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KENYA AGRICULTURAL RESEARCH STRATEGY AND PLAN

Volume 2: Priorities and programs

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International Service for National Agricultural Research

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LIST OF ACRONYMS

ADC	Agricultural Development Corporation
AERLC	Agricultural Extension/Research Liaison and Communication
AI	Artificial Insemination
AIC	Agricultural Information Center
ARD	Agricultural Research Department of KARI
BAT	British American Tobacco Company
CAIS	Central Artificial Insemination Center
CARS	Coastal Agricultural Research Station, Mtwapa
CBPP	Contagious Bovine Pleuropneumonia
CCPP	Contagious Caprine Pleuropneumonia
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CRF	Coffee Research Foundation
CRSP	Small Ruminant Collaborative Research Support Program
DAO	District Agricultural Officer
DEO	Divisional Extension Officer
DM	Dry Matter (referring to plant material)
DVS	Director of Veterinary Services
EATRO	East African Trypanosomiasis Research Organization
EAVRO	East African Veterinary Research Organization
ECF	East Coast Fever
FAO/UNDP	Food and Agriculture Organization/United Nations Development Programme
FTC	Farmers Training Center
FYM	Farm Yard Manure
GDP	Gross Domestic Product
GOK	Government of Kenya
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (German Technical Assistance)
HCDA	Horticultural Crops Development Authority
IARC	International Agricultural Research Center
IBAR	Inter-African Bureau for Animal Resources
ICIPE	International Centre of Insect Physiology and Ecology
IDS	Institute of Development Studies, University of Nairobi
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
IPAL	Integrated Project for Arid Lands (UNESCO)
IPM	Integrated Pest Management
KARI	Kenya Agricultural Research Institute
KCC	Kenya Co-operative Creameries
KETRI	Kenya Trypanosomiasis Research Institute
KFA	Kenya Farmers Association
KREMU	Kenya Rangeland Ecological Monitoring Unit

LSU	Livestock Unit
MLD	Ministry of Livestock Development
MOA	Ministry of Agriculture
MOALD	Ministry of Agriculture and Livestock Development
NABC	National Animal Breeding Council
NAHRS	National Animal Husbandry Research Station
NARC	National Agricultural Research Center
NDDP	National Dairy Development Program
NHETP	National Horticultural Extension Training Program
NHRS	National Horticultural Research Station
NIDRC	National Irrigation and Drainage Research Center
NORAD	Norwegian Agency for Development
NRC	National Research Center
NRRS	National Rangeland Research Station
NSWMRC	National Soil Water Management Research Center
OAU	Organisation of African Unity
ODA	Overseas Development Administration of the U.K.
PAD	Provincial Agricultural Director
PAREAC	Provincial Agricultural Research and Extension Advisory Committee
PDA	Provincial Director of Agriculture
PDVS	Provincial Director of Veterinary Services
RRC	Regional Research Center
RTDU	Rural Technology Development Unit
SMS	Subject Matter Specialist
SRD	Scientific Research Division
TA	Technical Assistant
TLU	Tropical Livestock Unit
TRF	Tea Research Foundation
T&V	Training and Visit Extension Model
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USAID	United States Agency for International Development
VIL	Veterinary Investigation Laboratory
VRD	Veterinary Research Department (of KARI)
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.0 It is widely accepted that no agricultural research system in any country, however well funded and organized, can attempt to solve all the problems affecting agricultural production; certainly not in a developing country such as Kenya, where there is a mosaic of different agro-ecological zones, a limited area of high- and medium-potential land, rapid degradation of resources in the semi-arid and arid areas, a changing agricultural tenure situation, and a very rapidly increasing population. Under these circumstances, priorities for agricultural research must be established and available resources allocated to the solution of those problems that will contribute most to the overall development objectives of the nation.

