute foliar cover for species across stands. Positive significant correlations were found between species that occurred in similar sites, while negative significant correlations were found between species that occurred in dissimilar sites. Chloris roxburghiana and Digitaria milanjiana, which occur on basement complex, had a positive significant relationship with each other and a negative significant relationship with Chrysopogon aucheri and Heteropogon contortus, which occur primarily on the volcanic cone. Pennisetum mezianum and Ischaemum brachyatherum, which occur primarily on the alluvial areas, had a positive significant relationship with each other and a negative significant relationship with the species on the other landscape units. Coexistence is suggested for species that are positively correlated because they occur in similar areas; however, competition may occur if they share similar resources. Interspecific relationship is not suggested for species that are negatively correlated because they occur in different sites.

The overall picture is for species more common on stands with sandy clay or clay soils to be positively correlated to each other and negatively correlated to species common on the other soils of the study area.

DISCUSSION

The primary result of the ordination was to depict individual species' relationships to environmental complexes, and it grouped the sampled stands into four more or less distinct groups that were defined as landscape types: the upper volcanic cone, the lower volcanic cone, the basement complex, and alluvial systems.

Within the volcanic areas, Chrysopogon aucheri is dominant on the upper portion while Sehima nervosum is dominant on the lower slopes. Chrysopogon aucheri is found normally in rocky slopes up to 1,670 m above sea level in arid desert regions (Edwards and Bogdan, 1951). On the other hand, Sehima nervosum is common from approximately 600 m to 1,500 m in altitude in relatively limited areas of scattered broadleafed trees of the low-tree/high-grass type within the dry vegetation extending toward

the coastal belt (Dale, 1939). Between altitudes of 750 m and 1,200 m it also is found as a dominant of the grass cover on moister parts of the semidesert grassland on volcanic areas and lava rock. In few sites that had the most runoff water, Themeda triandra is the dominant grass. This grass is widely distributed in eastern Africa and occurs in all zones above 3,000 m in altitude (Edwards and Bogdan, 1951; Lind and Morrison, 1974; Pratt and Gwynne, 1977). In Kenya, the grass is not dominant below 1,200 m in altitude; but, in this study, it was found only locally in the wetter habitats. The grass is adapted to periodic burning because its seeds are buried beyond the range of heat from surface fires (Heady, 1966). Commiphora baluensis, Cordia gharaf, and Acacia brevispica are dominant on the least-weathered lava. Acacia hockii is dominant on the upper portion of the volcanic cone. Triumfetta flavescens is the dominant shrub on stony and rocky volcanic areas that have practically no soil between the rocks. Between the lava-flow mounds on the lower slopes of the cone, Cenchrus ciliaris is present in association with Sehima nervosum and Heteropogon contortus. Acacia tortilis and Combretum apiculatum are two dominant woody species. These areas also receive runoff moisture from the mounds, which act as catchment areas (Hemming, 1965). That is why Combretum apiculatum (which is characteristic of wetter areas) occurs.

Within the basement complex, Digitaria milanjiana and Chloria roxburghiana are the dominant grasses, while Commiphora riparia, C. africana, and various Acacia species are the dominant woody species. Digitaria milanjiana is found normally in dry grassland or scattered bush areas from 600 m to 1,300 m in altitude (Edwards and Bogdan, 1951; Pratt and Gwynne, 1917). Chloris roxburghiana is widely distributed from sea level to 1,200 m in altitude, and it also occurs occasionally at higher altitudes up to approximately 1,600 m. It is common in the semidesert grasslands (ecological zone V) where it is the most important perennial grass. Enteropogon macrostachyus is distributed from sea level to 1,300 m, although it is rather rare above 1,050 m (Edwards and Bogdan, 1951). It is common under woody vegetation in ferrasols (Lind and Morrison, 1974). Panicum maximum, however, which occurred together with Enteropogon macrostachyus in most cases, occurs between 1,200 m and 2,000 m, mainly in the wetter Acacia-Themeda vegetation type (ecological zone IV). Panicum maximum also occurs in areas with black cotton soils (Pratt and Gwynne, 1977). Other species within the basement complex are characteristic of similar climates and soil conditions.

Variations in plant communities within the basement complex may be attributed to various factors. The disturbance factors of grazing and burning seem to be the most important factors at the National Range Research Station and have reduced the vegetation to a secondary state. Continuous heavy grazing by herbivores removes fuel, which reduces incidence of burning and allows woody species to encroach and dominate the plant community. Palatable species are reduced by grazing, while the unpalatable ones increase as a result of reduced competition (Heady, 1966). Reduced vegetation cover and an increase of bare ground results in invasion by annual species that take over the bare areas during the growing season. In Kenya, disturbance species include Aristida keniensis, A. adoensis, Microcloa kunthii, Eragrostis caespitosa, and Rhynchetytrum roseum (Pratt and Gwynne, 1977). Continuous light grazing allows large amounts of fuel to accumulate and, in case of burning, hot fires would kill some woody plants, especially the immature ones (Ivens, 1970). However, Ivens (1970) reported that many species are resistant to burning, while only a few species are moderately resistant or susceptible to burning. He found that Acacia brevispica, A. drepanolobium, A.

hockii, A. senegal, and Combretum apiculatum were resistant to burning, while Commiphora spp. was moderately resistant to burning. Duosperma spp., however, was susceptible to burning. This could explain why the species was found in some heavily grazed areas of the station in which hot fires were unlikely because of lack of fuel. So the combination of disturbance factors with soil, topographic, and microclimatic conditions produce variations in plant communities (Lind and Morrison, 1974). Chance factors also may play a part in the species variation within the basement complex. Presence or absence of seed or the first species to establish itself may explain plant composition and structure in an area (Krebs, 1978).

Within the alluvial areas, Pennisetum mezianum is dominant. This grass is widely distributed in Acacia-Themeda bushed or wooded grassland. The reason for its dominance along rivers or at the moister depressions with vertisols is that the soils have higher moisture than where it normally occurs in the Acacia-Themeda association. Ischaemum brachyatherum, also found on alluvial areas, normally is distributed from sea level to 1,800 m in altitude on vertisols (Edwards and Bogdan, 1951). The woody species common within alluvial areas are those that require a high water table -- seasonally in the case of Acacia drepanolobium and all year in the case of Acacia xanthophloea. Sporobolus spicatus is common in saline soils (gleysols). The grass is distributed from sea level to approximately 1,800 m in altitude in plains with alkaline soils (Pratt and Gwynne, 1977). It is an indicator of alkaline conditions.

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Table 1. Correlation coefficients between stand position on the ordination axes 1 and 2 and their respective soil characteristics and between-soil parameters.

Soil characteristics	Axis 1 position	Axis 2 position	Topographic position	Sand (%)	Silt (%)	Clay (%)	pH	EC	$CaCO_3$	OM (%)	CEC
CEC (meq/100 g)	-.04	.72**	- .06	- .61**	.63**	.34*	.40*	.25	.28	.46*	1.00
OM (%)	.46**	.11	- .49*	- .03	.60*	.25	.45*	- .01	.01	1.00	
$CaCO_3$ (%)	-.16	.38*	- .18	- .18	.11	.24	.47*	.34*	1.00		
EC (mmhos/cm^2)	-.30*	.35*	- .26	.18	.15	.27	.14	1.00			
pH	.29	.33*	.24	.08	.01	- .10	1.00				
Clay (%)	-.78**	.46*	- .73**	- .89**	- .15	1.00					
Silt (%)	.35*	.30*	.23	- .32	1.00						
Sand (%)	.59**	-.58**	.60**	1.00							
Topographic position	.92**	-.22	1.00								

* P<.05
** P<.001

Table 2. Mean and range of environmental variables of stands grouped by landscape type.

	Upper		Lower		Basement complex		Alluvial	
No. of stands	14		7		15		8	
Soil:								
Physical								
Textural class	SL		SCL		SCL/SC		C	
Textural fraction	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Sand (%)	79	(88-60)	61	(78-60)	60	(78-34)	36	(46-20)
Silt (%)	12	(24-8)	20	(22-14)	7	(28-4)	15	(26-6)
Clay (%)	9	(26-6)	19	(32-8)	33	(42-16)	49	(64-42)
Chemical								
OM (%)	2.2	(4.1-.6)	1.0	(2.0-.7)	.8	(1.2-.4)	1.3	(3.4-.6)
pH	7.4	(7.1-7.9)	7.1	(6.7-7.5)	6.5	(7.1-5.6)	7.5	(8.3-5.5)
EC (mmhos/cm^2)	.1	(.2-.1)	.2	(.1-.4)	.3	(3.5-.1)	.8	(3.5-.2)
CEC (meq/100 g)	20.3	(26.0-4.6)	16.7	(20.8-14.2)	14.8	(31.6-6.5)	31.2	(41.0-23.6)
$CaCO_3$ (%)	2.0	(4.7-.1)	.3	(.58-.1)	.2	(2.0-.1)	3.7	(16.1-0)
CEC-clay	2.3		.9		.4		.6	
Topographic position	4.8	(4-5)	2.3	(3-1)	2.0	(2-2)	1.3	(1-2)

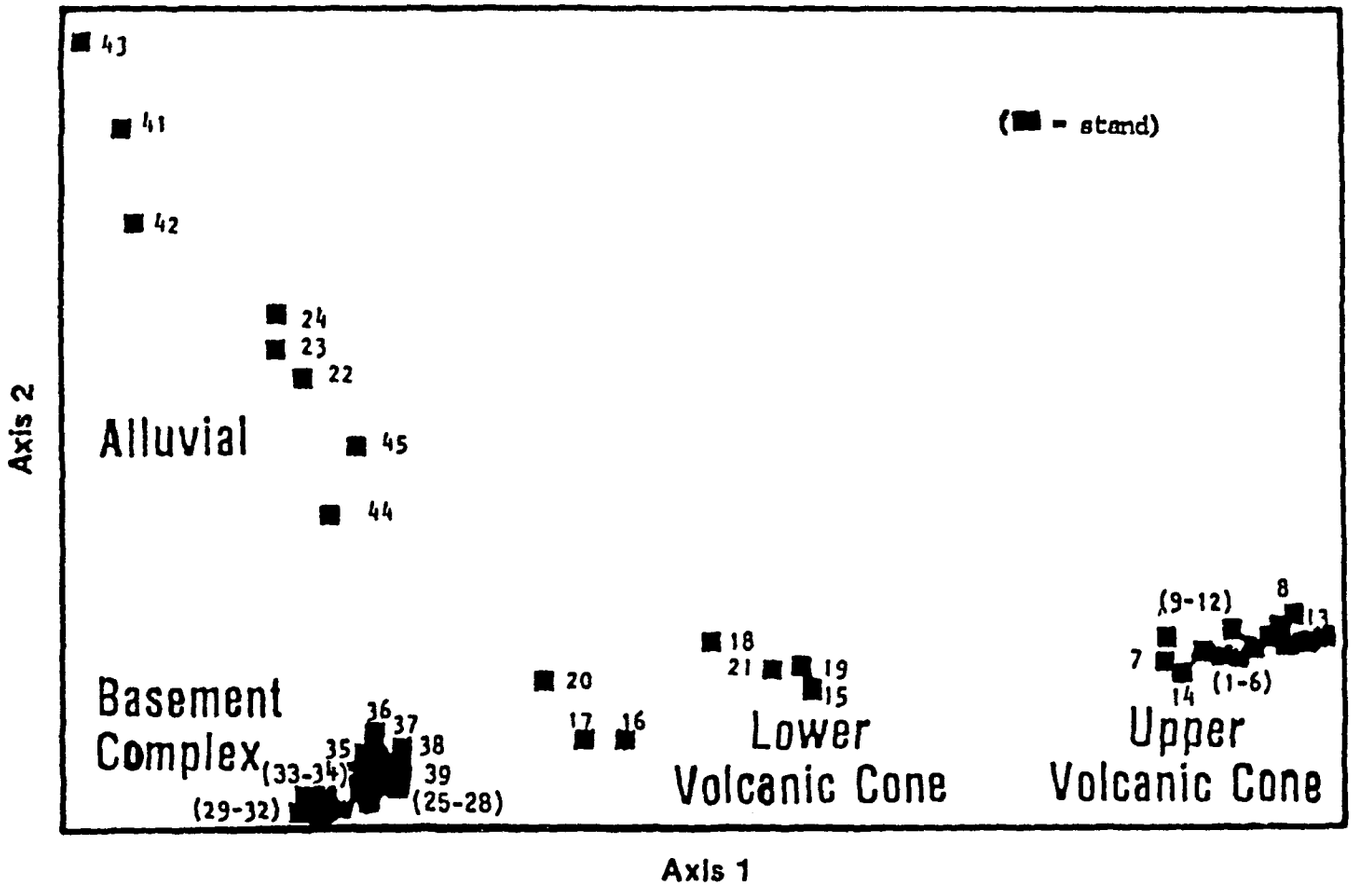

Figure 1. Display of 44 stands within the two-dimensional ordination.

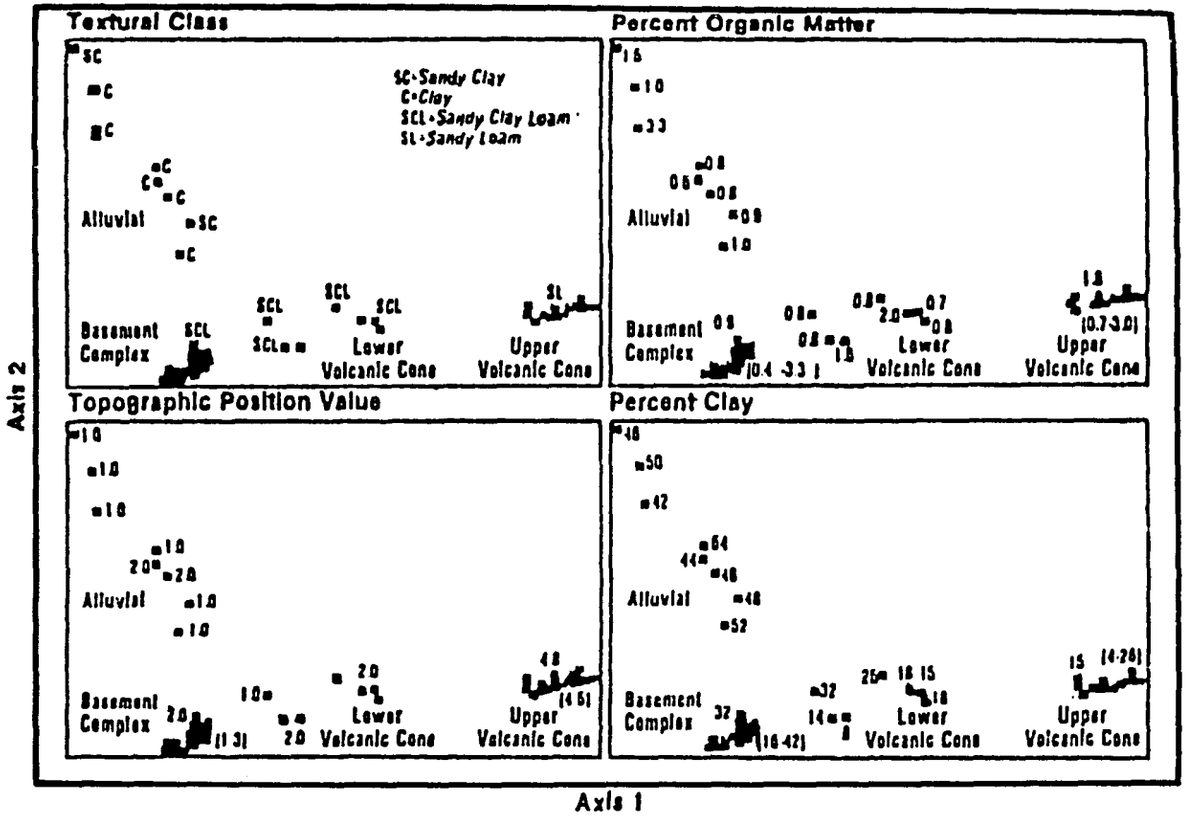

Figure 2. Environmental variables plotted against the two-dimensional ordination. Where several stands occur together, the average and range of values for those stands are given.

SOCIOECONOMICS AND MARKETING

EVOLUTION OF INDIVIDUATION OF GROUP RANCHES IN MASAILAND

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INTRODUCTION

The Masai first settled in Kenya in the early seventeenth century (Huntingford, 1953). Because of their well-organized military system, the Masai were able to defeat such tribes as the Kikuyu, Kamba, Kalenjin, and Laikipia, and alienated large tracts of these tribes' lands. At the height of their economic and political power in the early nineteenth century, their sphere of influence extended from Kwale near Mombasa northward to Laikipia, east of Lake Baringo, and westward nearly to Lake Victoria (figure 1). They grazed their livestock from the Indian Ocean to Lake Victoria (Kenya Land Commission, 1932; Sindiga, 1984).

The Masai developed an extensive nomadic pastoral system regulated by the availability of water and pastures and sometimes the existence or absence of diseases. Their lifestyle was spatially and ecologically designed to provide a stable foundation for their economy. Thus, at the coming of the Europeans, the Masai regional spatial economy was neither stagnant nor isolated (Sindiga, 1984). Colonial intervention in Masailand led to the breakdown of traditional ecosystems through proscribing native reserves in 1904 and again in 1911. This marked the beginning of the loss of their much-valued dry-season grazing areas in the Kenya highlands, which were crucial to the proper management of the Masai pastoral system. Masai in Kajiado continued to lose such areas around Ngong Hills, Mt. Kilimanjaro, and lately Nkurman Escarpment through encroachment by agriculturalists (Campbell, 1979).

The object of this paper is to investigate the circumstances that have led to the evolution of individuation of group ranches in Masailand. The paper discusses development of the group-ranch concept and the achievements and failures of the group-ranch program as a background to the analysis of the stultifying failure of the concept and the factors that actually caused subdivision of group ranches in Kajiado District.

FORMATION OF GROUP RANCHES

The Kenya Livestock Development Program (KLDP) began in 1968. It was intended as a pilot project on which subsequent World Bank livestock projects for African countries would be based (Crotty, 1980). The group-ranch concept, initiated as part of KLDP I, was to be the principal entity by which Masailand (formerly trustlands) would be transformed into deeded holdings with rights and responsibilities of land ownership devolving to the group-ranch members (IBRD, 1977).

Because the proposal for titled communal ownership was unlike existing forms of land tenure, legislation had to be drafted and enacted specifically in the form of the Land (Group Representatives) Act, 1968. However, unofficially, the group-ranch concept was more honestly recognized as simply the least-objectionable means by which to implement tenurial change in Masailand (McCauley, 1976). According to Goldschmidt (1981), acceptance by Masai of the group-ranch concept has derived from "fear of alternative governmental actions rather than enthusiasm for the proposal." Other writers have observed that group-ranch formation has been welcomed as a means of guaranteeing the political integrity of

Masailand by replacement of the spear with the title deed (Cossings, 1980; Fumagalli, 1978; Galaty, 1980).

Although many Masai did not fully grasp the ramifications of the group-ranch approach, it appears that the desire for the security of land tenure (that is, prevention of alienating land to elite Masai and non-Masai individuals) and the opportunities for developing water facilities and dips that the supporting project offered seemed to have coalesced to make the Masai receptive to the concept of group ranches (Galaty, 1977; Hedlund, 1977).

ACHIEVEMENTS OF THE GROUP-RANCH CONCEPT

The group-ranch concept has had a lasting and far reaching impact on Masai pastoralists, albeit some of them unintended or unforeseen. Firstly, it has achieved the major goal for which it was accepted by the Masai. The group ranches have been instrumental in keeping Masailand in the hands of the Masai by effectively preventing further incursion of other tribes in post-independence Kenya. The fact that most of the land was adjudicated to groups who cannot sell the land has prevented wholesale alienation of land through the market. However, it also has provided the medium of transition from a communal form of land tenure to individual tenure, to which we shall return later.

Secondly, group ranches have fostered sedentarization among the Masai, who have developed a sense of group-ranch identity. Masai tend to graze their livestock inside their group ranches during years of nominal rainfall.

Thirdly, Masai have improved the management of their livestock. Through the livestock-development project that accompanied the adjudication of group ranches, new water sources were developed and dips constructed (Bekure and Pasha, 1986).

FAILURE OF THE GROUP-RANCH CONCEPT

While the above are the positive impacts of group ranches, in some areas the intended consequences have not materialized or new, unforeseen or unstated motivational consequences have developed. A major rationale for the group-ranch concept was range conservation. Planners felt that the "tragedy of the commons" was operating in pastoral areas as each individual herd owner was maximizing herd size in unregulated competition with other pastoralists (Bekure and Pasha, 1986).

By the mid-1970s it was widely accepted that group ranches were "much more a concept than a working proposition...and more an exercise in acquiring title to land than an effective means of commercializing beef production" (IBRD, 1977). This assessment has remained essentially unaltered to the present day (White and Meadows, 1981). This failure of the group-ranch program cannot be attributed to any single factor, but certainly an inability or unwillingness to assign liability -- by the government to the group ranch, and by the ranch to its members -- has restrained development. Group ranches also have been described as a "short-term palliative, and in their present form can only hinder regional and national economic development in the long run" (Cohen, 1980).

INDIVIDUAL TENURE

Pressure to subdivide group ranches in Kajiado has been building over the years. It is believed that the desire and haste for individual tenure stems from a variety of factors, including:

- change of government policy
- desire for title deeds as collateral for loans
- desire by the second generation to be registered as members
- frustration with the inefficiency of the organization and management of group ranches

Policy Adopted by Government

In 1981, the government adopted a policy to encourage pastoral people, especially the Masai and the Samburu, to subdivide their group ranches and settle down in individually owned farms or ranches. This policy was adopted with the belief that such a move would improve land productivity in these areas.

Following this move by the government, politicians and administrators in Kajiado District became very vocal in calling for subdivision of group ranches. In turn, this became the major agenda for discussion in nearly all group-ranch committee meetings in the district. As a result, several group-ranch committees passed resolutions in general-assembly meetings to dissolve their group ranches. The required quorum of 60% was achieved in all the general-assembly meetings called to dissolve group ranches (personal communication, 1985).

Individual Title Deeds

Another factor that has triggered subdivision of group ranches is their members' desire to obtain individual title deeds through which they can procure loans from financial institutions to advance their livestock productivity and improve their standards of living. Many group-ranch members in Kaputiei area in Kajiado believe that individual ranchers in the area enjoy a better standard of life, are wealthier, and have improved cattle due to this very factor.

Efficiency of Group-Ranch Committees

The ranch committee is assumed to represent the collective interests of the producers who are the ranch members. The actual situation is more complex because the committee members represent variable ties of age-set and clan within the ranch; are individually subject to age-set, clanship, and friendship pressures from outside the ranch; and are variably subject to regional and national political pressure according to their own beliefs and ambitions. Taking the latter two points together, there are plenty of reasons for disagreement and few organizational options for resolving them. For these and other reasons, the group-ranch committees have in general been ineffective in discharging their duties and responsibilities. They have been unable to manage and maintain dips, water pumps, and engines properly. They have failed to allocate and enforce stock quotas. They have not attempted to organize or effectively control grazing patterns, nor have they managed to enforce the group-ranch boundaries. They have been unable to collect repayment of the AFC loans. In short, they have failed to manage the affairs of the group ranches as the planners envisaged.

As Dyson-Hudson (1982) noted, "There is a tendency for the committee not to meet; or if it meets to deal in noncontroversial generalities; or if it addresses specifics, to be unable to reach a conclusion; or if it reaches a conclusion to be unable to enforce it..."

Second-Generation Issue

The most important factor that has triggered subdivision of group ranches is the pressure from the second generation wishing to be registered as group-ranch members. This pressure has existed in most group ranches in KLDP I for 10 to 13 years (Pasha, 1985). On one hand, young men in the second generation believe that it is their birthright to have access to water and grazing resources in their respective areas of birth. On the other hand, elders believe that this birthright has been superseded by the incorporation of group ranches, whereby a certain group is recognized as the legal owner of a given unit of land.

In the very recent past in Masailand, land has replaced livestock as the dominant resource defining socioeconomic status. Registered members of the group ranches thus resist or refuse to accept any further recruitment of members so as to stake a bigger claim of land when the group ranch is subdivided.

FEAR OF FURTHER LAND ALIENATION

Population pressure on the land in the higher-altitude areas forces families to move down the ecological gradient into marginal lands. Migrants are pressing on the pastoralists and increasing the precariousness of survival (Sindiga, 1984). With the present 4% population growth in Kenya, ethnic groups neighboring the Masai probably will exert even greater pressure to cross over into what appears to be empty land. Signs of such pressure were felt in Kajiado and Narok districts when, in 1984 and 1985, there was insurgency by the Kenya and Kisii tribes respectively to enter Masailand. In the past, such attempts have been repulsed by Masai through resistance by their warriors. This force, which has played a big role in the past to protect Masailand, has slowly been weakened by the government's call to the Masai to abandon outdated practices.

Realizing the consequences of their weakening power to repel intruders, Masai elders have resolved to ask for individuation of group ranches. Under the individual-tenure system, Masailand would be less vulnerable to such insurgence from other ethnic groups. Masai also believe the individual tenure will lessen the government's tendency to devote large tracts of Masailand to special projects such as game parks and settlement schemes that are not directly beneficial to them.

SUBDIVISION OF GROUP RANCHES -- THE PROCESS

All AFC loans must be cleared before the government will approve the subdivision of any group ranch. Once this has been done, the group-ranch committee (assisted by range-management planners and the administration) sets about to partition the group's land. The acceptable practice has been to subdivide the ranch on the basis of equal shares of land for all registered members.

Personal communication with one government official in Kajiado District revealed that the exercise of partitioning group ranches into individual holdings has not always gone smoothly. Sometimes squabbles have arisen

over the sizes of tracts that committee members tended to allocate to themselves and to their close associates. Problems arising during such exercises are beyond the scope of this paper, but what so far has been experienced is just the tip of the iceberg. More complex issues will arise as more Masai begin to realize fully the consequences of subdivision.

Table 1 is a list showing the status of subdivision of group ranches in Kajiado District. The list was compiled toward the end of 1984 and includes:

- all group ranches that have been subdivided (+)
- all group ranches that have passed resolutions to subdivide (-)
- all group ranches that have not considered subdivision at all (?)

It becomes apparent that the Kaputiei subtribe has undertaken the exercise of subdivision more than the other subtribes. Ironically, the same subtribe was the first to accept land adjudication and formation of group ranches in Masailand in the mid-sixties.

Out of a total of 51 group ranches, 7 ranches (14%) already have been subdivided, 22 ranches (43%) have passed resolutions to subdivide, and 20 ranches (43%) have not considered subdivision at all (tables 2 and 3). Sizes of individual holdings, once subdivided on the basis of equal shares, range from 23 ha to 298 ha per member. If all the group ranches subdivided their land on the basis of equal shares, each member would receive on the average about 100 ha (Jacobs, 1984).

A closer look at the seven group ranches that already have implemented subdivision shows that proximity to urban centers, availability of arable and irrigable land, and a long experience with group ranching seem to have added influence. A common feature of those that have resolved not to subdivide seems to be the lack of arable land. All of them are located in the drier parts of the western, southern, and south-eastern parts of the district (figure 2). The only exception to this is Kimana group ranch, which has patches of irrigable land along the Kimana swamps.

SUBDIVISION -- PROS AND CONS

In the preceding section, this paper has touched on factors that are believed to have triggered subdivision of group ranches. The following section focuses on the reasons given by Masai respondents for supporting or opposing subdivision of group ranches.

Those who support subdivision of group ranches pointed out that it would

- help self advancement and uplift the standards of living for the Masai

- help the Masai procure loans since most banks accept freehold title deeds as security

- minimize exploitation of poor households by richer households

- encourage the Masai to engage in other agricultural or industrial enterprises

- facilitate better operation and maintenance of infrastructures that currently are being poorly maintained by inefficient committees

A majority of the Masai who own individual ranches in Kajiado are regarded as wealthy. Most of them own permanent stone houses, automobiles, business premises in trading centers, and, above all, large herds of Sahiwal cattle (a breed of cattle believed to be superior to the African zebu). Many group-ranch members, particularly the young, believe that if they too owned individual ranches they could have easy access to AFC loans and their standards of life would be nearly the same as those of the individual ranchers. Furthermore, in the light of the frustrations of operating group ranches, they seem intent to recognize the autonomy that characterizes the herd owner in the traditional system, but which is hedged about in the group ranches by the natural resources. They are thus convinced that subdivision of group ranches would enhance their self advancement.

What the Masai that reside in group ranches may not have taken into consideration is the size of land that was allocated to individual ranches in the sixties. In those days, each individual was allocated 800 ha.

There are great differences in stock wealth between the members of the same ranch. In a study carried out by ILCA researchers in eastern Kajiado, it was found that in each ranch the wealthy households have eight to ten times the livestock holdings of the poorest households. Thus, while poor households own about 30 to 40 head of cattle, richer households own about 300 head (ILCA, 1984).

The unequal distribution of livestock holdings leads to control of the communal grazing resources by the large producers; in fact, in some instances the rich indirectly claim 70% of the grazing. One of the clauses in each group-ranch constitution reads, "Every member shall be deemed to share in the ownership of the group land in equal undivided shares." To this end, it is apparent that there is an element of exploitation of poorer households by richer households. A majority of group-ranch members believe that such exploitation can be halted only by privatization of land use, which gives each individual member absolute control over his piece. This move would force large-scale producers to destock, which in turn would increase their offtake. The move also would force the rich to buy grazing from the poorer households, thus ensuring some kind of income for those with few or no livestock.

Subdivision of group ranches will limit the area available for continuing, large-scale livestock production. This will force Masai with individual farms to switch to other enterprises such as cropping and keeping other types of livestock (for example, poultry). It will force others to specialize in intensive beef/dairy production or small-stock projects. Where individuals are allocated farms with sand, gypsum, building rock, etc., these individuals probably will concentrate on the sales of those commodities, thus abandoning cattle raising altogether.

BETTER OPERATION AND MAINTENANCE OF INFRASTRUCTURE

When group ranches were incorporated in the early seventies, water points and dips were constructed at great expense. However, very few of these installations have functioned well continuously. A simple survey conducted in 1981 in Kaputiei revealed that only 50% of the dips and 62% of the boreholes were functional (Grandin, 1981).

On many group ranches, dipping has occurred only when acaricide was being provided through loan money. No adequate systems for dividing acaricide or dip attendants have been developed. In many ranches, distances to the only dip are prohibitive for a majority of members. Borehole engines and water pumps frequently break down, and sometimes pipelines leak. It usually takes 1 to 2 months before these malfunctions are corrected. Whereas the cause of these delays is the inefficiency of government organs charged with these responsibilities, the biggest blame is leveled at the ineffective group-ranch committees.

In most cases, chairmen, treasurers, and secretaries of these committees are illiterate and therefore are ill equipped to discharge their duties. In some instances, group-ranch members select a separate committee to run dips. These committees also have failed to run the dips because of interference from chairmen of the main ranch committees or from local politics. Thus, the dips stay unused for long periods of time, forcing most individual producers to resort to hand spraying.

The Masai who support subdivision of group ranches contend that such a move would lead to the removal of weak and inefficient committees, giving a chance to a few able individuals to run and maintain dips and boreholes. They further believe that such a move would enable those with adequate resources to construct their own dips on their individual farms. In the group ranch, no member is allowed to set up a permanent structure like a dip for personal use.

Masai who are opposed to the subdivision offer four reasons:

- Alienation of land to non-Masai. They believe that other ethnic groups that were warded off by the group ranches now will find it easy to buy pieces of Masailand; therefore, they fear an influx of outsiders taking up especially the arable parts.

- They fear, concomitant to this, the cultivation of large tracts of land, which will result in severe erosion like that experience in other parts of Kenya such as the Machakos District.

- They fear that an influx of non-Masai settling among them will result in the erosion and eventual loss of Masai culture, which they want to see preserved.

- They see a danger that, once subdivision of group ranches has been effected, individual owners will tend to protect their private property much more. The usual livestock movements across the group ranch thus will be curtailed, especially by those individuals who might opt to undertake cropping. They will be forced to fence their farms or gardens to protect the crops from wildlife and livestock. With such new developments, the usual free movement of livestock in the ranch will be further constrained.

CONCLUSION

The issue of subdivision of group ranches is a complex one. The pros and cons of subdividing these ranches as expressed by Masai elders balance out. However, the overriding factor in the development of a greater part of Masailand, which must be accepted, is the challenge of the ever-increasing human population. Greater consideration also should be given to the ecological variability and the erratic rainfall pattern.

Just as the majority of Masai did not grasp the ramifications of the group-ranch approach, the implications of subdividing group ranches into smaller holdings does not seem to be well understood. The haste in which the issue has been handled may have far-reaching consequences. Masai with large herds and flocks will have to sell off their animals or buy or rent land for lack of adequate grazing areas. The small farms they each receive will not sustain their big herds. Those with few animals will hire grazing, and they probably will purchase more livestock with the added income. This will result in further overstocking of small farms. The young and adventurous will sell their pieces indiscriminately, squander the money, and render themselves landless and unemployed.

Subdivision of group ranches also will have important implications for the supply of beef to the urban areas. There will be limited land on which to raise beef cattle on a large scale.

Therefore, both the Masai and the government must approach cautiously the question of subdividing group ranches. The government should use its resources to research this complex issue and to design means to ease the pain that the Masai will feel while adjusting to the new land tenure.

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Table 1. A list of group ranches in Kajaido District showing membership for 1984.

Name	Size(ha)	Members	Ave. ha/mem	Est. ha/SU	Est. total/SU	Subdiv. status	Sub-tribe
Phase I							
Poka	8926	30	298	6	1925	+	Kaputiei
Kiboko	15870	64	240	7	3510	-	"
Olkarkar	10280	93	111	7	2402	-	"
Merueshi	18546	125	148	6	3695	-	"
Mbilin	14723	89	165	4	2879	-	"
Mbuko	18477	88	210	7.5	3603	-	"
Nkama	39760	490	81	4.5	7575	-	"
Arroi	18692	107	175	6	3972	-	"
Imaroro/ Mashuuru	19483	381	51	6	5358	-	"
Erankau	8985	90	100	6	2124	-	"
Ilmamen	12194	125	98	5	2586	-	"
Emarti	13211	126	105	5	2032	+	"
Empuyiankat	15270	97	157	5	3864	+	"
Embolioi	24000	302	79	6	3602	+	"
Olkinos	6020	115	52	5	2263	+	"
Subtotal	244437	2322	(105)	(6)			
Phase II							
Rombo	38365	760	50	5	5540	?	Kisongo
Kuku	96000	604	159	6	37507	?	"
Kimana/ Tikondo	25120	168	150	6	5542	-	"
Osilalei	38629	419	92	5	12932	?	Lodokilani
Oldoinyo-Nyokie	68566	247	278	3	13304	?	"
Kilonito	25685	174	148	5	5286	-	"
Shombole	62689	366	171	8	8253	?	"
Olkiramatian	21612	187	116	8	4247	?	"
Olkeri	24852	222	112	5	10163	?	"
Torosei	46445	165	281	5.5	2864	?	"
Elangata Wuas	59497	658	90	5	3695	-	"
Nkoile	6208	271	23	6	2309	-	Ildamat
Esokuta	4109	65	63	5	1755	-	"
Olkiloriti	6439	87	74	5	2402	-	"
Oloyiankalani	9606	117	82	4.5	2402	-	"
Enkaroni	11378	336	34	5	2864	-	"
Subtotal	545197	4846	(113)	(5)	121065		

Table 1. A list of group ranches in Kajaido District shoving membership for 1984 (continued).

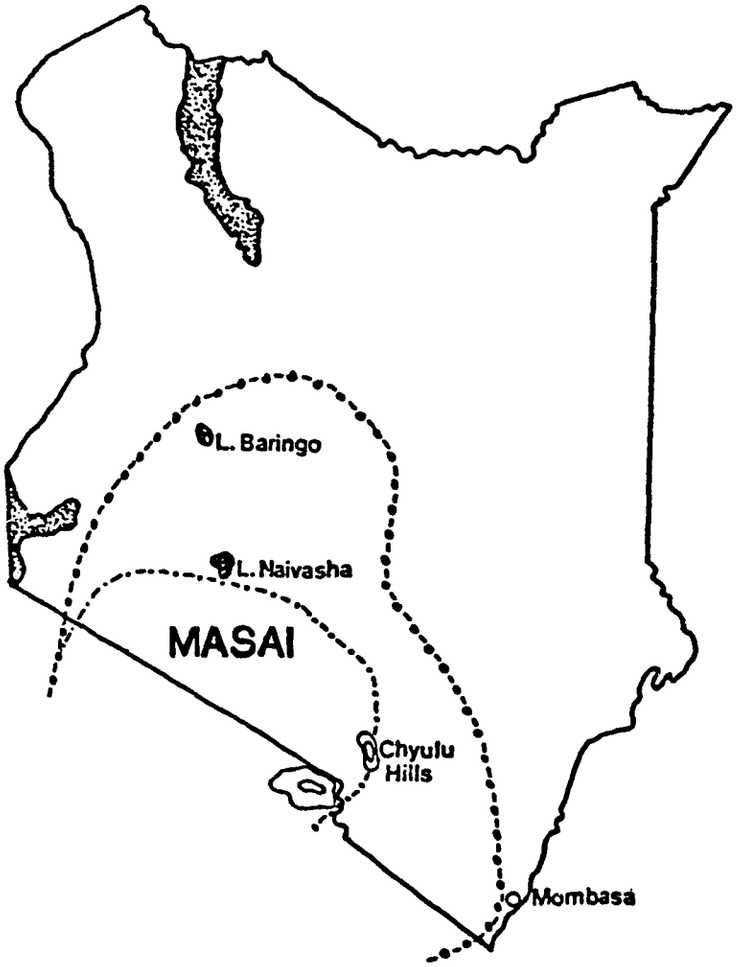
Phase III							
Ewaso Kedong	53136	484	108	5	17074	?	Keekoonyokie
Loodo Ariak	57065	500	114	5	14704	-	"
Oldoinyo Orok	28701	322	89	5	5235	-	"
Nentanai	3692	51	72	5	2093	?	"
Olpartimaro	19645	324	61	6	5358	?	"
Saikeri	7531	114	66	6	2540	?	"
Olosho-oibor	3000	127	24	6	2078	?	"
Sajiloni	15711	450	35	6	2879	-	Dalalekutuk
Enkorika	15923	369	43	6	2879	-	"
Oloomunyi	10057	157	64	6	3233	?	"
Olgirra/ Oloolotugum	12925	157	84	6	4002	?	"
Olgulului/Olo Olarashi	147050	1031	143	6	20785	?	Kisongo
Mbirikani	125893	922	137	7	21092	?	"
Selenkei/ Motoroki	74794	400	187	6	16167	?	"
Kitengela	18292	233	79	5	3972	+	Kaputiei
Kipeto/Kisaju	4945	44	112	6	1925	+	"
Meto	28928	425	68	5	5260	?	Matapato
Olngosua	38282	472	81	6	4003	?	"
Mailna	63026	642	98	6	17013	?	"
Subtotal	731283	7420	(99)	(5.8)	153293		

Table 2. Frequency distribution of various sizes (ha) for the 51 group ranches in Kajiado District.

Size (ha)	Number	Percentage
<10,000	12	24
10,000-50,000	29	56
50,000-100,000	8	16
>100,000	2	4
	51	100

Table 3. Frequency distribution of varying plot size per member for the 51 group ranches in Kajiado District.

Size of plot (ha)	Number	Percentage
<50	7	14
50-100	21	41
100-200	18	35
>200	5	10
	51	100



Masai sphere of influence, late 19th century

Masai territory after colonial period, early 20th century

Figure 1. Masailand in the early nineteenth century.