A strategy for development during the next four years has been published by the Government of Kenya (GOK) - the Fifth Development Plan (1984 - 88). Specific objectives include: the improvement of food production; promotion of employment in agriculture; expansion of agricultural exports; conservation of resources; and the alleviation of poverty. The most urgent short-term objectives are an expansion in food production and employment and the alleviation of poverty, but of major importance in the long term is the conservation of resources. Unless increased production and conservation of resources can be achieved at the same time, the future will be sacrificed for immediate present gains - a short-sighted and disastrous policy. Agricultural exports are also of major importance to the economy, but cannot be produced at the expense of food supplies for a rapidly increasing population or of the conservation of resources. Thus, in choosing priorities for agricultural research, there must inevitably be an element of compromise.

Not only is it essential that agricultural research priorities should be established, but within the research organization the methods by which these can be established and the programs implemented merit attention, as do the methods by which research results can be translated into farm practice. In the past, when the research service was primarily concerned with seeking solutions for the problems of large scale and relatively well-educated farmers, socioeconomic research was neglected and the extension service was somewhat limited in scope. Changes in land tenure, with smallholdings replacing large farms in high-potential areas, and a very rapidly increasing farm population in the medium and semi-arid areas have produced a situation in which socioeconomic research, particularly the study of crop and livestock production systems, must be accorded higher priority and where the introduction of improved research/extension linkages are essential (Chapters 8 and 10). In addition, the growth of agribusiness, particularly for the production and marketing of food and export crops, requires a reappraisal of the relationship between GOK and private agricultural research organizations (Chapter 9).

1.1 Conservation of Resources

Kenya is a land of climatic and topographical contrasts: tropical beaches at the coast and snow on the highest peaks; well-watered temperate conditions in the central highlands and dry, near-desert conditions in the north and northeastern pastoral regions. As a consequence, a very wide range of temperate and tropical crops can be grown, many different types of domestic livestock can be husbanded, and there is a wealth of wildlife. Land and water resources are, however, very limited. Almost three-quarters of the country consists of semi-arid and arid lands, the major part of which is occupied by pastoralists. Of that area of land considered suitable for crop agriculture, only 16 percent is located in high-potential areas and 29 percent in transitional zones, while more than half is in the semi-arid and arid regions. The latter suffer from varying degrees of severe moisture stress that limit crop and animal choice and production. Even the transitional zones suffer a considerable degree of moisture stress due to high evaporative water losses. In addition, surface water resources are limited, there being few major rivers in Kenya. This restricts irrigation possibilities, estimates of which are provided in Chapter 2.

Measures to stop present degradation and to ensure future conservation of soil and water resources must be taken. Unfortunately, there has been little research in Kenya on soil and water management, on the operation of livestock systems in the pastoral regions, and on farming systems in the dryland farming areas. Without an adequate knowledge of soil and water management and how the pastoral livestock and dryland farming systems operate, it is very difficult for the GOK to formulate and establish a rational conservation policy. Thus, some of the most important overall research priorities are:

- the establishment of a National Soil/Water Management Research Center at Katumani (discussed in detail in Chapter 2);

- investigation of existing farming systems in the dryland farming areas and elsewhere (discussed in Chapter 8);

- investigation of livestock systems in the pastoral regions (discussed in Chapter 6);

- generation and application of improved technologies for increased crop and livestock production in the major zones of agricultural production.

It is not only essential to prevent loss of topsoil by introducing adequate soil conservation and other measures, but it is equally important to prevent a decline in soil fertility. This can be achieved by the proper use of legumes in crop rotations and in pastures and by the efficient use of fertilizers, both chemical and organic. The GOK has stated that irrigation development will receive priority, but because water resources in Kenya are limited, it is essential that investigations should be conducted on the most efficient use of the water that is available.

Thus in the field of conservation of resources the Mission have proposed (Chapter 2) that there are two other important priorities. These are:

- the establishment of a coordinated agronomic experiment project that will generate recommendations as to the most efficient use of soil, crop varieties, and fertilizers on a national basis;

- the establishment of a National Irrigation and Drainage Research Center at Ahero, with a subcenter at Garissa.

1.2 Crop and Livestock Research

The overall priorities in crop (including horticultural crops) and livestock research are provided in Chapter 2, Volume 1, and more detailed information is provided in Chapters 3, 4, 5, 6, and 7 of this volume.

Research into the provision of better-adapted high-yielding crop varieties is essential for most commodities. Likewise, higher-producing but adapted livestock (particularly dairy cattle) are required, especially in the warmer and drier agro-ecological zones, and the most suitable methods of integrating crop and livestock production in all agro-ecological zones must be further investigated, particularly on smallholdings. In addition, there are some special problems of crop and livestock production to which greater research priority should be allocated.

Maize and wheat are the most important cereal crops, and intensified research on these crops is justified. Although wheat production can be expanded, particularly on smallholdings, the crop can only be grown in high-potential areas, while maize is not too well adapted to dryland farming conditions. Sorghum and millet are better adapted to these conditions, but for a number of reasons they are not generally favored by the farming population. A high priority in crop production research is to develop higher-yielding varieties of these crops that are less susceptible to pests and diseases than presently available varieties and that are generally acceptable as palatable foods by the people.

Pulse crops are important, not only because they are valuable protein foods, supplying essential amino acids that are deficient in the staple food - maize, but also because they are legumes that improve soil fertility by biologically fixing atmospheric nitrogen. Research on these crops must therefore also be accorded a high priority.

As Kenya imports large quantities of edible oils, even though oil-producing crops could be grown in the country, priority must also be accorded to research on these crops as part of an endeavor to increase their production and thus reduce foreign exchange outflows (Chapter 3).

Proposals are made in Chapter 5 for the reorganization and expansion of horticultural research based on further development of the National Horticultural Research Center at Thika, not only because there is a possibility of expanding the export of horticultural crops, mainly through the activities of large-scale agribusiness companies, but also

because for nutritional reasons an expansion is required in the consumption of 'protective foods' by the people. Priority must therefore also be accorded to horticultural research. Aspects of the research activities of agribusiness companies in this context are detailed in Chapter 9.

Apart from the horticultural, plantation, ranching, and pastoral livestock sectors in Kenyan agriculture, crop and livestock production are generally integrated at the farm level. Unfortunately, however, crop research has never been fully integrated with livestock research. Furthermore, within livestock research there has been in the past an imbalance between production and disease-orientated research (Chapter 6). The reasons for this imbalance are partly historical; disease was the major constraint on animal production in the past but is not necessarily so today.

The results of this lack of integration of crop and livestock production research and the imbalance within livestock research has meant that the research needs of smallholders have been to some extent neglected, as have many important aspects of the breeding, nutrition, and management of livestock. In particular, the present requirements of smallholders, particularly those in the dryland farming areas, for productive and well-adapted livestock have not been met, and priority must be accorded to the establishment of a national livestock breeding program (Chapter 6). Priority is also required for some aspects of animal nutrition research, especially the nutritive requirements of grade dairy cattle and the possible use of all available roughage and concentrate by-produce resources for the feeding of ruminant livestock (Chapter 6).

Priorities for veterinary research must obviously change with changing farming systems and control or partial control of major epidemic diseases. In future, as discussed in Chapter 7, in deciding veterinary research priorities, more emphasis must be placed on the results of surveys in which existing disease and parasite constraints on production in the different livestock systems are identified. Overall priorities in veterinary research are detailed in Chapter 7.

Integration of all research into one service, which is semi-autonomous in its functioning as proposed by the Mission, should assist in the solution of many of the problems presently confronting mixed farming, redress the present imbalance in livestock production research, and generally improve the organization and management of agricultural research for increased productivity and greater economic welfare in Kenya.