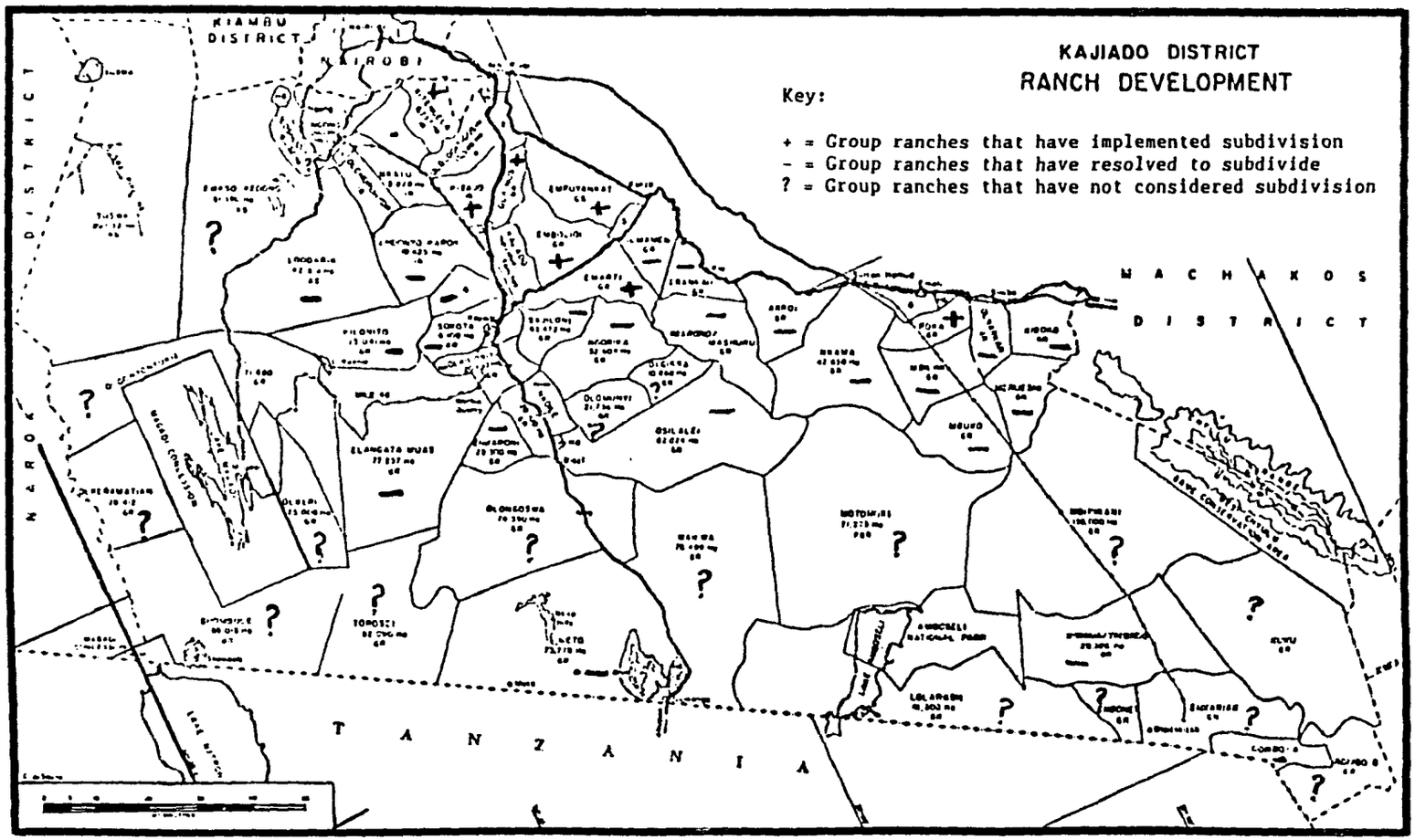


Figure 2. Group ranches' positions on subdivision.

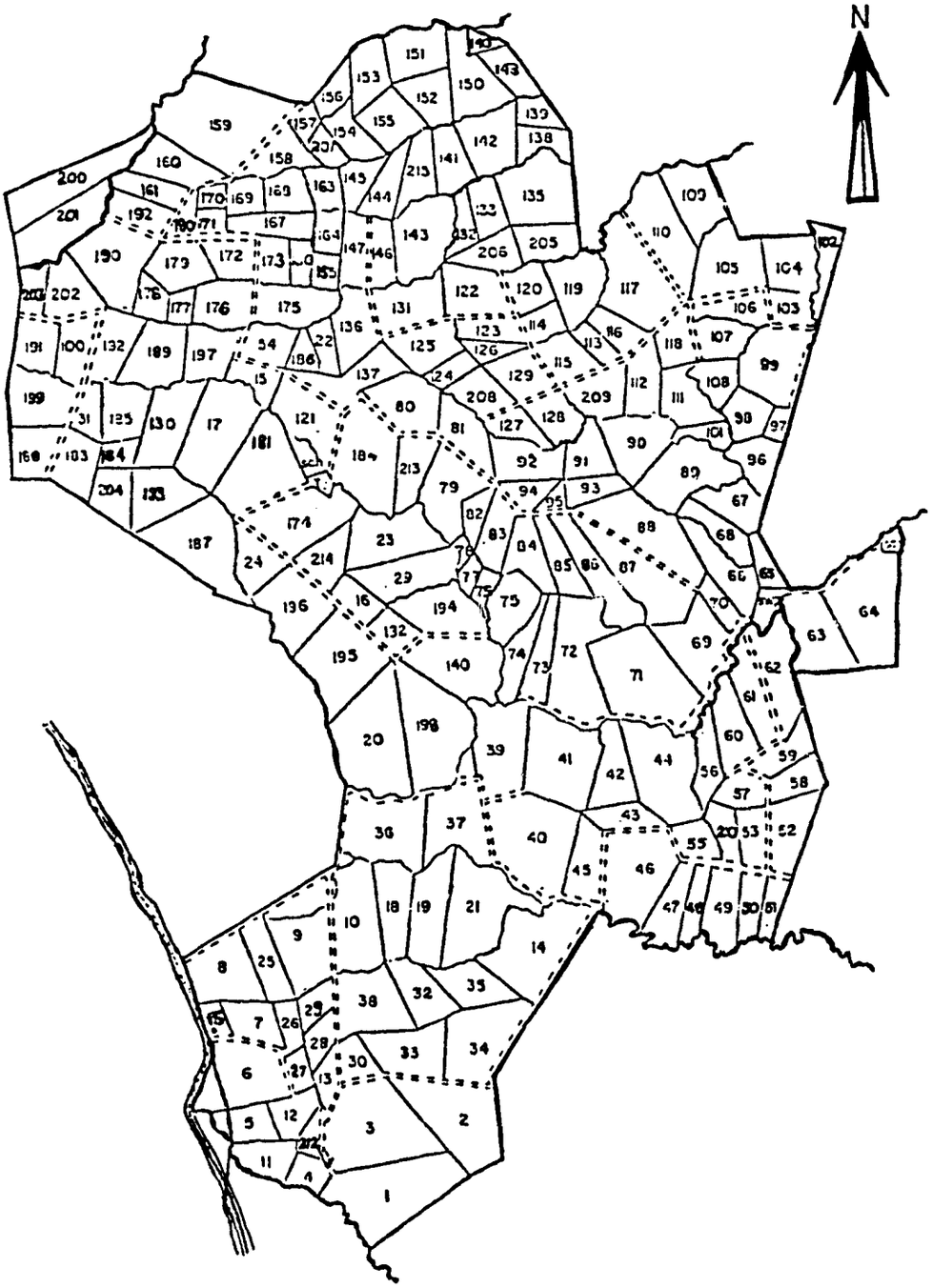


Figure 3. Kitengela group ranch subdivision.

ECONOMIC JUSTIFICATION FOR RANGE RESEARCH IN KENYA

Adrian Wekulo Mukhebi

RANGELAND DEFINED

Kenya's rangeland is defined as the land area that is unsuitable for arable farming or intensive livestock production and that often is referred to as the low-potential or arid and semiarid lands (Bernsten and Jacobs, 1983). Periodic droughts and high rainfall variability and unreliability are constant features of the rangeland, which also displays marked differences in vegetation types and cover influenced largely by variations in altitude and rainfall. Table 1 summarizes the major ecological zones covering Kenya's rangeland.

RANGE RESOURCES AND USE

In economic terms, Kenya's rangeland occupies 80% of the total land area and supports about 20% of the human population, 50% of the national cattle herd, 78% of the shoats flock, 99% of the camel population, and over 90% of the wildlife population (Bernsten, 1983). The four major types of land-use systems in the rangeland are commercial (individual, company, and cooperative) ranching, which holds about 25% of all rangeland cattle; pastoral (group and grazing-block) ranching with 50% of rangeland herd; traditional (agropastoral and free-ranging) systems, holding 25% of the rangeland herd; and the national game parks and reserves, which contain over 75% of the national wildlife population.

Although the rangeland comprises a large share of national resources in terms of the land area and human, livestock, and wildlife populations, its potential for substantial contribution to the national economy remains underexploited. In its quest to increase food production to feed a rapidly rising human population, Kenya has hitherto concentrated upon the high-potential (arable) areas that constitute less than 20% of the land mass. As the capacity for increased food production in the high-potential areas becomes stretched, the country is increasingly turning toward the rangelands for more food production (Mukhebi, 1985). The national food policy (Kenya, 1981) and livestock policy (Kenya, 1980b) both underline the need for the development of rangelands for increased production of food and agroindustrial raw materials.

NEED FOR RANGE RESEARCH

Increasing and sustaining production from the rangeland will require application of new and improved crop- and animal-producing technologies for all the rangeland production systems. There are no appropriate technologies on the shelf awaiting application. Both basic and applied research based in the rangeland will have to be undertaken to develop them. Even technologies that can be transferred in from elsewhere will require research on farms and ranches to test and evaluate them for feasibility under Kenya's rangeland conditions. Rangeland research is needed for generating information and technologies for improving range-resource productivity, resolving rangeland-use conflicts, and protecting and enhancing the rangeland environment. These activities would enhance and sustain the capacity of the rangeland to support and improve the welfare of an increasing human population and the national economy.

IMPROVING PRODUCTIVITY OF RANGE RESOURCES

The major products of rangeland-production systems are meat, milk, hides and skins, tourism, and crops (to some extent limited by soil and weather conditions). Land is the most important resource of the rangeland in its current use. Given the climate, its capacity to produce crop products depends upon the varieties of crops grown and the types and quantities of inputs applied. On the other hand, its capacity to produce animal products from both livestock and wildlife depends upon its ability to produce edible forage and the management of the use of that forage. The low productivity per unit of land and livestock for these products in the rangeland, with consequent low standards of living of the rangeland peoples, is well documented (Pratt and Gwynne, 1977; Sullivan et al., 1980; Rukandema et al., 1983; ILCA, 1983). For instance, the International Livestock Centre for Africa (ILCA) indicates that, for agropastoral systems, farmers' crop yields are less than 50% of what could be achieved with application of improved technologies; milk yield is merely 400 kg per lactation; only about 30% of farm area is cropped; and per capita farm income is extremely low (Ksh. 246 or US $20 in 1983).

Rangeland studies have advanced various causes of low productivity: recent droughts (Pratt and Gwynne, 1977), low and erratic rainfall (ILCA, 1983), communal land tenure (Sullivan et al., 1980; Hopcraft, 1980), use of unimproved traditional technologies (Rukandema et al., 1983; ILCA, 1983), underdeveloped infrastructure and animal diseases (Kenya, 1980b), implementation of inappropriate projects such as provision of water- and disease-control services that lead to livestock populations beyond the sustaining capacity of the rangeland (Hopcraft, 1980), and simple misallocation of rangeland resources to producing inappropriate products (for example, using land for cropping that has comparative advantage for producing animal products).

The enumeration of general constraints to increased rangeland productivity, as is often done by those concerned with rangeland development, is not very useful for developing technologies that address problems of specific rangeland areas. Some of the constraints such as recurrent droughts are simply a given feature of the rangelands, while others such as communal land tenure and inappropriate land use are area specific. Research is needed to identify and rank area-specific constraints, especially from the producers' point of view, to guide the development of appropriate technologies. Such research also may identify area-specific pressing but nonresearchable constraints that require institutional or political solutions as a precondition for any other development strategy. In this regard, the National Range Research Station (NRRS) at Kiboko, in collaboration with ILCA and Egerton College, has initiated systems research in Kajiado and the southern part of Machakos District aimed at identifying and ranking area-specific rangeland constraints and at designing and testing technologies on the farm and ranch for alleviating some of the constraints. The work of the National Dryland Farming Research Station at Katumani and the Integrated Programme for Arid and Semi-Arid Lands (IPAL) in northern Kenya have similar aims. These efforts should be continued and expanded to wider range areas to achieve greater impact.

RESOLVING RANGELAND-USE CONFLICTS

The rapid growth of human population, both from natural increase and immigration from the high-potential areas (Jacobs, 1983), has precipitated several land-use conflicts in range areas (Mukhebi, 1985).

The most apparent of these conflicts are livestock versus wildlife, livestock versus crops, and crops versus wildlife.

The conflict between livestock and wildlife has been discussed in several studies (Pearse, 1968; MacDowell, 1983; Ayoko, 1985; Aboud, 1985; Mwangi and Sulberti, 1985). Livestock primarily produce food (meat and milk) needed by the growing human population. On the other hand, through tourism wildlife is a significant source of foreign exchange required by the national economy for the importation of essential commodities and settlement of external debts and obligations. The conflict arises from the competition between livestock and wildlife for forage and water, predation by wildlife on livestock, and transmission of diseases and parasites between the two animal types.

Most studies that discuss the livestock-wildlife conflict merely describe the existence of the conflict and expound the multiple-product-optimization economic theory for resolving the conflict. Research is now needed to quantify the input-output, product-product, and price (value) relationships for determining practices and management strategies for optimal allocation of rangeland resources for the production of livestock and(or) wildlife under various rangeland conditions, taking into account the interests of both the rangeland peoples (traditional values) and the national economy (commercial values).

Population growth has led to the expansion of sedentary agriculture into some range areas that were used traditionally only for grazing livestock. As the human population has continued to grow, the cultivation and cropping of areas that are even unsuitable for any arable farming has accelerated, notwithstanding the frequent crop failures. The issue of whether to crop or graze these areas has received heightened discussions in several forums. Although some studies (O'Leary, 1980; Brandstrom et al., 1979; Dahl et al., 1976) show a complementary relationship between cropping and grazing in these areas, the competitive relationship appears to assume greater proportions with population increase. The competition is accentuated by the fact that the encroachment of cropping in these areas denies traditionally vital dry-season grazing to pastoralists who inhabit the lower-rainfall rangelands. Research-generated information is needed for the formulation of policy guidelines for the use of these areas or for designing alternative production systems that would alleviate existing conflicts.

The last of the major rangeland-use conflicts is the one between cropping and wildlife, caused by the predation of wildlife on field crops and stored grain. Birds and herbivorous wild game often cause extensive damage to crops. Although the government is committed to paying compensation to the victims of damage, such compensation often is delayed or inadequate and sometimes never paid at all (Aboud, 1985). However, the authorities point out that such problems about compensation often arise due to inadequate or inaccurate information provided by claimants. Presumably, the claimants are not adequately educated as to the legal requirements for filing their damage claims. Research can assist in quantifying the extent and nature of damage for various areas, and extension can assist in education to facilitate timely and adequate payment of compensation.

PROTECTING AND ENHANCING RANGELAND ENVIRONMENT

Most of the rangelands in Africa are in a state of decline (Muchena, 1985). Increased cropping of rangelands, cutting of trees for fuel and

construction, and continuing build up and concentration of livestock herds and flocks to support growing human population have depleted vegetation cover in many areas. This has exposed the ground surface to serious soil erosion from wind and water leading to growing desertification of the rangeland.

Increased and sustained use of the rangeland for the benefit of both the rangeland peoples and the national economy require careful management and conservation of the limited rangeland resources (plants, animals, soils, water). Child et al. (1984) stated that a compelling reason for conserving the range environment is that the values received from rangeland (production) often are not high enough to justify the large investments required to correct land damage caused by past mistakes. Furthermore, they point out that direct rangeland-improvement practices such as revegetation, water conservation, brush management, and prescribed fire should be undertaken only as a last resort in semiarid and arid regions because insufficient rainfall often causes them to fail. Research in plant-animal-soil-water relationships can generate management and conservation techniques that would maintain a productive state of the rangeland for its multiple uses without costly degradation.

RANGE RESEARCH IN KENYA

The author is compiling an annotated bibliography of range-research and development projects in Kenya. It was not ready at the time of writing this paper, but it will be available soon from the Socioeconomics Division of the National Range Research Station at Kiboko.

Current major range research is conducted by the NRRS at Kiboko in Machakos District and its substation at Buchuma in Taita Taveta District. The NRRS has the national mandate for conducting research in all arid and semiarid areas of Kenya. The bulk of its current basic- and applied-research activities, which are supported by the United States Agency for International Development (USAID) through Winrock International, are in the area of biological research (understanding and developing management strategies for plant-animal-water-soil relationships) and socioeconomic research (provision of socioeconomic input into biological research and socioeconomic characterization of rangeland production systems).

Range research also is conducted by several other national institutions and international organizations. Notable among these are the Range Management Division of the Ministry of Agriculture and Livestock Development, which conducts short-term studies from time to time for policymaking and other uses; the National Dryland Farming Research Station at Katumani; the Kenya Rangeland Ecological Monitoring Unit (KREMU) in Nairobi, which undertakes inventory and analysis of range-resource base; the Survey of Kenya in Nairobi, which carries out land-use planning for the rangelands; the University of Nairobi's Range Management Department and the Institute of Development Studies; Egerton College's Range Management Department, which conducts a variety of basic and applied range research; and the International Livestock Centre for Africa (ILCA) in Nairobi and the Integrated Programme for Arid and Semi-arid Lands (IPAL) in northern Kenya, which do applied research in pastoral systems.

The list of institutions at which range research is performed in Kenya is by no means exhaustive, and the brief descriptions of what range research has been or is being conducted by the various institutions is

not comprehensive. Representatives of the institutions mentioned who are present at this workshop can give a full account of their range-research activities at a moment's request. Indeed, one of the hidden agenda for a workshop of this nature is to provide opportunity for participants to interact with each another and exchange information and views about each other's activities at their respective institutions with a view to establishing some degree of networking in the future.

Various areas of needed future research have been alluded to in this paper. Perhaps an appropriate approach now for those interested in range research is to take stock of what range research has been proposed (Pratt, 1975; Galaty et al., 1980) and done in the past and what is being done currently, and chart a coordinated strategy for range research to the year 2000. If this cannot be accomplished at this workshop, the author proposes it as a priority agenda for the Kenyan Range Management Society.

SUMMARY

Kenya's rangeland is a vast, fragile, and underused resource. Its importance to the people who inhabit it and the national economy is gaining recognition as the country strives to produce adequate food supplies to feed a human population that is experiencing runaway growth.

Increasing and sustaining production from the rangeland will require application of appropriate new and improved technologies that have yet to be developed or adapted. Range research is needed to generate necessary information and technologies for improving range resource productivity, resolving current range-use conflicts, and protecting and enhancing the range environment. These activities would enhance and sustain the capacity of the rangeland to support and improve the welfare of an increasing human population and the national economy.

Some national and international institutions are conducting range research in the country with little national coordination or planning. Those interested in range research should take stock of what has been done in the past and what is being done currently and chart a coordinated strategy for undertaking future range research.

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Table 1. Ecological zones of Kenya's rangeland.

Zone	Classification	Av. annual rainfall (mm)	Vegetation	Maize failure rate (%)
IV	Semihumid to semiarid	600-1100	Dry forest and bushland	10-25
V	Semiarid	450-900	Bushland	25-75
VI	Arid	300-550	Bushland and scrubland	75-95
VII	Very arid	150-350	Desert scrub	95-100

Source: Kenya MALD, 1980; Pratt and Gwynne, 1977, in Jacobs, 1984.

MARKETING OF RANGE CATTLE IN KENYA

Evans P. Mveya

SUMMARY

Marketing of range cattle in Kenya begins when the cattle part with the primary producer and ends when they reach slaughterhouses (or ports in the case of export cattle). The process of marketing involves changing ownership, backgrounding, transporting, and quarantining.

The Kenya Meat Commission, which was established by the government in 1952, provides a guaranteed terminal market and is supplemented by other smaller slaughterhouses so the terminal market is more or less guaranteed. Since 1952, the main emphasis has been on moving cattle to market.

Between 1968 and 1982, the government implemented the first and second phases of the Kenya Livestock Development Project. During this period, the Livestock Marketing Division (LMD) of the Ministry of Agriculture developed the physical facilities necessary for smooth flow of livestock from the range areas to the market. The Livestock Marketing Division also developed into a major middleman who bought cattle from both traders and producers and was the main supplier of slaughter cattle to the Kenya Meat Commission and feeder cattle to the ranchers.

Since 1903, the Livestock Marketing Division has not been provided with funds for purchase of cattle. The Kenya Meat Commission and the traders effectively have taken over the trade for slaughter stock but have shown little interest in feeder cattle, mainly because of the quarantine requirements. In turn, the supply of feeder cattle to ranchers has been adversely affected. This problem has to be solved if ranches are to succeed.

INTRODUCTION

Marketing of range cattle in Kenya, like the marketing of other agricultural products, begins when the cattle part with the primary producer and ends when the meat reaches the consumer. However, for purposes of this paper, emphasis is placed on the marketing of the live cattle, and the process is presumed to end when the cattle reach the slaughterhouses or, in case of cattle destined for export markets, when they reach the port.

In its simplest form, for example, marketing range cattle involves the producer selling a steer to a local butcher for slaughter. In its more complicated form, a trader may buy an immature steer from the primary producer and sell it to a bigger trader, who in turn sells the steer to the Livestock Marketing Division for quarantining and subsequent resale to a rancher. The rancher fattens the steer and finally sells it for slaughter or export. The process involves changing ownership, backgrounding, transporting, quarantining. This paper attempts to explain how these processes have developed over time and how they take place.

GROWTH OF RANGE-CATTLE MARKETING

Cattle in Kenya's rangelands always have been marketed. One of the most important early developments was the establishment of the Kenya Meat Commission (KMC) by Kenya's government in 1952.

The Kenya Meat Commission was charged with the responsibility of regulating cattle and meat prices and providing a guaranteed market for slaughter cattle. With the opening of more slaughter facilities in urban centers in later years, the availability of the terminal market for range cattle has generally been taken for granted, and the major problem has been how to get the cattle to the terminal market at minimum cost.

EFFECT OF RANGE DEVELOPMENT ON MARKETING

In 1968, the government -- with financial assistance from the World Bank -- started Phase I of the National Livestock Development Project, which ended in 1974 and was followed closely by Phase II, which ended in 1982.

One of the main premises on which the project was based was that the quality and quantity of beef produced in Kenya could be greatly increased if the low-potential pastoral range areas could be developed as a source of feeder cattle to be sold to ranchers in the high-potential range areas for fattening and final sale for slaughter. Therefore, livestock marketing was considered an important component of the project.

In 1970, the Livestock Marketing Division was created and charged with the responsibility of developing physical facilities such as buying centers, stock routes, collection holding grounds, and quarantine holding grounds and the organizational structure necessary to ensure steady flow of feeder cattle from the source to the ranching areas for fattening before final sale for slaughter. In addition to providing the organizational structure and developing physical facilities, the Livestock Marketing Division was responsible for buying the feeder cattle, quarantining them, and reselling the clean feeder cattle to ranchers for fattening.

By 1976, the Livestock Marketing Division had become the major middleman, buying from both producers and traders, transporting the cattle to quarantine facilities, and later reselling them to ranchers. The numbers of cattle handled by the Livestock Marketing Division from 1970 to 1983 are as follows:

Year	Number
1970-71	52,068
1971-72	45,432
1972-73	53,970
1973-74	23,043
1974-75	62,227
1975-76	4,546
1976-77	22,844
1977-78	1,234
1978-79	21,954
1979-80	31,166
1980-81	17,101
1981-82	5,970
1982-83	190

By the end of the project in December 1982, most of the physical facilities that had been planned had been developed. However, as the cattle-purchase figures show, the number of cattle purchased by the Livestock Marketing Division had started to decline. During fiscal year 1983-84,

the treasury did not provide the Livestock Marketing Division with funds for the purchase of cattle, and no funds have been provided to the Livestock Marketing Division for livestock purchase since then.

LIVESTOCK TRADING WITHOUT THE LIVESTOCK MARKETING DIVISION

At the height of Livestock Marketing Division's trading activities, around 1975, traders had come to accept the division as the official middleman. Instead of treating it as a competitor, they treated it as a convenient shock absorber for risk since they could buy their cattle and almost immediately resell them to the Livestock Marketing Division without having to risk losses during trekking and quarantining that normally took more than six months. The division was then left to do the trekking and quarantining. Even the Kenya Meat Commission found it convenient to buy slaughter stock from the Livestock Marketing Division.

When the division ceased to receive funds for cattle purchase and instead concentrated on the maintenance of the physical facilities used by livestock traders, the traders and the Kenya Meat Commission took over almost all the slaughter-stock trade without any apparent serious problem. However, the sector that has suffered greatly from the stoppage of the Livestock Marketing Division's trading activities is that of the provision of feeder cattle to ranchers. The Kenya Meat Commission is only interested in slaughter stock, while the traders are reluctant to take the risk of having to purchase feeder cattle and hold them for more than 4 months during the quarantine process. This means that ranchers cannot get adequate supplies of fattening immatures, and this is affecting the ranches' viability. This problem needs solution if ranches are to be rescued from this dilemma; but, as of now, no solution has been found.

CASE STUDY OF LIVESTOCK MARKETING AMONG THE RENDILLE OF MARSABIT

G. K. Njiru

INTRODUCTION

This paper reports the findings of a study among the Rendille of Marsabit District. This is a tribe of approximately 21,000 people (1979 Census). Of these, 19,856 occupy Laisamis Division of Marsabit District, forming the bulk of its population of 24,143 people. They are pastoral nomads who keep camels, sheep, goats, cattle, and a few donkeys. Due to low potential of the land, the animals must keep moving from place to place because grazing or browse in each place is quickly exhausted. The Rendille therefore remain in a place only while grazing is good and move as soon as it is depleted. The development of trading centers has changed this, and some portions of the Rendille are now more or less permanently settled.

The Rendille occupy about 22,000 km^2. Their home range is bounded by Lake Turkana to the west, Oldoinyo Mara and Ndoto Mountains to the southwest, River Marille to the south, Chalbi Desert to the north, and Marsabit Mountain to the northeast. Figure 1 shows the position of Rendille country in Kenya. Most of the area lies between 400 m and 700 m above sea level and receives annual precipitation of 100 mm to 200 mm in the lowlands, which generally increases to 700 mm in the highlands. The predominant vegetation types are annual grasslands, dwarf shrubland, and shrubland which cover approximately 80% of the land (Herlocker, 1979). Woodland, bushland, and perennial grassland occur along seasonal rivers and on the slopes of Mt. Marsabit and Kulal and the Ndoto Range.

Their economy is subsistent, and until recently little was produced for market. Livestock, livestock products, and natural vegetation supplies most of the people's demand for food, clothing, housing, and domestic utensils. Most of their diet -- 60% to 90% -- is milk, of which 80% is camel milk because the milk supplied by cattle and goats is available only in very small quantities during the dry season. The rest of the diet is composed of blood and purchased maize meal, sugar, and tea that are brought in from outside the area. Money for the purchase of these foods and a few other items comes from livestock sales and earnings of a few Rendille who have jobs.

The objective of this paper is to describe the livestock marketing system among the Rendille and the constraints to raising offtake and to recommend how the constraints can be overcome.

METHODS OF DATA COLLECTION

The data were collected between January 1980 and April 1982 (but with observations continuing to this day) through library and archival research; participant observation; and formal and informal interviews of chiefs, councillors, missionaries, district heads of livestock, marketers, traders, providers of veterinary services, range-management personnel, and approximately 90% of all traders with shops in the study area. Structured questionnaires of traders, pastoralists, and wage-income earners among the Rendille also were administered.

Trading centers in the area and all livestock-purchasing visits to the area by the Kenya Meat Commission and the Livestock Marketing Division

between 1980 and 1985 also were attended. The author has since this time become engaged in livestock-trading activities in the area as the manager of West Marsabit Integrated Development Pilot Project. He therefore has been able to ascertain the correctness of the observations made here. Data for 1980 and 1981 are used most extensively because they have been fully analyzed and because, with modifications in price levels, the situation has not changed substantially since then.

RESULTS AND DISCUSSION

Historical Background

Although the Rendille supply most of their subsistence needs directly from their livestock and the environment, they always have traded with neighboring people. In these exchanges, livestock and livestock products were offered for tobacco, red ochre, beads, spears, knives, and various types of metal or ornaments. In time of drought, grains were in great demand, and these were often supplied from the agricultural Merus to the south. Oral sources indicate that, since the nineteenth century, people in the Marsabit area have had trade ties with the coastal areas and even with the Sudan and Egypt, which supply the multicolored beads that are very popular among them (Sobania, 1979).

Few Rendille actively participated as traders. This role was played by itinerant Somali traders in normal times. In times of drought, however, caravans from various manyattas would make the long trips to Meru to barter grains for hides and skins, small stock, and even camels and cattle. The Merus also used to bring tobacco, often together with Samburu middlemen.

Within the tribe itself, specialist blacksmiths made and exchanged iron goods while medicinemen cured people and asked for payment in livestock and livestock products. It was also common to repay special kindnesses, help with herding, and loans of breeding bulls, milk cows, etc., with gifts of livestock. In some cases, the kind and type of animal paid and expected was specified by tradition, while in other cases the payment was dependent on ability or negotiations between the parties.

Establishment of Trading Posts and Auctions

The colonial administration found the Rendille with a small but significant barter trade among themselves and with neighboring tribes. The establishment of administrative centers, trading posts, and roads by the new rulers made regular and fast travel to areas like central Kenya, Somalia, and Ethiopia possible and helped to create new contacts or strengthen the existing ones. These new centers had resident populations of askaris, clerks, and others who needed to be supplied with food, clothing, kitchenware, and other essential goods. The government encouraged traders to set up businesses in such centers to provide these supplies. Initially, taxes were levied as a percentage of a person's small stock, cattle, or camels. The administrators found local traders useful buyers of the animals that were collected as taxes. In later years, the system of collecting taxes in kind was reversed, and in Marsabit the district commissioner resorted to organizing auctions mainly to provide pastoralists with money for paying cash taxes (Sobania, 1979).

The present centers of Kargi, South Horr, Loiengalani, Logologo, and Laisamis therefore grew through the establishment of such posts. Others

like Gatab and Ngurunit grew because they were convenient stopping places when the district administrators were on safari around the district or to Nairobi and other centers in the colony. The traders who started doing business in these places soon replaced the former long-distance, itinerant traders and popularized the exchange of livestock and livestock products for clothes, tea, sugar, posho, cooking fat, tires, tobacco, blankets, cooking pots, cups, torches, and other manufactured products.

In the last two decades, missionary organizations have located themselves at Laisamis, Logologo, Korr, Ngurunit, Gatab, South Horr, and Loiengalani. This has often followed or been followed by chiefs' camps, dispensaries, schools, water-supply systems, famine-relief distribution centers, and more traders. These facilities have attracted many Rendille, and in the 1979 Census approximately 30% of all Rendille were found to be resident in or near these centers.

The result is that the Rendille have become even more exposed to contacts with the outside world. The schools, dispensaries, and shops all charge money for some or all of the goods and services offered. Purchased goods have become increasingly accepted by most households, as shown in table 1. The most popular items are simple, light things like plates and spoons. Mattresses and clocks are still very few.

Purchases of foodstuffs like posho and sugar have become equally popular, especially in the dry season. At the same time, an increasing number of families are sending children to school. All these things cost money and the Rendille have had to sell more and more livestock to get them. The sections below look at how this is done.

Trade in Camels

The Rendille territory is unlike other camel-keeping areas of North Africa and Arabia and even northeastern Kenya, where trade in camels is well developed and regular markets for them are held. In Marsabit, such markets do not exist. The little trade in camels that takes place is conducted within the manyattas and hardly in public places. This is because the demand for camels in the monetary sector is small and restricted to the following:

- sales to other pastoralists who want to build their own camel herds
- sales to Marsabit butchers for slaughter
- local slaughter in the trading centers by the owners with the intention of selling the meat
- sales to traders for export outside the district

Sales to other pastoralists. Of a sample of 119 Rendille interviewed in 1981, 7% indicated that they sold camels. All sold them locally to other Rendille who wanted to build their domestic camel herds. Mature camels are usually difficult to find, and such sales consisted of young heifers sold for about Ksh. 800 to Ksh. 1,000. The buyers were men with paid employment or Rendille traders. Sale of mature females was not common because their owners prefer to keep them for milk supplies and other functions. When females have to be sold, pastoralists prefer to exchange the camels using local exchange rates that are more favorable than selling the animals or slaughtering them and selling the meat.

Sales to Marsabit butchers and local slaughter for sale. Table 2 shows the total number of camels slaughtered in Laisamis Division and Marsabit

District between 1980 and 1982. As the total population of camels in Marsabit during these years was over 200,000 head, it is clear that the number of camels demanded for domestic slaughter is a very small proportion of this population. Indeed, most of this slaughter takes place during the later part of the dry season when small stock and cattle have lost weight and provide lean meat but camels, which do not suffer loss in weight in an ordinary dry period, are still capable of providing fat meat, which is preferred. None of Marsabit town's butchers slaughter camels regularly. However, most of their customers are civil servants who come from areas where camel meat is not popular. The low numbers slaughtered in Laisamis Division, which is a rural district occupied by Rendille, reflects the fact that pastoralists depend more on other types of meat. Most of the camel meat eaten is from animals that are sick or that die. The habit of purchasing meat from butchers is common only where a large number of people live far from their animals, as in the trading centers. In the manyattas outside such centers, sale of meat is still a rare phenomenon.

Sales to traders for export outside the district. Export sales also are very few. In the three years between 1980 and 1983, only two camels were reported officially as having left the district (taken to Isiolo in February 1983). The only camel butcher at Isiolo indicated that he did not like slaughtering Rendille camels because, although they are fat, they are light and bring in less money than those from Wajir and Garba Tula where he gets his supplies. This was confirmed by Field (1984) who showed that there are significant weight differences between Rendille and Somali camels of all age groups. The highest domestic demand for camels in Kenya is among the Somalis of North-Eastern Province (Njiru, 1984; Bremaud, 1967). The large Somali camel also is found in these areas. It is therefore most likely that the small size of the Rendille camel reduces its competitiveness and is responsible for the lack of demand outside Marsabit. Other potential markets like Baragoi, Maralal, and Wamba to the south have very low demands for camel meat. (Interviews of meat inspectors there revealed that only 54, 2, and 12 camels were slaughtered in Baragoi, Maralal, and Wamba in 1981.)

This results in a very low level of trading in camels in the study area, and only one of the 33 traders interviewed in 1980 and 1981 was dealing in camels. This one was importing camels from Samburu and Turkana districts, where camels are cheap, and exchanging them for small stock at traditional rates. He said he was able to get at least 25 head of stock valued at over Ksh. 3,000 for a mature female camel, which he bought at Ksh. 800 and thus made substantial profits. It was said that Samburu itinerant traders also were doing this, but this was difficult to verify since they operate among the Rendilles without a license and were not cooperative with information.

Cattle, Sheep, and Goat Marketing

Except for camels and donkeys, other livestock kept by Rendille have better options. The channels for cattle, sheep, and goats are shown in figure 2. These can be sold to other pastoralists live or after slaughter, to local butchers, or to traders.

Sales to other pastoralists. There are always pastoralists who want animals for ceremonial slaughter for a special occasion, for food, or for an investment. Sometimes the prices are determined by market forces, but sometimes social and cultural considerations are predominant so the price can be higher or lower than the market price. At times,

the owner of an animal cannot even refuse a request to exchange it for another that he may or may not desire without being seen as antisocial.

The option of selling meat after slaughter is becoming increasingly popular in the trading centers that do not have butcheries, especially during the long dry season. For cattle, this is not a lucrative option because buyers are few and relatives and friends beg for the meat. Small stock, however, are easier to handle in this way since only a few kilograms of meat are available, and any remaining meat can be taken home.

It is not possible to estimate the number of animals going through this outlet without an intensive household-budget study over at least one full year, which was not done. The other outlets of selling to local butchers and traders were easier to monitor, and table 3 shows their relative importance in 1980.

Local Slaughter. Local slaughter figures were estimated from district health-office records of animals slaughtered by local butchers who must have them inspected. These accounted for 16.2%, 7.4%, and 18.8% of goats, sheep, and cattle traded, respectively. Most of the people in these centers are pastoralists who are more or less dependent on their own herds for meat. It is only where there is a large concentration of traders, mission workers, and primary-school teachers that a significant market for meat exists. In places such as Kargi, Logologo, Laisamis, and Korr, animals are slaughtered every day, with peak slaughter at weekends and at the end of the month. The prices charged in these centers were between 50% and 80% of prices in Marsabit butcheries. Despite this, these butchers were able to offer prices that were 10% to 15% better than those offered by local traders because they wanted better-quality animals. They also bought animals for immediate slaughter and did not incur costs from deaths, trekking, and hiring of herdsmen, which local traders had to incur.

Sales to itinerant traders and at Marsabit market. This outlet is next in importance to sales to traders in the case of small stock and slightly less important than local slaughter for cattle at 18.0%, 20%, and 17.9% for goats, sheep, and cattle traded, respectively. Its significance is likely to have been underestimated because these types of traders tend to keep away from trading centers and do their business in the remoter places. They buy animals, transport them to the larger towns, and pocket the difference. Since none were licensed to trade in Marsabit and they are responsible for illegal movement of animals out of Marsabit, whether or not quarantine restrictions have been imposed, they do not discuss their activities very freely. Our estimates of numbers of animals they bought had to be gathered from local informants, including some chiefs who had monitored their activities. However, they are very popular with the pastoralists because they offer higher prices than local traders and are said to be less arrogant. When, in the course of their migrations or for other reasons, pastoralists have to visit the area around Marsabit, they usually sell their animals at the market there. They often do this through itinerant traders, and these estimates have been lumped together.

Livestock Marketing Division and Kenya Meat Commission. In 1980, Livestock Marketing Division (LMD) purchases accounted for 26.1% of the Rendille sales of cattle; therefore, the LMD was a more important outlet than sales to itinerant traders and local slaughter. Between 1979 and 1983, LMD purchased cattle in Marsabit at least once every year at

prices that were 20% to 30% higher than what pastoralists were getting. Traders could get slightly better prices at Isiolo, but even for them LMD prices were quite competitive as they removed the risks and costs of trekking to Isiolo.

Analysis of sales to LMD in the above years shows that, on average, small and large traders sell about 50% of the animals, while the rest are sold by pastoralists. Pastoralists interviewed indicated that many more animals could have come from them if LMD fulfilled some or all of the following conditions:

- Gave adequate warning of intended dates of purchase and stuck to them. Its 2-week notice of impending purchases is too short.

- Was more consistent in its purchasing requirements. In 1980, out of 814 cattle offered by Rendille, only 62 were purchased. The rest were rejected because they were female, too small, or too old. In 1979, LMD had accepted these type of animals.

- Could come at a certain month every year. In 1980 they came in July and October, in 1982 not at all, and in 1983 in February. This confuses anybody intending to sell to them.

- Regularly included small stock in their buying. This happened only in 1983.

In 1984 and 1985, livestock purchasing has been done by the Kenya Meat Commission, but it suffers from the same weaknesses as LMD.

Sales to traders with shops. Traders with shops make up the most significant outlet, accounting for 65.7%, 72.6%, and 37.1% of goats, sheep, and cattle sold in 1980. Their main strong point is that the traders are at their shops all the time and available to anyone wanting to sell. They also offer credit to many pastoralists -- the individual brings in an animal, agrees on a price, and draws food and other purchases until the animal's value is exhausted. The main weakness of this outlet is that the bargaining power of the pastoralist is very poor since usually only one trader in a center is buying animals at any given time, and that trader knows that the pastoralist is desperate to sell and will accept a low price.

The small traders buy livestock from pastoralists who bring the animals to the shops over periods ranging from a few months to one year. When a sizeable herd has accumulated, the trader prepares to sell them. Several options are available:

- The trader can take the animals to Marsabit or Isiolo and sell them to a larger interdistrict trader.

- The trader can take the animals to Isiolo, Marsabit, Nairobi, Mombasa, or some other large city and sell them to meat wholesalers, butchers, or the Kenya Meat Commission.

- The large traders sell the animals to meat wholesalers, butchers, the Kenya Meat Commission, or exporters. The commission and meat wholesalers slaughter the animals and sell the meat to butchers for sale to consumers. Some institutional customers such as schools, colleges, and prisons are supplied directly by the commission and meat wholesalers.

These channels are summarized in figure 2. The most common channel, however, is pastoralist to small trader to meat wholesaler to butcher to consumer.

Most large traders are located in Isiolo and Maralal, while meat wholesalers are located in the larger municipalities. Hence, only the first step -- when animals move from pastoralist to small trader -- takes place in Rendille territory.

Table 4 presents information on the importance of these channels. This table shows that 67.1%, 86.1%, and 73.4% of cattle, goats, and sheep sold by small traders were exported out of the district. The proportion is likely to be larger because some of the animals sold at Marsabit and falling under "others" were sold to large traders who later transported them out of the district. Though 32.9% of cattle were sold at Marsabit, most of these were sold to LMD, which took them out of the district. The traders indicated the 37.5% of their sales were to a few large traders outside Marsabit, 58% to any buyers, and 4.2% to traders who came for the animals at the shop. Large traders took the lion's share of small traders' offerings, especially since some of those who sold to any buyer were still selling to large traders. Most of those selling to any buyer took their animals to Nairobi where meat wholesalers are the predominant buyers. The wholesalers buy animals, take them to abbatoirs at Dagoretti and Ngong or to private slaughterhouses, and sell the meat wholesale to Nairobi butchers.

Potential Offtake

In terms of the total Rendille herd, the commercial offtake of cattle, sheep, and goats of 2,305, 2,769, and 8,349 head respectively represent 12.1% and 8.8% (small stock). (The total population of Rendille herds between 1976 and 1981 has been estimated as averaging 18,976 camels, 126,523 small stock, and 36,104 cattle (Field, 1984).) At the same time, herd-structure data (Field, 1984) show that the proportion of castrated males in nomadic herds ranges between 15% and 30% for small stock, is approximately 25% for cattle, and ranges between 9.3% and 14.5% for camels. Together with cull and barren females, castrated animals and excess bulls (both immature and mature) are kept for consumption, for ceremonial purposes, and for sale. If we assume that consumption requirements are met by death, cull females, and males and that 50% of all castrates are too young or are needed to replace animals that die or are culled and that 60% are required for transport in the case of camels, crude estimates of potential offtake from Rendille herds can be attempted.

Following these assumptions, offtake could therefore be increased by 7.5% for small stock, 12.5% for cattle, and 4.8% for camels on top of offtake levels being maintained at the time. This suggests that a large potential remains untapped. That assumption is reinforced by the fact that over 75% of the pastoralists interviewed indicated that they would have liked to sell more animals in 1981 than they did and that traders did not complain of lack of livestock at any time.

The following section looks at some of the main constraints to increased offtake.

Constraints to Increased Offtake

Low prices. A major complaint often heard from pastoralists is that prices paid for their animals are so low that they have little incentive to sell. This is partly true since the prices of livestock products are very low while the price of cereals, sugar, clothes, and other goods are much higher than elsewhere in Kenya because of high transportation costs and a poor distribution network. For instance, in 1980 the farm-gate price paid for small stock per kilogram live weight was only about 20 cents above the price of one kilo of locally ground maize meal, while the price of cattle was 27 cents below it. (The actual prices were Ksh. 2.57 per kilogram of locally ground maize meal and Ksh. 2.30 and Ksh. 2.77 respectively per live weight for cattle and small stock.)

There is general belief that traders can afford to pay better prices but push prices down to increase their margins. In an attempt to test the validity of this belief, we tried to record each trader's costs and returns. This proved to be extremely difficult for a number of reasons. First, most herding labor was family labor that was paid in kind; therefore, it was difficult to estimate its monetary worth. At the same time, many of these costs were shared with animals belonging to the trader's subsistence herd or to other traders that were herded together with the trade animals. For these reasons, it was not possible to make meaningful estimates of the costs that related to each trader's trading herd. However, we got enough information to be able to calculate the costs for the average trading herd of 140 small stock, comprising 80 goats and 60 sheep. In the case of cattle, actual costs and returns of a trader's herd of 93 cattle, which was followed from purchase to sale, are summarized in table 5. The returns on capital of 12%, 19%, and 18% for sheep, goats, and cattle shown in table 5 are fair given the high risks, the hard work involved, and the returns to trading in other sectors of the economy. Of course, the more efficient traders make higher margins by keeping the animals for a shorter period, controlling losses, and looking for better prices; but traders cannot be accused of exploiting pastoralists at these rates of return.

Asked how, in their opinion, the price paid to pastoralists could be raised, 60% of the traders said the only way that prices could be improved was through the establishment of a sure market for livestock in the district. A further 15% thought that it was the poor condition of the animals that led to poor prices; hence, if their condition could be improved, traders would be able and willing to pay higher prices.

However, it was noted that, even at these relatively low prices, there was no shortage of animals for sale. As long as they were patient, traders were able to buy as many animals as they wanted. Indeed, 75% of a sample of pastoral households from the area interviewed a year later indicated that there were long periods when they want to sell animals but could not get a buyer.

Asked to given the reasons that they were unable to expand so they could take all the animals available for sale in their areas, 42.5% of the traders blamed lack of markets to buy and sell the livestock, 39.4% lack of capital to finance buying, 36.4% transportation problems, and 27.3% high losses from death. (Percentages do not total 100 because of multiple replies.) Since these traders control a major share of the market and hold the key to its expansion, it is useful to look at these problems.

Availability of markets. Most of the traders in the area believed that the market for livestock inside Marsabit District is poor. This is why a large proportion prefer to sell their animals in Isiolo, Nairobi, Meru, or Baragoi (table 4). However, taking animals to these markets has the following disadvantages:

- The distances involved are large, and transportation costs are high.
- Due to poor communications, it is difficult to get information on supply and demand and prices to supply animals at the right time.
- The risks of losing the animals to new diseases and from long periods of waiting to get a buyer at these markets are very high.

The cumulative effect of these problems is that the costs and risks of carrying livestock trade are much higher than if the markets were located within the district.

Buying the animals from pastoralists also poses some problems. Except at Marsabit town, there are no marketplaces for sheep and goats. Pastoralists bring animals to the trading centers when they need money. A trader wanting more animals than the trickle that is offered for sale in this way must look for them in manyattas. This is an expensive and difficult undertaking because the animals are widely dispersed over the range. The herdsmen with them often do not have authority to sell animals, so consultations with owners in distant manyattas may be necessary.

As a result, most traders depend on the trickle that is brought irregularly by pastoralists and take long periods to buy a given number of animals. Because of the isolated nature of each transaction, other pastoralists do not get to know how much was paid and may avoid selling animals for fear of getting poor prices even when prices are high.

Lack of capital. It is not surprising that many traders identified lack of capital as a major constraint to expansion. A large proportion were sole proprietorships (72.7%) and family businesses (15.2%) dependent only on their owners' resources for capital.

Table 6 shows the value of cattle and small stock purchases in 1980. The amounts spent were not large, with 57.5% and 75.6% of all traders spending less than Ksh. 10,000 on small stock and cattle respectively, while only 18.2% were able to spend more than Ksh. 40,000 on small stock. For cattle purchases, only 3% of the traders spent over Ksh. 40,000. This problem was further compounded by the fact that there are no financial institutions in the area that could lend money. The District Joint Loans Board is the main source of loans, but it gives only very small loans of less than Ksh. 10,000. In any case, only 27.3% of the traders had ever received these loans, and all claimed that they were very inadequate.

Borrowing from banks and other financial institutions outside the district is a possibility. However, lack of acceptable security and transportation difficulties faced by bank officials who may want to visit a trader's business have so far proved insurmountable. Only one trader had received a loan from a bank in Nanyuki, and this was negotiated while he was working with the government.

In 1980, the cost of buying, herding, and selling a truckload of 180 head of small stock was over Ksh. 20,000. This meant that many of those wishing to sell their animals further than Isiolo where trekking was not possible could do so only if they combined their herds to make a truckload. It often was difficult to get willing partners, and this forced them to sell animals to larger traders at lower levels of profit per head than they could have gotten elsewhere.

Trekking cattle and small stock to Isiolo often was done in groups of at least 100 cattle and 100 to 300 head of small stock. Here again, few individual traders could do it on their own, and this again necessitated cumbersome arrangements or entrusting their animals to friends, with all the risks involved.

With low turnover and profit per unit, the process of capital formation is extremely slow, justifying the traders' complaints of lack of capital.

Transportation problems. There are two types of transportation problems:

- Because of inadequate watering facilities on the routes to the various markets, trekking animals is possible only after the rains. The ample water available from pools that gather on the surface along the route enables the animals to move over the large expanses without wells. This means that animals must be kept for long periods because they cannot be sold at other times unless a truck can be hired, which is three times more expensive for small stock and almost ten times more expensive for cattle.

- For those wanting to take their animals to market by truck, few trucks were available in the study area. In fact, none of the traders working among the Rendille owned a truck, and getting a truck to carry small stock is not easy. Also, the state of the roads is so poor outside the Marsabit-Isiolo highway that large parts of the study area are inaccessible during the wet season to ordinary trucks. An inexperienced driver can cause high losses from deaths by moving too fast, causing the animals to crush each other as the truck swings and bumps along. Because of poor roads, weight losses of up to 20% between the study area and Nairobi are frequent for trucked animals.

High losses from deaths. The loss of trade animals varies from year to year with climate, luck, and the effectiveness of the herdsmen. Because pastoralists often sell sick animals, the probability of a disease outbreak in a trader's herd is very high. Indeed, many try as much as possible to separate trade animals from their subsistence herds until they have had time to observe them. On the other hand, losses from diseases, predators, theft, and accidents are quite high even for ordinary herds in the area. Traders indicated that losses of from less than 5% to 30% of the animals were quite possible. The risk of drought deaths is even higher for traders, who usually buy animals hoping that the rains will fall. Drought losses are a common feature of Marsabit pastorlism. Even when there is no drought, lack of water over most of the area places a constraint on grazing.

This is a general problem over the area. During the dry season, animals are forced to congregate near the few waterholes. The immediate environs of such waterholes become overgrazed, and the animals lose

condition from malnutrition and disease to which the weakened animals are more susceptible.

RECOMMENDATIONS

Markets

The discussion above makes it quite clear that lack of a market for livestock in the study area is a major drawback to trade. To overcome this problem, it is recommended that marketplaces for livestock be established in each trading center and that market days for each center be designated so that anyone wishing to buy or sell animals can go there. It is further recommended that, one or twice a year, large auctions be held where the Kenya Meat Commission, the Livestock Marketing Division, and other large traders can attend together. The livestock marketing officer and the county council of Marsabit should explore ways to publicize and popularize these auctions to attract big buyers. Eventually, this should eliminate the need for each small trader to take animals all the way to Isiolo and other urban centers.

The establishment of marketplaces and market days should start immediately. Past experience at Laisamis, where several thousand head of small stock had been brought for LMD purchases in 1983 (which was cancelled on instructions from Nairobi while many animals still were on the crush) indicates that the idea of auctions can easily catch on. In the 1950s, auctions and trade fairs, where traders were encouraged to bring goods to sell to pastoralists, proved popular and successful (Sobania, 1979).

Market Information

In the meantime, information on the prices of livestock and market conditions in Meru, Isiolo, Baragoi, Nairobi, and other markets of interest to traders in the study area should be broadcast regularly on the Rendille radio. This should give both the traders and pastoralists information with which to plan their sales strategies in Marsabit and in other markets.

Itinerant Traders

Itinerant traders are well adapted to trade in nomadic conditions because they are mobile and do not require much capital. The present policy of discouraging this type of trade should be revised, and efforts should be made to encourage them. The establishment of viable markets could help spread this type of trade by decreasing the distances traders must travel to sell the animals they purchase.

Livestock-marketing Groups

In each trading center, livestock-marketing associations or organizations to compete with traders and try to raise prices should be set up. However, the livestock marketing officer should watch these groups carefully to avoid the problems of corruption and misappropriation of funds. Presently, funds from various sources are available to such groups. This can help inject some money into the system. The groups should not be allowed, however, to become monopolies since that could lead to problems later if they fail.

Transportation

Trekking. Whether or not new markets develop to cater to all traders within the district, those who buy the livestock ought to be able to trek them out of the district for most of the year. To facilitate this, trekking facilities such as resting places and wells should be provided between Marsabit and Isiolo at regular intervals.

Roads. The number of roads that are passable for a large part of the year should be increased so that at least the major centers of Korr, Kargi, and Illaut are accessible all the time. Since building roads is expensive, attention should be concentrated on the sections that become impassable due to flooding.

The scarcity of trucks for hire can be solved only if ways to finance the purchase of trucks by the larger, more enterprising traders are devised. Improving the state of the roads would go a long way to encourage transporters from other parts of the country to agree to come to these places at reasonable charges.

Provision of Trading Capital

Lack of money to expand business also had been identified as a constraint. It is recommended that the district livestock marketing officer work with the managers of the commercial bank that has been opened in Marsabit, of the Agricultural Finance Corporation (AFC), and of any other relevant credit institutions to see how short-term working capital could be provided to marketing organizations and livestock traders. Traders should be encouraged to seek loans to expand business from any available sources.

The county council and the district development committee, which now will be controlling government-funds allocation, also should devise more effective ways of helping traders other than the District Joint Loans Board or increase the amounts of the loans that individual traders get from this board.

The provision of supplementary feeds to animals just before sale could greatly improve their market prices especially during the drier years. AFC and other credit institutions should experiment with financing such finishing operations to see whether they are cost effective.

Reduction of Losses

Currently, the mortality rates of both traders' and pastoralists' herds are very high. Efforts should be made to improve the delivery of veterinary services to livestock in the area. Regular monthly clinics at all the major livestock-concentration centers have been shown to be effective. The benefits of health programs are not substantial in dry years because, at that time, nutritional stress is more constraining than disease. However, in good years, disease-free animals will be able to build up better reserves for the inevitable poor years.

Nutritional stress in the dry periods could be reduced further if dams and wells were well distributed so that animals were more evenly spread over the range in dry periods. At present, large concentrations of livestock around the few watering points deplete grazing and increase such stress.

CONCLUSION

The above recommendations have been accepted by Unesco and the governments of Kenya and the Federal Republic of Germany as the basis for a new development project in Marsabit West. As a result, the West Marsabit Integrated Development Pilot Project started in January 1985 in the southern part of Rendille country.

Improvement of the transportation network, starting of market days, and organization of regular markets appear to be helping to improve the price of livestock at the farm gate within the area and to increase people's willingness to sell. However, the impact of this program has not been analyzed, and it may be too early to say exactly what it is going to be.

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Table 1. Ownership of selected purchased items by a sample of 119 Rendille households in 1981.

Item	% of household owning it
Cups	99.2
Plates	86.6
Spoons	94.1
Jerrycans	80.7
Cooking pots	97.5
Drinking glasses	20.2
Bowls	39.9
Mattresses	5.8
Clocks	5.3
Torches	72.6

Table 2. Camels slaughtered and inspected in Marsabit town and Laisamis Division, 1980-82[a].

	Marsabit Town	Laisamis Division
1980	34	74
1981	124	124
1982	2	4

Source: District Public Health Office, Marsabit.
[a]Local inspected slaughter more or less represents slaughter for the purpose of selling the meat because pastoralists rarely ask for meat inspection for domestic consumption; however, it is a legal requirement that meat for sale must be inspected.

Table 3. Sales of goats, sheep, and cattle through various channels in Rendille territory, 1980.

	Goats		Sheep		Cattle	
	No.	%	No.	%	No.	%
Local slaughter	1353	16.2	208	7.4	434	18.8
Sales to traders with shops	5489	65.7	2030	72.6	856	37.1
Sales to itinerant traders and at Marsabit market	1507	18.0	558	20.0	413	17.9
Livestock Marketing Division and Kenya Meat Commission	0	--	0	--	602	26.1
Total sales	8349		2769		2305	

Table 4. Proportion of small traders' cattle, goats, and sheep going to various destinations, 1980.

	Cattle		Goats		Sheep	
Town	No.	%	No.	%	No.	%
Isiolo	409	47.8	1132	23.6	325	22.0
Nairobi	0	--	1720	35.9	680	46.1
Baragoi	15	0.02	633	13.2	22	1.4
Meru	150	17.5	642	13.4	60	3.9
Marsabit	282	32.9	420	8.8	330	22.3
Others			239	5.0	57	3.9
Total	856		4786	99.9	1474	99.8

Table 5. Average costs and returns for a trader's herd of 140 head of small stock and 93 head of cattle, 1980 (Kenya shillings)[a].

	Sheep	Goats	Cattle
Revenue from sale per animal costs	146.0	160.0	736.0
Purchase price per animal	93.50	97.5	480.5
Herding costs	17.15	17.15	58.4
Losses from diseases, theft, etc.	9.35	9.75	67.1
Transportation costs	10.0	10.0	17.7
Total costs	130.0	134.4	623.7
Trader's margin revenue -- costs	16.0	25.6	112.3
Returns on trader's money (%)	12.3	19.10	18.0

[a]In calculating sheep and goat costs and returns, the following assumptions are made:

- that the trader bought the animals in the dry seasons of July to October and December to March and sold them sometime in April to July after they had put on weight from the April to May long-rains flush; therefore, the trader had the animals for 12 months

- that one herdsman was employed for a salary (in-kind or cash) of Ksh. 200 a month

- that the probability that the animals would be sent to the market by truck at Ksh. 15 per animal or walked there on foot at Ksh. 5 an animal was 5 either way

  - In the 1980 survey, the number of traders transporting their small stock to market by truck was slightly less than those trekking them.

  - Truck transportation to Isiolo and beyond was about Ksh. 15 per animal.

  - Costs per animal per trek depend on the number of animals involved. The cost of Ksh. 5 was for a herd of 1,200 head of small stock monitored from Korr to Isiolo over a 1-month period. This gives an expected transportation cost of Ksh. 10 per head of small stock.

- that losses from diseases, theft, etc., averaged 10% of the animals initially purchased

- that 1980's average purchase of 140 small stock, consisting of approximately 80 goats and 60 sheep, was representative of other years

Table 6. Value of cattle and small stock purchased by traders in Rendille, 1980.

Value in KSh.	Percentage of traders buying livestock within this value			
	Small stock		Cattle	
0	27.2)		48.4)	
1 - 5,000	12.1)	57.5	3.0)	75.6
5,001 - 10,000	18.2)		24.2)	
10,001 - 15,000	0		6.1	
15,001 - 20,000	0		3.0	
20,001 - 25,000	3.0		3.0	
25,001 - 30,000	3.0		3.0	
30,001 - 35,000	9.1		0	
35,001 - 40,000	9.1		6.1	
Over 40,001	18.2		3.1	

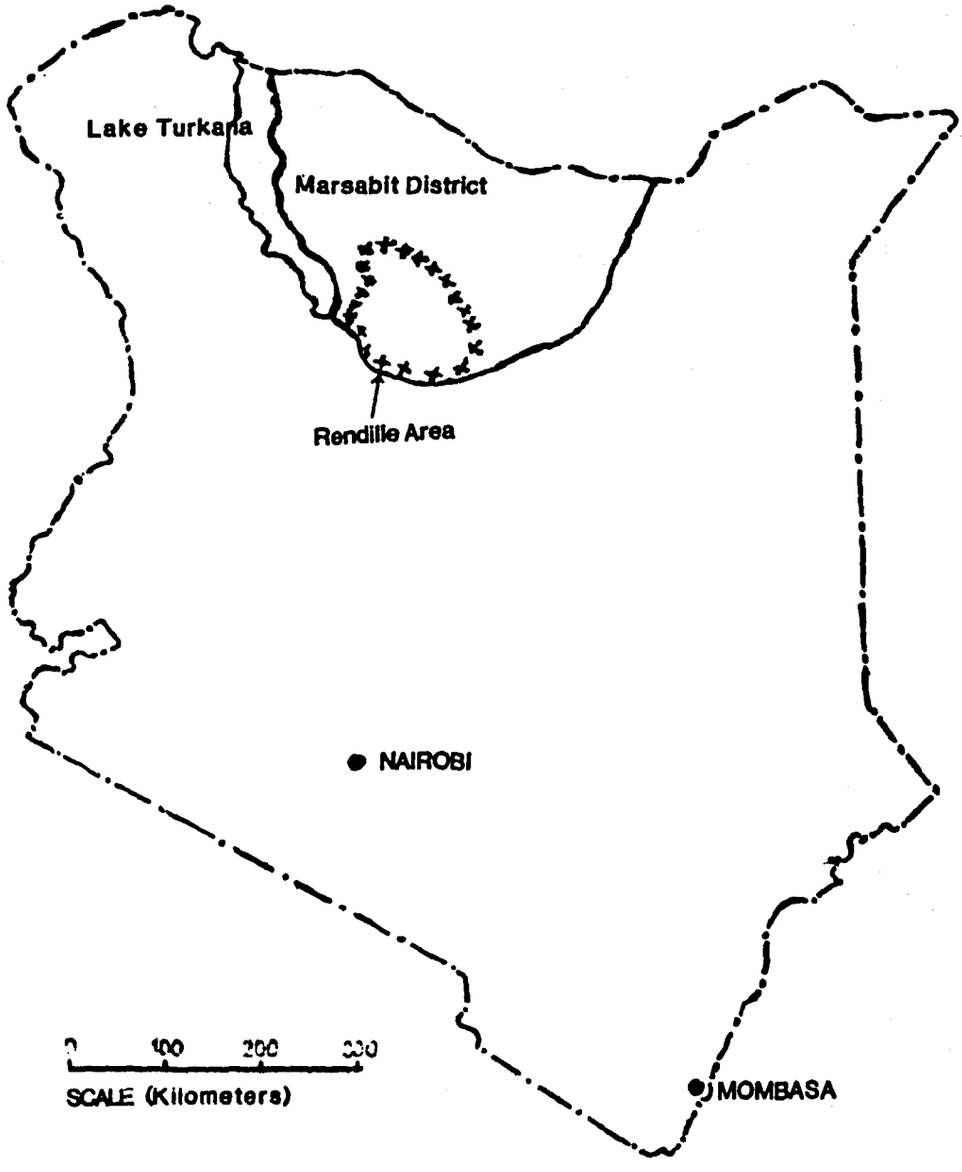

Figure 1. Location of study area.

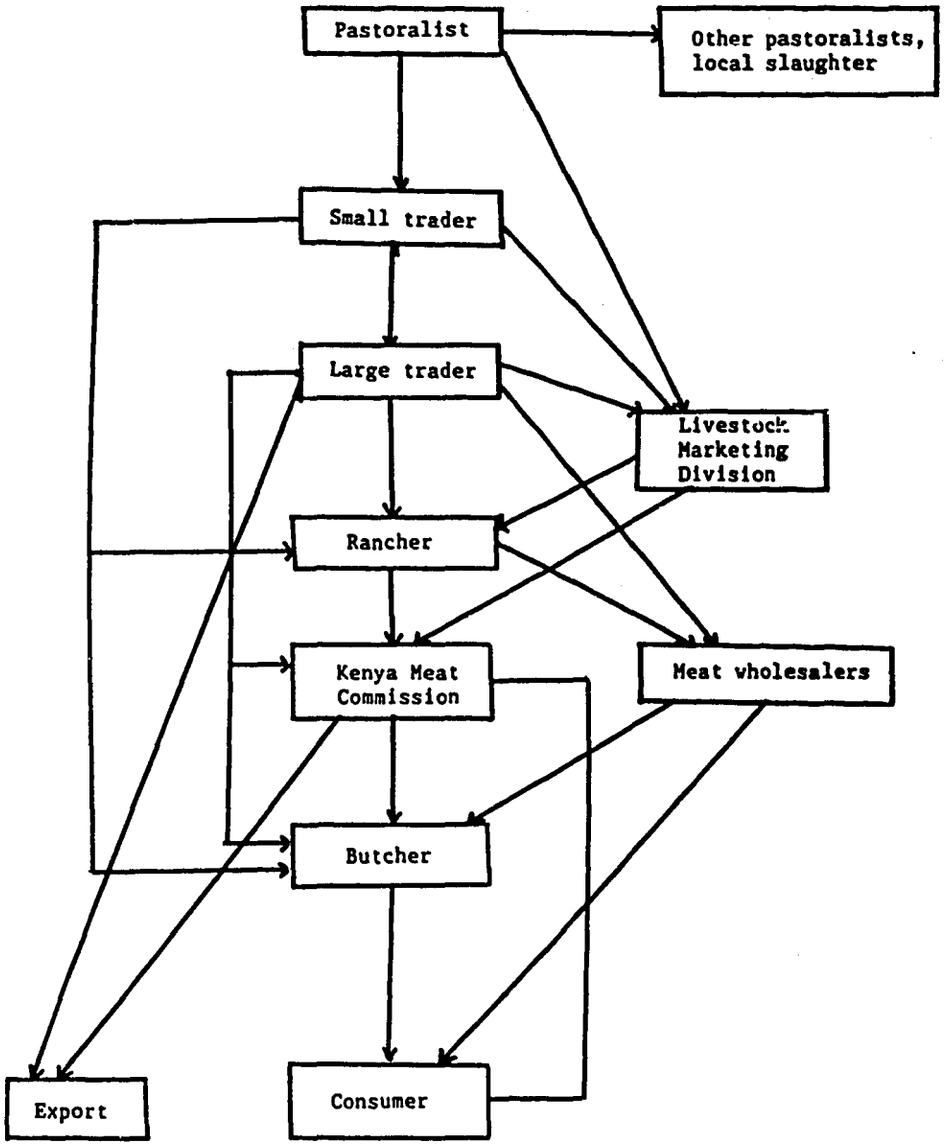

Figure 2. Marketing channels for cattle and small stock from Rendille territory, 1983.

LIVESTOCK MARKETING IN EASTERN KAJIADO, KENYA

Solomon Bekure and Francis Chabari

INTRODUCTION

From 1981 to 1984 the International Livestock Centre for Africa (ILCA) conducted an interdisciplinary investigation of the Masai livestock-production system, embracing its biophysical and socioeconomic aspects. Livestock marketing is an important aspect of Masai livestock production. It provides the mechanism whereby the Masai exchange their livestock for cash, which in turn is used for acquiring goods and services to satisfy a variety of needs, ranging from food items, clothing, medication, and schooling to the purchasing of breeding stock and livestock inputs for production purposes. A study of livestock marketing was therefore an integral part of this investigation, which was conducted in eastern Kajiado.

This paper describes how the cattle market operates in eastern Kajiado. (Although small stock are traded by Masai, there is no organized market that operates on a regular basis. Unlike other pastoral areas, one rarely sees a flock of small stock being trekked to market. In eastern Kajiado, trade in small stock is confined to small trade centers. Since very little of the small stock from eastern Kajiado enter the national market, the focus of this study is on cattle marketing.) It is organized in six sections: introduction; methodology employed in the study of the cattle market; operation of the market, including volume, sources, destination, and characteristics and prices of the cattle traded at Emali, the major cattle market of the area (three sections); and the efficiency of the market and the problems encountered by sellers and buyers.

METHODOLOGY

Emali is the only place in eastern Kajiado where enough cattle are traded regularly to warrant the name "market." Trading centers like Simba, Olandi, and Mbirikani in the study area form only part of several staging points for the collection of cattle destined for the Emali market, which takes place every Friday. As the arrows show in figure 1, the hinterland of the Emali cattle market extends from the nearby group ranches of Arroi, Nkama, Poka, Olkarkar, and Kiboko all the way south to those along the Tanzania border (Lolarash, Endonet, Enkariak, and Rombo). A negligible amount is supplied from Machakos District.

A preliminary survey of the Emali market was undertaken during the last quarter of 1980 and the first quarter of 1981. Information was solicited from 60 cattle sellers and buyers on general cattle-trading activities and specific transactions that took place on the day of the interview. This survey provided background information about how the Emali cattle market operates and a description of the activities of traders who purchase cattle from its hinterland.

Recording of time-series data began in September 1981. Each Friday, data was collected on the total number of cattle offered and the numbers of suppliers and buyers. Additional information was recorded for a sample of transactions: age of animal (adult, immature, calf); sex (male, castrate, female); and breed (East African zebu, Sahiwal- or Boran-cross). Sellers of these cattle were identified as traders or

producers, and information was recorded about where they had bought the cattle and the prices paid, if applicable. Buyers were asked the purpose of their purchase, the prices they paid, the destination of the animals, and their mode of transportation.

The analysis of this paper is based on data thus collected over a period of three years from September 1981 to August 1984.

On the first Friday of each month in 1982, cattle transacted were weighed and assessed to correlate prices to class of cattle, weight, and condition. Cattle weighing is a laborious exercise, alien to the marketing system. It was therefore restricted to once a month to reduce the interference in the market process to a tolerable level and thereby obtain the cooperation of buyers and sellers. Even so, permission to weigh newly bought animals was not given readily by buyers still in the midst of the purchasing process. Moreover, when traders finished purchasing, they did not want to delay the movement of their cattle. Consequently, only 359 head were weighed during the first year of the study.

OPERATIONS OF THE EMALI CATTLE MARKET

Transactions

Buying and selling cattle at Emali is not organized on an auction basis. Individual sellers or groups of two or three traders congregate their cattle in small herds and stand nearby. The market may have 15 to 20 such herds. Buyers of cattle inspect these herds and identify the animals they want; then they approach the owners to negotiate prices. Many transactions occur simultaneously, making it difficult to spot when agreement on a sale has been reached. Reselling of cattle bought on the same day also contributes to this difficulty.

It was estimated that about 80% of the cattle offered at Emali are sold. About two-thirds of the cattle that are not sold at Emali are taken home and later brought back to Emali for sale. The remaining one-third are trekked to the Ong'ata Rongai, Dagoretti, or Athi River markets.

The analysis presented in this paper is based on the 7,644 transactions that our enumerators were able to record properly.

Sources of Cattle Supply to the Emali Market

Out of the 7,644 cattle transactions recorded at the Emali market, the source of supply was clear for only 60% (4,607 head), of which almost all (96%) came from producers in Kajiado District. However, at times cattle are bought from Tanzania and sold at the Emali market. These are not reported by traders as originating from Tanzania for obvious reasons; however, the number is so small that it does not affect the analysis. Table 1 shows the breakdown by source. Individual ranchers in Kajiado rarely sell their cattle at Emali; they sell directly to butchers and traders in Ong'ata Rongai and Dagoretti and to the Kenya Meat Commission (KMC), where they can obtain better prices.

Suppliers were identified clearly for only 6,756 head, of which 95% (6,431) were supplied by traders. The remaining 325 head, representing only 5%, were supplied directly by producers. Traders were asked to identify from whom they bought the cattle they sold at Emali. It was possible to identify the source for only 2,506 of these animals. Of

these, 42% (1,064 head) were purchased directly from producers and 58% from other traders.

Characteristics of Traders Supplying Cattle to the Emali Market

The number of traders supplying cattle to the Emali market varies from week to week, ranging from 25 to 75 with each trader supplying between 5 and 20 head. Although these suppliers consider cattle trading to be their occupation, all of them also are producers. For many, cattle trading is a part-time job, and the distinction between trader and producer is rarely clear cut. Trading is entered into and left as circumstances allow or require, with temporary or long-term labor shortages at home being a major determinant. One of the producers interviewed, for example, trades regularly during school holidays, when children are available at home for herding animals. Trading is adversely affected during periods of drought, which necessitate the splitting of herds and thus impose additional labor and management requirements. Even the most regular traders interrupt their trading activities for weeks or even longer if circumstances involving their personal herds so require. For example, in one instance a trader who normally sells cattle weekly at Emali was absent for 6 weeks when the borehole failed on which his household's herd depends, and water had to be obtained from other sources. Primary responsibility among traders is to one's personal herd. Livestock trading for the majority may be a full-time occupation, but trading is secondary in importance when obligations concerning one's own animals arise. Thus, an impediment for many Masai who aspire to becoming livestock traders is the problem of finding someone else to look after the herd.

According to the preliminary survey, the average age of traders was 26.5 years, indicating that cattle trading is a young man's activity. The time over which they had been in business ranged from 6 months to over 15 years, the mean being 6.5 years. Initially, they engaged in trading to earn additional income to meet basic family needs. Firmly established traders indicated that they use their profits from trading to increase their breeding stock. Occasionally, especially the older traders engage in the purchase of immature steers for sale after fattening. A number of traders mentioned that cattle trading made life more enjoyable than simply staying at home looking after cattle. Contributing to this aura is the fact that livestock trading is one of the few forms of employment that does not compromise the Masai lifestyle. The culture is fully retained and even enhanced for young men through the acquisition of more livestock that trading profits make possible.

Cattle-trading Operations

Although, theoretically, traders can buy cattle from anywhere in Masailand, they seem to concentrate their efforts in particular areas, often around their own residences, where kinship and familiarity with the producers commands a degree of trust and credence in their transactions (Evangelou, 1984; Bekure and McDonald, 1984). Many Masai still are suspicious of traders whom they do not know. Familiarity enables credit transactions, which are frequent. Transactions may take place at the producer's "boma" (homestead) and at watering points, as well as the small trading centers in the livestock-producing areas.

A degree of camaraderie is exhibited by the traders. Of the traders interviewed in the preliminary survey, 30% indicated that they help each

other out by forming loose partnerships. Profits may be shared or, more frequently, earnings are loaned back and forth between partners as needed. Cattle traders also coordinate the movement of their animals to market. Usually, a group of traders collects their cattle at one site and arranges to trek them to Emali as a single herd, with arrival timed for the eve of the market day. This tends to facilitate handling, decrease costs, and reduce the risks associated with trekking cattle to Emali.

Destination of Cattle Traded at the Emali Market

The destination of cattle traded at the Emali Market depends upon the purpose for which they are bought. Of the 7,407 transactions whose purposes were recorded, 62% (4,615 head) were clearly destined for slaughter, and the remaining 38% (2,792 head) were mainly bought by producers and traders for rearing and transaction purposes. Table 2 shows the destinations of these cattle by purpose.

Ong'ata Rongai and Dagoretti are the major destinations of slaughter cattle bought at Emali, drawing about 24% and 22%, respectively. About 18% are bought for slaughter by butcheries of the neighboring trade centers of Emali, Sultan Hamud, Konza, and Machakos. About 16% of slaughter cattle are destined to KMC Athi River, and 20% to the Coast meat market. In 1977, slaughterhouses at Dagoretti and Ong'ata Rongai provided 21% and 30%, respectively, of the total supply of beef to the Nairobi meat market, while KMC supplied 26% (Matthes, 1979). Between 1961 and 1967, KMC supplied 75% to 85% of Nairobi's beef consumption (Aldington and Wilson, 1968). This shows how KMC has lost its dominance in the market over the last 15 years. Traders at Emali ascribe their reluctance to sell to KMC to several factors including low prices, delayed payments, and the risk of carcass condemnation (in which event, the loss is completely absorbed by the traders). These reasons also were given by traders who buy livestock from the high-potential areas in Kenya (Gatere and Dow, 1980).

Characteristics of Cattle Traded at Emali

Breed. Small East Africa (SEA) zebu is predominant breed traded at Emali. Of 7,644 head of cattle sampled in the study, 7,389 (97%) were SEA zebu. Only 3% (231 head) were identified as Sahiwal crosses. The number of Boran crosses (24 head) was negligible. This reflects the fact that Sahiwal and Boran breeds form an insignificant part of Masai herds and that Masai keep them for breeding purposes. These breeds have been introduced only recently to Masailand (since the early 1970s) through the Kenya Livestock Development Project (KLDP). The ILCA study on the three group ranches of Olkarkar, Merueshi, and Mbirikani found that, while zebus constituted 94.8% of Masai herds, Sahiwals and their crosses represented only 4.6% (5,451 head).

Sex and age. The distribution of the sample of cattle marketed at Emali is shown in table 3. Castrates form the major proportion (42%), followed by males (39%), and females (19%). Since immatures and adults were classified by visual assessment, the figures may reflect observer bias; however, the number of immature males (1,873) appeared to be almost double the number of adult males. A majority of these immature males (69%) are bought for transaction purposes by agriculturalists in Machakos District. The number of mature castrates is about 48% more than that of immature castrates. An analysis of the pattern of sales by Masai households shows that poorer households are forced to sell

immatures to generate cash for their subsistence requirements (Grandin and Bekure, 1982). The fact that 87% (1,459) of the females marketed are cows suggests that Masai hold onto their heifers for breeding and cull old and barren cows. A detailed disaggregation of characteristics of cattle marketed at Emali by breed, sex, and age is given in table 3.

Characteristics of Cattle Bought at Emali Destined for Machakos and Kajiado Districts

Table 4 shows the characteristics of cattle that were purchased at Emali and destined to Machakos and Kajiado districts. About 77% (1,684) of those destined to Machakos were males purchased for draft purposes. Castrates constituted about 18% (303 head) and females only 5%. In contrast, those destined for the Kajiado group and individual ranches were mainly castrates (62%; 1,515 head) purchased for fattening purposes. Males represented 26% and females only 12%. Some cattle traders, especially those with access to private water connections on the Loitokitok-Sultan Hamud pipeline, are engaged in buying immature steers for fattening and sale at a considerable gross margin. Some reported buying young steers at Ksh. 700 per head and selling them at Ksh. 1,500 per head about a year later. Breedwise, 98% of the cattle bought for production purposes were Masai zebu. Sahiwal and Boran crosses are rarely sold by the Masai because they are prized as breeding stock.

CATTLE SUPPLY AND PRICES AT THE EMALI MARKET

The total supply of cattle estimated for the 104 market days during the first 2 years of the study was about 36,525 head. This is an average of 18,262 head per year. The mean weekly supply was 374 + 102 head with a coefficient of variation of 27%. The data shows that there is an upward trend in the supply of cattle. The mean weekly supply of cattle during the first 12 months (September 1981 to August 1982) was 287, compared to 417 during the following 12 months. This can be ascribed to a combination of two factors: a general increase in production, and the rise in prices of cattle during 1982 and 1983. Prices paid for males and castrates increased by about 8% and for cows by about 1.6%. Although a slight drought was experienced during the first 6 months of the study, the rains generally were normal for the remaining period of the study. Data on livestock production for Olkarkar and Merueshi show that the population of cattle increased 13% and the population of small ruminants increased 10% between 1982 and 1983.

The data indicate a marked seasonality in the supply of cattle to the Emali market. The general picture that emerges is that the supply of cattle increases as the dry season progresses from the beginning of June to the beginning of January. Peaks in supply occur from mid-November to the end of December. Calving of cattle is concentrated in two peaks: during October to December, coinciding with the short rains; and during February to April, coinciding with the long rains. The milk supply increases in the succeeding months, resulting in reduced purchases of food. A smaller peak in supply also occurs during June. This is the period during which milk is in short supply and the Masai have to increase their purchases of food, mainly maize meal. Old cows and old bulls are in their best condition soon after the use of green grass in two succeeding rainy seasons represented by only 2 months.

EFFICIENCY OF THE CATTLE-MARKETING SYSTEM IN EASTERN KAJIADO

The analysis of prices received by producers, prices received by intermediate traders (between producers and final markets), and the marketing costs involved in moving livestock through the market chain provides an indication of the efficiency of the marketing system. For the purpose of this analysis, the Ong'ata Rongai market, which takes a major proportion of the slaughter cattle from Emali, is considered to be the final market.

The mean prices of adult SEA zebu and their marketing costs from September 1981 to August 1983 are given in table 5, which shows that producers receive a mean price of Ksh. 1,012 per head or Ksh. 3.97 per kilogram live weight. The mean price that traders at Emali obtain is Ksh. 1,396 per head or Ksh. 5.48 per kilogram live weight. Deducting their marketing costs of about Ksh. 65 per head or Ksh. 0.26 per kilogram live weight, they obtain an average gross margin of about Ksh. 320 per head or Ksh. 1.25 per kilogram live weight as a return to their capital, labor, and management. This represents a gross margin of about 23% per head, which is quite high. Traders were interviewed about the margins they normally realize. Depending on the time of the year and the condition of the cattle, they gave a range of Ksh. 100 per head on poor-conditioned animals to about Ksh. 600 per head on heavy steers in an excellent body condition.

Traders buying cattle at Emali and selling at Ong'ata Rongai incur marketing costs of about Ksh. 120 per head or Ksh. 0.47 per kilogram live weight, as shown in table 5. The mean price they receive is about Ksh. 1,920 per head or Ksh. 7.60 per kilogram live weight. This compares to about Ksh. 4, 5.50, or 7.25 per kilogram live weight, depending on whether the animal grades commercial, standard, or high, respectively. It is obvious, in addition to reasons already discussed above, why traders are reluctant to sell to KMC. Traders' gross margin at Ong'ata Rongai is Ksh. 394 per head or Ksh. 1.56 per kilogram live weight. This represents a gross margin of about 21% on their capital, labor, and management. Again, considering the high turnover they realize, this margin is on the high side.

PROBLEMS OF THE CATTLE-MARKETING SYSTEM

Both suppliers and buyers of cattle at the Emali market were asked to identify the problems they face in their respective trades. The suppliers complained about the high prices they pay at the boma and the low prices they receive at Emali. The buyers complained about the high prices they pay at Emali and the low prices they receive when they sell the animals. In view of the discussion above, this is not a genuine problem; rather, it is an expression by both parties of their desire for getting more profit.

Of the problems identified by suppliers, the genuine ones seem to be

- poor condition of animals due to diseases and frequent drought, which causes losses of animals during the trek to market
- lack of capital to increase the volume of cattle trade
- difficulties of trekking small numbers of cattle, which tend to be wild when in small herds

- occasional sales at a loss

The problems of poor condition and sales at a loss are normal hazards of the trade. It is well known that the Masai try to get rid of sick animals by selling them (Bekure, Grandin, and de Souza, 1982). In the long run, improved veterinary services and animal-health management may reduce losses from diseases.

Making credit available to country traders can solve the remaining two problems by making it possible for them to purchase more animals than they do at present. This has the potential of increasing their competitiveness and perhaps can result in increased prices to the pastoralists and reduced margins per head to the traders. However, making credit available to Masai traders will call for a bold approach both by bankers and big-town cattle merchants. After all, their counterparts in western Africa do finance small, up-country cattle traders. The problems of trekking small herds can be alleviated through cooperation among the traders, as is already practiced by some, to trek several small herds together as a single large herd.