CHAPTER 2: SOIL AND WATER MANAGEMENT

2.0 The objective of any research program is not only to "reverse the declining trend" in agricultural production but to continuously improve the production base of all natural resources which are basic to agriculture. In view of the fact that agriculture in the past was restricted to potential areas of assured rainfall and on soils generally free of physical, chemical, and microbiological constraints to agricultural production, emphasis in research was on crop improvement and crop protection, and only service roles were assigned to scientists in associated disciplines, including soil science. As agricultural research was restricted to a few commodities and agriculture practised on a limited number of large farms, it was possible to service them from a single centrally located research laboratory in soil science and agricultural chemistry. However, during the last two decades, on account of a growing population, crop production has been gradually moving into areas where there are increasing ecological constraints, and large farms are being replaced by smallholdings. In this changing pattern of Kenyan agriculture it will not be possible to sustain the future population if immediate attention is not paid to efficient use of limited soil and water resources of the country. The growing complexity and magnitude of emerging problems demand an immediate reorganization of research in soil and water sciences.

2.1 Proposed Reorganization of Research in Soil and Water Sciences

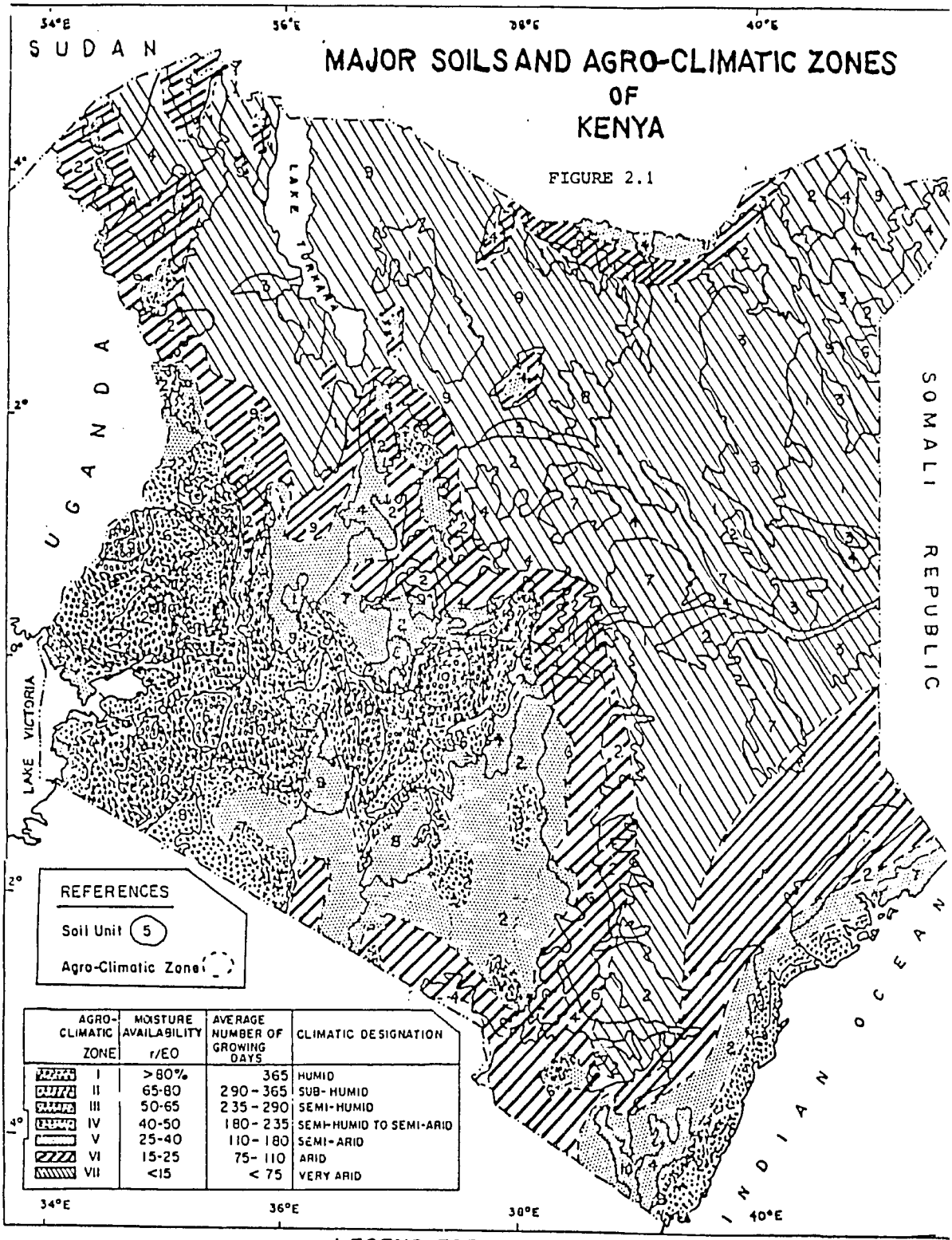
The research programs and priorities in soil science can be grouped in the following categories:

* inventory and cataloging of soil resources
* supporting research to production agriculture
* applied research for developing and updating economically viable technologies for solving emerging soil problems
* basic and fundamental research in soil science

2.1.1 Inventory: cataloging and classification of soils

Information on potentials and limitations of well-defined soil units is essential for the planning of land use and agricultural development. Kenyan Soil Survey, in collaboration with the International Soil Museum, has completed an exploratory soil survey covering the whole country (58 mha) on a scale of 1:500,000. The exploratory soil map on a 1:1,000,000 scale, published during 1982, shows in a general manner the distribution of 392 soil types and forms a good basis for broad regional planning.

An effort has been made to combine various categories of the most important taxonomic units with extensive area coverage. These are; Acrisols (Ultisols), Arenosols (Psamments), Cambisols (Inceptisols), Ferralsols (Oxisols), Luvisols (Alfisols), Nitisols (Ultisols/Alfisols), Planosols (Ustalfs), Solonchaks (Orthids), Solonetz (Natrustalfs), and Vertisols. The other important taxonomic units are Fluvisols (Fluvents), Gleysols (Aquents), Pheaozems (Mollisols) and Xerosols (Aridisols), Regosols and Audosols (Figure 2.1).



LEGEND FOR SOILS

1. Solonchak and Solonetz (Saline & Alkalina Soils)
2. Acrisols and Luvisols.
3. Arenosols. (Sandy Soils)
4. Cambisols, Fluvisols & Gleysols.
5. Nitisols.
6. Ferralsols.
7. Planosols & Phaeozems.
8. Vertisols (Black Soils)
9. Regosols and Xerosols.
10. Andosols, Histosols & Greyzems.

The work on systematic reconnaissance, semi-detailed and detailed soil surveys is in progress, and so far has covered 10.7 million ha, 0.2 million ha and 4000 ha respectively. Work on land evaluation has been initiated, but it has to be strengthened by the development of land evaluation methodologies most appropriate for use under different farming systems. The next logical step is research on land-use planning. These programs will demand not only the establishment of the present infrastructure on a permanent basis but also the strengthening of professional competence in areas such as soil correlation, land evaluation, land-use planning, and the use of remote sensing equipment. This can be achieved through the establishment of a Kenya Soil Survey and Land-Use Planning Unit at the National Agricultural Laboratories (NAL), Nairobi.

2.1.1.1 Kenya soil survey and land-use planning unit

Objectives

a) Conduct standard soil surveys using different scale base maps, and preparation of interpretive maps from lowest administrative units to the country level.

b) Conduct high-intensity soil surveys in selected areas, including research station farms, University farms, dryland farming centers, etc. to suggest experiments for refining interpretation.

c) Conduct correlations to delineate important soils of the country at different category levels of soil classification and provide suitable legend for different types of soil survey to maintain uniformity and technical excellence.

d) Prepare land resource maps at different scales.

e) Develop rationale for modification and adoption of soil classification systems in the country.

f) Organize soil and agro-climate-based problem-oriented research projects to meet regional needs.

g) Identify benchmark soils for pedological studies for better understanding of soil genesis to develop definitions and criteria for characterization and classification.

h) Use remote sensing techniques and other remote sensing data in soil surveys and interpretation.

i) Establish soil libraries, data banks, soil museum, and documentation center for research and extension.

j) Conduct need-based training in soil survey methods, classification, and interpretation for soil survey personnel.

k) Promote the use of soil maps for land-use planning by various user agencies by training extension staff, field/research officers, etc.

l) Coordinate and supervise soil surveys conducted by different agencies for uniformity and nomenclature, through correlation.