Buyers of cattle at Emali also mentioned poor body condition of cattle due to disease and dry seasons, resulting in death. Many of the buyers custom slaughter their cattle at Ong'ata Rongai and Dagoretti to sell on a weight basis. Some of these buyers indicated that they occasionally misjudged the kill-out weight of the cattle they buy since they visually assess their condition, and they thereby incur trading losses. This problem may give an entry point for improving the general operation of the cattle market at Emali by introducing weighing and grading of cattle. Once this practice is accepted, the process can be taken a step further to introduce a system of auctioning, which eventually can yield higher prices to producers since bidding is done in the open and prices are known to all participants in the market.

Buyers also mentioned that lack of holding grounds at Ong'ata Rongai and Dagoretti forces them to sell their cattle immediately upon arrival. this problem can be solved if the County Councils of Kiambu and Kajiado allocate land for this purpose at Dagoretti and Ong'ata Rongai respectively and organize the management of the holding grounds. Some also indicated that at times the number of cattle offered for sale at Emali does not meet the demand. This problem could be alleviated if capital were made available to the traders that supply cattle to the Emali market. As is the case in many other countries, such credit may have to be financed by the buyers since they have a better access to the financial markets.

There is a general lack of time-series data on livestock marketing in Kenya. Gatere and Dow (1980) state that "the lack of market information is perhaps the weakest link in the beef marketing chain in Kenya." ILCA's cattle-market recording at Emali and Ong'ata Rongai was the only time-series data of its kind being collected in Kenya. There is no systematic source of market information on the various links in the marketing system to producers, traders, butchers, and more importantly to government policymakers who, by law, fix floor prices to producers and wholesale meat prices. It is clear that such price fixing cannot be done effectively in the absence of accurate information on supply and demand, production, and marketing costs. The notoriously dismal record of Kenya's meat-pricing policy up to 1984, which has resulted in discouraging beef production in the face of a deteriorating supply, is a

telling testimony to this fact (Fugile, 1973; IBRD, 1977; Chemonics, 1977; Cronin, 1979; Matthes, 1979).

We submit that the type of data that was collected by ILCA at Emali and Ong'ata Rongai can be collected at various regional livestock markets by the Ministry of Agriculture and Livestock Development at a marginal cost by deploying already existing field staff to collect this information as part of their routine work. The recommendations of Matthes (1978) and Gatere and Dow (1980) for a livestock-market information system, hitherto unheeded, should be seriously considered for implementation.

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Table 1. Source of cattle supply to the Emali market.

Source of supply	No.	%
Group ranches	3628	79
Trading centers		
Kajiado District	600	13
Machakos District	132	3
Individuals (nongroup ranch)		
Kajiado District	186	4
Machakos District	61	1
Total	4607	100

Table 2. Destinations of cattle traded at Emali.

Purpose	Destination	No.	% of slaughter or production	% total
Slaughter	Ong'ata Rongai	1105	24	15
	Dagoretti	1016	22	14
	KMC			
	Athi River	732	16	10
	Mombasa	242	5	3
	Mariakani	716	15	10
	Emali	25	1	0
	Machakos	305	7	4
	Others	474	10	6
Subtotal		4615	100	62
Production	Machakos District	1348	48	18
	Group ranches, Kajiado	1073	39	15
	Individual ranches, Kajiado	371	13	5
Subtotal		2792	100	38
TOTAL		7404		100

Table 3. Mean prices of cattle at Emali by breed, sex, and age, September 1981 to August 1984.

Breed	Sex		Immature Per head	Immature Per kg	Mature Per head	Mature Per kg	All Ages Per LWT	All Ages Per kg
SEA zebu	Male	Ksh.	751	4.28	1572	4.88	1043	4.51
		(N)	(1840)	(32)	(1016)	(20)	(2856)	(52)
	Castrate	Ksh.	952	5.07	1660	5.75	1369	5.57
		(N)	(1296)	(59)	(1805)	(163)	(3101)	(222)
	Female	Ksh.	789	4.80	986	4.92	960	4.91
		(N)	(187)	(7)	(1245)	(52)	(1432)	(59)
	All sexes	Ksh.	831	4.79	1436	5.49	1164	5.18
		(N)	(3323)	(98)	(4066)	(235)	(7389)	(333)
	% All breeds and sexes		44		53		97	
Sahiwal cross	Male	Ksh.	1174		2278		1874	
		(N)	(26)		(45)		(71)	
	Castrate	Ksh.	1409		2640		2239	
		(N)	(28)		(105)		(133)	
	Female	Ksh.	1060		1363		1307	
		(N)	(5)		(23)		(27)	
	All sexes	Ksh.	1276		2382		2018	
		(N)	(59)		(172)		(231)	
	% All breeds and sexes		1		2		3	
Boran cross	Male	Ksh.	1186		2597		1872	
		(N)	(7)		(7)		(14)	
	Castrate	Ksh.	1029		1840		1272	
		(N)	(7)		(3)		(10)	
	All sexes	Ksh.	1108		2342		1622	
		(N)	(14)		(10)		(24)	
	% All breeds and sexes		0		0		0	

Table 3. Mean prices of cattle at Emali by breed, sex, and age, September 1981 to August 1984 (continued).

Breed	Sex		Immature Per head	Immature Per kg	Mature Per head	Mature Per kg	All Ages Per LWT	All Ages Per kg
All breeds	Male	Ksh.	758		1608		1067	
		(N)	(1873)		(1068)		(2941)	
	% All breeds and sexes		25		14		39	
	Castrate	Ksh.	962		1723		1403	
		(N)	(1331)		(1913)		(3244)	
	% All breeds and sexes		17		25		42	
	Female	Ksh.	796		993		966	
		(N)	(192)		(1267)		(1459)	
	% All breeds and sexes		21		17		19	
All breeds and sexes		Ksh.	840		1476		1193	
		(N)	(3396)		(4248)		(7644)	
		%	44		56		100	

Table 4. Characteristics of cattle bought at Emali and destined for Machakos and Kajiado districts.

	Destined to Machakos District				Destined to Kajiado District				
Breed	Male	Castrate	Female	All sexes	Male	Castrate	Female	All sexes	All breeds
Masai Zebu									
Immature	1176	166	7	1349	319	734	121	1174	2523
Mature	114	120	63	297	49	178	55	282	579
Subtotal	1290	286	70	1646	368	912	176	1456	3102
Sahiwal cross									
Immature	11	5	--	16	15	20	5	40	56
Mature	1	6	9	16	4	6	9	19	35
Subtotal	12	11	9	32	19	26	14	59	91
Boran cross									
Immature	--	6	--	6	--	--	--	--	6
Mature	--	--	--	--	--	--	--	--	--
Subtotal	--	6	--	6	--	--	--	--	6
All breeds: No.	1302	303	79	1684	387	938	190	1515	3199
%	77	18	5	100	26	62	12	100	n.a.

Table 5. Cattle-marketing costs at Emali and Ong'ata Rongai, September 1981 to August 1982.

		Ksh. per head	Ksh./kg live weight
Mean purchase price from producers		1012	3.97
Marketing costs up to Emali			
- Trekking fee	Ksh. 20.00		
- Watering fee	Ksh. 2.00		
- Food and lodging	Ksh. 12.00		
- Transportation	Ksh. 4.00		
- Loss			
trading	Ksh. 10.00		
death (1/60)	Ksh. 17.00		
Mean sales price at Emali		1396	5.48
Trader'e mean gross margin at Emali		319	1.29
Mean purchase price at Emali		1396	5.48
Marketing costs up to Ong'ata Rongai		119	0.49
- County council fees	Ksh. 7.00		
- Trekking fee	Ksh. 20.00		
- Watering fee	Ksh. 2.00		
- Food and lodging	Ksh. 20.00		
- Transportation	Ksh. 12.00		
- Miscellaneous costs	Ksh. 12.00		
- Loss			
trading	Ksh. 14.00		
death (1/60)	Ksh. 32.00		
Mean sales price at Ong'ata Rongai		1919	7.6
Trader's mean gross margin at Ong'ata Rongai		394	1.55

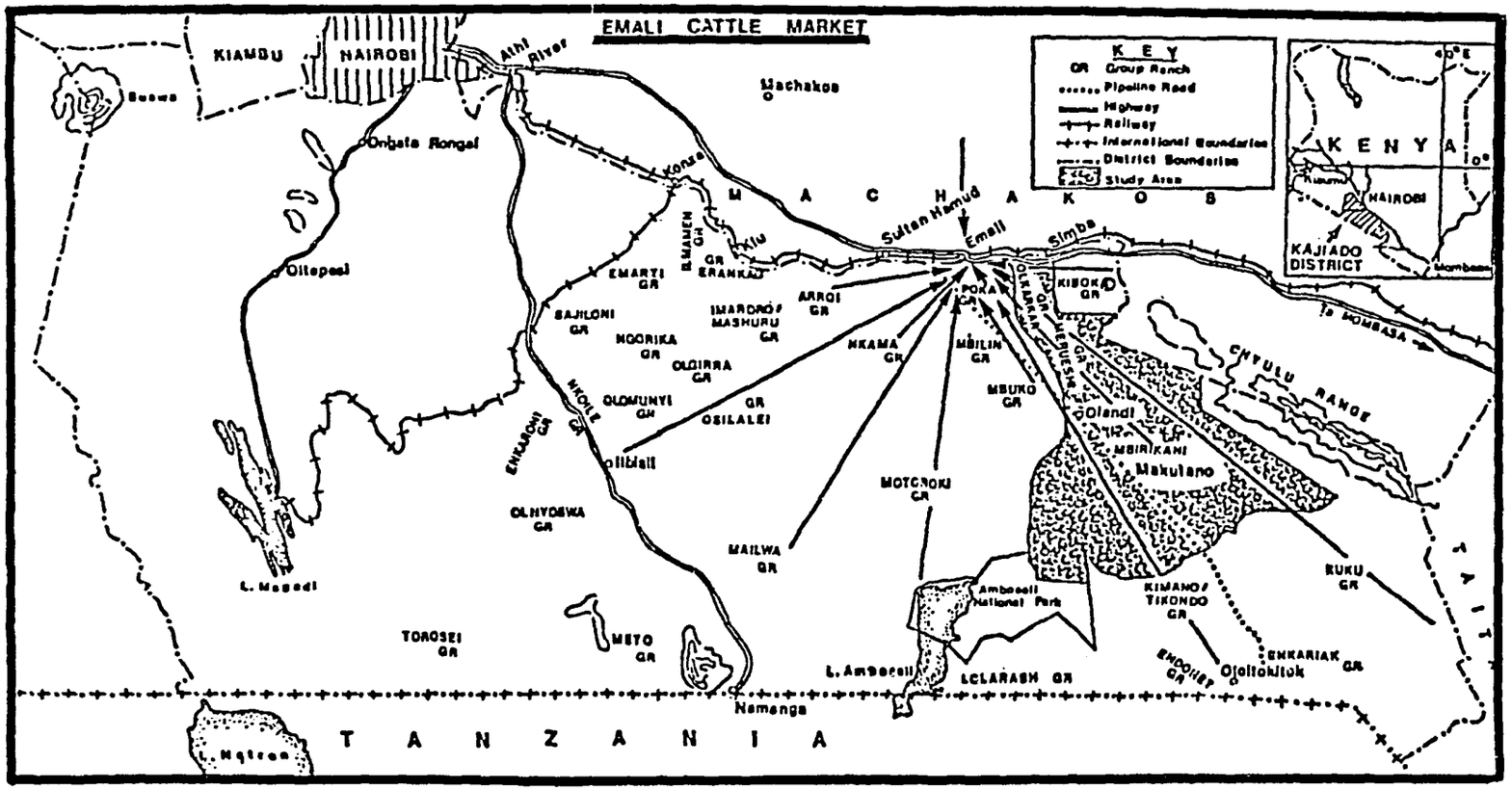

Figure 1. The hinterland of Emali cattle market.

RANGE-DEVELOPMENT CONSTRAINTS AND RESEARCH IN KENYA

Abdillahi A. Aboud

INTRODUCTION

With the attainment of political independent in early sixties, Kenya strived for economic independence also. It was imperative, therefore, for the country to take stock of its resources, exploit them, produce for domestic demands, and export the surplus to generate foreign exchange.

Rangelands, constituting 80% of the total land area, ranked among the priority resources. Besides their vastness, the rangelands were of high potential and played an important socioeconomic role in production, according to Kaufmann (1976). The contribution of the livestock sector was quite significant in the nonmonetary sector of the economy in terms of livestock products for food and for home use (Senga, 1976). Furthermore, the rangelands, and especially the pastoral lands, had been denuded through poor use, and the danger of desertification was eminent, as was the case in most sub-Saharan countries (Monod, 1975).

Consequently, the Range Management Division (RMD) was established in 1963 and charged with effecting rangeland development to ensure increased and sustained production and curbing range deterioration. Manned and advised by expatriates, the division based its development decisions on the concepts of range management developed in the United States. These concepts advocated:

- delineating areas of land as the basic management units
- dividing the units into several pastures to allow rotational grazing
- providing water and other range improvements and structures
- maintaining proper stocking rates
- providing modern animal husbandry
- injecting financial and other inputs

Sustained outputs were expected in the form of livestock and products to meet domestic demands and surplus to be exported to generate foreign exchange. The United Nations Special Fund/Range Management Project was decreed in 1964 to assist the newly established RMD in conducting predevelopment surveys and formulating rangeland-development plans, to be funded by the World Bank (FAO, 1971).

The resulting development created projects in two broad types of production systems: commercial-production systems in the form of company, cooperative, and individual ranches; and pastoral-production systems in the form of group ranches and grazing blocks. These groupings were dependent largely on land tenure and social organizations (Ayuko, 1981).

Recent evaluation and monitoring of the first two phases of development have revealed many discrepancies that have hindered the accomplishment of the projects' objectives and wasted tremendous financial and range resources. No wonder the World Bank became reluctant to finance a third phase.

What went wrong? This paper contends that the predevelopment data often were too inadequate and short sighted to be useful, were not used in the

planning and implementation of the projects, or were not appropriate for Kenyan conditions.

This paper attempts to accomplish two tasks:

- to point out and briefly discuss the relevant discrepancies, categorized as socioeconomic, ecological, and technical constraints

- to suggest some alternative approaches that the contemporary range researcher can consider for improving the performances of the range projects.

In most of the discussion, the terms "rangelands" and "pastoral lands" are used interchangeabley since the pastoral lands constitute the majority of the rangelands and play a major role in supporting the commercial sector of Kenya's rangeland development. By the same token, the terms "ranchers" and "pastoralists" are used interchangeable unless otherwise specified.

SOCIOECONOMIC CONSTRAINTS

Socioeconomic constraints that have affected implementation of range development include primarily

- pastoralists' suspicious attitudes toward range-development projects as an influence of their history

- strong sociological attachment to livestock that contravenes projects' objectives of livestock commercialization

- disregard of traditional innovations by range planners and implementors

- disregard for the pastoral social organization and institutions in the choice and use of project leadership

Pastoralists' Poor Attitudes

Pastoralists' attitudes toward range management have been affected adversely throughout the history of the people. Up to this era, many pastoralists viewed any form of range project with suspicion and contempt, recollecting the fateful events they have been subjected to in the past.

In the beginning, during the precolonial era, the pastoralists were happy and survived comfortably with their livestock in their harsh environment. They had always lived in this environment, so they had become adapted and had learned the tricks of survival. Through pastoral nomadism, extensive knowledge of their environment and resources, and use of efficient traditional innovations, all of their socioeconomic and ecological needs were met, so they lived harmoniously (Aboud, 1985b).

The problems started during the colonial era when, in the name of economic development (Aboud, 1971)

- they were confined forcibly in ecologically unviable land units and sedentarized

- a livestock-quota system was introduced

- destocking was emphasized
- livestock markets were established where even unwilling herders had to supply stock
- ruthless punishment was instituted for defaulters

The pastoralists entered the independence era with hope, but they were suspicious of any new development projects that would involve their livestock and grazing lands. This attitude has been shown to have affected the performance of the contemporary pastoral projects -- the group ranches and grazing blocks -- that seemed similar to those of the colonial era. Needless to say, such an attitude cannot help effective implementation of range projects involving pastoralists and their stock.

Strong Sociological Attachment to Livestock

Pastoralists' strong attachment to their livestock has been a serious constraint to range development that advocates commercialization of the livestock and maintenance of proper stocking rates. To pastoralists, maximization of their cattle is tradition, prestige, power and status, and wealth. It is their bank -- a means of subsistence and means for purchase and exchange of goods. It is security in times of disaster and old age and, above all, cattle are for ceremonial and ritual obligations. As Dyson-Hudson (1970) adds for the Karamojong, their social, economic, and sentimental outlay is cattle oriented, and thus it is difficult to introduce a cash economy because livestock is considered to be cash and wealth. Maximization of livestock, then, is the rule, defeating the basic purposes of commercial ranching and causing the failure of many pastoral projects.

Disregard for Traditional Innovations

Yet another sociological issue that has inhibited effective range development is range planners' disregard for traditional knowledge and technology for livestock and range management. Pastoralists' knowledge about range resources is vast. The Somalis, for instance, make useful classifications of their soils, know the mineral content of each soil, and know the best times and frequencies for livestock to graze different types of vegetation on different types of soil.

Pastoralists also have names for the plant species growing in their ecosystems, know their nutritive values, and know which species livestock prefer. The herders know their individual animals and the diseases that affect their stock. Interestingly, they also have traditional cures and precautions for some of the diseases. The concepts of livestock quarantines, isolation of sick animals, and provision of disease immunity are not new to them.

There are many more such useful traditional techniques and innovations that range planners and implementors could blend with modern techniques to enhance their chances for adoption and thus the range projects' chances for success, but they do not.

Disregard for Pastoral Social Organizations

The final sociological problem affecting range development is disregard by planners and implementors for the pastoral social organization and institutions in the choice and use of leadership.

Based mainly on age-group and ritual systems, pastoral leadership is decentralized, with a council of elders making decisions through dialogs and compromise. Coercive authority, like that used in most range-project implementation, is not helpful. The use of chiefs and extension agents who make unilateral decisions and enforce ideas have not always been very successful in pastoral projects. This has been a problem also.

ECOLOGICAL CONSTRAINTS

Ecological constraints that have inhibited effective range development are

- those associated with the harsh pastoral ecology and disregard of drought occurrence in planning
- attempts to sedentarize pastoral people in unviable ecological land units
- reduction of traditional grazing lands through encroachment of dry-land farming and group-ranch subdivision
- establishment of wildlife parks and reserves, which do not directly benefit the pastoralists, in pastoral lands.

Harsh Pastoral Ecology

In most pastoral lands, precipitation is erratic and scarce, and other ecological factors combine to limit the moisture that is available for plants and livestock to use.

Probably the most important characteristic of the pastoral ecology, and the one that has escaped the attention of most range planners, is the frequent droughts. Bernsten and Jacobs (1983) have determined that droughts take several forms -- localized, regional, and national -- and vary enormously in intensity. Masai pastoralists assert that they tend to experience a mild drought once every 3 to 5 years, a severe drought once every 7 to 8 years, and a devastating drought (often preceded by insect infestation and followed by heavy rains) once every 11 to 15 years. Thus, there is seldom a single year when some part of Kenya's rangelands is not suffering a local drought, in spite of the fact that regional or national droughts occur less frequently. It is inexcusable for a ranch plan to overlook the frequency of such droughts.

Sedentarization of Pastoral People

Most range-development projects were based on policies that aimed at sedentarization of the pastoral people to simplify administering the projects providing socioeconomic services. Unfortunately, confinement of large herds in ecologically unviable land units has resulted in over-grazing, while injudicious construction of permanent water sources has caused the pastures to be overused.

Given the common commitment to their livestock as value and as a means of subsistence, and given the marginal, unreliable environment in which they operate, the pastoralists recognize no artificial ranch boundaries and, as a matter of necessity, move their herds as conditions dictate. Consequently, their loyalty to assigned ranch confinements becomes questionable and difficult to honor.

Encroachment of Dryland Farming

Reduction of grazing lands through encroachment of dryland farming into marginal range areas is a historical phenomenon. As high-potential agricultural lands became overpopulated, the tendency was for the farming communities in the vicinity of the pastoral lands to venture into dryland farming. Lacking the appropriate technology to cope with the unreliable environment, these vast lands were degraded rapidly, rendering them unavailable for grazing.

More relevant is the recent proposal to subdivide the group ranches into individual holdings. As Aboud (1985b) argued, the pastoralists, especially those in marginal areas, will opt for arable cultivation in one form or another for subsistence and survival. This not only will reduce the scope of grazing lands, but it also will result in land denudation if no guidance is provided for the new agropastoral production systems.

Establishment of Wildlife Parks and Services

Wildlife, as our national heritage and an important contributor to the national economy, deserves protection. Wildlife parks and reserves thus were established to provide conservation and management, mostly in the rangelands. Some significant wildlife values include: tourism, hunting, game cropping, game ranching, aesthetic, scientific, and cultural.

The discrepancy involved in the establishment of the parks and reserves lies in the fact that the ranchers' interests were not considered adequately, therefore their attitudes toward wildlife have not been supportive. Consequently, the relationship between wildlife and ranching is competitive and distrustful rather than complementary, as it should be. Aboud (1985b) determined that many problems occurred because of this discrepancy, affecting the performance of both the parks and reserves and the ranches.

The main area of conflict is in the commonly used ecological niche and the resources involved. The ranchers feel that, although their contribution and sacrifice toward maintenance of the wildlife is abounding, their returns are negligible and, thus, they are on the losing end.

TECHNICAL CONSTRAINTS

The three major technical constraints affecting range development in Kenya are

- erroneous planning and implementation of range projects
- ineffective extension programs
- inefficient ranch management, especially in the commercial sector

Erroneous Range Planning

The unviable sizes of the pastoral projects and disregard for the frequent droughts, as discussed above, contribute to erroneous planning. Furthermore, if the socioeconomic issues (also discussed earlier) were considered adequately in planning, most of the present problems probably would have been averted.

But the most serious error in planning was the lack of adequate involvement of the pastoralists in making decisions about and implementing their projects. Aboud's thesis (1982) looked into this discrepancy and determined that the top-to-bottom approach of designing and implementing range projects generated sociotechnical constraints that were responsible for the failures of the projects. A devastating repercussion was that the ranchers did not identify themselves with the projects. This naturally creates doubts about the relevancy of the intended projects, people's recognition of the need for the projects, and worse still, the possible violation of social values. All of these factors contribute to project failures.

Ineffective Extension Programs

Probably the most discouraging phenomenon in the extension programs is the nature of the extension messages. Sedentarization and destocking are among the cardinal teachings of the range principles; however, when an extension agent mentions them, the battle already is half lost. The pastoralists are extremely sensitive to such innovations and certainly will resist.

Related to this problem is the sophisticated nature of some innovations that prove cumbersome for the pastoralist to grasp and adopt; for example, maintenance of livestock quotas and adherence to a calendar grazing system, as opposed to the traditional wet- and dry-season grazing system.

Another discrepancy is in the utility of extension methods. Most extension agents use group meetings (barazas) with no follow ups instead of teaching the ranchers individually. The assumption is that the new innovation will be adopted first by the more-advantaged "innovators" from whom the "laggards" ultimately will learn. Research has shown that this may not necessarily happen; and, if it does, then it takes too long, causing the disadvantaged laggards to remain laggards forever.

A training-and-visits (T&V) approach was introduced recently that is a consolidated agricultural-extension package in which range-management is to serve. While the concept is relevant and useful, weaknesses already have been identified, and it is quite obvious that range extension has found little or no utility in it.

Finally, range-extension programs are handicapped by administrative problems that affect extension work and performance, as listed by the extension agents in Aboud's thesis (1982). Transportation and mobility problems ranked highest.

Inefficient Ranch Management

Several problems affect the management and performance of ranches, especially in the commercial sector. Some urgent ones include managerial incompetency, high investment costs and low returns, pricing and marketing policies, complicated credit procedures, high interest rates on loans, slow loan repayment and default, unavailability of stock, frequent droughts, and disease outbreaks. The most critical of these problems, however, is the unavailability of experienced and competent ranch managers.

ALTERNATIVE APPROACHES TO RANGE RESEARCH

The diffusion-of-innovation paradigm advocates testing innovations through research and passing them through agricultural-education institutions in the client country so they can be modified for local conditions before they are presented to the people. Given the many problems associated with Kenya's range development, it is logical to assume that the borrowed range innovations did not comply with this requirement. It also is tempting to assume that contemporary range research has had little or no impact on the trend of development. This paper suggests that it is now of paramount importance for the range-research programs to adopt alternative approaches to solving the problems so the range projects will have better chances to succeed. At least the following five suggestions should be considered:

- Adaptive research must be used in problem solving. That is, research efforts and resources should be directed only toward the relevant existing problems affecting range development. This paper and several others have exposed most of the problems, although independent study may be necessary to confirm them. Priorities should be set, and research activities should be phased and implemented.

- On-ranch research must be conducted. That is, present institutional research should be extended to the ranches, involving the ranchers and extension officers in the process. This will allow the relevant and pressing needs of the ranchers to be identified and tackled giving full regard to the problems perceived by the ranchers and the solutions they prefer. On-ranch research should be directed to specific, localized areas to benefit a cluster of ranchers living within the vicinity. Stratification and clustering of ranchers in similar ecological conditions and with similar problems may help to economize on resources.

- Ranchers have rejected many useful, modern innovations because they found them too sophisticated. Yet, each modern innovation has a corresponding similar, traditional innovation that has been used successfully. If new innovations are blended with traditional ones, cultural shock is reduced and the innovations are accepted more easily. Such innovations are provided in the ranchers' sociocultural profiles, which are compiled and published for each district by the Institute of African Studies. Better still, the information can be obtained from close interaction with the ranchers themselves. The National Range Research Station needs to take this seriously, recognizing that the traditional sector offers a wealth of usable information. Besides, a standing rule of the diffusion model is that borrowed innovations must be modified to suit local situations.

- Considering the multidisciplinary nature of range-development constraints, a multidisciplinary team of researchers must be involved. Joint efforts of a range ecologist, an agronomist, a meteorologist, and an extensionist should yield relevant information that could be used to solve the present problems and guide future projects. Each of these scientists will find immediate utility in the discussions of problems presented in this paper.

- Finally, research is worthwhile only if the findings are used. It is the obligation of the National Range Research Station to

propagate research information to the beneficiaries (the ranchers) through the extension service as a matter of procedure. The on-ranch research approach suggested earlier would make this easier.

The station's mailing list must include educational institutions that train future range technicians and professionals; and closer cooperation and interaction with the institutions is necessary.

CONCLUSION

Though the problems presented in this paper are alarming, range development in Kenya has had some successes, especially in the commercial sector. The objective of this paper is to provoke the consciousness of those concerned so that they strive harder to encourage progress in the interests of our ranchers and the national economy. The National Range Research Station already has taken some strides in the right direction. We recently have witnessed a sort of on-ranch research, undertaken in the areas around the station, involving socioeconomic disciplines. Now these efforts must be intensified, and adaptive research must be introduced in other disciplines to justify the tremendous financial and other resources invested in the livestock industry. There is potential and ability to do so, but we have to make the first move.

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RANCH-CREDIT FACILITY AND ADMINISTRATION

E. M. Kachula Ruel

ABSTRACT

Ranch credit became institutionalized in the late 1960s. The Livestock Development Credit Programme has been jointly sponsored by the government of Kenya, the World Bank, USAID, and the Swedish government, among others. In processing the credit facility for ranchers, officials of the Agricultural Finance Corporation work closely with range-management officials. The loan application goes through a loans committee to the board of directors; thereafter, if the applicant has fulfilled the legal formalities, authority is issued to incur expenditure. Disbursements start on the basis of incurred and(or) contracted expenditures. The credit facility is very closely supervised, and it is for all ranch-development inputs and working capital (including operating expenses). The ranch-credit facility has been adversely affected by poor input/output price ratios and recurrent droughts.

INTRODUCTION

Ranch credit became institutionalized in the late 1960s as a component of the Kenya Livestock Development Project, for which phase II ended in December 1982.

The major objectives of the Kenya Livestock Development Project (KLDP) were to increase marketed production of meat and the incomes of pastoralists and other livestock investors through ranch and livestock improvement, contributing to the improvement of the economy in project areas and, consequently, of the country. In keeping with these development goals, a comprehensive range program, designed to increase productivity at all levels, has been under way in the range areas of Kenya since 1968, when the initial credit was approved by the World Bank and the Swedish government, among others. Phase II of the project was sponsored by the World Bank, USAID, and the Kenya government jointly. The two phases involved an equivalent of Ksh. 230.0 million.

The principal objective of the first phase of the project was to increase beef production by providing credit for four different types of ranching enterprises and feedlots. The ranch-credit facility has been and is being administered by the Agricultural Finance Corporation, a Kenyan government statutory body charged with the responsibility of administering the government's financial and credit packages for agricultural development. Commercial banks and other financial institutions generally do not extend credit to ranchers because of the high risks involved in the ranching enterprise.

WHAT TO FINANCE UNDER THE RANCH-CREDIT PACKAGE

Two types of loans are defined by purpose and duration: development capital, which is a medium- or long-term loan; and working capital, which is a short-term loan.

Medium- and Long-term Loans

A medium- or long-term loan is a 10- to 25-year development-capital loan. It may carry a maximum grace period of 4 years within the 10

years. The development-capital loan is given for the following categories and items of development inputs:

Category	Items
Water	Pumps, pipes, dams, tanks, troughs, etc.
Dips	Plunge dips, crushes, spray races, handling yards
Buildings	Staff houses, stores, ranch offices
Machinery	Vehicles, tools, tractors
Firebreaks	Access roads, boundary lines
Fencing	Night bomas, boundaries, paddocks
Breeding stock	Beef or dual-purpose bulls, cows, heifers
Bush clearing	Boma sites, pasture improvement
Other	Fodder crops

Short-term Loans

Short-term loans are given for working capital for a period of 2 years but may be revolved within a maximum period of 20 years. During the revolving period, the reborrowing may be allowed under declining ceilings.

Declining ceilings for reborrowing aims at giving the loan recipient the opportunity to plow margins back into the business instead of diverting them to some other business investments.

A working-capital loan is given partly for the purchases of immature cattle for fattening and partly for operating expenses such as

- vehicles, tractor maintenance
- salaries and wages
- maintenance of roads and firebreaks
- rents (land)
- pump and engine maintenance
- dip fluids
- salts and other minerals
- drugs and veterinary services
- contigencies

Loans may be considered for registered and national legal entities only. Loans may be considered for foreign-controlled entities with the approval of the Central Bank of Kenya.

LOAN-APPLICATION PROCEDURES

Applying for a Loan

The rancher approaches the local branch office with a loan request and is given an application form. The branch manager helps the applicant complete the loan application form. Then the branch manager makes a field inspection and requests the loan-application fees (.3%). The loan-application form is then forwarded to the district range officer of the Range Management Division for completion of the ranch plan. If problems or doubts arise concerning the application, a representative from the head office of the Agricultural Finance Corporation attends to the field appraisal of the ranch.

Forwarding the Loan-application Dossier

The loan-application form amd ranch plan are forwarded to the head office of the Agricultural Finance Corporation with the following additional material:

- certificate of company registration incorporation
- memorandum and articles of association/company
- list of directors
- minutes of last meeting
- resolution to borrow from Agricultural Finance Corporation
- authority to borrow, if a cooperative
- management: if by agent, copy of management agreement; if by employed manager, mention of auditors and secretaries
- ranch plan, development program, and ranch layout
- breakdown of loan amount required by items of expenditure
- security offered, document proof
- any financial projections
- latest balance sheet
- latest herd register
- ranch inventory
- financial commitments and mortgages

RANCH-PROJECT PLANNING AND APPRAISAL

The loans-processing officer at the head office of the Agricultural Finance Corporation examines and clears all outstanding points with the branch manager and the Range Management Division. Then the application is passed to the head of the Ranch Division.

Investment Plan

The investment plan is prepared, and a report is produced for the loans committee, which comes up with a recommendation for the Agricultural Finance Corporation's board of directors.

Appraisal-report Format

The format of the report has been standardized and contains the following:

- organization structure
- structure formation
- location
- the sponsors
- shareholders/ownership
- directors and management
- technical aspects
- acreage and carrying capacity
- ranch planning
- costs and income projections
- costs: fixed, variable, income
- financial analysis
- investment structure
- Agricultural Finance Corporation investment development and working capital
- financial structure
- breakeven sales analysis/financial breakeven analysis
- income-statement analysis

- cash-flow analysis
- discounted cash-flow analysis
- debt/equity ratio
- conclusions and recommendations

Approving and Granting the Loan

The loans committee papers are presented to the board of the Agricultural Finance Corporation and thereafter endorsed by the general manager and the chairman. If approval is given, the application is forwarded to the corporation secretary who follows up on all conditions of the loan and completes the legal formalities and the loan agreement. Finally, the legal section issues a letter that states that the loan can become operative, the Authority to Incur Expenditure is issued, and the loan account is opened.

Loan Disbursements

Disbursements are on the basis of incurred or contracted costs:

- Incurred expenditure. The clients have spent money on the project, and the Agricultural Finance Corporation reimburses the clients.

- Contracted costs. The clients obtain services and submit an invoice certified by the client (or official representative) and Agricultural Finance Corporation representative.

- Through advances to the joint bank account of the Agricultural Finance Corporation and the client, at the field level, the account is replenished as it is exhausted. Reimbursement claims are made through the Agricultural Finance Corporation's branch office.

LOAN SERVICING AND SUPERVISION

On-ranch Management Back-up Service

As a supervised credit, the livestock credit demands that the Agricultural Finance Corporation's field representative be very closely involved and consulted on the ranch operations and management decision making. Many of the ranches' loans have been secured by chattels' mortgage and debentures. Most of the assets on the ranch are very fluid and(or) perishable, and maximum management care and appropriate decisions must be taken as and when required. Today's decision cannot be made tomorrow, whether it is administrative or operationally technical. Therefore, the main duties of the field officer in rendering on-ranch management back-up service are

- to make sure management decisions on problem situations (financial or technical) are made as and when the need arises or is identified

- to make sure the actions resulting from the decisions are implemented and check on any variations and deviations in the implementation of the decisions reached by the management committee, the board, and the annual general meetings of the clients.

Effective handling of the above, under conditions of supervised credit by the field officer, means effective management control.

EXPERIENCE OF RANCH-CREDIT FACILITY ADMINISTRATION

Ranch Client/Borrower

The ranch clients -- the target group of the ranch-credit program -- have not been appropriate. The clients are required to contribute 20% equity, but this has not been forthcoming and therefore capital structure is poor and loan burdens are heavy. Most of the clients are from the low-income/subsistence brackets of society. Also, the clients have lacked experience in commercial-ranch management.

Factors Affecting Loan Repayments

In addition to the lack of equity and experienced commercial-ranch management, four other basic factors are largely responsible for ranch-loan deliquencies:

- a sharp rise in production costs since 1973
- a steep decline in producer prices in real terms
- extended and recurrent droughts during the last 12 years
- lack of adequate marketing arrangements and policy

CONCLUSIONS

For the ranch-credit facility to be a success and serve the interests of the producers, special attention must be given to harmonizing the input/output price ratios. At present, the ratios do not favor commercial-ranch development in the country.

The ranch-credit facility has laid a strong base for future rangeland-livestock development in Kenya by capital investments in livestock infrastructures and related institutions.

TRAINING, EDUCATION, AND EXTENSION

DIPLOMA AND CERTIFICATE RANGE-MANAGEMENT EDUCATION IN KENYA

I. K. Kemei

DIPLOMA EDUCATION IN RANGE MANAGEMENT

The Republic of Kenya consists of approximately 582,300 km^2, of which approximately 492,000 km^2 or 84% of the country is classified as rangeland. In these areas, the human population, composed mostly of pastoralists, is approximately 2 million people who own 50% of the nation's livestock. Range areas produce 60% of the nation's beef cattle, estimated at 9 million head, and more than 70% of the estimated 8.5 million sheep and goats (Kemei, 1982). The livestock and wildlife in range areas depend on natural vegetation for their nutritional requirements and production (Kemei, 1979). The human population, in turn, depends on the livestock for its livelihood. Before giving objectives and course content of range-management education at Egerton College, the history of the college is briefly described.

Egerton College started in 1939 after Lord Egerton of Tatton donated 400 ha of his farm for training farmers in short, practical courses in general agriculture. In 1952, the institution became the agricultural college, offering a 1-year course for a certificate in agriculture and a 2-year course for a diploma in agriculture, in addition to the shortcourses previously offered. In 1955, the Egerton Agricultural College Ordinance was promulgated and provided for the establishment of a board of governors. The ordinance also specified that the college should function as a self-governing institution or parastatal organization. The college has been expanding rapidly in terms of facilities and services to meet the increasing demands for qualified and competent agricultural personnel for Kenya and other African states. At the moment, the college offers 16 diploma programs, including one in range management that started in 1965.

Range-management training at Egerton is designed to prepare students for work in the fields of extension, training ranchers at training centers, performing research at range-research stations, managing ranches for private or semiprivate companies, or even as agricultural loan officers within some agrofinance agencies. Table 1 shows the numbers of Egerton graduates in range management from 1965 to 1985.

The objective of the program is to provide the students with knowledge and practical skills or techniques in range management and related fields that are applicable in tropical, semiarid areas. The college farms and a field station located in a semiarid area are used for practical training to supplement the lectures. The department also has a grass nursery and herbarium. After graduation, the trainees should be able to provide information, advice, action, or any other service required in range areas.

In eastern Africa, the areas receiving low, erratic rainfall and supporting natural grazable vegetation are not fully or properly used. In the interests of national economics and the welfare of pastoralists, the realistic economic values of these resources must be exploited fully and properly. To do this, these areas should be conserved, developed, and where necessary rehabilitated. They should be conserved because they are ecologically sensitive to improper land use, particularly

overgrazing. These areas must be used by proper numbers and kinds of livestock. Protection of desirable, actively growing forage plants must be ensured. The development of range areas involves raising technical efficiency in water development, livestock improvement and management, disease control, rangeland education, and financing. Not only would success in rangeland use ensure adequate domestic meat supplies for the growing population and enable beef exports to make a major contribution to foreign-exchange earnings; but also a thriving beef industry would generate a multiplier effect in the other sectors of the economy, particularly those in the range areas where pastoralists live.

In the first year of the 3-year program, the students are offered courses in basic science and introductory courses in agriculture. The objective at this early stage is for the students to appreciate and understand the interrelationships between range management and the basic sciences of biology, chemistry, and mathematics.

In the second and third years of the program, the students are offered courses that are of practical significance with respect to knowledge and skills that they will need when they graduate. The courses are offered so they follow each other in a logical sequence and are supplemented with practicals, reading assignments, seminars, and visits to ranches and other places of academic interest.

The major departments participating in the range management program are as follows:

- Range Management
- Animal Science
- Agricultural Engineering
- Agricultural Education and Extension
- Crops
- Economics

The college's library also plays a significant role in the range-management curriculum.

Range-management training is adequate in its present form; that is, at the diploma level. The only major weakness is that the institution is located in a high-potential mixed-farming area, so the students are not exposed to arid or semiarid conditions on a daily basis. In spite of this condition, we feel that the college has the potential to produce more diploma graduates. The facilities at the college and those at Chemeron Field Station are adequate for theoretical and practical training. However, physical structures, equipment, and qualified staff would have to be expanded to cope with increased student numbers.

Course Content

The courses offered for a diploma in range management are listed in table 2.

Proposed Options in Range Management

Range-wildlife option. This option requires the following courses in addition to those listed for the diploma in range management (table 2).

Range-wildlife Relationships	competitive and complementary relationships between wildlife and other uses of rangelands; competition

	for forage between wildlife and other uses of rangelands; competition for forage between domestic livestock and big game; impacts of grazing and browsing upon wildlife populations
Game Birds and Mammals	taxonomy distribution and life histories of game birds, mammals, and big game
Wildlife Management	principles of wildlife and fisheries management, emphasizing population and habitat approaches to management
Management of Wildlife Habitat	biological requirements of terrestrial wildlife, methods of creating or enhancing wildlife habitat and integrating them with other land-use practices
Management of Wildlife Populations	population characteristics of big game and game birds and their implications for human exploitation
Management Aspects of Wildlife Behavior	behavioral principals important in the management of wildlife

Range-forest option. This major will require the following courses in addition to those courses listed for a range-management diploma (table 2).

Range Management	field identification of forest and dryland plants; methods and advanced techniques in vegetation-analysis practices for forest and dryland forage use
Forest Surveying	practical field problems in surveying methods commonly employed in forest, range, and wildlife management
Forest Practice	field studies in inventories, successional stages, and growth of stands for woody plants including trees
Dendrology	taxonomy, nomenclature, identification, geography, and ecological characteristics of major Kenyan forest trees
Forest Measurements	measurements of timber in log, tree, and stand; log rules and scaling; statistical methods useful in analyzing forest data; timber cruising practical; aerial-photo interpretation of land
Introduction to Forest-resources Economics	overview of forest economic systems as they interact with social, political, and resource-environmental systems on national level; forest-commodity economics
Logging	principles and methods of harvesting wood products with emphasis on cost, values, and application of forestry to the harvesting process

CERTIFICATE EDUCATION IN RANGE MANAGEMENT

The aim of the 2-year program is to train competent technical assistants in range management for the rangeland extension services. More than 50%

of the training time is devoted to practical aspects because the students will be in constant touch with the livestock owners in the field. They will be at the front line of the range management extension service in the rangelands. The practicals include training in practical skills, demonstrations, farm/ranch visits, and field work with relevant institutions within the Ministry of Agriculture and Livestock Development. Specifically, the students spend 6 weeks at Ngong Veterinary farm and 6 weeks at the National Range Research Station, Kiboko. At Ngong, the students are familiarized with routine farm work and farm-production techniques. At Kiboko, the students are exposed to range-research methods and practices in range-forage use and conservation. They are also exposed to problems and solutions in rangeland areas.

Course Content

The range-management subject syllabus for the 2-year period commencing in June and ending in late April 2 years later is shown in table 3. All terms are 10 weeks in duration.

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Table 1. Numbers of range, ranch, and wildlife graduates, Egerton College, 1965 to 1985.

	Course			
Year	Range	Ranch	Wildlife	Total
1965	20	--	--	20
1966	16	--	--	16
1967	19	--	--	19
1968	14	--	--	14
1969	18	--	--	18
1970	16	--	--	16
1971	16	--	--	16
1972	18	--	--	18
1973	25	--	--	25
1974	29	--	--	29
1975	21	--	--	21
1976	20	--	--	20
1977	29	--	--	29
1978	27	--	--	27
1979	20	--	--	20
1980	28	--	--	28
1981	21	--	--	21
1982	16	10	--	26
1983	11	10	8	29
1984	24	15	18	57
1985	25	16	8	50

Table 2. Courses offered, by departments, for diploma in range management.

Biology Courses	
0211	Agricultural Botany
0222	Vertebrate Anatomy and Physiology
0213	Taxonomy
0225	Genetics
0226	Agricultural Entomology
0214	Ecology
0227	Parasitology
0241	Environmental Science
Chemistry Courses	
0311	Basic Inorganic Chemistry
0321	Soil Genesis and Classification
0312	Basic Organic Chemistry for Biological Science
0331	General Agricultural Biochemistry
0341	Pesticides and Plant-Growth Regulators
Home Economics Courses	
0032	Planning for Better Family Living
0041	Introduction to Human Nutrition
Economics Courses	
0611	Introduction Economics
0614	Production Economics
0650	Farm Records and Accounts
0621	Farm Management
0673	Agricultural Marketing and Policies
0672	Rural Development
Education Courses	
0711	Introduction to Language Communication
0712	Technical Writing and Reporting
0741	Introductory Psychology
0751	Introduction to Rural Sociology
0752	Principles of Extension Education
0753	Extension Program Planning Teaching & Evaluation
0756	Government Procedure
Engineering Courses	
0811	Introductory Statistics
0815	Introductory Drawing
0820	Basic Workshop Practice
0841	Tractor Serving and Operation
0873	Soil and Water Management
0881	Water Development and Supply
0865	Farm Structures

Table 2. Courses offered, by departments, for diploma in range management (continued).

Animal Science Courses	
0112	General Practicals
0124	Animal Nutrition
0122	Animal Breeding
0113	Livestock Duties
0135	Dairy Production
0137	Sheep Production
0136	Beef Production
0127	Animal By-products
0130	Bee Keeping
0134	Goats Production
0133	Camels and Donkey Husbandry
Range Courses	
0950	Ranching in East Africa
0923	Principles of Range Management
0924	Range Plants and Ecology
0960	Outside Visits
0942	Range Inventories
0925	Wildlife and Range Use
0933	Bush Management & Grazing Systems for Rangelands
0929	Special Problems in Pastoral Societies
0961	Range Observations
0951	Range Planning
0911	Seminar
0914	Range Projects
Crops Courses	
0411	Principles of Crops Production
0430	Pastures and Forage Management
Dairy Courses	
0512	Dairy Industry
Animal Health Courses	
1113	Animal Reproduction
1121	Animal Health and Diseases

Table 3. Range-management subject syllabus for 2-year certificate.

Subject	Lecture	Practical	Total
Term 1			
Anatomy and Physiology	70	20	90
Chemistry	20	20	40
Physics	10	20	30
Animal Production	10	-	10
Organization of Government	10	-	10
Ecology/botany	100	20	120
	220	80	300
Term 2			
Range Pastures	132	44	176
Parasitology	33	11	44
General Pathology	11	55	16
Immunology and Vaccines	11	5.5	16.5
Agriculture	22	-	22
Farm Business Management	11	-	11
	253	77	330
Term 3			
Animal Production	16	280	296
Animal Health	16	-	16
Agriculture	16	-	16
Farm Machinery	8	16	24
Apiaculture	8	-	8
Farm Dairy	8	-	8
Extension	16	-	16
Range Management	16	48	64
Naivasha	15	15	30
Kiboko	16	112	128
	135	471	606
Term 4			
Range Management	88	22	110
Metabolic & Nutritional Disorders Including Plant Poisoning	11	11	22
Tickborne Diseases, Trypanosomiasis, and Their Control	22	22	44
Animal Health Practical Skills	-	11	11
Animal Production	55	11	66
Farm Business Management	33	-	33
Extension	22	22	44
	231	99	330
Term 5			
Range Management	77	44	12
Infertility and Neonatal Diseases and Mastitis	22	-	22
Bacterial & Fungal Diseases	22	-	22

Table 3. Range-management subject syllabus for 2-year certificate (continued).

Subject	Lecture	Practical	Total
Animal Production	55	11	66
Farm Business Management	33	-	33
Extension	22	22	44
Animal Health Practical Skills	-	44	44
	231	121	352
Term 6			
Range Management	80	20	100
Viral & Ricketsial Diseases	10	-	10
Zoonoses	5	-	5
Clinical & Field Aspects	5	-	5
Disease Control Legislation	10	-	10
Simple Treatment & Elementary Pharmacology	10	-	10
Animal Health Practical Skills	-	20	20
Animal Production	50	10	60
Farm Business Management	30	-	30
Extension	30	10	40
Government Procedure	10	-	10
	240	60	300
Second year total hours	702	280	982
First year	608	628	1,236
Second year	702	280	982
Total hours for course:	1,310	908	2,218

THE HISTORY OF UNIVERSITY RANGE EDUCATION IN KENYA

T. J. Njoka

INTRODUCTION

The need to train range-management professionals was recognized by the Kenyan government soon after the establishment of the Division of Range Management in the Ministry of Agriculture in 1963. The Division of Range Management took over the functions of the African Land Development Board that was established by the colonial government to improve the management of the native lands in Kenya in 1946.

The initial manpower to run the Division of Range Management came from UNDP/FAO expatriates. Diploma and certificate training in range management was started at Egerton College and the Animal Health Industries Training Institute at Kabete in the mid-1960s.

Soon after the diploma and certificate graduates were trained, the need for university graduates in the field of range management was identified even before the Faculty of Agriculture was started in the University of Nairobi in 1970.

In 1969, the University of Nairobi established a link with the University of California. Professor H. F. Heady and M. Love from the Davis Campus were consulted about how the range-management curriculum could be incorporated in the Bachelor of Science in Agriculture curriculum of 1970-71.

In 1971, Professor Heady forwarded his proposal for four undergraduate courses in range management to be taught in the curriculum; however, the curriculum was overloaded to the extent that no additional courses could be accommodated.

Professor Contant, a former dean of the Faculty of Agriculture, followed up on the development of a range-management curriculum in the Faculty of Agriculture through the Australian Embassy in Nairobi. In 1973, the Australian government seconded Dr. Robbins, who was attached to the Department of Crop Science, to work out the details of a range-management curriculum.

Dr. Robbins spearheaded the establishment of a Master of Science in Range Management course in the Department of Crop Science in 1974. Unfortunately, none of the agriculture graduates who applied for an M.Sc. program opted for the range-management course in 1974 and 1975.

At the thirty-first meeting of heads of departments in 1975, the dean of the faculty established a committee to study and recommend a suitable range-management curriculum for the Faculty of Agriculture. The members of the committee included Professor P. M. Ahn, Soil Science (convenor); Professor A. Weber, Agricultural Economics; Dr. A. B. Carles, Animal Production; and Dr. R. G. Robbins, Crop Science. Dr. Theuri J. Njoka became involved in November 1976.

The committee explored many issues and reported its activities to the dean of the Faculty of Agriculture in November 1977. The following is a brief summary of the issues discussed in the nine meetings that the committee held between 1975 and 1977.

The committee recommended three alternatives for teaching range management in the faculty:

- To establish a new Bachelor of Science in Range Management program that would parallel similar programs such as B.Sc. Food Science and B.Sc. Agricultural Engineering in the Faculty of Agriculture. The curriculum would require 3 academic years, with a total of 2,333 contact hours, and a ranch-practice period of 6 to 9 weeks. However, this program would require 570 contact hours for specialization in range management, while the rest of the contact hours would be taken in the B.Sc. Agriculture curriculum. Several advantages for choosing the first alternatives were listed.

- To teach the range-management curriculum at M.Sc. level. The only advantage in this proposal was the ease of establishing master's courses compared to undergraduate courses. However, because of the poor response to the M.Sc. Range Management course in Crop Science, it was felt that this alternative would not be feasible. In addition, the agriculture graduate opting for an M.Sc. in Range Management would not meet the prerequisites for the course.

- To teach a new B.Sc. program in which dryland farming and range management would be emphasized equally. This proposal considered the B.Sc. Agriculture curriculum, which had little input in dryland farming. This option did not receive much attention from the committee.

Among the several advantages for establishing B.Sc. Range Management curriculum were:

- A demand already existed for graduates with B.Sc. Range Management degrees. The Kenyan government was spending an average of $11,000 per year to train the personnel in the United States.

- The program would be in line with the trend in the faculty; that is, establishment of the B.Sc. curricula in Food Science and Agricultural Engineering in 1974 and 1975, respectively.

- The B.Sc. Range Management graduates would meet the requirements for an M.Sc. course.

- There would always be sufficient entrants from school level and through sponsorship by the Ministry of Agriculture.

- The B.Sc. Range Management course would attract applicants from neighboring countries since the curriculum would be more relevant to the local conditions than the programs offered in the United States.

- The program would be attractive to foreign donors because of its regional impact.

The committee was not unanimous in recommending the first option of a B.Sc. Range Management program.

In 1978, Professor C. N. Karue, then the dean of the Faculty of Agriculture, requested Professors D. Dwyer and T. Box to propose a B.Sc. Range Management curriculum for the faculty, taking into consideration the deliberations of Professor P. M. Ahn's committee on range management.

The curriculum that is now being taught at the faculty is based on the final recommendations of Professor Dwyer and Professor Box.

The University of Nairobi Senate approved the range-management curriculum in 1979. In July 1980, the Department of Range Management was established in the Faculty of Agriculture to administer the B.Sc. Range Management program. The first nine students were admitted in the same year; and 4 years later, in July 1984, the program produced its first seven graduates.

DEMAND FOR RANGE-MANAGEMENT STUDENTS

The demand for B.Sc. Range Management graduates was estimated in 1977 at about 10 students per year for the next 10 years (Strange, 1977). But, according to T. Box, this was an underestimate, and an average of 20 students per year would be adequate for Kenya. If the department is to cater to neighboring countries, the student intake could be increased to 50 per year.

If agriculture training is to be relevant to ecological zones, then all the range districts should engage range-management graduates to teach in the high schools. At an average of five high schools per district, the 30 range districts would demand an additional 150 teachers.

FACILITIES

The Kabete library reflects more of the degree programs that were started before 1980. There is a great shortage of books and journals on range management. One solution to this problem is for Kenya range professionals to write books on their experiences in range management in Kenya.

In the meantime, we request our colleagues in U.S. universities and the American Society of Range Management to make the Kabete library a depository of books, journals, and other materials on range management. In particular, the International Livestock Centre for Africa (ILCA) can assist in this direction because of the ILCA's emphasis on documentation of livestock production in Africa.

The department now has two large laboratories, 3 seminar rooms, a teaching herbarium, 5 offices, the chairman's office, and six residential four-bedroom houses on the campus. In addition, the department is developing a field-experimentation station at Kibwezi, on 5,000 ha, with student and staff facilities costing about Ksh. 11 million.

At Kabete, the department has been allocated a 2-acre plot for teaching demonstrations and another 23-acre plot near Duduville, which is earmarked for seed multiplication of exotic and indigenous browse species.

CURRICULUM DEVELOPMENT (B.SC.)

The current curriculum for the B.Sc. Range Management program includes the following courses, which are taught within the department (as proposed by Dwyer).

Course	Hours
Taxonomy of Higher Plants	40
Ranching in East Africa	40

Range Ecology	40
Introduction to Range Management	40
Range Plants and Their Values	40
Principles of Range Management	40
Economics of Livestock Production and Farm Management	40
Ranch Practice (Fieldwork)	8 weeks
Range Improvements and Grazing Systems	40
Ranch and Range-Management Planning	40
Methods of Rangeland Inventories	40
Range-Management Seminars	40

The students spend only 30% of their time in the department taking the above 12 courses. The rest of the courses, taken jointly with B.Sc. Agriculture students, compose 70% of the degree program.

Courses from other departments include:

Course	Hours
Economics I	40
Introduction to East African Agriculture	40
Mathematics	40
Chemistry	40
Zoology	80
Biochemistry	80
Statistics	60
Plant and Crop Physiology	60
Animal Physiology	60
Economics II	40
Agricultural Policy or Agricultural Law	64
Animal Production I	160
Genetics and Animal Breeding, Nutrition and Feeding	160
Agricultural Engineering I	80
Soil Science I	100
Farm Management I	70
Agricultural Marketing and Agricultural Extension	40
Animal Production II: Ecology and Management	40
Agricultural Engineering II: Soil and Water Structures and Mechanization	80
Soil Science II	100
Animal Health and Hygiene	40

Some important subject matter is still to be included in the departmental courses, although it can be argued that the students pick up the information from other related courses that are taught outside the department. Courses in watershed management, recreation/tourism management, range policy, wildlife-livestock interactions, pastoral sociology, and human population dynamics in rangelands will be included later. The development of course content with local relevance is not an easy task for the staff members.

Problems of development in the rangelands are changing very quickly. There is now strong justification to offer a course on dryland farming because of the need to integrate crop-livestock systems in marginal areas. The ideas of agroforestry are very relevant as the ranches become smaller in size through subdivision. In addition, the Department has identified a need to train students to write good funding and evaluation proposals and to understand administrative changes.

STAFF-DEVELOPMENT PROGRAM

The department has seven established positions, all of which have been filled. Four members of the academic staff are on study leave in the United States.

In the meantime, the department relies heavily on part-time lecturers from the Ministry of Agriculture and Livestock Development, and it will continue to do so for the next 3 to 4 years.

CONTINUING EDUCATION

The members of the academic staff are very involved in reviving the activities of East Africa Society of Range Management because such a society is one of the best avenues for exchanging ideas with former students and graduates from other institutions.

The department also admits students with a minimum of a credit diploma from Egerton; and, for the last 2 years, the top students in the department and the whole Faculty of Agriculture were diploma holders.

The development of a postgraduate program in the department will cater to the demand for continuing education from employees of the government and parastatal and other institutions. This development will foster research for rangeland development in Kenya. An M.Sc. curriculum is being prepared with a view to launching the program by the 1988-89 academic year.

RANGE-MANAGEMENT PERSONNEL AND DEPLOYMENT

J. M. Muteti

ABSTRACT

Before the establishment of the Range Management Division (RMD), most of the services of government had been available only nominally to the range areas of the country because no personnel were specifically trained in the discipline of range management and ecology. Immediately after the establishment of the Range Management Division in 1963, training schemes were developed to provide range-management technical personnel of graduate, diploma, and certificate standards. At the moment, RMD has 49 range officers (professionals) with at least bachelor of science degrees in range management/range science, 199 technical officers (assistant range officers) with diplomas in range/ranch management, and 387 technical range assistants with certificates in range management. Range-management activities are confined to the arid and semiarid areas of the Kenya, and most range-management personnel are deployed to these areas to perform assignments relating to range-management extension and development, despite a few constraints.

HISTORY AND DEVELOPMENT OF RANGE-MANAGEMENT PERSONNEL

Before the Range Management Division (RMD) was established, livestock-production activities in the range areas were handled by veterinary officers assisted by livestock officers, while agricultural officers supervised livestock-production activities in high-potential areas. The major emphasis was on control of disease and livestock numbers.

By the time of independence, however, experience had shown that the problems of range areas could not be attended to satisfactorily by veterinary and agricultural officers. That realization led to the establishment of a technical division with personnel specifically trained in the discipline of range management and ecology. Consequently, the Range Management Division was established in 1963 within the Ministry of Agriculture. At that time, RMD was at a considerable disadvantage because there were no personnel trained in range management and ecology who could take up assignments with the division.

To meet the immediate, short-term need for range-management personnel, officers were recruited from what was then the Department of Agriculture who had experience in the country's rangeland and who had been responsible for the operation of grazing and range-rehabilitation schemes started under the African Land Development (ALDEV) organization. At the same time, negotiations started with the United Nations Development Programme (UNDP) and the United States Agency for International Development (USAID) to provide skilled, expatriate manpower to support the division's program pending the training of graduate Kenyan officers.

Shortly afterward, training schemes were initiated, with the assistance of USAID, to provide local officers of graduate, diploma, and certificate standards. USAID provided scholarships, and eight of the division's pioneer officers (diplomates) were selected and sent for graduate training in universities in the United States. At the same time, a 3-year diploma course in range management was started at Egerton

College, Kenya, in 1965, followed by a 2-year certificate course in range management at the Animal Health and Industry Training Institute (AHITI), Kabete, in 1966. The first local graduate officer returned from training in the United States in 1966. In July of the same year, 10 diplomates in range management graduated from Egerton College, followed by 25 certificate holders from AHITI, Kabete, in 1967.

The primary sources of range-management personnel have been AHITI, Egerton College, and universities in the United States. Also, a 3-year bachelor of science degree program in range management was started in the University of Nairobi in October 1980.

The initiation of training schemes marked the beginning of RMD's growth and expansion in both personnel and development programs. The magnitude of the division's expansion and its replacement of its 1963 expatriate staff can be gauged by its staff strength as of December 1985:

Professional officers	49
Technical officers	199
Technical assistants	387

The division also has a contingent of support staff including cartographers, clerical officers, drivers, and support staff, most of whom are deployed in the district offices.

CATEGORIES OF RANGE-MANAGEMENT PERSONNEL

RMD employs three main categories of personnel:

Technical Range Assistants

Technical range assistants are certificate holders who graduate from AHITI after 2 years of training and then take up assignments with the division in field extension. A few of the range assistants are deployed in range research.

Technical Officers

Technical officers are middle-level technicians who are trained mainly at Egerton College and who take up assignments with the division as assistant range officers and ranch managers.

Professional Officers

Professional officers are university graduates (trained in the United States in the past) who take up assignments with the division at the district level as range-development planners and district range officers, at the provincial level as provincial range officers, and at the head office as heads of branches and sections.

DEPLOYMENT OF RANGE-MANAGEMENT PERSONNEL

The occupations and locations of technical staff members vary from district to district, depending on the main ranching activities (group ranching, commercial ranching, grazing-block development). Range-management activities are confined to arid and semiarid areas; that is, medium- to low-rainfall districts of Kenya. Most range-management personnel, therefore, are deployed in such districts.

The Range Management Division is organized along lines similar to other technical departments of the government: field service represented at ranch/local, divisional, district, and provincial levels, all controlled by the head of the division at the head office in Nairobi. At the head office, the head of RMD (who is also the division chief) is supported by an assistant director (who is also deputy chief of the division), two heads of branches, and five section heads.

The division operates in 24 districts in 5 provinces: 9 districts in Rift Valley Province, 5 districts in Coast Province, 6 districts in Eastern Province, 3 districts in North-Eastern Province, and South Nyanza District in Nyanza Province. In each province except Nyanza, a provincial range officer is responsible through the PDA to the chief of the division for all matters relating to range management and development in that province. Each of the 24 districts has a district range officer who is responsible through the DAO to the provincial range officer for all matters relating to range-management extension and development. At present, each district range officer has at least four assistant range officers and at least nine technical assistants (range assistants).

The division's staffing and deployment strategy is to have one graduate with at least a bachelor of science degree in range management and ecology in each of the 24 districts, one assistant range officer in each grazing block/administrative division, one range planner in each project district/area, one ranch manager in each new commercial/company branch, and one range assistant in each location or ranch unit. Table 1 shows the division's technical staff strength as at December 1985.

DUTY ASSIGNMENTS FOR VARIOUS CATEGORIES OF RANGE-MANAGEMENT PERSONNEL DEPLOYED IN THE FIELD

Provincial Range Officers (PROs)

Provincial range officers perform the following duties:

- supervise the overall implementation of range-management and range-livestock projects
- supervise and coordinate the production of appropriate range-management development plans

District Range Officers (DROs)

District range officers perform the following duties:

- prepare work programs
- guide and train technical officers in the district to ensure efficient supervision, planning, and management of projects
- work with relevant agencies in the district on issues concerning range management and development
- supervise management of range-development projects

Range-Development Planners

Range planners are deployed mainly to specific-duty assignments as follows:

- work with DRO to set up priorities and determine possible development areas in the district

- carry out range inventory and gather data about production coefficients, input costs, and prices necessary for range planning

- prepare range-development and district-development plans

- implement approved development plans

Range-Resource Monitoring Officers

Range-resource monitoring officers presently are deployed in Kajiado, Narok, and Taita Taveta districts, and they are responsible for:

- interpreting aerial photos
- interpreting Landsat imagery
- monitoring range conditions and trends
- monitoring livestock statistics and projected herd composition
- collecting, evaluating, and analyzing data about development projects

Rural Sociologists

At present, the division has no personnel deployed as rural sociologists; however, arrangements are under way to train range personnel in the discipline of rural sociology because this discipline augurs well for pastoral livestock-production systems. Rural sociologists will perform the following duties:

- assist range planners in understanding local livestock-production systems

- assist range-project implementers in the introduction of new developments

- carry out sociological preinvestment studies

- recommend and advise on approaches to implementation of developments that will be acceptable to local livestock owners

Technical Officers (Assistant Range Officers)

Technical officers perform the following duties:

- supervise and manage grazing blocks
- carry out general range-management extension in the field

Ranch Managers

Ranch managers are trained specifically to perform the following duties:

- formulate functional grazing systems for each ranch

- assist ranchers to identify problems that limit production or waste ranch resources, and help to minimize or overcome such problems

- assist and advise ranchers, particularly group ranchers, to maintain proper stocking rates and records to reduce overstocking and overgrazing

- advise ranchers on when to market their animals to get maximum return per investment made

- supervise accounting of group ranches

- carry out inventory and collect data on production coefficients, input costs, and prices necessary for ranch planning

Technical Assistants

Technical assistants are deployed to group ranches, grazing blocks, commercial ranches, and company ranches to deal directly with the ranchers/pastoralists and provide appropriate extension services at the grassroots level.

CONSTRAINTS TO EFFECTIVE DEPLOYMENT OF RANGE-MANAGEMENT PERSONNEL

Some constraints that tend to interfere with smooth and effective deployment of range-management personnel include the following:

- inadequate logistic support in terms of transportation, equipment, and finance

- lack of housing and office accommodations in most range areas

- loss of range-trained personnel to private sector and(or) parastatals

- deployment of range-management personnel to duties or assignments outside areas of range-management activities; for example, the current training-and-visits extension project that has disoriented range-management extension to crop-production extension

Table 1. Technical staff position, December 1985.

District/station	Graduates (ROs)	Diplomates (TOs)	Certificate (TAs)
Head office	6	1	-
Provincial headquarters	4	1	-
South Nyanza	-	7	12
Turkana	2	4	9
West Pokot	2	5	15
Samburu	1	8	21
Laikipia	2	9	11
Elgeyo Marakwet	1	6	9
Nakuru	1	8	9
Baringo	3	8	19
Narok	4	10	24
Kajiado	3	11	22
Garissa	1	8	17
Wajir	1	11	18
Mandera	1	6	16
Kwale	1	9	12
Kilifi	2	10	14
Taita Taveta	2	11	18
Tana River	2	9	17
Lamu	1	7	11
Embu	2	6	9
Kitui	2	9	20
Marsabit	1	8	17
Meru	1	8	15
Isiolo	1	10	26
Machakos	2	10	21
	49	199	387

RANGE-MANAGEMENT EXTENSION IN KENYA, 1945 TO 1985

N. C. Towett

INTRODUCTION

This paper examines the historical development of the pastoral lands, popularly referred to as the rangelands, of Kenya from 1945 to today. 1945 was chosen as the beginning date because that is when a move began to separate Kenyan agriculture into high-rainfall agriculture and arid and semiarid agriculture, signaling the beginning of government efforts to forge a more unified approach to extension, especially with regard to the attitudes of the officers involved.

This is not to say that there was no specified approach before this period. The creation of European agricultural officers to act as advisors to the administration and supervisors of the native instructors was set out in a circular from the Deputy Director of Agriculture in 1926.

Again in 1931 the Department of Agriculture very clearly stated that methods such as agricultural shows, demonstration plots, advice by agricultural instructors, and the use of progressive farmers were the most suitable methods. Despite these statements, famines and cases of extensive and severe soil erosion seem to have generated frustration among the extension staff and a strong belief that persuasion and education could not work for the native farmer. Among other things, it was such an attitude that the African Land Development Programme (ALDEV) attempted at later stages to remove.

The history of the development of range extension since 1945 reflects changing attitudes among both the pastoralists and the extensionists. What is striking in this brief historical perspective is the repetitive nature of the objectives set out at various times over these four decades and the amount of change that has occurred in how the problems have been formulated, presented, and accepted or rejected.

EXTENSION APPROACH UNDER THE AFRICAN LAND DEVELOPMENT BOARD (ALDEV), 1945 TO 1954

The first 10-year development plan of 1945 is an important landmark in the consideration of the program of extension carried out in Kenya's rangelands to date. The development plan, first and foremost, reflects a comprehensive policy for administration and development of extension for the areas outside those designated for white settlers. Secondly, the formulation of the plan recognized an undesirable situation in the then-scheduled areas of the country, which initially was attributed to overpopulation and the effects of extreme land pressure. The strategy, therefore, initially involved attempts at destocking; but this approach later was abandoned in favor of resettlement in unoccupied areas and a program of land rehabilitation.

Although the program was intended for broader application, the agency responsible for implementing it emphasized the arid and semiarid areas. Specific programs involved.

- tsetse eradication
- vaccination against rinderpest

- soil conservation
- grazing rotation
- borehold and dam construction
- small irrigation schemes (Ministry of Agriculture, 1962)

While they gave some deserved attention to the problems of the arid and semiarid environments, the most important aspect of the objectives was that they were backed by bylaws, reflecting a desire to move away from educational or persuasive approaches.

ALDEV AND SWYNNERTON PLANS, 1954 TO 1962

As policy and emphasis changed, it was felt that rehabilitating the land was not sufficient and that the central concern should be to bring about a complete revolution in agriculture.

In the areas with dense populations and higher agricultural potential, a program of enclosures, consolidation, and land registration was to be carried out. Of greater relevance to this study is that the blueprint for the land-tenure reform -- the Swynnerton Plan of 1954 -- recognized the need to consider the pastoral areas separately from the areas of cultivated agriculture. As in the plans for high-potential areas, plans for pastoral areas emphasized a revolution in modes of production by promoting a rational and economically oriented approach to land use. In the rangelands, this was done through the establishment of grazing schemes that emphasized the following:

- strict limitation of stock numbers
- encouragement to improve livestock by using better bulls, such as Sahiwals
- development of facilities such as water sources and handling crushes
- better use and management of grazing
- control of diseases

RANGE-EXTENSION STRATEGY AND PROCESS

A great deal of criticism has been leveled at the "cattle complex" and the intention to remove it forcibly if necessary (Ministry of Agriculture, 1962). This orientation -- the intention to handle a social phenomenon in such a forceful way -- was distasteful to more education-oriented extension workers. Moreover, this stand gives some credibility to the claim that the overall approach was too strictly regimented, thus creating resentment.

Other features, such as the use of colonial chiefs for surveillance duties and the punitive measures used to impose sale of livestock, did not help matters much and may have led to the termination of the programs soon after independence.

While what has been stated above may be true, the program helped to provide a new channel of approach in some areas. The concept never was intended to portray resistance to change (Ministry of Agriculture, 1962). Herskovit's 1962 study introduced the term "cattle complex" to indicate a set of socioeconomic patterns associated with cattle rearing. The context within which the so-called complex was used is best understood by considering Herskovit's own description of the concept:

> We may then come to the conclusion that a culture area is an empirical grouping of tribes which manifest similar culture;

> that being descriptive does not necessarily include time depth, that its boundaries are not fixed but that there is a shedding from the culture of one area to another, geographical conditions permitting...The elements of these complexes are not invariably fixed but may have individual distribution.

The second justification for the stand that ALDEV took on cultural diffusion is given further credence by the parallel strategies of the time in agricultural-production areas, summarized by Migot and Little (1979) as follows:

> In the long run the Swynnerton plan aimed at revolutionizing African agriculture through the introduction of individual tenure and the cultivation of profitable export crops hitherto prohibited to Africans.

The critical part of the statement is the mention of the cultivation of export crops and the rearing of valuable, exotic dairy animals. The materials and the ideas really were not novel -- they were held and practiced in neighboring farms. Therefore, the program allowed the process of diffusion from the contingent European farms to take its natural course.

Although it was not explicit, the implied strategy for social change during this period was one that relied on a natural process of diffusion. The extension organization at this stage (if it might really be called that) was in its infancy. Staff deployment was thin. The Kenyan government's report (Ministry of Agriculture, 1962), citing the case of the South Baringo grazing scheme, notes that a large part of recurrent expenditures were for "the large force of grazing guards needed to prevent trespass." Specialization in research and development was left in the hands of the staff of the Department of Agriculture proper. The main functions of the ALDEV officers remained largely administrative; for instance, the government's 1962 report gave some attention to the conflict that was arising between the provincial and district administrations and ALDEV about who was responsible overall on issues of administering and setting out policies in the ALDEV districts.

KENYA LIVESTOCK DEVELOPMENT PROGRAM, PHASES I AND II

After independence, the Range Management Division took over ALDEV; but the outlook, understandably, did not change drastically. Predevelopment surveys were commissioned by the UNDP/FAO Range Project, and the group-representatives bill was passed by Parliament in 1968, indicating that structural changes were carried out smoothly in the former traditionally pastoral properties. In what previously were individual and commercial properties, the cooperatives and company act ensured that ownership would change over without any drastic structural changes. The similarity of objectives between the Kenya Livestock Development Program and ALDEV should not be surprising.

RANGE MANAGEMENT DIVISION

The Kenya Livestock Development Program, initiated in 1970, specified the following areas of attention for extension programs:

- efficient land use and rational use of resources through the establishment of appropriate ownership

- improvement of livestock through introduction of better breeds

- control of grazing through introduction of appropriate grazing-control systems

- control of disease by provision of relevant facilities, mainly by construction of dips

- provision of finances in the forms of both loan and grants

Following an ambitious program of staff training and development, within 10 years after independence the majority of districts were manned by range graduates and the ranches were manned by at least one technical assistant. Of course, staff levels and functions varied according to the type of ranching organization that prevailed in each area.

RANGE-EXTENSION STAFF -- FUNCTIONS AND DUTIES

Several conditions influenced the deployment of range-extension staff, but the most important factor was the nature of ranch organization:

- Commercial companies and remnants of former European and large-scale units often required no staff.

- Company and cooperative ranches taken over or recently started by the locals often required the presence of a technical assistant who, in many cases, performed the duties of a manager. This created problems of precedent. If there was a strong manager or management board or committee, disagreements on matters of principle often arose between the manager or managing body and the technical assistant. Most ranches were managed for production and received little extension input.

- Because of their informal natures and traditional outlooks, group ranches' staff contact was confined to "barazas." Later, when the ranches built dips, these became the central focus.

- In grazing-block development, the local residents had little participation or involvement in planning and implementing the design of the program. One type of approach was later actively adopted and promoted throughout the extension organization -- the formation of planning and implementation units. These units were manned by graduate range-management officers who operated separately with their own staffs and transportation under the umbrella of the District Range Office. Ideally, each unit was to train and use the staff working in each block to collect and collate data and draw plans, after which a new team would be formed for the next block.

In the grazing-block approach, where there was little consultation between the livestock owner and the planner, all the planned structural developments were carried out successfully. Unfortunately, and mostly because of lack of local involvement, the grazing plans never were followed, and the system generally was paralyzed by widespread vandalism.

In most of the newly formed cooperative and company ranches, the initial phase of planning and providing for facilities seemed to have been carried out. After the initial phase, however, management (mainly financial management) became a problem; and the financing body, the

Agricultural Finance Corporation (AFC), found it necessary to be closely involved in the management of these ranches. Also, RMD's decision to allow the formation of directed company ranches instead of the earlier public companies indicated its desire to increase its power and control over the management of such ranches.

For group ranches, the pace was even slower. The World Bank Supervision Report of 1976 noted: "...The whole programme seems to be an exercise o f allotment of title...and is not having an economic impact."

Even where the group ranchers agreed to implement the plans, they were very selective about the items they accepted.

The National Agricultural Extension Project proposal of 1982 elaborated the above issue in greater detail by noting that the production-oriented, "packaged" type of approach backed by credit had the weakness that greater emphasis was placed on the credit aspect of the operation at the expense of the extension part. Further, the attention paid to the credit aspect of the program resulted from failure to ensure that the required husbandry practices were adopted in the first place. Therefore, credit is used in situations where the results are no better than if the credit had not been used. The project paper then suggests that the emphasis should be shifted to a series of recommendations that the farmers could adopt wholly or in part.

ADOPTION OF RANCH PRACTICES

Crouch (1974), in a study of the process of adoption of several practices used at farms in different stages of development, found that all the practices are grouped together in interrelated and interdependent fashion. All farmers/graziers adopted all practices in the same logical way. This observation is significant for a number of reasons:

- The presence of this predictive, common-sense pattern should enable the extension worker to talk of the diffusion process and change in precise, quantitative terms.

- By examining the process of ranch development and change, more progressive and meaningful types of proposals can be developed. After looking at the objectives of project proposals over the last 40 years (1945 to 1985), the repetitive nature of the components of the proposals become obvious.

- In an interview of ranchers in Narok District, Towett (1983) found that out of 54 ranchers interviewed only one rancher confessed that he did not dip his animals at all. The other 53 dipped their animals irregularly, depending on whether the nearest dip was functioning, money was available, and the animals had many ticks. Obviously, the ranchers were not very knowledgeable about the control of tick-borne diseases. Research is needed about the minimum requirements for dipping under such conditions. A more significant observation in the above interview was that the rancher who never dipped appeared to own more livestock than the rest. Therefore, it appears possible that the greatest present constraint to cattle rearing in this area is not tick-borne disease but survival during periods of severe drought.

CONCLUSION

In this paper, I have tried to look at the programs of extension from 1945 to date. Although it was not obvious (and even assumed) and it was given a rather controversial name in the initial stage, an approach that relied on the social process was initiated. It is time for us to review changes that have taken place since then and quantify how far those changes have been adopted by our pastoral people. Such a move would reduce repetition.

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RANGL INVENTORY

MONITORING LIVESTOCK AND WILDLIFE IN KENYA

Susan W. Mbugua

INTRODUCTION

The Kenya Rangeland Ecological Monitoring Unit (KREMU), a division within the Ministry of Planning and National Development, was established in 1975 as an ecological monitoring unit. It was charged with providing a continuous flow of ecological information. Before KREMU was established, the only ecological data available were for isolated areas of particular interest to researchers.

Since 1977, KREMU has carried out ecological surveys in the rangelands of Kenya, collecting information on numbers and distribution of livestock and wild herbivores. Also collected is information on environmental attributes; for example, herbaceous- and woody-vegetation covers, soil erosion, and water distribution. Human settlement activities and agricultural practices also are recorded.

Since 1982, censuses of animals have been extended to include the high-potential agricultural districts of Kenya. Previously, animal censuses were restricted to the rangelands, which constitute about 80% of the country (figure 1). The high-potential agricultural districts were included in the survey to complement the land-use studies that aim at contributing to the district-focus development strategy.

This paper summarizes results of animal censuses carried out by KREMU from 1977 to 1985 for selected districts in northern Kenya's rangelands (figure 2).

METHODS

The methodology employed by KREMU for censusing animals is described by Norton-Griffths (1978). Between 1977 and 1981, all surveys were conducted using systematic reconnaissance flights oriented on an east-west direction, with transects spaced either 10 km or 5 km apart, with a flying height of 91 m or 122 m. In 1985, the districts surveyed were stratified according to animal concentrations. Information from district livestock officers and previous KREMU animal distributions were used for stratification.

Two parallel metal rods hooked to the lower part of the wing and the body of the aircraft determined the strip width, which varied from 224 m to 400 m between 1977 and 1985. During flights, two observers seated at the back of the plane counted and taperecorded the number of each animal species observed between the metal rods. Herds exceeding 10 members in size were photographed. For herds less than 10, the visual counts were used directly in analysis. Since animal censuses before 1985 were carried out on an ecounit basis, the data used in this paper were resorted to provide district summaries.

Population estimates (PE) and their standard errors (SE) were obtained using Jolly's method 2 (Norton-Griffths, 1978). The stocking levels of the various districts were compared according to tropical animal units (TLU), where each unit equals 250 kg (table 1) (Peden, 1984).

RESULTS

Livestock and wild herbivore numbers are summarized in tables 2 through 8. Livestock numbers in all districts have continued to decline since 1977. Between 1977 and 1978, livestock numbers decreased in all districts except Wajir and Marsabit. With the exception of Laikipia, where an increase was observed in 1981, numbers continued to decline. By 1985, livestock numbers in all districts were considerably lower than the 1977 numbers.

In Laikipia, Wajir, Garissa, and Samburu districts, cattle numbers continued to decrease throughout the survey period. The most noticeable decline occurred between 1978 and 1985. In Laikipia, numbers fell by 65%, considerably more than in any other district. Between 1977 and 1978, cattle increased in Marsabit, Isiolo, and Mandera districts. By 1985, however, numbers in the latter two districts fell by more than 50%.

Sheep and goats increased in numbers between 1977 and 1978 in Marsabit, Wajir, Isiolo, and Garissa districts. By 1985, numbers had fallen to lower levels than those observed in 1977. Conversely, in Mandera, though they decreased between 1977 and 1978, they had increased in 1985 to levels higher than those in 1977. In Samburu, they decreased between 1977 and 1981 and increased between 1981 and 1985. In Laikipia they increased throughout the survey period, and the highest increase was observed between 1978 and 1981.

Camels were most common in the northern Kenya rangelands, where they occur in large numbers. Over the survey period, camels decreased in all districts. In Mandera and Wajir districts, camels increased between 1977 and 1978 and then decreased in 1985, particularly in Wajir. In Garissa, there was an increase of 17% between 1977 and 1985, though a decrease was observed between 1977 and 1978. Population of camels fell by 87% between 1977 and 1985 in Isiolo while, in Marasbit, the most notable decrease occurred between 1978 and 1981. There was a decrease of 44% in Samburu over the survey period, though an increase of 42% was observed between 1977 and 1981. In Laikipia, the 1985 camel population was only 7% of that counted in 1981. None had been observed in any of the earlier surveys.

Donkeys increased between 1977 and 1985 in Isiolo and Garissa districts; whereas in Samburu they declined, notably between 1977 and 1981 when a drop of 58% was observed. In Marsabit and Laikipia, donkeys almost doubled between 1977 and 1981 but fell in 1985. Though the donkey population fell slightly between 1981 and 1985, there was an almost twelvefold increase between 1977 and 1985. Lowest numbers were observed in Mandera, where they almost doubled between 1977 and 1978. None were observed in 1985.

Wild herbivore numbers decreased by between 36% and 67% in the various districts between 1977 and 1985. Species composition was as varied as the distribution in the individual districts. The elephant, giraffe, oryx, Grant's gazelle, gerenuk, ostrich, and lesser kudu were observed in all districts.

1985 elephant numbers were considerably lower than those of 1977. In Isiolo and Garissa, numbers increased between 1977 and 1978 and then decreased between 1978 and 1985, and poaching is believed to be active again. The overall decline was 80% and 96%, respectively. In Mandera

and Wajir, none were observed in 1985; whereas, in Laikipia and Marsabit, numbers increased between 1981 and 1985 after falling sharply between 1977 and 1985; however, a decrease of more than 50% occurred between 1977 and 1981.

The highest giraffe numbers were observed in Garissa District, where numbers fluctuated only slightly between 1977 and 1985. In all other districts, numbers showed marked fluctuations during the survey period, with the 1985 numbers being lower than those observed in 1977.