Organization

In order to take care of future research needs, the Soil Survey Unit should be organized into five sections. The important activities of each of these sections are outlined below:

a) Soil survey, mapping, classification, and correlation. To prepare soil maps of the country on different scales by conducting standard soil surveys, such as reconnaissance surveys on 1:50,000 scale, with soil series associations as mapping units and detailed soil surveys on 1:10,000 and larger scales with phases of soil series as mapping units.

The survey may be conducted by Technical Officers whose work may be coordinated and correlated by experienced Soil Survey Officers. The supervisory officers will also be responsible for collection of the data from other sections and laboratories required for report writing and finalization of maps.

This section should also undertake research programs in the following areas:

i) identification of benchmark soils, their characterization and classification, with the objective of providing soil data base for edaphological research, results from which will be helpful in refining the interpretation of the soils mapped in respect to soil-crop responses and yield predictions;

ii) testing the existing classification system and evaluating criteria for any required modifications for mapping the soils based on tested interpretations and soil correlation procedures. This will help in developing utility soil maps.

b) Pedology. To provide laboratory support for comprehensive understanding of soil genesis and development in relation to influence of dominant soil-forming factors and processes on benchmark soils identified in different geomorphic units.

Emphasis may be on the identification and quantification of clay minerals and their effects on nutrient adsorption. Primary mineral analysis and micro-morphological studies may also be undertaken to understand the nutrient reserve and supply capacity and to support pedological investigations. This will eventually help in soil fertility improvement programs.

c) Land evaluation and land-use planning. To provide scientific land-use plans of economic viability by interpreting the soil, vegetation, land-use and other thematic maps for various user agencies and do research on crop yield prediction in different benchmark soils.

Land evaluation and land-use planning will consist of interpreting the soil survey information for land suitability classification, land irrigability classification, hydrological groupings, vegetative groupings, existing land use and suggested land use consistent with ecology and economy and preparation of the thematic maps for incorporation into the report.

In addition, soil data may be interpreted for rural and urban land uses. Research may be conducted for prediction of yield data on different benchmark soils for different crops.

This section may comprise one Research Officer and two Technical Officers.

d) Remote sensing. To assist the field survey units and provide the base for soil mapping.

Interpretation of aerial photographs and other remote sensing imageries in collaboration with an existing and well-established Remote Sensing Center. From the interpreted aerial photographs and imageries, base maps indicating physiographic units and other cultural features may be prepared for use by the field parties.

e) Documentation and soil information data bank. To share and disseminate the data generated from soil survey reports, maps, and other related publications. One Research Officer (Soil Survey Officer) should be adequate to undertake this work.

Research activities

The important research projects which could be undertaken by the Soil Survey Unit can be summarized as follows:

a) soil physiography relationships in different agro-climatic zones to develop key legends for ease of survey and mapping of soils;

b) identification and characterization of benchmark soils, study of the criteria of the categories in the existing soil classification, and suggested modifications;

c) genesis and transformation of clay minerals in selective benchmark soils;

d) micromorphological studies in the above selective benchmark soils;

e) soil management levels and crop performance studies on selective bench-mark soils based on actual agronomy experiments and on collection of data from National and Regional Research Centers (NRCs and RRCs).

2.1.2 Soil Science Research Supporting Production Agriculture

For meaningful interpretation of field experimental data on crop production and input use efficiency, it is essential to have information on site characteristics (physico-chemical properties) and dry-matter analysis of the produce (plant material). The perusal of the available annual reports on agronomic research at all the National and Regional Research Stations of the country indicated that research effort in this direction is lacking. However, in some of the ARCs Chemistry Sections have been established, and soil scientists are in position as members of multi-disciplinary teams to provide analytical support to the crop improvement and agronomic research programs.