Oryx were mainly concentrated in Marsabit, where numbers remained comparatively the same except between 1978 and 1981, when they decreased by 50%. In Wajir and Garissa, the oryx population increased between 1977 and 1978 but was much lower in 1985. Mandera and Samburu registered decreases throughout the survey period. Marked fluctuations were observed in Isiolo and Laikipia.

Grant's gazelles occurred in large numbers only in Marsabit, Isiolo, Wajir, and Garissa districts. Lowest numbers were found in Mandera, where they were observed only during the 1978 surveys. With the exception of Samburu, numbers decreased between 1977 and 1985. The most notable decline of 90% was observed in Garissa.

Though observed in all districts, gerenuk occurred in large numbers only in Wajir and Garissa. Between 1977 and 1985, the gerenuk population decreased by 71% and 80% in the two districts, respectively. In Laikipia they were observed in very low numbers and only during the 1981 surveys. In all other districts, except in Samburu where numbers increased between 1981 and 1985, gerenuk continued to decrease throughout the survey period.

The highest numbers of ostriches were observed in Wajor District, where they remained almost constant between 1977 and 1985. In Mandera and Samburu, ostrich populations increased over the survey period, while in all other districts decreases were observed.

The lesser kudu population is lowest in Laikipia, Marsabit, and Samburu districts. In the former two districts, they were observed only during the 1981 surveys; in Samburu, numbers remained the same between 1977 and 1985. In Mandera, Wajir, and Garissa they decreased while they increased over the same period in Isiolo.

Buffalo, elands, and Burchell's zebras were observed in Isiolo, Garissa, Samburu, and Marsabit districts. Buffalo occurred in very low numbers in the southern part of Isiolo District, adjacent to Meru National Park. They decreased between 1977 and 1978, and none were observed in 1985. In Garissa, they occurred along the Tana River; while, in Samburu, they were observed mainly in the protected areas and increased between 1977 and 1985. They were confined to Marsabit National Park in Marsabit District and increased by more than 50% between 1981 and 1985. Numbers in Laikipia increased during the survey period.

Except in Samburu and Laikipia, elands were sparsely distributed in districts where they occurred. In Isiolo and Garissa, none were observed in 1985, while they were observed only in 1981 in Marsabit.

Heavy concentrations of Burchell's zebras occurred around Maralal in Samburu and in the southern parts of Laikipia and Garissa districts. In Samburu and Marsabit, numbers decreased slightly from 1977 to 1985 and

from 1977 to 1981, respectively. Large decreases in the Burchell's zebra population occurred in Isiolo and Garissa during the survey period. In Laikipia they increased between 1977 and 1985, and the highest increase was observed between 1978 and 1981.

Grevy's zebra was observed in Isiolo, Garissa, Samburu, Laikipia, and Marsabit districts. With the exception of Laikipia and Garissa, where they increased between 1977 and 1985, they decreased in all districts, particularly in Wajir, Marsabit, and Samburu.

Impalas and waterbucks occurred in Isiolo, Garissa, Samburu, and Laikipia districts. Impalas decreased notably in Laikipia during the study periods and increased elsewhere. In Marsabit and Isiolo, they were observed only in the 1981 to 1985 and 1985 periods, respectively. In Garissa, they increased between 1977 and 1983, though none were seen in 1985.

Waterbucks have a very localized distribution and occur mainly near water courses or riverine vegetation. They decreased considerably between 1977 and 1985 in all areas except Garissa, where an increase was observed. None was seen in Isiolo in 1985.

Thomson's gazelles were found only in Laikipia and Samburu districts, and their numbers decreased by 75% and 96% respectively during the survey period. In Laikipia, numbers increased from 1977 to 1978 and then decreased. The 1985 census showed a slight increase. In Samburu, they decreased continuously throughout the period.

Topi were observed only in Garissa and Marsabit districts. In Garissa, they occurred mainly in the southern part and increased by more than 300% between 1977 and 1983. In 1985, the topi population had fallen to a level lower than that of 1977. The topi found in Marsabit belong to the northern race or tiang, and were concentrated in the Sibiloi (East Rudolf) National Park. Large numbers were observed during 1977, but a very small number was observed in 1978. None were seen during the later surveys. The species is migratory.

Hunter's hartebeests occurred only in the southern part of Garissa District. Large numbers were observed between 1977 and 1978. The population increased between 1977 and 1983 by 235% but registered a decline in 1985. This species also is migratory.

Since 1977, the black rhino has continued to decline both in range and numbers (Stelfox et al., 1981). They were observed in Garissa in very low numbers only during the 1977 surveys. None was seen in any of the subsequent surveys.

Table 9 compares the average livestock and wild-herbivore numbers for 1977 to 1983 and 1985 and gives a measure of the animals that died after the 1984 drought, although other factors might have contributed to the decrease.

Table 10 shows the average stocking levels for the selected districts from 1977 to 1983. Both livestock and wildlife densities were highest in Laikipia District. All the districts had higher densities for livestock than for wildlife. The high livestock TLUs per person indicate the relative importance of livestock to the pastoralists in the arid areas. Table 11 shows stocking levels for 1985 and indicates reduction in both livestock and wildlife densities.

DISCUSSION

The 1977 and 1978 surveys were conducted during the dry season, while the 1981 and 1985 surveys were undertaken during the wet season. Livestock from Marsabit move into Ethiopia during the dry season and return during the wet season. This has been documented (Kufwafwa, 1985; Field et al., 1979) and is further evidenced by the fact that livestock increased considerably in the Ileret area between 1978 and 1981. Herds from Samburu and Isiolo move into Buffalo Springs and Shaba Reserve during the dry season (Stelfox et. al., 1979). Similar movements were observed in Garissa, where livestock move to or away from the River Tana during different seasons. During drought, herds move from Garissa into Isiolo and Meru districts (Kufwafwa, 1985).

The tiang is believed to move across the border from Kenya during the wet season, while the Hunter's hartebeest in Garissa moves into Somalia during the same season. Due to land subdivisions in Laikipia, the range, habitat, and numbers of Thomson's gazelles and impalas are declining; hence, the large reductions in population sizes between 1977 and 1985. Despite strict controls, the rhino continues to decline at an alarming rate. This calls for more effort to ensure the survival of this endangered species.

The 1985 surveys were carried out immediately after the 1984 drought and, compared to previous censuses, the livestock numbers were substantially lower in all districts. It is difficult to give a precise estimate of the animals that died because of the drought since no survey was done immediately before the drought. Decreases also can be attributed to marketing and emigration. Immigration also can mask the effects of drought. On the average, wild herbivores were slightly less affected by the drought than livestock.

To determine trend, all districts should be monitored once every year and at different seasons. KREMU already has embarked on this. Survey methods (for example, height and strip width) should be standardized to allow comparability of data. In its future programs, KREMU intends to introduce age- and sex-structure studies for both livestock and wildlife. With this information, there will be a better understanding of the changes in animal numbers and their impacts on the environment. This will allow for the formulation of sound management and conservation policies required for long-term planning.

KREMU has large quantities of habitat data. In the future, this will be analyzed through a geographical information system that allows overlaying of maps of various environmental attributes so that stocking levels, distributions, etc., can be correlated to habitat condition. This will enhance multiple analysis of habitat data and thus give insight into the carrying capacities of the various ecosystems and a means of determining more effectively trends in the use and state of our natural resources.

KREMU has a wealth of information on animal numbers and distribution, vegetation, and habitat conditions for the whole country, which is readily available to users. It will continue to gather, process, and bank the information for retrieval and dissemination to users for better management of our natural resources.

SUMMARY

Animal censuses for Mandera, Wajir, Isiolo, Garissa, Samburu, Laikipia, and Marsabit districts in the northern Kenya rangelands were conducted between 1977 and 1985. Population estimates and densities of both livestock and wild herbivores are summarized in this paper. There was a considerable reduction in animal numbers during the 1985 survey, which was mainly attributed to the 1984 drought. More frequent and seasonal surveys will be undertaken by KREMU to determine trend in animal numbers and distribution. Conflicts in land-use practices also affect numbers of wildlife species.

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Table 1. Tropical animal unit equivalents.

Animal	TLU	Animal	TLU
Cattle	.72	Sheep and goats	.072
Donkeys	.6	Camels	1.2
Wildebeests	.5	Elephants	6.9
Zebras	.8	Kongoni	.5
Hunter's hartebeests	.5	Topi	.45
Waterbucks	.42	Ostriches	.46
Thomson's gazelles	.06	Grant's gazelles	.16
Impalas	.16	Rhino	3.26
Sable antelope	.5	Gerenuk	.1
Elands	1.36	Buffalo	1.8
Lesser kudus	.16	Giraffes	3.0
Oryx	.4	Greater kudus	.8

Table 2. Estimated animal population sizes for Mandera District, 1977-1985.

Animal type	Aug. 1977 Number	Aug. 1977 SE	July-Sept. 1978 Number	July-Sept. 1978 SE	Feb. 1985 Number	Feb. 1985 SE	Average Number	Average SE
Livestock	591,172	277,543	442,378	67,198	109,800	29,819	381,117	95,705
Cattle	33,681	11,460	37,799	7,063	18,227	11,940	29,902	5,998
Sheep and goats	451,698	276,832	286,597	65,513	48,322	26,085	262,206	95,224
Camels	105,314	16,204	117,135	13,178	43,251	8,134	88,567	7,471
Donkeys	479	205	847	294	-	-	442	119
Wildlife	7,268	1,083	9,375	933	3,058	737	6,567	536
Giraffe	1,808	530	3,168	427	561	414	1,846	266
Elephant	612	391	342	213	-	-	318	148
Gazelle	-	-	192	131	-	-	64	44
Oryx	969	368	790	225	289	170	683	155
Lesser kudu	1,202	351	1,575	349	489	276	1,089	189
Gerenuk	2,526	686	2,576	348	941	416	2,014	292
Ostrich	151	98	732	576	778	307	554	220
Total animals	598,440	277,545	451,753	67,204	112,858	29,828	387,684	95,707
Livestock TLUs	183,437	-	188,920	-	68,504	-	146,954	-
Wildlife TLUs	10,549	-	13,057	-	2,298	-	8,635	-
Total TLUs	193,986	-	201,977	-	70,802	-	155,589	-
Density (TLUs/km^2)								
Livestock	6.9	-	7.1	-	2.6	-	5.6	-
Wildlife	0.4	-	0.5	-	0.1	-	0.3	-
Total	7.3	-	7.6	-	2.7	-	5.9	-
TLU ratios								
Livestock:Wildlife	17.4	-	14.5	-	29.8	-	17.0	-
Cattle:Sheep and goats	0.7	-	1.3	-	3.8	-	1.1	-
Dead elephant %	0.0	-	18.8	-	-	-	-	-
No. of transects	22	-	40	-	13*	-	-	-

Data have not been adjusted for observers' biases.
District area = 26,470 km^2
TLU = tropical animal unit (250 kg)
SE = standard error
* = total transects in all strata

Table 3. Estimated animal population sizes for Wajir District, 1977-1985.

Animal type	Aug. 1977 Number	Aug. 1977 SE	Jul.-Sept. 1978 Number	Jul.-Sept. 1978 SE	Feb.-Mar. 1985 Number	Feb.-Mar. 1985 SE	Average Number	Average SE
Livestock	622,857	84,098	902,713	70,677	447,343	55,409	657,638	41,012
Cattle	197,626	53,401	197,805	29,352	70,323	15,654	155,252	20,972
Sheep and goats	304,885	62,446	502,442	61,725	242,542	48,048	349,957	33,363
Camels	119,468	17,920	199,502	17,923	133,103	22,719	150,691	11,346
Donkeys	878	467	2,964	1,591	1,375	580	1,739	586
Wildlife	67,248	7,508	95,130	6,633	41,187	10,071	67,855	4,735
Giraffe	7,958	1,676	7,971	770	6,690	1,702	7,540	837
Zebra	1,127	820	-	-	223	221	450	283
Elephant	-	-	93	88	-	-	31	29
Gazelle	34,521	6,875	60,498	6,183	21,665	9,687	38,895	4,464
Oryx	5,574	1,300	6,315	1,483	4,576	1,619	5,489	851
Lesser kudu	2,067	481	2,272	635	1,226	453	1,855	305
Gerenuk	12,609	1,818	13,344	1,323	3,637	813	9,864	797
Ostrich	3,392	627	4,637	905	3,170	1,075	3,733	513
Total animals	690,105	84,432	997,843	70,988	488,530	56,317	725,493	41,284
Livestock TLUs	308,131	-	419,776	-	228,644	-	318,850	-
Wildlife TLUs	35,681	-	40,591	-	27,367	-	34,546	-
Total TLUs	343,812	-	460,367	-	256,011	-	353,397	-
Density (TLUs/km^2)								
Livestock	5.5	-	7.4	-	4.0	-	5.6	-
Wildlife	0.6	-	0.7	-	0.5	-	0.6	-
Total	6.1	-	8.1	-	4.5	-	6.2	-
TLU ratios								
Livestock:Wildlife	8.6	-	10.3	-	8.4	-	9.2	-
Cattle:Sheep and goats	6.5	-	3.9	-	2.9	-	4.4	-
Dead elephant %	-	-	19.1	-	-	-	19.1	-
No. of transects	38	-	73	-	45*	-	-	-

Data have not been adjusted for observers' biases.
District area = 56,501 km^2
TLU = tropical animal unit (250 kg)
SE = standard error
* = total transects in all strata

Table 4. Estimated animal population sizes for Isiolo District, 1977-1985.

Animal type	Aug.-Sept. 1977 Number	SE	Aug.-Oct. 1978 Number	SE	Apr.-May 1985 Number	SE	Average Number	SE
Livestock	646,471	144,693	592,321	79,744	375,104	64,047	537,965	59,064
Cattle	115,908	37,996	159,652	27,891	69,948	20,304	115,169	17,107
Sheep and goats	371,853	82,521	389,940	74,405	278,326	60,536	346,707	42,177
Camels	154,996	112,597	38,363	6,593	20,922	4,368	71,427	37,624
Donkeys	3,714	2,144	4,366	1,266	5,908	2,453	4,663	1,165
Wildlife	90,774	32,905	59,684	6,397	30,364	5,174	60,274	11,306
Buffalo	2,501	2,593	467	367	-	-	989	582
Giraffe	3,175	1,222	2,217	360	1,511	698	2,301	484
Burchel's zebra	979	605	945	344	242	162	722	238
Grevy's zebra	3,280	2,079	1,894	626	1,440	410	2,205	737
Elephant	828	511	1,722	1,340	165	122	905	480
Grant's gazelle	61,820	32,564	38,871	5,902	17,029	4,448	39,240	11,131
Oryx	4,757	1,764	2,078	626	4,343	2,216	3,726	967
Lesser kudu	212	140	340	142	319	215	290	98
Eland	1,522	1,284	1,020	909	-	-	847	349
Waterbuck	256	226	144	134	-	-	133	59
Gerenuk	6,005	1,136	4,008	515	2,407	813	4,140	496
Ostrich	5,439	1,746	5,978	1,415	2,470	768	4,629	792
Impala	-	-	-	-	438	289	146	96
Total animals	737,245	148,387	652,065	80,000	405,468	64,256	598,239	60,136
Livestock TLUs	298,451	-	191,680	-	99,053	-	196,395	-
Wildlife TLUs	40,255	-	33,348	-	12,907	-	28,837	-
Total TLUs	338,706	-	225,028	-	111,960	-	225,232	-
Density (TLUs/km^2)								
Livestock	11.7	-	7.5	-	3.9	-	7.7	-
Wildlife	1.6	-	1.3	-	0.5	-	1.1	-
Total	13.2	-	8.8	-	4.4	-	8.8	-
TLU ratios								
Livestock:Wildlife	7.4	-	5.7	-	7.7	-	6.8	-
Cattle:Sheep and goats	3.1	-	4.1	-	2.5	-	3.3	-
Dead elephant %	46.5	-	6.0	-	30.6	-	-	-
No. of transects	24	-	48	-	31*	-	-	-

Data have not been adjusted for observers' biases.
District area = 25,605 km^2
TLU = tropical animal unit (250 kg)
SE = standard error
* = total transects in all strata

Table 5. Estimated animal population sizes for Garissa District, 1977-1985.

Animal type	Feb.-Aug. 1977 Number	SE	Feb.-Sept. 1978 Number	SE	Apr.-May 1983 Number	SE	Mar. 1985 Number	SE	Average Number	SE
Livestock	713,853	120,799	671,892	68,726	630,222	58,569	441,681	48,829	614,413	39,631
Cattle	3*2,315	97,817	306,769	52,813	282,913	34,821	184,626	30,899	289,206	30,129
Sheep and goats	279,674	69,450	322,617	43,561	298,018	45,658	194,399	35,979	273,677	25,125
Camels	50,808	14,168	40,820	5,997	47,250	11,522	58,553	11,577	49,608	5,610
Donkeys	1,056	481	1,486	722	2,041	688	3,103	1,022	1,922	177
Wildlife	71,778	7,629	101,563	7,997	85,370	9,735	24,132	2,836	70,716	3,750
Buffalo	-	-	96	85	6,269	3,464	-	-	1,595	866
Giraffe	9,635	2,038	11,268	1,356	13,527	2,651	9,576	2,057	11,002	1,038
Burchel's zebra	2,730	1,858	3,543	1,527	4,733	2,114	1,250	694	3,064	819
Grevy's zebra	660	312	650	231	568	182	1,018	687	724	203
Elephant	6,511	2,211	7,673	2,216	3,661	1,330	292	294	4,534	853
Kongoni	837	432	1,735	817	589	424	-	-	791	254
Hunter's hartebeest	2,778	1,404	8,243	2,064	9,320	3,706	917	410	5,315	2,271
Topi	4,482	2,050	18,453	5,033	24,740	7,095	2,250	927	12,482	2,246
Impala	495	331	553	449	1,241	755	-	-	572	235
Grant's gazelle	17,671	5,355	21,631	4,368	5,386	1,674	1,726	578	11,604	1,772
Oryx	4,035	1,701	6,830	1,562	3,198	1,036	1,740	782	4,051	662
Lesser kudu	5,287	1,[illegible]54	4,865	945	2,735	637	833	353	3,630	397
Eland	2,215	1,679	231	169	168	164	-	-	653	424
Waterbuck	-	-	656	234	252	107	667	344	394	107
Gerenuk	11,688	1,795	10,110	993	6,753	952	2,285	587	7,709	584
Rhino	44	41	-	-	-	-	-	-	11	11
Ostrich	2,310	442	5,026	929	2,230	517	1,578	470	2,786	331
Total animals	785,631	121,040	773,455	69,190	715,592	59,373	465,813	48,912	685,130	39,808
Livestock TLUs	357,007	-	293,978	-	283,079	-	220,253	-	288,579	-
Wildlife TLUs	91,281	-	114,540	-	102,267	-	36,235	-	86,081	-
Total TLUs	448,288	-	408,518	-	385,346	-	256,488	-	374,660	-
Density (TLUs/km^2)										
Livestock	8.1	-	6.7	-	6.4	-	5.0	-	6.6	-
Wildlife	2.1	-	2.6	-	2.3	-	0.8	-	2.0	-
Total	10.2	-	9.3	-	8.7	-	5.8	-	8.5	-
TLU ratios										
Livestock:Wildlife	3.9	-	2.6	-	2.8	-	6.1	-	3.4	-
Cattle:Sheep and goats	13.7	-	9.5	-	9.4	-	9.5	-	10.6	-
Dead elephant %	20.1	-	12.6	-	27.5	-	22.3	-	-	-
No. of transects	34	-	66	-	65	-	51*	-		

Data have not been adjusted for observers' biases.
District area = 43 931 km^2
TLU = tropical animal unit (250 kg)
SE = standard error
* = total transects in all strata

Table 6. Estimated animal population sizes for Samburu District, 1977-1985.

Animal type	Aug. 1977 Number	Aug. 1977 SE	Feb.-Mar. 1981 Number	Feb.-Mar. 1981 SE	Apr. 1985 Number	Apr. 1985 SE	Average Number	Average SE
Livestock	490,748	77,205	322,022	33,312	328,912	26,684	380,562	29,406
Cattle	177,657	47,148	105,247	14,273	92,018	14,472	124,974	17,114
Sheep and goats	293,048	60,759	198,835	29,727	229,267	22,319	240,384	23,743
Camels	9,456	4,278	13,460	4,597	5,339	1,969	9,419	2,194
Donkeys	10,587	5,272	4,478	1,060	2,288	767	5,785	1,811
Wildlife	41,927	9,532	24,164	2,989	23,372	3,473	30,612	3,525
Buffalo	1,168	1,386	698	397	1,182	716	1,016	537
Giraffe	5,381	1,571	2,420	378	2,583	332	3,462	550
Burchel's zebra	7,405	5,397	7,201	1,959	6,630	2,163	7,079	2,045
Grevy's zebra	3,197	1,424	1,880	962	398	194	1,825	576
Elephant	1,702	843	935	536	1,449	630	1,362	394
Kongoni	34	43	-	-	-	-	12	14
Impala	3,315	1,552	1,274	680	3,538	1,864	2,709	840
Thomson's gazelle	9,558	6,790	1,692	1,037	332	259	3,861	2,291
Grant's gazelle	3,404	1,187	3,233	882	5,412	1,466	4,020	694
Oryx	3,005	1,313	1,702	582	1,002	377	1,903	495
Lesser kudu	68	60	64	30	72	30	68	24
Eland	1,628	1,632	1,524	859	627	474	1,260	635
Gerenuk	1,780	509	789	184	1,832	409	1,467	226
Ostrich	282	187	241	86	627	313	384	125
Waterbuck	-	-	486	386	37	36	175	129
Greater kudu	-	-	25	22	-	-	9	7
Total animals	532,675	77,791	346,186	33,446	352,284	26,909	411,174	-
Livestock TLUs	166,712	-	108,933	-	90,540	-	122,063	-
Wildlife TLUs	44,062	-	26,267	-	28,295	-	33,148	-
Total TLUs	210,774	-	135,200	-	118,835	-	155,211	-
Density (TLUs/km^2)								
Livestock	9.5	-	6.2	-	5.2	-	7.0	-
Wildlife	2.5	-	1.5	-	1.6	-	1.9	-
Total	12.0	-	7.7	-	6.8	-	8.9	-
TLU ratios								
Livestock:Wildlife	3.8	-	4.1	-	3.2	-	3.7	-
Cattle:Sheep and goats	6.1	-	5.3	-	4.0	-	5.2	-
Dead elephant %	14.4	-	0.0	-	6.5	-	-	-
No. of transects	21	-	43	-	60*	-	-	-

Data have not been adjusted for observers' biases.
District area = 17,521 km^2
TLU = tropical animal unit (250 kg)
SE = standard error
* = total transects in all strata

Table 7. Estimated animal population sizes for Laikipia District, 1977-1985.

Animal type	Sept. 1977 Number	Sept. 1977 SE	Sept.-Oct. 1978 Number	Sept.-Oct. 1978 SE	Sept. 1981 Number	Sept. 1981 SE	May 1982 Number	May 1982 SE
Livestock	377,244	48,069	356,255	55,925	392,149	23,642	329,997	40,587
Cattle	285,891	43,644	244,662	22,848	237,271	16,829	168,611	22,795
Sheep and goats	91,300	20,146	111,184	47,910	151,295	16,589	159,819	33,571
Camels	-	-	-	-	2,869	668	61	66
Donkeys	53	42	409	94	711	294	1,506	807
Wildlife	91,376	13,618	148,623	34,127	105,649	12,347	65,322	8,999
Buffalo	247	150	2,575	1,558	2,024	1,203	883	506
Giraffe	3,254	949	642	266	4,623	863	3,134	960
Burchel's zebra	10,989	5,060	19,796	6,677	46,655	11,569	23,592	7,756
Grevy's zebra	269	207	292	175	37	22	240	156
Elephant	3,524	2,841	2,577	1,324	1,786	687	707	522
Kongoni	4,157	1,397	8,063	1,501	10,514	1,731	6,771	1,643
Impala	25,886	9,533	25,657	9,052	6,740	1,135	5,509	1,360
Thomson's gazelle	25,475	7,139	29,630	10,470	3,169	884	5,203	1,753
Grant's gazelle	6,954	1,903	1,781	508	10,648	1,727	4,565	884
Oryx	1,432	729	527	316	1,822	576	1,843	811
Eland	6,297	1,487	54,692	30,354	14,002	2,703	11,386	3,190
Waterbuck	1,069	492	2,040	473	682	163	381	195
Ostrich	1,825	643	351	111	2,801	467	1,003	268
Lesser kudu	-	-	-	-	62	44	30	21
Gerenuk	-	-	-	-	84	46	75	55
Total animals	468,620	49,961	504,878	65,515	497,798	26,672	395,319	41,573
Livestock TLUs	212,447	-	184,407	-	185,598	-	133,884	-
Wildlife TLUs	63,323	-	126,815	-	96,874	-	57,205	-
Total TLUs	275,770	-	311,222	-	282,472	-	191,089	-
Density (TLUs/km^2)								
Livestock	21.9	-	19.0	-	19.1	-	13.8	-
Wildlife	6.5	-	13.0	-	10.0	-	5.9	-
Total	28.4	-	32.0	-	29.1	-	19.7	-
TLU ratios	3.4	-	1.5	-	1.9	-	2.3	-
Cattle:Sheep and goats	31.3	-	22.0	-	15.7	-	10.6	-
Dead elephant %	1.4	-	0.0	-	0.0	-	0.0	-
No. of transects	13	-	14	-	37	-	19	-

Table 7. Estimated animal population sizes for Laikipia District, 1977-1985 (continued).

Animal type	Mar.-Apr. 1985 Number	Mar.-Apr. 1985 SE	Average Number	Average SE
Livestock	299,633	28,888	351,057	18,416
Cattle	92,193	12,543	205,726	12,161
Sheep and goats	206,501	25,021	144,021	13,828
Camels	313	261	649	144
Donkeys	626	194	661	177
Wildlife	58,688	5,101	93,939	8,023
Buffalo	1,987	1,150	1,544	468
Giraffe	1,895	527	2,710	341
Burchel's zebra	19,373	2,619	24,081	3,293
Grevy's zebra	386	330	245	91
Elephant	2,097	1,719	2,139	735
Kongoni	3,569	751	6,615	647
Impala	8,794	2,230	14,518	2,690
Thomson's gazelle	6,366	2,372	13,969	2,608
Grant's gazelle	6,384	1,110	6,067	596
Oryx	1,398	705	1,405	291
Eland	5,519	1,237	18,380	6,140
Waterbuck	37	35	842	146
Ostrich	883	261	1,373	177
Lesser kudu	-	-	19	10
Gerenuk	-	-	32	14
Total animals	358,321	29,335	444,996	20,088
Livestock TLUs	81,998	-	159,668	-
Wildlife TLUs	52,620	-	79,119	-
Total TLUs	134,618	-	238,787	-
Density (TLUs/km^2)				
Livestock	8.4	-	16.4	-
Wildlife	5.4	-	8.1	-
Total	13.9	-	24.5	-
TLU ratios				
Livestock:Wildlife	1.6	-	2.0	-
Cattle:Sheep and goats	4.5	-	14.3	-
Dead elephant %	1.7	-	0.8	-
No. of transects	22	-	-	-

Data have not been adjusted for observers' biases.
District area = 9,718 km^2
TLU = tropical animal unit (250 kg)
SE = standard error

Table 8. Estimated animal population sizes for Marsabit District, 1977–1985.

Animal type	Aug.-Sept. 1977 Number	SE	July-Oct. 1978 Number	SE	Feb.-Apr. 1981 Number	SE	Feb. 1985 Number	SE	Average Number	SE
Livestock	689,876	103,362	1,092,972	109,120	504,741	52,874	494,809	99,114	695,600	46,911
Cattle	120,446	22,295	213,240	34,325	78,225	14,041	100,689	25,975	128,150	12,617
Sheep and goats	452,789	98,949	769,105	102,048	377,118	50,696	347,548	92,956	486,690	44,311
Camels	114,992	19,885	107,885	17,733	46,553	5,271	45,645	22,530	78,769	8,822
Donkeys	1,649	567	2,542	843	2,845	801	927	809	1,991	381
Wildlife	106,608	11,553	103,288	5,576	64,322	4,225	55,449	11,868	82,423	4,495
Buffalo	-	-	-	-	646	557	1,347	832	499	250
Giraffe	5,863	1,305	8,120	1,277	3,107	585	3,084	1,718	5,044	644
Burchel's zebra	626	406	492	265	600	458	-	-	430	167
Grevy's zebra	6,563	2,445	5,074	1,198	3,285	718	1,588	710	4,128	726
Elephant	1,685	1,563	112	67	231	113	532	467	640	409
Impala	-	-	-	-	105	89	456	281	141	74
Grant's gazelle	53,563	9,202	51,789	4,154	41,493	3,486	29,381	8,392	44,057	3,396
Oryx	16,693	4,377	15,793	2,285	7,830	1,914	12,151	7,976	13,117	2,393
Lesser kudu	589	232	897	250	610	144	253	126	588	98
Eland	-	-	-	-	30	25	-	-	8	6
Gerenuk	8,419	1,472	7,323	869	3,561	414	4,238	1,191	5,886	531
Ostrich	9,209	3,338	13,595	2,159	2,824	665	2,384	960	7,003	1,036
Topi	3,398	2,445	93	83	-	-	-	-	873	612
Greater kudu	-	-	-	-	-	-	35	32	9	8
Total animals	796,484	104,006	1,196,260	109,262	569,063	53,043	550,258	99,822	778,023	47,126
Livestock TLUs	258,302	-	339,910	-	141,045	-	152,850	-	223,027	-
Wildlife TLUs	56,915	-	51,360	-	26,767	-	27,841	-	40,726	-
Total TLUs	315,217	-	391,270	-	167,812	-	180,691	-	263,753	-
Density (TLUs/km^2)										
Livestock	3.5	-	4.6	-	1.9	-	2.1	-	3.0	-
Wildlife	0.8	-	0.7	-	0.4	-	0.4	-	0.6	-
Total	4.3	-	5.3	-	3.2	-	2.5	-	3.9	-
TLU ratios										
Livestock:Wildlife	4.54	-	6.62	-	5.27	-	5.5	-	5.5	-
Cattle:Sheep and goats	2.66	-	2.77	-	2.07	-	2.9	-	2.6	-
Dead elephant %	0.0	-	0.0	-	15.5	-	0.0	-	0.02	-
No. of transects	35	-	69	-	65	-	46*	-	-	-

Data have not been adjusted for observers' biases.
District area = 73,952 km^2
TLU = tropical animal unit (250 kg)
SE = standard error
* = total transects in all strata

Table 9. Comparison of total livestock and wildlife numbers between average of all previous censuses by KREMU (1) and 1985 census (2).

District	Livestock 1	Livestock 2	Loss	Wildlife 1	Wildlife 2	Loss
Mandera	516776	109800	-406976	8322	3058	- 5264
Wajir	726785	447343	-279444	81189	41187	-40002
Isiolo	619396	375104	-244292	75229	30364	-44865
Garissa	671990	441681	-230309	86237	24132	-62105
Samburu	406385	328912	- 77473	33046	23372	- 9674
Marsabit	762530	494809	-267721	91406	55449	-35957
Laikipia	363911	299633	- 64278	102743	58688	-44055

Table 10. Average stocking level (TLU/km^2) and human population density (No./km^2) for selected districts in northern Kenya, 1977-1983.

District	Area km^2	Livestock density	Wildlife density	Total density	Ratio livestock/wildlife	Ratio cattle/shoat	Human pop. density	Livestock TLU per 1000 people
Mandera	26470	7.0	.4	7.5	15.8	1.0	4.0	1750
Wajir	56501	6.4	.7	7.1	9.5	4.9	2.5	2560
Isiolo	25605	9.6	1.4	11.0	6.7	3.6	1.7	5647
Garissa	43931	7.4	2.3	9.8	3.2	11.4	2.9	2552
Samburu	17521	7.9	2.0	9.9	3.9	5.8	4.4	1795
Laikipia	9718	18.4	8.9	27.3	2.1	18.2	13.8	1333
Marsabit	73952	3.3	.6	3.9	5.5	2.6	1.3	2538

Table 11. Stocking levels (TLU/km^2) for selected districts in northern Kenya rangelands, 1985.

District	Area km^2	Livestock density	Wildlife density	Total density	Ratio livestock/wildlife	Ratio cattle/sheep and goats
Mandera	26470	2.6	.1	2.7	29.4	3.8
Wajir	56501	4.1	.5	4.6	8.3	2.9
Isiolo	25605	3.9	.5	4.4	7.6	2.5
Garissa	43931	5.0	.8	5.8	6.0	9.5
Samburu	17521	5.2	1.6	6.8	3.2	4.0
Laikipia	9718	8.4	5.4	13.8	1.6	4.5
Marsabit	73952	2.1	.4	2.5	5.5	2.9

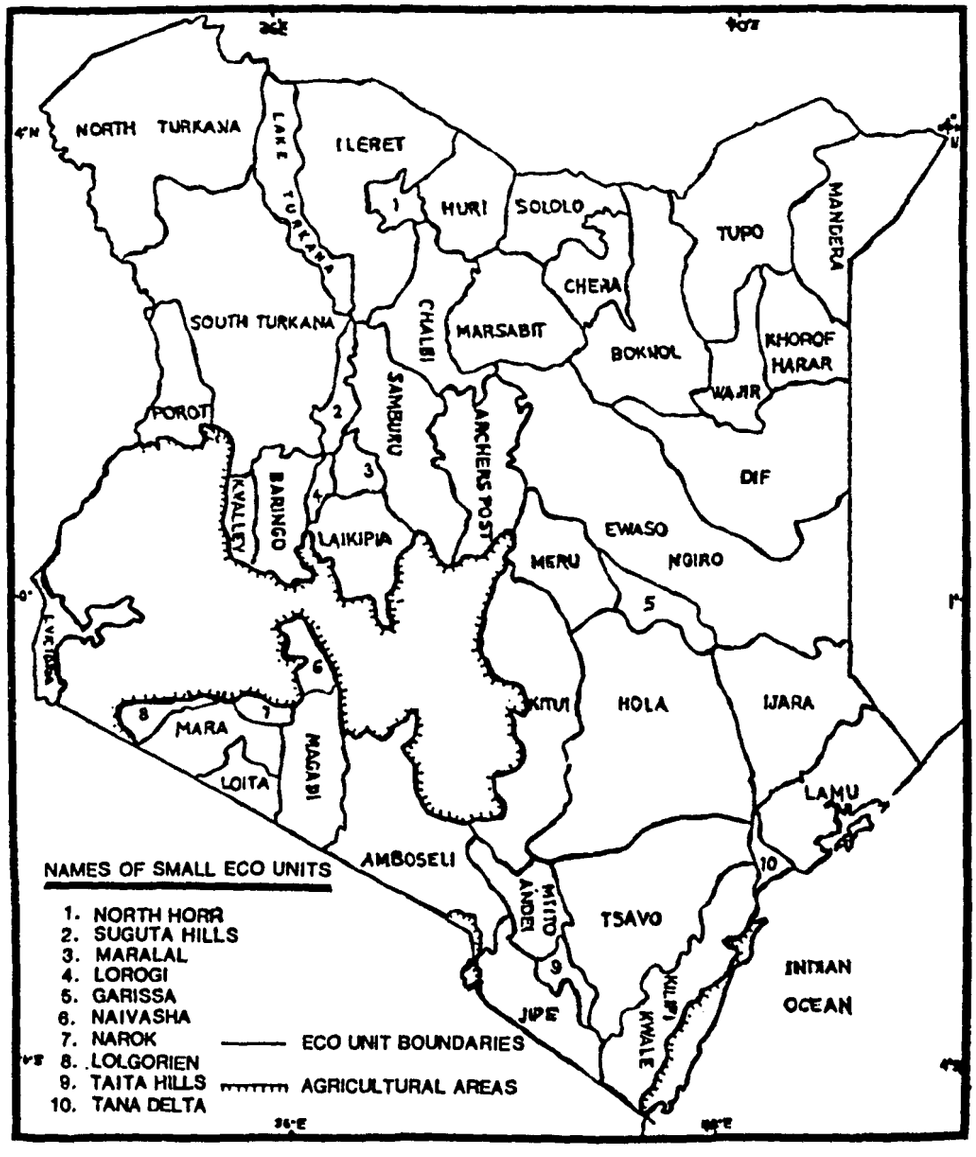

Figure 1. Ecounits of Kenya's rangelands that differ ecologically from each other.

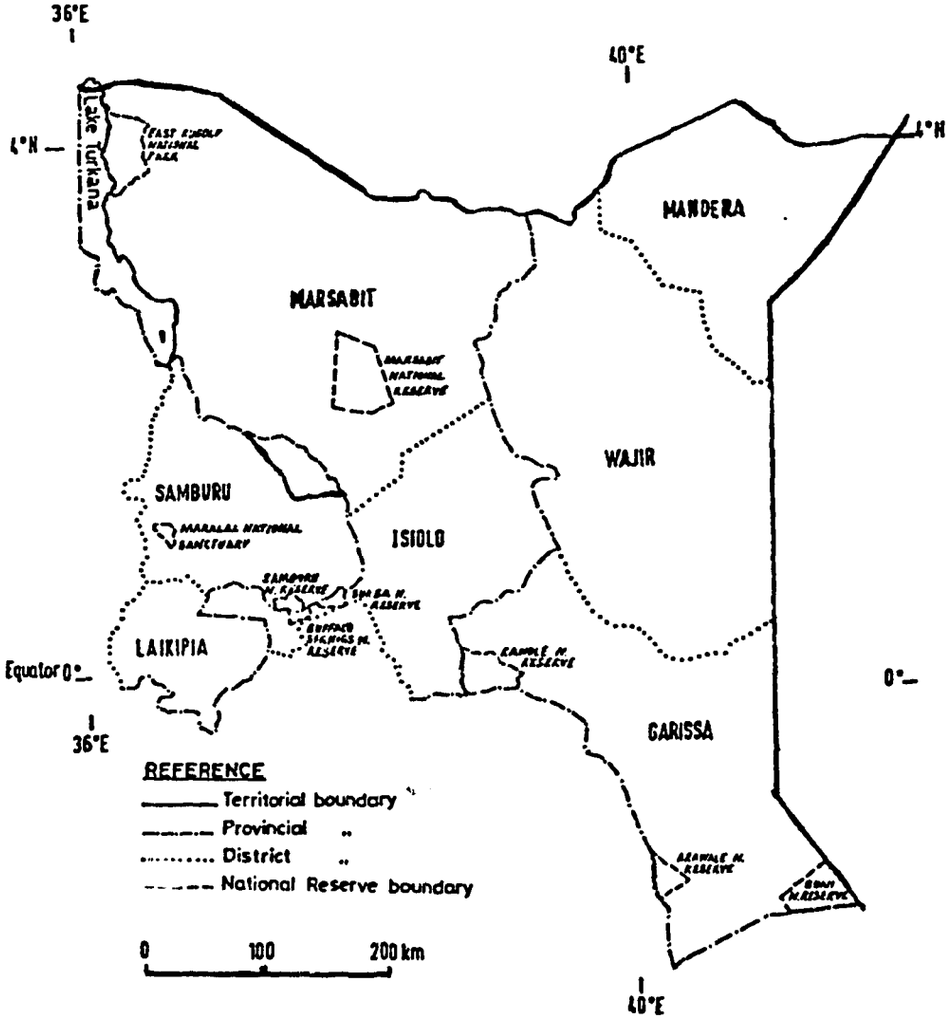

Figure 2. Selected districts of northern Kenya rangelands.

COMPARISONS OF AERIAL AND GROUND COUNTS OF BIG GAME AT THE NATIONAL RANGE RESEARCH STATION

T. Qureshi and F. K. Waweru

INTRODUCTION

Wildlife populations are observed in large numbers on Kenyan rangelands. These rangelands represent 80% of the country and are inhabited by the pastoral tribes and their livestock. With increasing human populations and the subsequent demand for land for settlement and grazing, conflicts occur between livestock and wildlife in partitioning of rangeland resources. It has become important to understand the interactions between livestock and wildlife for their mutual coexistence. Previous animal population estimates of the National Range Research Station (NRRS) have shown that 22% of the total animal biomass was wildlife. The wild-herbivore density was at 35 large ungulates per square kilometer (Drase, 1983). These wild herbivores are free ranging and can interact with livestock for range forage and disease intertransmission. The contribution of livestock owned by NRRS, trespass livestock on NRRS, and wild herbivores to range-resource partitioning, disease transmission, and local socioeconomic trends must be enumerated in the overall research plan for the station. The contributions of each of the three factors can be represented in terms of population levels. The NRRS, with the Kenya Rangeland Ecological Monitoring Unit (KREMU), carried out a series of surveys to assess the population estimates, density, and distribution of large herbivores on the NRRS and on the immediate adjoining area.

STUDY AREA

The NRRS, as described in the soils and vegetation survey report (Michieka and Van der Fouw, 1977), is located in latitudes 2°10′ and 2°25′ south and longitude 37°40′ and 37°55′ east. It is approximately 170 km southeast of Nairobi along the Nairobi-Mombasa road. The total area is about 31,000 ha. The altitude varies from 900 m to 1,100 m above sea level. The rainfall is bimodal, with rainy seasons from March to May and from October to December. The average precipitation is 600 mm per year with average evaporation of 2,000 mm per year. The average temperature is 23°C.

About half of the NRRS area is lava flows consisting of shallow to very shallow soils that are stony, rocky, and highly permeable. The vegetation on these areas is bushed thickets to bushed grasslands. The rest of the NRRS consists of erosional plains with small areas of bottomlands. These areas have red to brown sandy clay soils and bushed-grassland vegetation.

METHODS

Ground Counts

The wildlife were censused by use of the line-transect sampling method. Four transects were selected on the basement plains of the north ranch area (figure 1). The counts of the game animals were made from a vehicle driven in a straight line at a constant speed of 20 km/hr. Animals were counted by sight from both sides of the vehicle -- one observer on each side of the vehicle. Each count was carried out in the

evening starting at 1600 hours. The number of animals, the species, and the perpendicular distances of the animals to the transect line were recorded. The transect lines were run several times during a dry and a wet season for each year. The numbers of animals seen per census count were used as indexes to draw inferences of population.

Aerial Counts

A study area covering a total of 627 km^2 was demarcated for the purpose of this study. It included the NRRS (approximately 268 km^2, or about 43% of the study area) and approximately 359 km^2 of the adjoining area (a belt up to 5 km wide along the perimeter of the ranch) (figure 2).

Systematic transects oriented in an east-west direction were flown at 1-km intervals at a height of 400 m above ground level. In total, 31 transects were flown (figure 3).

A Partenavia twin-engine aircraft was used, flying at a constant speed of about 180 km/hr. The census transect belts, defined by two parallel rods attached to the aircraft struts, had an average strip width of 384 m on the ground (Ottichilo and Sinange, 1985).

Two rear-seat observers counted all large herbivores within the census strip, recorded the information using a tape recorder, and photographed any herds having more than 10 members. A front-seat observer scanned an undemarcated strip about 500 m wide on the right side of the aircraft and collected environmental information: herbaceous- and woody-vegetation cover, height and phenology, surface-water availability, and human-settlement activities.

Population estimates and standard errors were calculated using the Jolly method 2 (Jolly, 1979).

RESULTS

Ground Counts

Wild herbivores seen on the NRRS during drive counts were zebras (Equus quagga), kongoni (Alcelaphus buselaphus), warthogs (Phacocherus aethiopicus), waterbucks (Kobus ellipsiprymmis), lesser kudus (Tragelaphus imberbis), ostriches (Struthio camelus), giraffes (Giraffa camelopardalis), Grant's gazelles (Gazella granti), impalas (Aepyceros melampus), elands (Taurotragus oryx), oryx (Oryx gazella), dikdik (Madogua kinkii), and suni (Neotragus moschatus). A greater number of different large, wild herbivores were seen during the aerial census than during the ground census. Wildebeests (Connochaetes taurinus), buffalo (Syncerus caffer), and gerenuk (Litocranius walleri) were observed by the aerial census but were not observed during any of the ground counts except during the severe drought of 1984. The small herbivores, dikdik and suni, were observed and counted during the ground counts, but they were ignored during the aerial census because accurate identification was difficult.

Table 1 shows the mean number of animals seen per transect run during the drive counts on NRRS. More wild animals were counted during the dry seasons than wet seasons within any year. Comparisons of drive-count censuses over the years 1982 to 1985 indicate a general decline in the numbers of kongoni, warthogs, waterbucks, Grant's gazelles, impalas, and dikdik.

There was a marked increase in the total number of wild herbivores seen on the ranch during the drought of 1984. Following the drought, there were marked declines in the numbers of animals of every species observed in 1985.

Aerial Census

Table 2 shows the population estimates of wildlife and livestock observed on the NRRS and the adjoining area from aerial census, and table 3 shows the total numbers and biomass of wild herbivores and livestock seen on NRRS and the adjoining area.

Similar observations to ground counts were made in comparing the census data from 1982 to 1985. There were marked increases in the total numbers of animals seen and in the total animal biomass during the drought of 1984. An increase of about 118% in total number of animals was observed, compared to the previous years. This was followed by a decline of 81.73% in the total number of animals observed in 1985.

Aerial census always indicated a higher number of livestock present on the station than the actual numbers owned by NRRS (table 4). Aerial estimates of livestock population trends show a higher number of these trespass livestock on the station during the dry season than during the wet season. The greatest impact of trespass grazing occurred during the drought of 1984.

DISCUSSION

The ground-count census is best performed on grasslands or on areas with canopy cover of less than 10% to 15%. Most of the range on NRRS has a canopy cover of up to 40%. The wild herbivores also are wary of vehicles and tend to move away before they are sighted during a census drive. An assumption made in calculating the population estimates is that of random distribution of animals, which is not experienced in the field with our African wild-herbivore species. Calculations of population estimates, when using the conventional King's method or the Jolly method, result in a bias because of the above reasons. The population levels from ground counts are gross overestimates and therefore were disregarded. The data of the number of animals seen during a transect run were then used as an index of population trends. Aerial surveys overcome this bias by increasing the sampling intensity to approach a total count.

Wildlife prefer to be in areas of minimal human disturbance. These areas usually are inaccessible to vehicles and to grazing livestock, but the wildlife can be observed from the air. Thus, in aerial counts more large-herbivore species were observed than in drive counts.

Movement and population dynamics of wild herbivores are related to availability of food resources. The onset of the wet season makes food available in all areas, and wild herbivores can disperse and move to areas of minimal human disturbance. Results of both aerial and ground counts indicate higher population numbers of wild herbivores on the NRRS during the dry season and lower numbers during the wet season. The low numbers seen during the wet season could be attributed to a visibility bias because of dense vegetation cover that follows the green growth after the rains. This visibility bias is stronger for ground counts than for aerial counts. From the air, the wet season green-up does not alter the visibility of wild herbivores very much. Therefore, the low

numbers of wild herbivores seen during the wet season by both the aerial and ground counts must be attributed to dispersal.

Trespass is an endemic problem, as shown by the aerial census estimates of the NRSS. Higher numbers of trespass livestock were observed during the dry seasons, and the greatest impact was during the drought of 1984. The areas of the station that experienced the strongest impact were the southwest and southeast corners of the south ranch. This area is surrounded by a large concentration of human settlements and livestock and also is the farthest from the station headquarters; therefore, it is difficult to control for trespassers.

The total biomass supported by the range gradually declined for the years 1982 to 1983 and drastically increased in 1984. In 1985, the total biomass declined to less than one-half (1.15 kg/km^2) of the lowest recorded biomass in 1983 (2.63 kg/km^2). The implication is that during the dry season, especially during a drought, the grazing pressure on the range from all herbivores can cause deterioration of the pastures as a result of overstocking. This may cause a reduction in the potential carrying capacity and therefore require long deferment for recovery of the range. To allow the range to recover and maintain station animals in a healthy state, control of stocking rates and trespass grazers is of paramount importance. More surveillance should be employed during the dry seasons for better control of trespass grazers. The presence of trespass grazers is inevitable and must be considered in the station's grazing-management plan. Drive counts cannot effectively quantify the impact of trespass livestock, so here the aerial census is an invaluable tool for the livestock manger.

The total wild-herbivore biomass has remained in the range of 9% to 15% of the total animal biomass on the station. This wild-herbivore biomass consists of grazers, browsers, and mixed feeders. Since the number of species that compete with livestock has remained low, they are not significant competitors to livestock. The drive counts have shown results similar to aerial counts in wildlife population trends and are a cost-effective tool for the wildlife manager, who can draw reasonable inferences of population trends from the resulting data.

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Table 1. Mean number of animals seen per transect run (4 transects) during drive counts on the north ranch of National Range Research Station.

	1982	1983	1984		1985
Wildebeest (WL)				5.81	
Zebra (ZB)	10.1	.95		10.5	
Buffalo (BF)				5.94	
Kongoni (KG)	10.2	9.05	5.1	7.31	4.42
Ostrich (OS)	2.4	3.24	3.0	2.44	1.63
Warthog (WH)	4.6	2.67	1.8	1.75	.47
Waterbuck (WB)	9.7	2.48	1.1	.12	.05
Lesser kudu (LK)					
Giraffe (GF)	14.6	19.24	30.2	7.0	4.16
Gerenuk (GN)					
Grant's gazelle (GG)	8.6	10.28	8.3	5.0	3.73
Impala (IM)	17.3	12.71	14.9	6.81	5.47
Eland (EL)	1.6	2.19	1.6	.31	
Oryx (OX)	.4		.1	1.25	
Dikdik (DD)	7.9	9.19	5.6	1.25	.53
Suni (SU)					
No. of transects	10	21	10	15	18

Table 2. Population estimates of wildlife on Kiboko area from aerial census conducted by Kenya Rangeland Ecological Monitoring Unit.

	March 1982		Dec. 1982		June 1983		Aug. 1984		Nov. 1985	
	NRRS	AD	NRRS	AD	NRRS	AD	NRRS	AD	NRRS	AD
WL	0	235	0	3	0	19	0	184	0	56
ZB	51	20	0	0	0	0	170	0	0	97
BF	0	10	0	0	8	88	147	151	8	119
KG	76	68	317	67	142	207	90	52	16	78
OS	36	24	0	48	0	23	15	10	3	19
WH	14	31	0	0	12	0	19	19	0	2
WB	41	49	0	3	8	31	67	123	16	10
LK	7	7	0	10	20	0	10	0	10	0
GF	84	70	83	75	47	132	71	109	34	29
GN	0	7	4	0	0	0	0	0	5	0
GG	47	54	39	26	4	73	33	48	10	39
IM	65	105	293	26	32	127	10	66	89	10
ED	48	53	4	0	0	38	100	29	18	19
OX	0	4	0	6	0	4	0	0	0	2
DN	0	14	0	0	8	19	0	51	0	0
CT	4731	6219	2818	6077	3264	10572	10491	15543	1388	4105
SH	608	6225	2414	5842	2263	10183	379	6788	708	2742

See abbreviations used in table 1: DN = donkey, CT = cattle, SH = shoats for sheep and goats.

Table 3. Total numbers and biomass of livestock and wild herbivores on the NRRS and the adjoining area.

	March 1982		Dec. 1982		June 1983		Aug. 1984		Nov. 1985	
	NRRS	AD	NRRS	AD	NRRS	AD	NRRS	AD	NRRS	AD
Total No.	5808	13450	5972	12183	5808	21516	12656	23174	2312	7330
Livestock	5339	12456	5232	11919	5535	20774	11925	22383	2096	6847
Wildlife	469	994	740	264	273	742	732	791	206	483
Total biomass										
kg/km^2	3.65	3.92	2.53	3.58	2.63	6.50	7.98	8.85	1.15	2.60
Livestock	3.23	3.53	2.10	3.38	2.39	5.96	7.18	8.24	.99	2.24
Wildlife	.42	.39	.43	.20	.24	.54	.80	.61	.16	.36
% biomass of total										
Livestock	88.49		83.0		90.88		89.88		85.79	
Wildlife	11.51		17.0		9.12		10.02		14.21	

Table 4. Comparison of livestock population estimates from aerial census with livestock records of NRRS: assessment of trespass grazers on National Range Research Station.

	March 1982	Dec. 1982	June 1983	Aug. 1984	Nov. 1985
Donkey	0	0	8	10	0
Cattle	4731	2818	3264	10491	1388
Shoats	608	2414	2263	379	708
NRRS					
Cattle	1372	1626	1540	1529	1026
Shoats	870	848	475	356	591
Trespass					
Cattle	3359	1192	1724	8962	362
Shoats		1566	1788	23	117

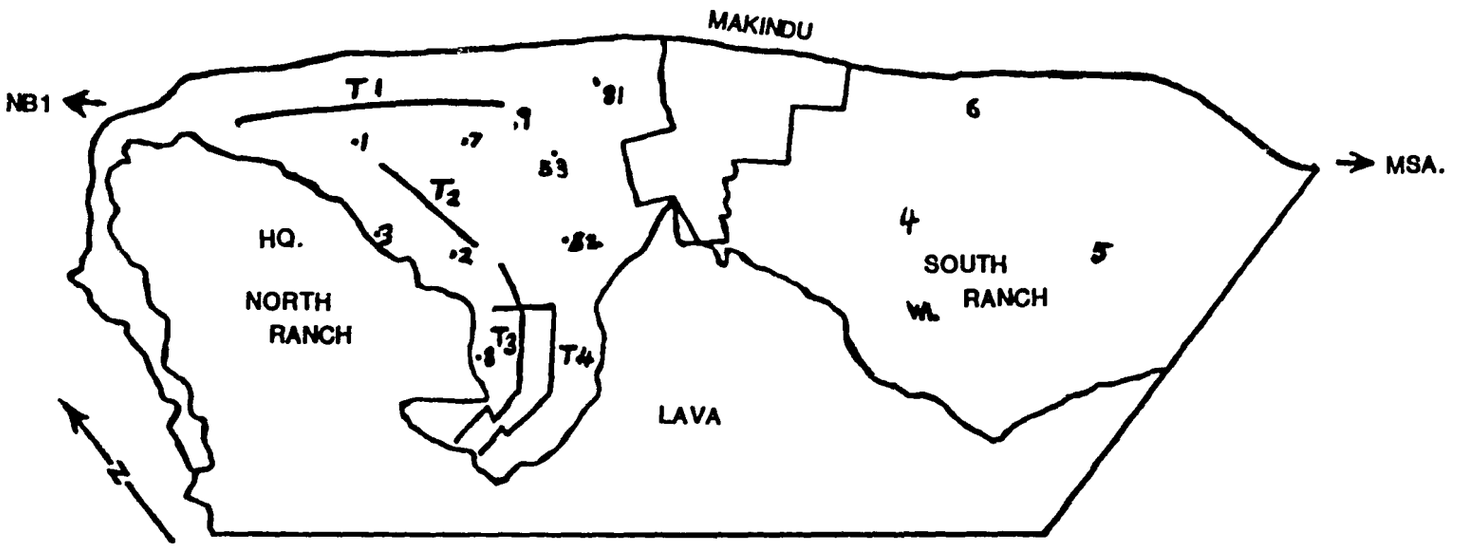

Figure 1. Locations of wildlife-census transects on the north ranch of the NRRS.

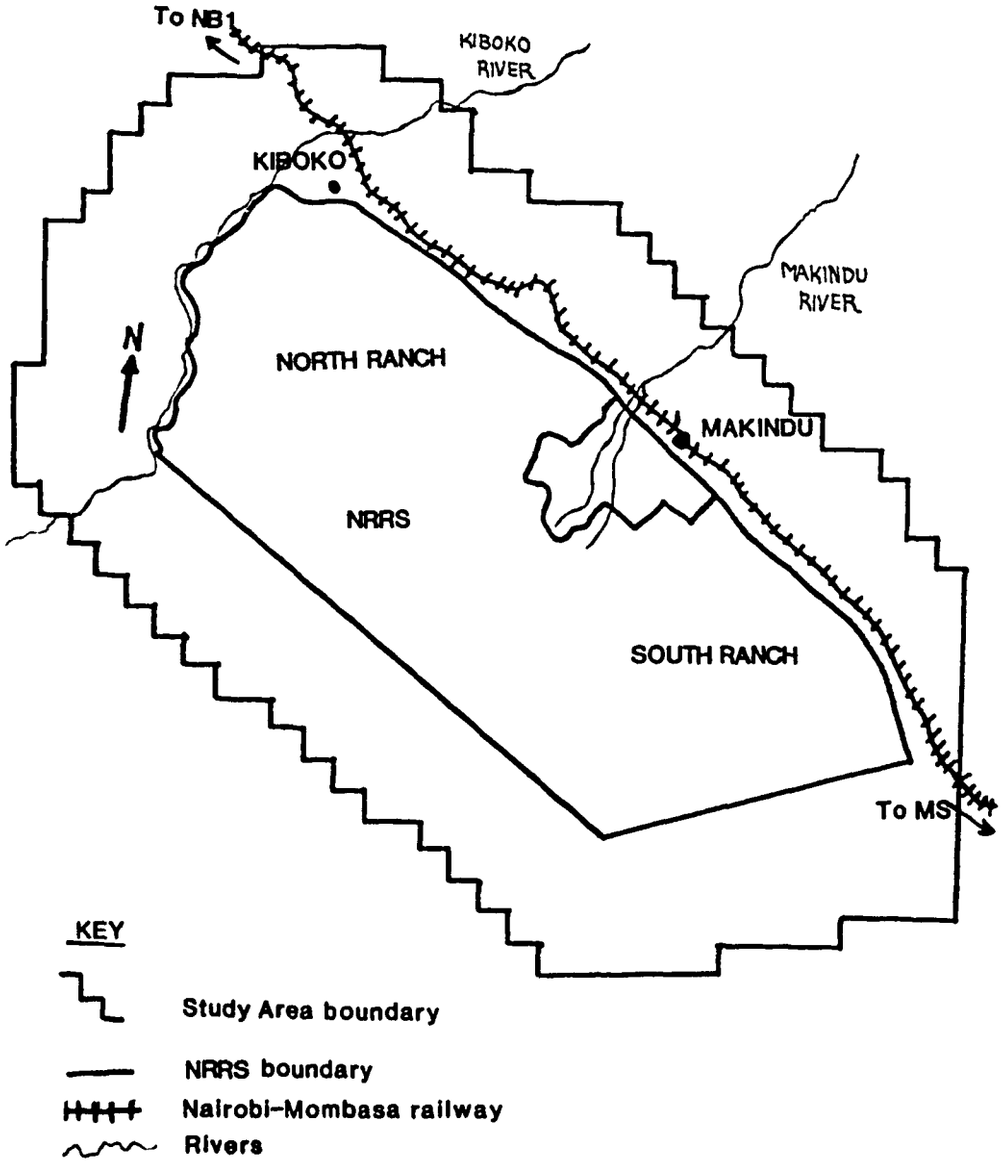

Figure 2. Location of the Kiboko study area: the NRRS and the adjoining area.

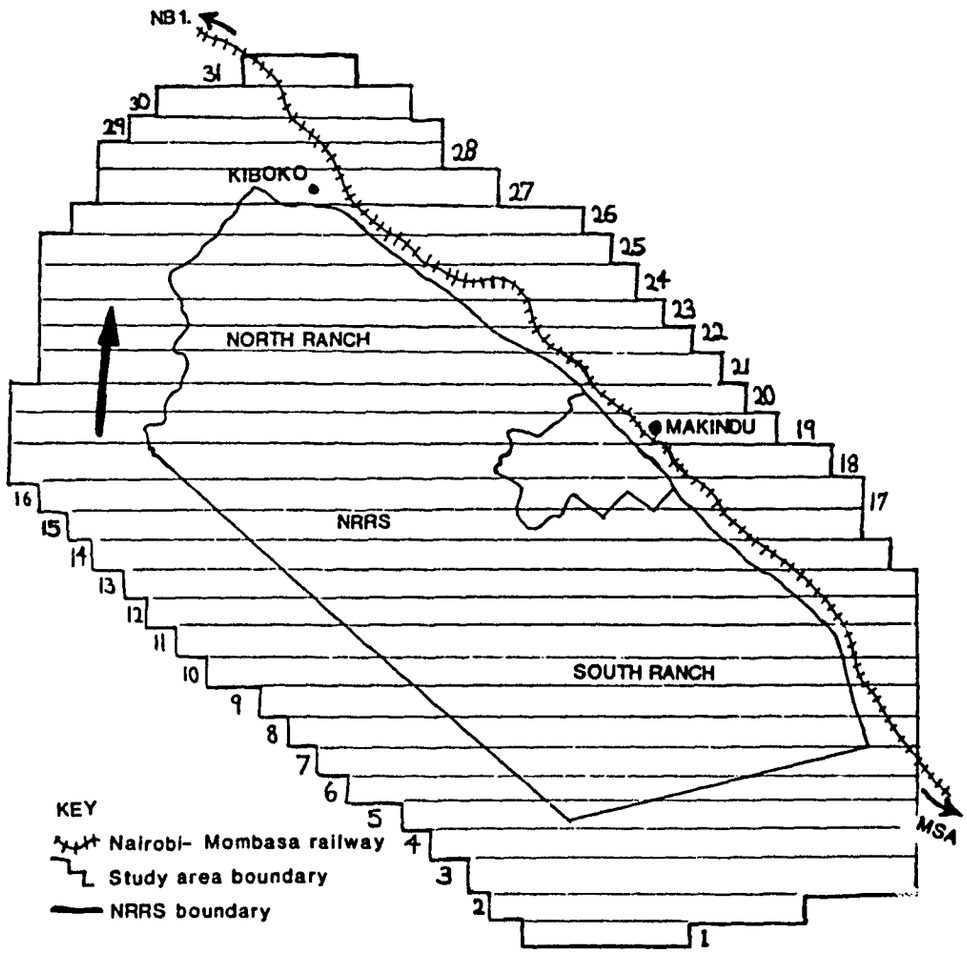

Figure 3. The 31 systematic transects flown over the Kiboko study area.

THE USE OF NOAA AVHRR IMAGERY FOR RANGELAND MONITORING

R. H. Lamprey and P. N. de Leeuw

INTRODUCTION

As land-use pressure in the Third World increases, the need becomes more urgent for the accurate assessment and inventory of agricultural and rangeland resources. Satellite remote sensing appears to offer a reliable means of assisting in such assessment. However, before satellite imagery can be used to its full advantage in monitoring vegetation, further research is needed to examine the reflectance characteristics of vegetation as recorded by satellite sensors.

Rangeland-vegetation studies from satellites rely on the differential absorption of red (R) and infrared (IR) wavelengths by green vegetation (figure 1). Using ground-based radiometers, it has been shown that the IR/R ratio is roughly proportional to green biomass (Pearson and Miller, 1972; Tucker, 1979; McNaughton, 1979). A more complex ratio, the "normalized difference vegetation index" (NDVI), has been developed (Rouse et al., 1973; Deering, 1978; Gatlin et al., 1984) where: NDVI = $\frac{IR - R}{IR + R}$. The NDVI has the effect of normalizing differences in vegetation response to a scale between 0 and 1 and has shown great potential in monitoring vegetation trends at the continental and national scale (Gatlin et al., 1984).

The success and failures of the LANDSAT series of satellites are well documented (NAS, 1977). The most serious drawbacks associated with the use of the LANDSAT series for regular and repetitive vegetation monitoring have been their relatively long repeat interval (16 or 18 days), the blanketing of large areas by cloud, and the limited life of the on-board tape recorder (Gywnne, 1977). The more recent NOAA series of satellites, equipped with AVHRR (advanced very high resolution radiometers), largely avoid these difficulties by recording images every day. The Global Inventory Monitoring and Modelling Study (GIMMMS) of NASA specializes in "temporarily compositing" AVHRR data, whereby 7- to 14-day series of NDVI data are combined to produce a relatively cloud-free image (Gatlin et al., 1984). Despite the low resolution of AVHRR data, which at the readily available "global area coverage" (GAC) scale is approximately 4 km, NOAA imagery has great potential for long-term and extensive vegetation monitoring. Examples of the successful application of NOAA data for vegetation monitoring are given by Townshend and Tucker (1984), Tucker et al. (1984), and Justice et al. (1985).

In February 1985, a workshop was held in Nairobi to discuss the future applications of the AVHRR satellite monitoring system. At this meting, it was acknowledged that no reliable or repeatable methodology of aerial photography or radiometric ground truthing has yet been developed to test AVHRR imagery. Further studies are needed to examine the relationship between satellite vegetation indexes such as the NDVI and vegetation parameters such as green biomass and cover. Research priorities also have to focus on the effects of tree cover, atmospheric haze, and sun elevation on sensor response. Difficulties in sampling are compounded by the GAC pixel subsampling procedure and the "random floating grid" of the pixels of the image. Thus, at the GAC scale, AVHRR users often were unable to locate ground-training areas accurately. Despite these difficulties, it appears that, for the foreseeable future,

AVHRR is the only reliable system capable of recording rangeland and cropland conditions over large areas at high frequency.

The ILCA/UNEP AVHRR Calibration Project was established in Nairobi in July 1985 to design and test suitable calibration methods for AVHRR data and to determine the accuracy of these data for monitoring the distribution of vegetation biomass and phenology. While it was anticipated that AVHRR data would be most useful to the range manager, another use of the data is to measure crop-growing seasons and thus provide accurate information on potential crop harvests for large administrative areas. For these purposes, the data would be incorporated and analyzed with other information stored in geographical information systems (GIS).

The project's program is based on the three-tier approach to environmental monitoring (Gwynne and Croze, 1977), in which measurements from the ground and air are analyzed and compared with satellite output. The program is divided into four parts, as follows.

Ground Calibration

The NASA radiometer available to the project was calibrated on the ground against herbaceous- and shrubby-vegetation cover, greenness, and biomass, as well as to additive and summative combinations of these parameters.

Long Transects

Every 2 months, radiometer transects are flown from Kisumu on Lake Victoria to Malindi on the coast and from Nairobi to Lodwar West of Lake Turkana. These transects cover the full range of environmental conditions in Kenya, and their orientations are such that the ecological-zone boundaries are crossed at right angles. As a result, the comparison of AVHRR data with aircraft NDVI data is relatively unaffected by small deviations in the aircraft track and by deviations in satellite response due to the "slop" in the AVHRR data. By averaging aircraft radiometer and AVHRR data into 20-km segments, regressions can be performed on the two data sets to test whether calibrations are consistent from one data set to the next.

Large-area Blocks

AVHRR data can be considered useful only if they are incorporated into a geographical information system (GIS) for correlation and association analyses with other component data of the system. The project aims to explore simple ways of compiling AVHRR and aircraft-radiometer data into such a system, using the UTM-grid system. At the same time, satellite NDVI digital data are more readily available in large-area block form (for example, 1-degree sheets). The large-area block approach, therefore, allows comparison between aircraft and digital data (in addition to color data). Four blocks are currently being flown every 2 months, in Kajiado, Masai Mara, Lodwar, and Kora. As a part of the long-transect and large-area block program, vertical aerial photographs are taken simultaneously with radiometer measurements to determine which vegetation parameters or combinations of parameters measurable on aerial photographs are most closely correlated with the radiometer NDVI. The blocks and transects have been designed to cover the full range of environmental conditions in Kenya, from moist forest (ecological zone I) to desert scrub (ecological zone VII).

The objective of this paper is to describe the methods and some initial results of the calibration project and to discuss future directions for research.

GROUND RADIOMETER MEASUREMENTS

Methods

In June 1985, radiometer measurements were taken of 20 0.5-m^2 vegetation plots for which the cover and greenness were assessed and wet and dry biomass were determined by clipping and drying. Nine systematically distributed radiometer recordings were taken of each plot at a height of 1.5 m in sunny conditions. Plots were divided into 10 herbaceous plots (located beneath the Ngong Hills and on Akira Ranch in Rift Valley) and 10 shrubby plots (located on the slopes of Mt. Suswa in the Rift Valley). Herbaceous species selected for study were Cynodon dactylon, Cynodon plectostachyus, Sporobolus spp. Themeda triandra, Chloris pycnothrix, and Ehrlangia spp. In the shrubby plots, shrubs were selected that had no underlying grass cover and that fitted into the 0.5-m^2 quadrat. After measurement, the shrubs were defoliated and the foliage was weighed. Shrubs selected were Euclea divinorum, Acacia drepanolobium, Ormocarpum trichocarpum, Tarchonanthus camphoratus, and Justicia spp., which all had widely different canopy structures.

Results

Highly significant regressions were obtained between the radiometer NDVI and dry biomass ($r = .87$: $n = 20$: see figure 2) and greenness % x cover % ($r = .94$: $n = 20$: see figure 3). Linear regression equations for shrubs and herbaceous vegetation were not significantly different. Cloud cover and height of radiometer recording had no measurable effect on NDVI. Although greenness can be considered only a subjective estimate, the parameter greenness x cover was highly correlated with biomass ($r = 94$: $n = 20$) and also can be determined from aerial photographs, justifying its incorporation into the calibration procedure.

LONG TRANSECTS

Methods

The long transects are flown every 2 months, and special emphasis is placed on the Kisumu-Nairobi-Malindi transect that covers all ecological zones in Kenya from the rainforest in trans-Mara (zone I) to the arid Acacia-Commiphora bushland in Tsavo (zone VII). Radiometer recordings are taken every 30 seconds at 1500′ a.g.l. Transects are segmented into 20-km lengths to test aircraft NDVI against AVHRR NDVI data. The 30-second interval was considered sufficient since the coefficient of variation of the 12 NDVI measurements/20-km segment was usually below 3% of the mean for each segment. In early September 1985, 35-mm color slides (scale 1:14,000) were taken along the Kisumu and Malindi transects and synchronized with NASA radiometer measurements. Data from these transects were used in two ways:

- To calibrate the aircraft NDVI against tree cover and greenness, grass cover and greenness as determined from aerial photography. The area of each photographed scene by the radiometer was analyzed for woody and herbaceous cover using dot-grid analysis. A 100-dot

grid was used, and the 50% rule was employed in which a contact was ignored if less than half the dot touched the vegetation.

- To regress average NDVI values of each 20-km segment with corresponding AVHRR NDVI values determined from the image color transparancies supplied by NASA. Kisumu-Malindi transect data from July 4-6, 1985, and AVHRR color NDVI data from July 1-15, 1985, were compared.

Results

Radiometer calibration. The aircraft NDVI was significantly correlated with overall vegetation cover (woody cover + herbaceous cover) for the Nairobi-Kisumu transect (r = .78 : n = 69), but poorly correlated with overall cover for the Malindi transect (r = .04 : n = 133) where large areas of high-cover but nongreen Acacia-Commiphora were traversed. When greenness is brought into the equation, a very high correlation (r = .97 : n = 202 : see figure 4) was obtained over the entire Kisumu-Malindi transect between the aircraft NDVI and the parameter woody cover x woody greenness + herbaceous cover x herbaceous greenness. For ground measurements, cover x greenness was well correlated with dry biomass (r = .94 : n = 20). Therefore, a link can be made between aircraft NDVI and biomass through the function cover x greenness.

AVHRR calibration against aircraft NDVI. The correlation between AVHRR NDVI color data and aircraft radiometer NDVI data for the first half of July 1985 was good (r = .91 : n = 30 : see figure 5), indicating that AVHRR color data can be used successfully for calibration purposes. By comparing AVHRR-NDVI/aircraft-NDVI regressions for each set of surveys and predicting color codes for each study area, the reliability of AVHRR NDVI data as a long-term monitoring system can be ascertained.

LARGE-AREA BLOCKS

Methods

The large-area blocks of Kajiado, Masai Mara, Lodwar, and Kora were flown every 2 months on a 10-km UTM base. Navigation was conducted using 1:250,000 topographical maps and 1:250,000 LANDSAT images, kindly provided by the Regional Sensing Facility in Nairobi. Radiometer measurements were taken every 30 seconds, together with 35-mm photographs (scale 1:14,000) at minute intervals in synchrony with every second radiometer recording. These photographs were analyzed for vegetation cover and greenness, soil color and extent of cloud cover. Aircraft radiometer data were averaged into 10-km x 10-km UTM grid cells by time-fitting between the beginning and end of each transect. It was hoped initially that satellite NDVI digital data would be available for all of the blocks; however, they have been supplied only for Kajiado (the most heterogenous block), which has therefore been used for comparisons of aircraft radiometer with NDVI-AVHRR digital NDVI. In the calibration process, AVHRR digitized data were grouped and fitted to 10-km grid cells by image measurement. The averaged AVHRR data for each cell were then regressed the averaged aircraft NDVI data for each cell.

Results

Radiometer calibration. Aircraft NDVI was found to be significantly correlated with the cover x greenness parameter (r = .92 : n = 111). The underlying soil type and the presence of cloud shadows had no

significant effects on this arelationship, although in areas with no vegetation cover, soil background appears to increase the minimum aircraft NDVI slightly from .37 for light soils to .41 for dark soils. A multiple-regression analysis was performed to test the calibration to the NDVI made by woody cover % x woody greenness % (WCG) and grass cover % x grass greenness % (GCG). The equation explained 85% of the data variation and indicated that, in rangeland areas, green woody and herbaceous vegetation make equal contributions to the NDVI: (NDVI = (6.58 WCG + 6.44 GCG) x 10^{-5} + 0.394) (R^2 = .85, Multiple R = .92, D. F. = 106).

AVHRR calibration against aircraft NDVI. The only aerial survey of Kajiado that corresponded to an available AVHRR digital data set was conducted on July 9-10, 1985. The correlation of the two data sets is strong (r = .94 : n = 45 : see figure 6), demonstrating that the aerial radiometer studies can provide an effective link between the satellite sensor and the ground.

DISCUSSION

The results of this research suggest that AVHRR data are extremely useful for monitoring rangeland vegetation. The NDVI appears to be an effective index for assessing green cover; however, radiometer and AVHRR sensors record a surface impression of vegetation, and if AVHRR data are to be used to measure herbaceous-forage resources over wide areas, the distribution and cover of the woody vegetation needs to be recorded, together with the green-flush status of the shrubs and trees.

A particular difficulty associated with the cover x greenness analyses is the while cover is empirically measurable from aerial photographs, the estimates of greenness remain subjective. Although different observers gave surprisingly close estimates of greenness percentage on aerial photos, it is impossible to completely standardize the exposure times (even with automatic cameras) and the processing of 35-mm color photography, especially if there are different illumination conditions along a transect. However, it was found that for the analysis of ground-plot data, greenness could be replaced by the ratio of wet weight/dry weight (W/D), following which the index became closely correlated with the term cover % x (W/D) (r = .95 : n = 11). This result, which implies that water content is proportional to chlorophyll activity, will be tested again in the forthcoming wet season.

A second point to emerge is that the relationship between aircraft and AVHRR-NDVI, although highly significant, is not constant over time. This is apparent from an examination of figures 5 and 6. The regular testing of the aircraft radiometer against reference areas (water surfaces, dry bare ground) indicates that the radiometer itself is not subject to internal fluctuations. It is probable the the AVHRR response is affected by different atmospheric conditions (Justice et al., 1985) or by an internal-response drift. If AVHRR data are to be used on a regular basis for rangeland assessment, a repetitive program of AVHRR/aircraft radiometer recalibration is needed. Similarly, since atmospheric haze levels may vary in different parts of the target area, such calibration transects need to be widely dispersed.

Recently, AVHRR data were used for estimating the length of the growing season in both rangelands and croplands (Hendricksen and Durkin, 1985). However, different areas have different dry-season (or dormant) NDVIs. Kikii district in Kenya, for example, has a high dry-season radiometer

NDVI of about 0.65 due to the presence of permanently green tea, coffee, and hedgerows; while in the Kora National Reserve, NDVI may drop to 0.40. On the other hand, if homogeneous land-use strata can be defined from LANDSAT image interpretation and water-balance models can be developed for reliable rainfall stations lying within these strata, it will be possible to define the start and end of growing seasons from predetermined NDVI threshhold values. Further long-term research will be needed to realize these objectives.

To date, NOAA imagery has been most readily available as preprocessed NDVI data, but there are strong possibilities for developing other types of analysis. Graetz and Gentle (1982), for example, showed that cover and greenness could be separately differentiated and determined on LANDSAT images of Australian rangelands; Lamprey (1984) used principal-components analysis of LANDSAT imagery to apply these techniques to determine seasonal vegetation-cover changes in the Masai Mara Game Reserve. These and other processing techniques remain to be explored.

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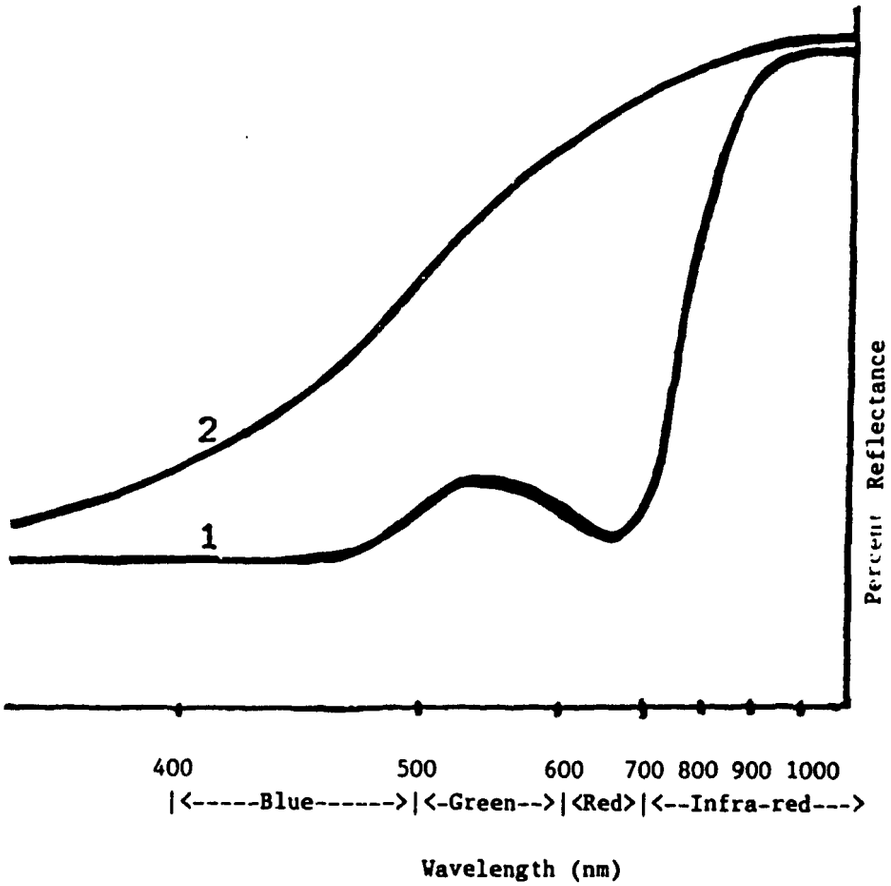

Figure 1. The spectral response of (1) healthy green vegetation and (2) dry or senescent vegetation. (Sources: Siegal and Goetz, 1977; Curran, 1980; Satterwhite, 1981.)

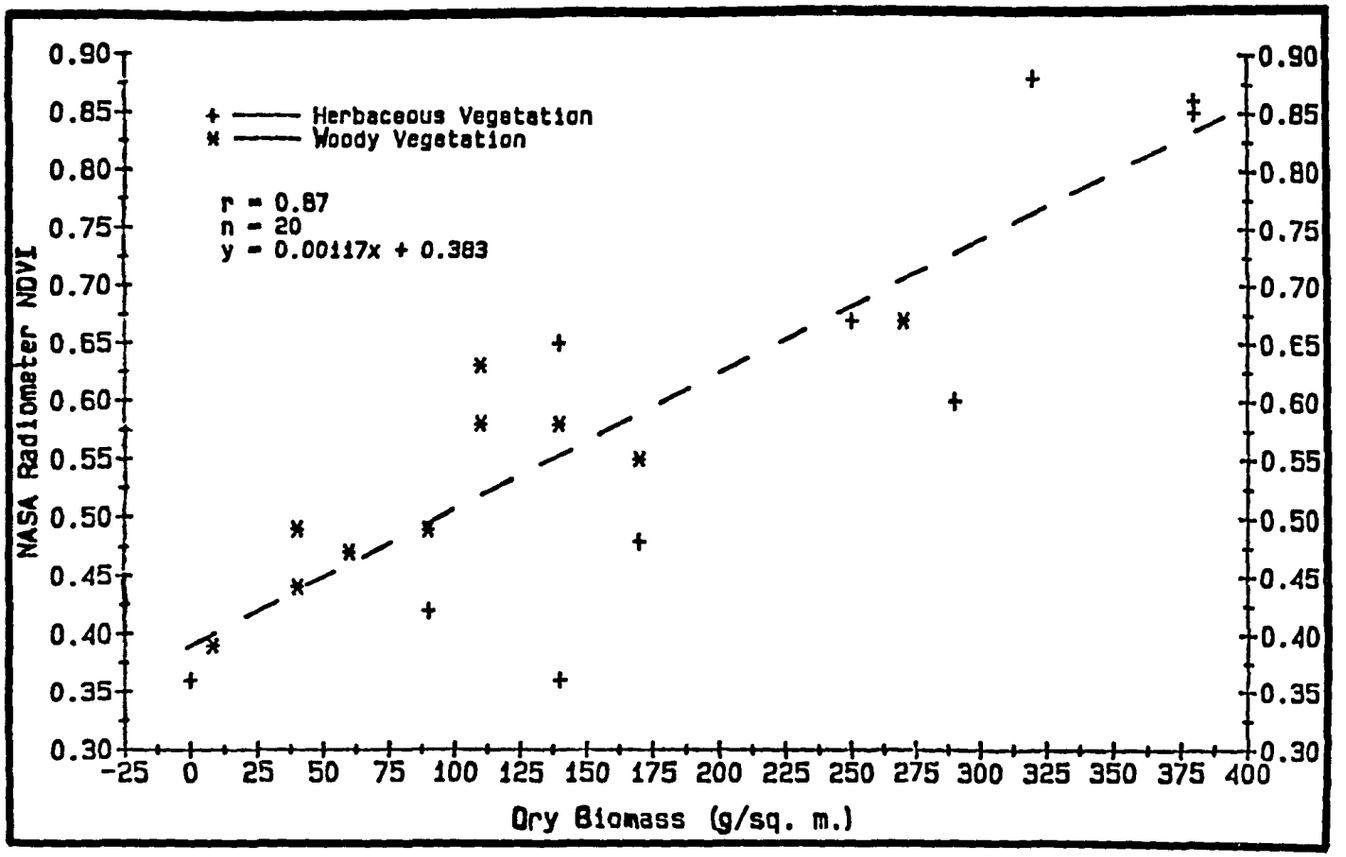

Figure 2. The relationship between NASA radiometer NDVI and biomass as recorded on the ground (herbaceous and woody vegetation).