It will not be possible to streamline the research thrusts unless the skeletal staff of scientists is provided a minimum set of analytical equipment. Except for NARS, Kitale and to some extent NPBS, Njoro and NSRS, Kibos, most of the commodity research institutes have not been provided the required analytical equipment. In addition, the existing positions have been filled with new agriculture and science graduates, and they need proper orientation in soil science research before they can provide the required professional support as members of multi-disciplinary teams. Therefore, simultaneous efforts to provide analytical facilities and training/orientation of personnel are essential. For the present, soil science research facilities and personnel should be strengthened at the following centers:

*	NRC, Kitale	2 soil scientists 1 soil microbiologist
*	NRC, Thika	2 soil scientists 1 analytical chemist
*	RRC, Njoro	2 soil scientists
*	RRC, Kibos	2 soil scientists
*	NRC, Tigoni	1 soil scientist

2.1.2.1 Research activities

The following research programs should be undertaken at the above centers:

a) establishing critical limits of nutrients in soils and plants for determining the fertilizer requirements of crops;

b) nutrient management studies through experiments involving time, method, rate, and sources of fertilizer application;

c) studies on nutrient economy through organic recycling and introduction of bacterial cultures;

d) characterization and amelioration of soil-based constraints (both chemical and physical) to crop production;

e) monitoring the effect of agricultural chemicals, including the fertilizers and pesticides, on soil environment and crop productivity.

2.1.3 Applied and Basic Research in Soil and Water Sciences

In view of the extent and magnitude of problems limiting crop production in Kenya, the following program/projects are proposed for developing and updating the economically viable technologies for solving emerging crop production constraints:

* Soil Fertility Network - establishment of diagnostic research laboratories and participation in coordinated agronomic experiments;

* strengthening basic and applied research in NAL, Nairobi and at Muguga;

* National Center of Soil and Water Management, Katumani, with cooperating centers in agro-ecological zones III, V, VI, and VII;

* National Irrigation and Drainage Research Center.

2.1.3.1 Soil Fertility Network

At current levels of crop production and fertilizer use, crop nutrients are not being replenished with the use of chemical fertilizers and organic manures. The problem is further accentuated through losses in soil fertility as a result of increasing soil erosion and other processes of soil degradation. The declining soil fertility is one of the most important reasons for the declining productivity of crops in Kenya. This has been rated as a major limitation in the high-potential areas and an important limitation in medium- and low-potential areas[1]. Therefore, it is very important to establish a 'Soil Fertility Network' for continuously monitoring changes in soil fertility. This can be achieved through the following programs:

* diagnostic soil and plant analysis laboratories;

* coordinated agronomic experiments at agricultural experiment stations and on farmers' fields.

Diagnostic soil and plant analysis laboratories

In order to promote the judicious use of costly and scarce crop production inputs, particularly fertilizers, research-based advisory services on soil and plant testing will have to be considerably augmented to meet the needs of smallholders, who in many cases are practising agriculture on marginal lands.

During the year 1980, the soil science and agricultural chemistry section of NAL analyzed 13,590 samples, 15 percent less than in the previous year. These included 9,970 soils, 2,880 plant materials, 306 agricultural chemicals, 234 irrigation water samples, 102 fertilizer/manures and 98 feedstuffs. These samples were received from the research stations and extension staff. The demand for research-related services by smallholders is going to increase substantially in the coming years, and therefore it is important to decentralize the services; for the present it is suggested that they be restricted to three locations at NAL Nairobi, RRC Kakamega, and RRC Mtwapa.