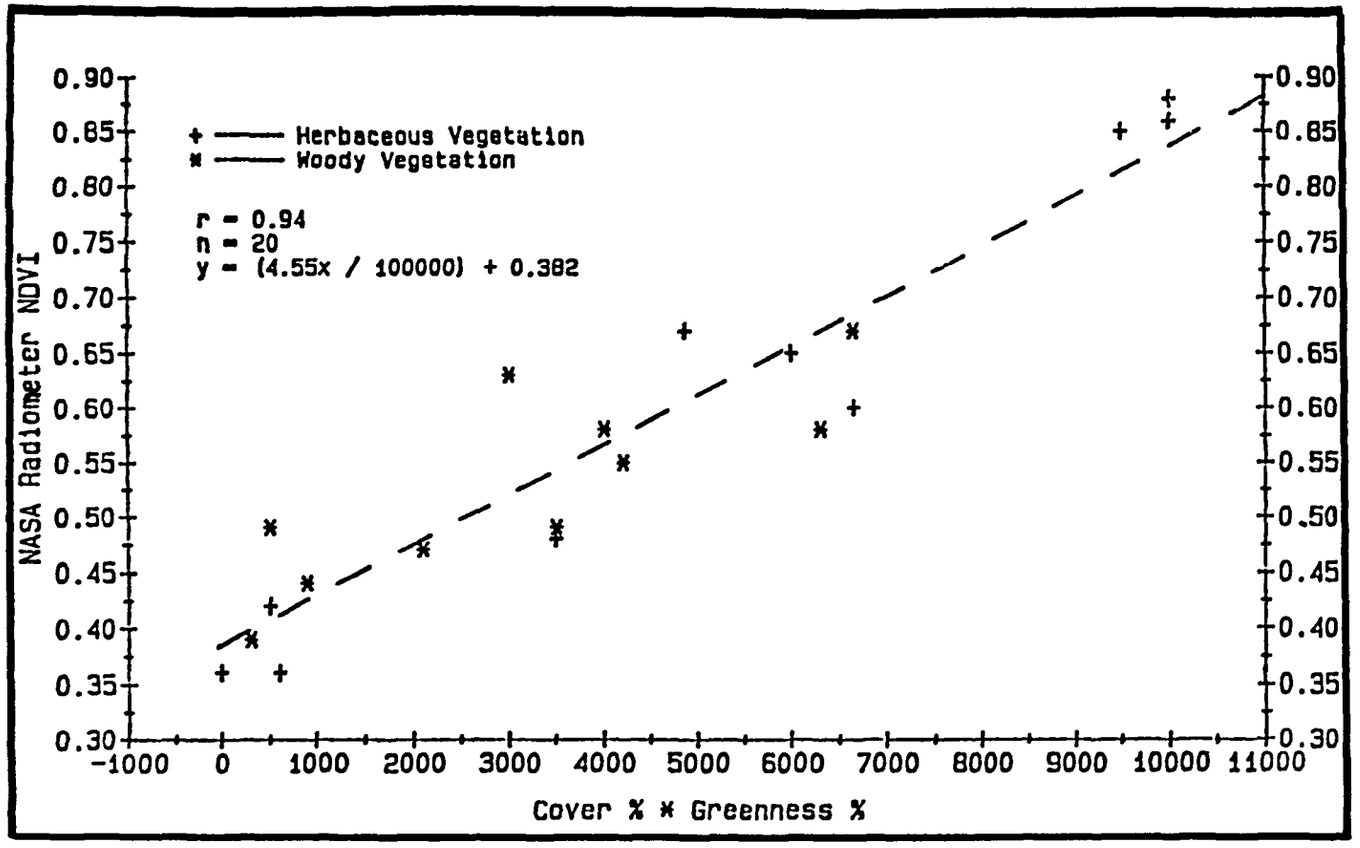

Figure 3. The relationship between NASA radiometer NDVI and cover % * greenness % as recorded on the ground (herbaceous and woody vegetation).

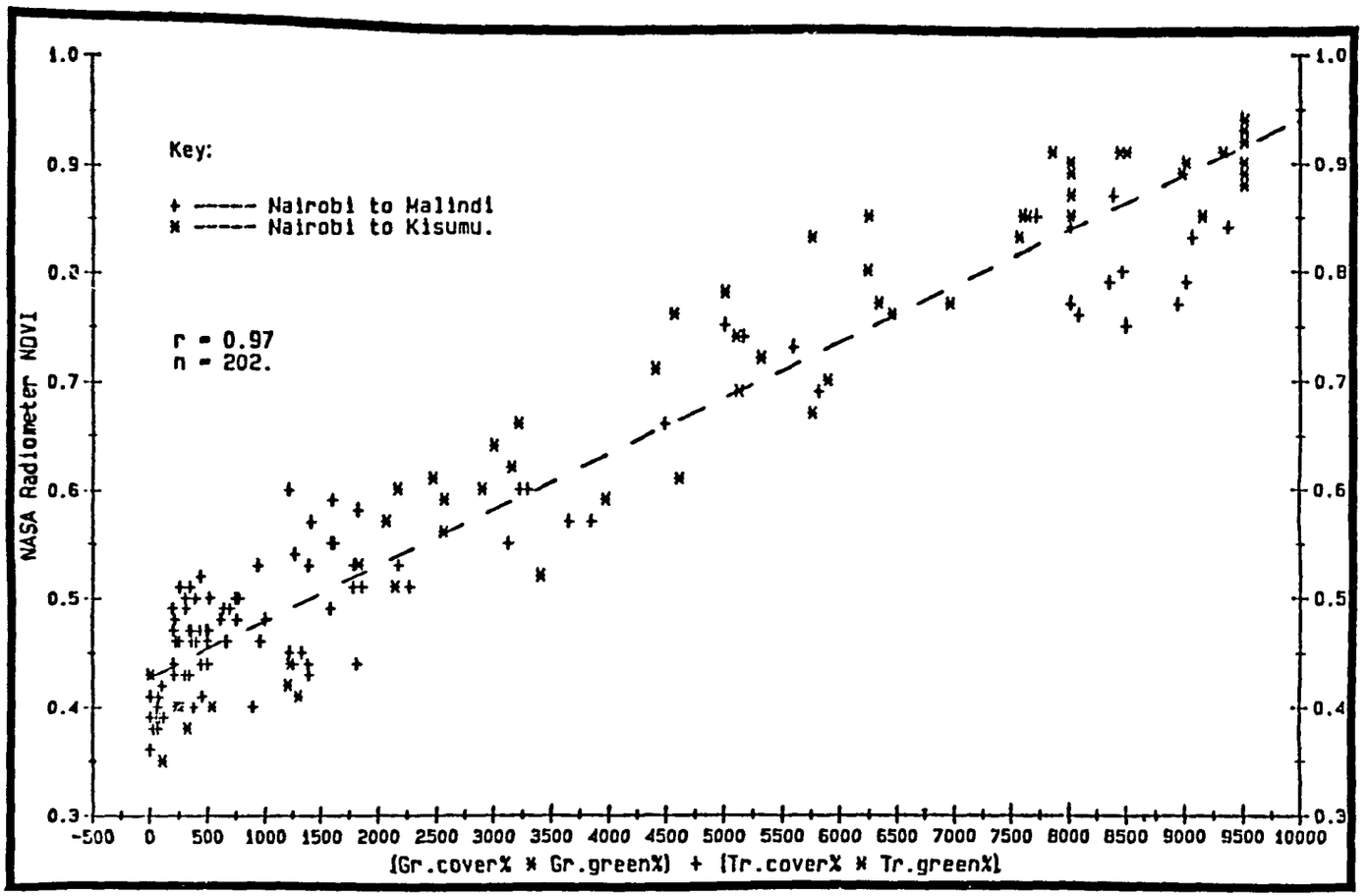

Figure 4. The relationship between NASA radiometer NDVI and the parameter (grass cover * grass greenness) + (tree cover * tree greenness) as determined from airphoto interpretation, Kisumu-Malindi transect.

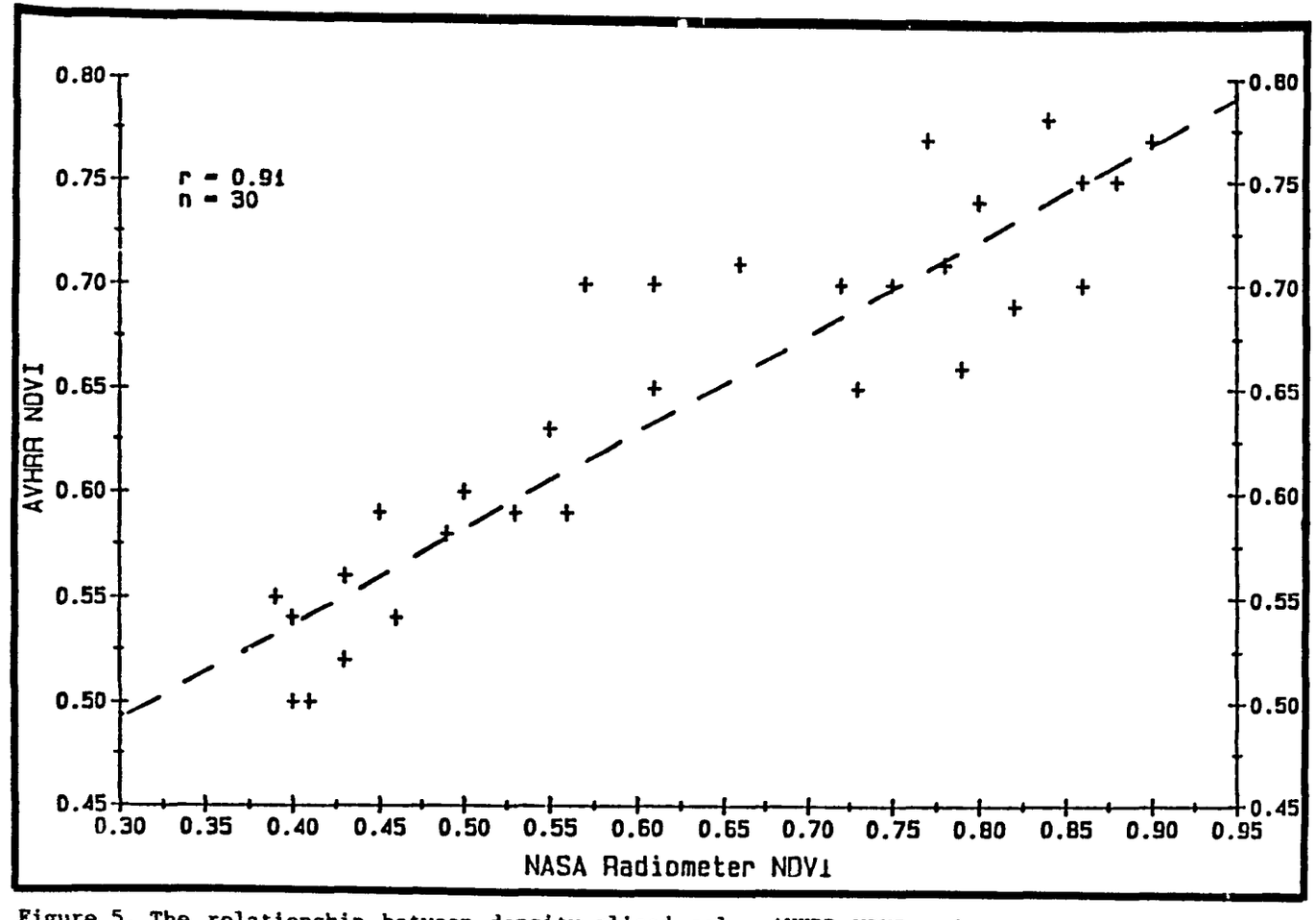

Figure 5. The relationship between density-sliced color AVHRR NDVI and NASA radiometer NDVI (averaged by 20-km segment) for Kisumu to Malindi transect, July 1-15, 1985.

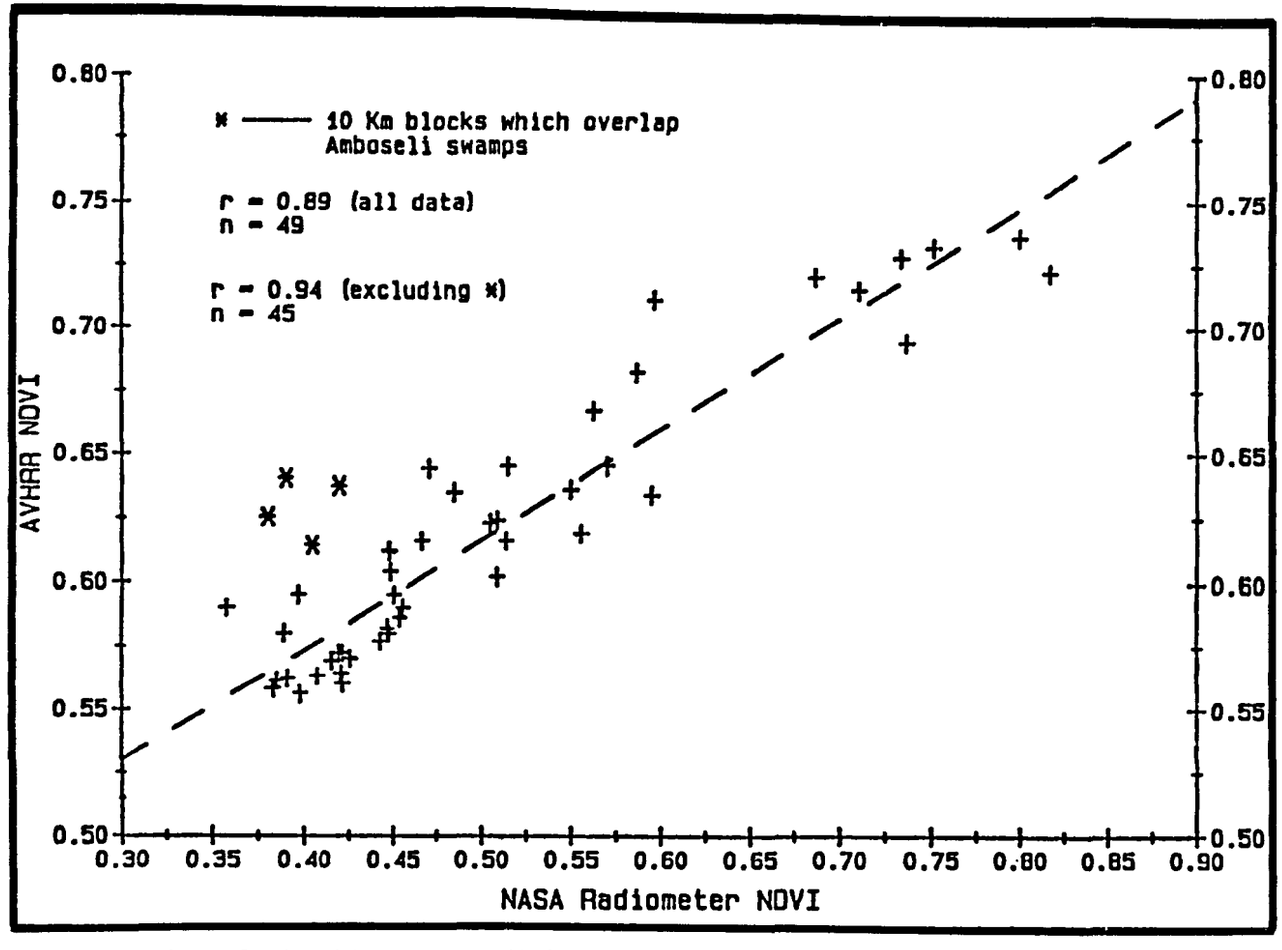

Figure 6. The relationship between digitized AVHRR NDVI and NASA radiometer NDVI (averaged by 10-km UTM grid cell) for Kajiado study area, July 1-15, 1985.

APPLICATION OF REMOTE SENSING TO RANGE-RESOURCES MANAGEMENT AND MONITORING

Luka Antonya Isavwa

ABSTRACT

The increasing need for better rangeland management requires more precise inventories of resource quantities and better information regarding location and condition. A knowledge of land use and land cover is important for many planning and management activities concerned with the surface of the earth.

Practical applications of remote sensing to natural resources have continued to play a significant role in many development-oriented programs. New remote-sensing programs are being made compatible with the needs of development, providing inputs for compilation of baseline data on the types, quantities, and locations of land resources. Such baseline data are needed to plan sustained and ecologically balanced economic development. Adoption of advanced remote-sensing technology and its application to resource mapping, inventory, and monitoring is essential to developing countries.

Monitoring plays an important role in effective natural-resource management. Regular inventories and assessments must be made of resources such as land-use patterns, hydrologic regimes, soil and water quality, vigor and health of vegetation, and status and effectiveness of range improvements and rehabilitation such as bush control and reseeding. Monitoring is essential at all levels of development: local, national, regional, and global.

The availability of LANDSAT data in image and computer-compatible-tape (CCT) formats enable the use of data analysis techniques that range from straightforward image interpretation to highly sophisticated digital processing.

INTRODUCTION

Rangeland is land that is unsuitable for cropping or intensive forestry and that is managed best for stock-raising purposes by manipulating natural vegetation (Perberdy, 1969). It includes areas from the Afro-Alpine moorland to drylands receiving average rainfall of less than 700 mm/yr. By this definition, two-thirds of Kenya can be classified as rangeland; however, variations in soil moisture and reliability of rainfall distribution make rangelands highly dynamic environments.

To date, the rangelands have not been surveyed and mapped. The use of panchromatic, medium-scale aerial photographs to map land use has been an accepted practice since the 1940s (Lillesand and Keifer, 1979). Most recently, small-scale aerial photographs and satellite images have been used to map land use and land cover of large areas such as rangelands.

Land Cover and Land Use

"Land cover" is the features on the surface of the earth; for example, lakes, trees, snow, urban buildings, and grasses. "Land use" is human activity associated with a specific piece of land. Land-cover information can be derived directly from appropriate remote-sensing

images. Additional information, supplementing land-cover data, is used to determine the use of the lands as game parks, water conservation areas, etc.

Remotely Sensed Data

"Remote sensing" is gathering information about an object and analyzing it without the gathering device coming in contact with the object. Remote sensing starts with our own eyes and progresses through the hand-held camera, balloons (as raised platforms), low-level aerial photography, high-altitude small-scale photography, and finally satellite imagery.

During aerial photography, the sun's reflected energy is sensed by photographic film that is later developed and printed before interpretation is undertaken. Satellite imagery is produced when the sun's reflected energy is detected by sensors placed on a sun-synchronous orbiting satellite. Only numerical data is recorded. It is later transmitted to a receiving station on the ground. In aerial photography, the airplane descends to earth so the film can be developed and printed; but the orbiting satellite does not return to earth.

Passive and Active Sensors

Passive sensors use the reflected energy of the sun's electromagnetic radiation. Most frequently used is the visible part of the electromagnetic spectrum, which includes wavelengths of 2.4 microns to 1.1 microns.

Active sensors produce their own energy, transmitting it to an object and receiving the returned energy. The strength of the returning signals determines the closeness of the object.

Both types of sensors are used in remote sensing. For example, LANDSAT systems use passive sensors, and radar uses active sensors.

Many platforms (including manned shuttles) carry different sensors. This paper discusses only LANDSAT systems and aerial photography.

RANGELAND SURVEYS

Rangelands must be managed effectively to preserve browsing and grazing areas, to guard against erosion, and to regulate mining, agricultural, and urban expansion. Gibson (1978) outlined some of the purposes for photographing vegetation and interpreting the photographs, the most important being to gather information about plant types, densities, deterioration, and changes.

The second purpose is to monitor land use to detect malpractices such as overgrazing and bush encroachment. Areas that exhibit stress from drought or flooding can be detected and protected. Recovery after fires can be monitored.

The third purpose is to map the rangelands. The capabilities of new and early rangelands can be inventoried. Rangeland surveys are essential in providing information for management. Early range maps were made from conventional black-and-white photographs and were not too useful for the study of vegetation. Since 1960, infrared photography and other remote-sensing techniques have become practical (Gibson, 1978).

Infrared renditions have the advantage of effectively showing the herbaceous and shrubby vegetation. They also are effective in delineating boundaries between grazing and non-grazing lands. For example, for the Tsavo East National Park and the Voi-MacKinnon road area, infrared photography clearly shows terrain features, plant densities, and vigor, phenological changes, and surface conditions of the rangeland.

Land-Use and Land-Cover Classification

Remotely sensed data has been used extensively by the United States Geological Survey (USGS) for land-use and land-cover classification. The criteria include:

- The minimum level of interpretation accuracy for remote-sensing data should be 85%.
- The accuracy of interpretation for the several categories should be about equal.
- Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
- The classification system should be applicable over extensive areas.
- The categorization should permit land use to be inferred from the land-cover types.
- The classification system should be suitable for use with remote-sensing data obtained at different times of the year.
- Categories should be divisible into more-detailed subcategories that can be obtained from large-scale imagery or ground surveys.
- Aggregation of categories must be possible.
- Comparisons with future land uses and land covers should be possible.
- Multiple uses of the land must be recognizable whenever possible.

Levels of classification have been developed from the general to the detailed. Level I is designed for use with small-scale imagery such as the LANDSAT images. Level II is designed to be used with small-scale area photographs. The most widely used image type for Level II mapping is high-altitude, color, infrared photography.

The minimum area that can be mapped as a land-use/land-cover class depends on the scale and resolution of the aerial photographs or satellite images. It also depends on the scale of data compilation and the final scale of the land-use/land-cover map. Rangeland is a Level I classification.

CHARACTERISTICS OF RANGELANDS

Rangeland is a highly dynamic environment. Examples of range characteristics that lend themselves to the applications of remote sensing include size, location, soils, drought, vegetation cover change, and water availability.

Extent of Rangelands

Rangelands characteristically occupy extensive areas. Until recently, conventional methods for surveying them have been tedious, slow, and costly. The synoptic coverage of LANDSAT data and radar systems continues to improve with new developments in technology. Each frame of data provides a synoptic coverage of 34.225 km^2 of ground area.

Location of Rangelands

Development of most rangelands has been neglected because of their economic productivity, and because they have few communication routes, making proper resource surveys impossible. Now, however, inaccessible areas can be imaged by LANDSAT for quick assessment of the natural resources.

Soils

Rangeland soils are varied and extensive. Some are characterized by impeded drainage, and others are overexposed, which makes them prone to soil erosion. Some soils are so dry that they cannot support normal agricultural use.

Drought Assessment

Remotely sensed data has been at the forefront in the assessment of Sahelian desert conditions. Assessment has been undertaken to quantify the rate at which desert conditions are spreading into existing bushlands and woodlands. Kenya's rangelands are becoming drier due to lack of rainfall. Drought conditions can be assessed from the repetitive imagery that is received every 18 days.

NOAA weather satellites are providing data for drought early warning and agricultural monitoring. Rangelands can benefit from these remote-sensing systems.

Change Detection

Remote sensing is one of the best techniques for detecting changes in an environment. LANDSAT data is repetitive over areas, and images can be compared to determine what changes have occurred. Conventional methods have revealed that range areas were in poor condition only after deterioration had progressed for a long time. Using LANDSAT data is likely to be more timely and cheaper.

Vegetation Cover

The most conspicuous element on the false-color composite is vegetation. Any changes of vegetation cover over the surface of the earth can be determined by comparison with previous imagery. A combination of black-and-white imagery with false-color composite yields up-to-date interpretation for assessment of vegetation cover. Vegetation is a primary indicator of the potential of rangelands.

Water Availability

Groundwater exploration in arid environments is very important. The survival of livestock and human beings depends heavily on the availability of water. Features that lead to the detection of groundwater

are readily depicted by remote-sensing data. Such features include alluvial fans, which are normally present at the bases of mountains. Drainage patterns point to the geological development and type of bedrock, which influence the availability of water (Taranik and Trautwein, 1976).

Usually, vegetation grows where underground water exists in dry environments. This phenomenon can be depicted readily by LANDSAT imagery. Being able to locate points for potential water exploration in the office lessens the time of search and the net costs.

RANGELAND MONITORING

Rangelands are characterized by diverse, dynamic environments -- they change throughout the year. Monitoring range resources would be one of the most appropriate techniques for assessing what would be available in the area of interest.

Rainfall in the rangelands is scarce and poorly distributed. Since the rangelands are extensive, a synoptic view of the area would show what is happening in different areas of the range. The repetitive advantage of remotely sensed data will greatly facilitate assessment of range conditions. Biomass availability in various locations can be calculated based on vegetative indexes that could be developed.

LANDSAT Interpretation

Remote sensing applications rely heavily on the sun's energy, in the visible and near-infrared wavelengths, reflected by the various features of the earth's surface. Different features reflect electromagnetic radiation differently. The sensors on board an orbiting satellite record the reflected energy according to the intensity of the signals received. Imagery, therefore, is a mixture of the signals from the surface features. An understanding of how the various signals are interpreted is very important.

Vegetation reflects all the near-infrared wavelengths, which are harmful to the plant cells. This energy is recorded strongly on infrared-reflection imagery (on black-and-white imagery, it is depicted as a light gray tone). On the other hand, vegetation absorbs the red portion of the electromagnetic radiation and, therefore, reflects nothing in this region (on black-and-white imagery, it is depicted as a dark gray tone). A combination of the two pictures would enhance the interpretation of the vegetation in the area. In addition, a false-color composite can be produced that highlights the vegetation in red rendition.

Water absorbs almost all of the energy that falls on its surface, reflecting very little information back into the atmosphere. On black-and-white imagery (and even a false-color composite), water is depicted in dark gray tones. However, if the water is not clean, the sediments reflect part of the energy, and imagery does not show dark gray tones.

Overused rangeland normally has less vegetative cover and more exposed soil or rock material. Sandy soils reflect all of the electromagnetic energy falling on them and are depected in light gray tones. Wet soil is depicted in dark gray tones. If the area is extensive, it is depicted on the synoptic view of the LANDSAT imagery. Such information can be used to assess the condition of the rangeland.

SUMMARY

Remote-sensing applications are steadily being accepted as timely and cost-effective techniques for obtaining information about the surface of the earth. Rangelands in Kenya are likely to benefit from these techniques since they are extensive and are accessible by them.

Remote-sensing techniques can be used to study range condition and deterioration, predict drought, detect change, and predict biomass. These phenomena can be assessed quickly and mapped for fast decision making and management of rangelands.

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IMPLICATIONS OF RANGE CONDITION AND TREND IN RESOURCE MANAGEMENT

J. C. Ng'Ethe

INTRODUCTION

Range condition and trend are perhaps the two most important concepts in the management of renewable natural resources in arid and semiarid lands.

In Kenya, rangelands occupy 582,000 km^2 (approximately 80% of the land mass) and support about one-third of the livestock population. This area constitutes one of the nation's valuable renewable resources.

Until recently, much of the grazing in this area has been seasonal, associated with exploitation of seasonal waters, salt licks, and responses of pastures to rains. Improper management of this resource has resulted in substantially reduced productivity in many areas. In light of the high and rapidly increasing population (estimated at 19 million and increasing by 4% annually), the need is urgent to manage this vast resource properly and maintain it at a highly productive and stable state so it can contribute to the national economy.

DEFINITION

"Range condition" is the state of the range's health (RISC, 1983). In a more complete sense, it includes the direct and indirect changes in vegetation composition, land productivity, and land stability over time under various regimes of livestock production. Range trend indicates the change in condition over time.

Purpose of Range-Condition Measurement

Proper management of renewable resources demands accurate assessment of the effects of management upon the resource. Measurement of these effects is the real reason for range-condition measurement (Hacker, 1973). Field data is collected and analyzed to quantify the way a given use is changing or has changed the resource. There are two basic approaches to range-condition rating for an ecological site (Hacker, 1973); one is ecologically based, and the other is productivity based. The former evaluates whether the long-term productive potential or ecological status of the site is being maintained; the latter measures condition in terms of the current productivity of the resource for a given use (RISC, 1983). Both methods depend on thorough knowledge of ecological-site classifications.

ECOLOGICAL SITE

Land surfaces, including arid lands, are characterized by high variability in various important attributes such as topography, vegetation, soils, and climates. Similar areas in similar conditions will respond in same way to the same management strategies. To accommodate both of these considerations, condition assessment demands identification or breakdown of the extensive, highly variable landscape into smaller, less-variable land units. These distinct land units, which have similar topography, vegetation, soils, and climate that form recognizable areas within the overall landscape, have been called "rangeland types" (Stoddart, Smith, and Box, 1975), "land systems" (Christian, 1958), and

"ecological sites" (RISC, 1983). Hereafter, such units will be referred to as ecological sites. More specifically, an ecological site is a kind of land with a specific potential natural community and specific physical-site characteristics differing form other kinds of land in its ability to produce a certain vegetation mixture and respond to management in a certain way. Ecological sites are recognized on the basis of production and on the kinds of proportions of plant species constituting the core of the plant community. The Range Inventory Standardization Committee identified three criteria for differentiating ecological sites:

- significant differences in the kinds (composition) and proportions of species groups that are in the plant community

- significant differences in the production of the plant community due to significant differences in soil properties, climate, and topographic position

- significant differences in soil properties, slope, and topographic position, reflecting different use potentials and hazards that are not reflected in plant community

The potential natural plant community is the assumed end product of the progressive natural succession for that site in the absence of disturbances and physical-site deterioration (RISC, 1983). The resulting vegetation assemblage is best adapted to a unique combination of environmental factors and is in dynamic equilibrium with the environment. Natural disturbances such as drought, wildfires, grazing by native fauna, and insects are an important component in the development of the natural plant community. They should always be expected. Communities that are protected from these natural influences for long periods do not typify the potential natural vegetation.

The potential natural community of a site is dominated by one or a few species. The species are constant from place to place and from year to year. These species, which have high fidelity in the community, are used to identify and differentiate one ecological site from another. In most communities, associated species fluctuate greatly from place to place.

Determination of the potential plant community of an ecological site is not easy. RISC (1983) has stipulated five methods for determining potential natural community in an ecological site:

- Evaluation of relict vegetation and associated soils on areas that have been subjected to minimal disturbances. Both production and the species-composition of the plant community should be evaluated.

- Interpolation and extrapolation of plant, soil, and climatic data from existing relict areas along a continuum to other points on that continuum for which no suitable relict is available.

- Evaluation and comparison of areas currently grazed or disturbed in varying degrees, and comparison of such areas with similar areas that are not disturbed.

- Evaluation and interpretation of research data dealing with ecology, management, and soils of plant communities.

- Review of early historical accounts and botanical literature of the area, where possible. It is assumed that, in most cases, the potential natural vegetation will reestablish following detrimental moderate influences that modify or destroy vegetation. In other words, potential natural community in a site is permanent unless detrimental influences are too severe. The overall cumulative effects of drought, various harvesting systems, and cultivation reduce the chances of successful reestablishment of the original vegetation and also reduce the productive capacity of the site. Extreme deterioration alters the site's potential permanently.

ECOLOGICALLY BASED METHOD

The basic principle in the ecologically based method is that the difference between the current productivity level of a given ecological site and its potential under a given climatic regime can be determined and employed to express (Smith, 1979)

- the extent the resource has been changed by management; that is, the effectiveness of the management

- the extent to which aggregate potential has been reduced; that is, the potential for improvement

Repeated comparisons to the benchmark over time allow detection of trend and ultimately indicate the suitability of the present management. By defining condition as departures from restive state, the measurements become use-independent (RISC, 1983). They represent the present state of vegetation and soil protection of a site in relation to the potential of natural community for the site. The method embraces the concept of successional stage of the vegetation and the stability of the soil.

The stage of succession expresses the relative degree to which kinds, proportions, and amounts of plants in the community resemble those of the potential natural community. The benchmark is the mirror against which the effects of all types of land uses and management systems are compared. The benchmark vegetation has evolved under various climatic fluctuations; consequently, effects of the past history of the benchmark are indirectly incorporated in the method.

The soil-stability measurement is viewed as the relative amount of protective cover furnished by vegetation and litter compared to the level of protection that would be provided by the potential natural community for the site. Potential natural community recognizes past influence by people, including past use history of the site.

PRODUCTIVITY-BASED METHOD

The productivity-based method measures range condition in terms of the current productivity level of the resource for a defined land use (Hacker, 1973). Every use of the site has a different condition rating. A site in excellent condition for cattle production is producing forage for cattle near its potential; but it might be in fair condition in terms of producing forage for goats, camels, or wildlife. The main objective of management based on this system is to maintain and improve the suitability of the ecological site for the given use (Hacker, 1973). The major problem associated with this type of management is that it precludes other uses in the present or the future, and current use of the resource may be inappropriate within the overall ecological setting.

In this method, absolute measure of plant species is required -- cover, density, weight, or frequency -- and must be related to use; for example, vegetation composition is assessed in terms of relative abundance of desirable and undesirable species for the current land use (Hacker, 1973). This implies that the method denies the importance of preserving the potential of land for other uses. This method provides an index of acceptability for a particular purpose. The greatest advantage of this method is that it is easy to use.

In reference to forage resources, productivity and stability of the range site are very important. Stability should be viewed in terms of stable soils and stable vegetation community. Proper management must halt deleterious effects on forage production and enhance recovery of degraded lands. Some ranges naturally regenerate under rest periods, supporting the view that grazing is largely responsible for the degradation (Ayyad and El-Kadi, 1982).

Stable, unproductive landscapes result from poor management in the past, while unstable productive landscapes are currently poorly managed (Hacker, 1973). The concept of stability should not be limited to the vegetation alone but should include the entire landscape. Vegetation should be viewed within the framework of fluctuating forage supplies due to short periods of moisture supplies in relation to the effect of inadequate moisture on plant vigor (Ogden, 1973). If management is right, high sustained yield is possible. The sustained-yield concept implies that potential site productivity cannot be impaired by proper management actions.

TREND

"Trend" is the directional change in kind, proportion, and amount of plant species in an area or in some characteristic of the soil (RISC, 1983). Trend may be interpreted either in ecological context or in terms of resource value for various uses. The vigor and reproductive success of the plant species that characterize current seral stage are compared to those of an earlier seral stage for the site. For management purposes, trend implies the change in utility of the vegetation for a specific use. The important question is whether the ensuing changes in vegetation and soil condition are desirable or not for the use in question. Trend assessment includes examination of changes in lifeforms of dominant species and gross changes in cover and density of various species. Early detection of trend is very difficult since vegetation attributes fluctuate widely within and between years as dictated by climate.

DESERTIFICATION AND RANGE-CONDITION CLASSES AND TRENDS

The traditional five or six range-condition classes (from excellent to very poor) are descriptive and coincide with various degrees of desertification (Dregne, 1983). Desertification of rangelands includes the following stages:

- Quantity, quality, and persistence of native vegetation (commonly associated with reduced cover) deteriorate. Bush encroachment may be an associated factor, largely due to overgrazing.

- In areas with dense human population, gathering fuelwood and clearing and burning for agriculture lead to structural changes in vegetation cover seen in loss of trees and shrubs.

- Significant changes in soil-surface condition occur, particularly compaction through livestock trampling.

- Erosion by wind or water removes the topsoil and, therefore, most seeds. Ultimately, hard pans develop that resist vegetation.

The exact pattern followed in desertification depends on the initial vegetation composition, climatic region, inherent soils, and intensity of use. However, Dregne (1983) equated slight desertification with excellent to good range condition, moderate desertification with fair range condition, and severe desertification with poor range condition. Very severe desertification was equated with land completely denuded of vegetative cover. The process of desertification in rangelands is similar, following a downward trend in range condition.

CONCLUSIONS

Resources should be always managed for multiple uses. Consequently, the need is urgent to develop a single, defensible technique for measuring range condition and trend. Possibly the revitalized East African Society of Range Management should take leadership in developing such a technique. The system to be developed should not only measure forage for livestock but also should estimate the capability of land to sustain multiple uses. Measuring ecological potential of the land and animal counterparts and relating them to both plant and soil resources would be suitable for determining resource capability. The system adopted for condition assessment must be sensitive and repeatable (Hacker, 1973). In addition, a single system should be applicable to a variety of range sites and uses. It should be used rapidly in the field, easily understood, and able to accommodate seasonal and annual fluctuations. In other words, it should be flexible enough to accommodate new information that may be developed (Hacker, 1973).

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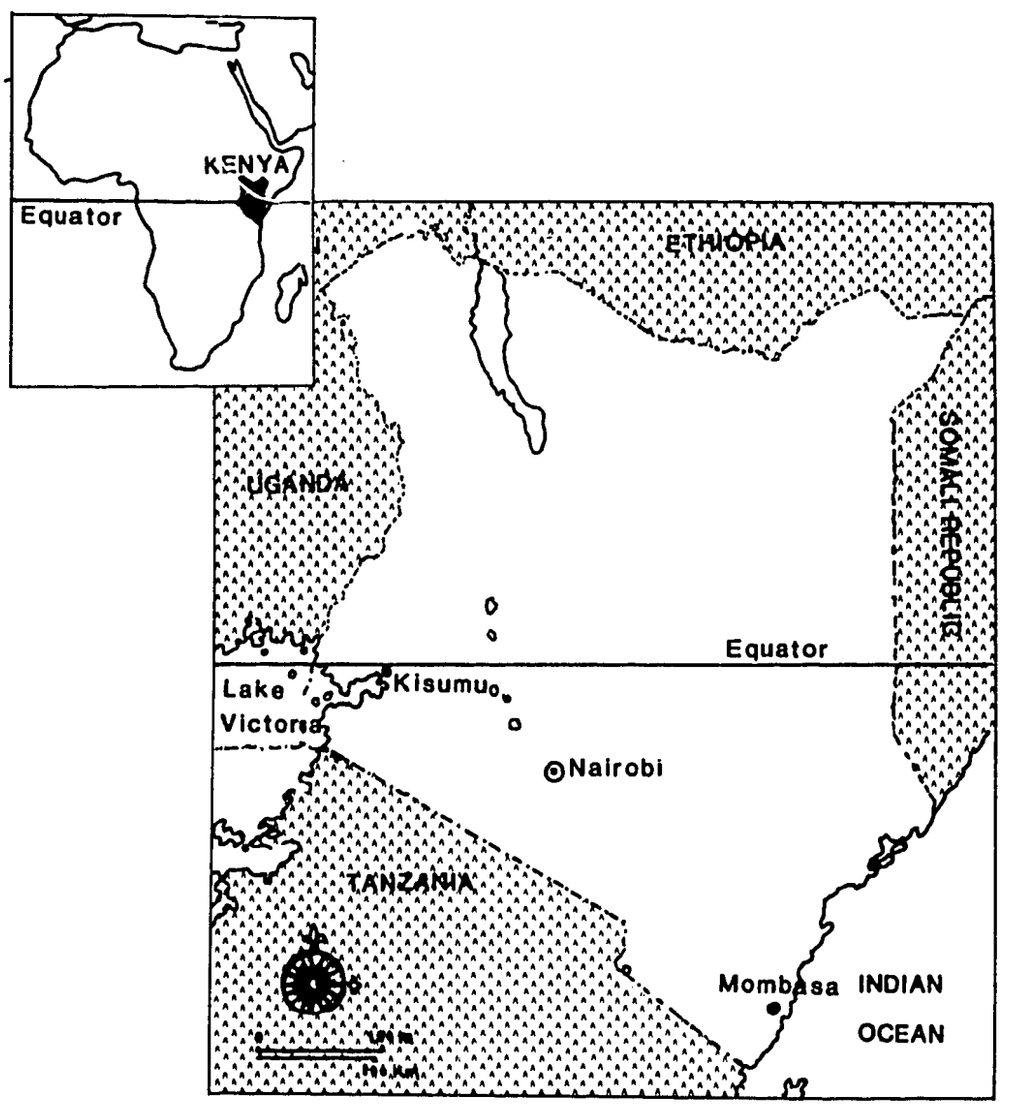
KENYA

Enjoo iyook engeraa.
Give us children.

Injoo iyook ingishu.
Give us cattle.

Iye akekisilig.
Our hope is with you always.

Masai prayer