The soil and plant analytical data generated by these diagnostic service laboratories can be used for continuous monitoring of the soil health by preparing the nutrient ratings and updating them at the end of each year. In order to improve upon the fertilizer recommendations from these laboratories, follow-up fertilizer demostration trials on 0.5 to 1.0 percent of samples analyzed are highly desirable. This data can be used for modifying soil test limits for different soils-cropping systems and management levels. The chemistry section of NAL can act as a coordinating center to keep a check on precision in analyses by sharing

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[1] Sombroek et al 1982

standard reference samples and also for pooling and cataloging the analytical data from all laboratories in the country. NAL should also organize training programs in soil and plant testing services for the field staff.

Coordinated agronomic experiments

Currently, the field experiments on time, rates, methods, and sources of fertilizers are conducted by agronomists at NRCs and RRCs and on farmers' fields in isolation from one another, without any mechanism for coordination at the national level. In most cases, there is no effort to monitor the effect of crop production inputs on soil health and crop productivity. It is proposed to overcome this deficiency through the establishment of model agronomic experiments at selected agricultural experiment stations and simple experiments on farmers' fields, and as an integral part of the national coordinated research program in soil/water management.

The major objectives and the research programs in each of these areas are enumerated below.

a) Model agronomic experiments
Objectives:

(i) to study the interaction of the amounts of fertilizer application with intensity and frequency of irrigation, sowing dates and plant density;

(ii) to study the manuring requirements of important crops and crop rotations and their effect on soil fertility;

(iii) to study relative efficiency of various sources of nitrogen and phosphorus for different crops;

(iv) to monitor the direct, residual, and cumulative effect of fertilizers and organic manures;

(v) to study the nutrient uptake pattern and efficiency of use for improved cropping systems;

(vi) to develop technology for amelioration of problem soils such as acidic, saline-alkaline, etc.;

(vii) to undertake studies on interaction among major, secondary, and micronutrients;

(viii) delineation of areas responsive to fertilizer application;

(ix) studies on chemical, cultural, and mechanical methods of weed control;

(x) long-term effect of fertilizer application under intensive cropping on soil environment and crop productivity.

Research Topics

Research on the following topics would be organized:

(i) economics of crop sequences and their effect on soil fertility and crop productivity over the years;

(ii) crop technology for optimum production under resource constraints;

(iii) studies on intercropping, alley cropping, and mixed cropping systems;

(iv) a permanent plot experiment on an integrated nutrient supply system in a cereal-based crop sequence;

(v) the long-range effect of continuous cropping and manuring on soil fertility and yield stability;

(vi) varietal adjustments for increased production in important crop sequences specific to a region;

(vii) crop choice for drylands;

(viii) enhancing cropping intensity in rainfed dryland areas;

(ix) long-term studies on the relative efficiency of legume-cereal or cereal-legume rotations, over cereal-cereal rotations, on crop productivity and soil fertility;

(x) slow-release nitrogen fertilizers;

(xi) relative efficiency of various sources of phosphorus;

(xii) weed-control studies in crop sequences;

(xiii) nutrient economy through application of crop residues, organic manures, and bacterial cultures.

Organization

The results obtained from model agronomic experiments would be simultaneously verified by RRCs under the management conditions available on farmers' fields in different parts of the country.

b) Experiments on farmers' fields
Objectives:

(i) to study crop responses to nitrogen, phosphorus, and potassium when applied separately and in different combinations under field conditions;

(ii) to investigate the relative response of different fertilizers in various broad soil groups and to work out the optimum fertilizer combinations for different agro-ecological zones;

(iii) to study the relative performance of different nitrogenous and phosphatic fertilizers;

(iv) to study the nutrient economy through application of organic manures and bacterial cultures;

(v) to undertake benchmark nutrient indexing studies.

Research Topics

Research on the following topics would be organized:

(i) comparative performance of pre-release/newly released, and standard varieties of crops and their nutrient requirements under irrigated/rainfed conditions;

(ii) soil moisture fertilizer interaction studies under rainfed dryland conditions;

(iii) relative efficiency and economics of the crop sequences under irrigated conditions;

(iv) intercropping under irrigated/rainfed conditions;

(v) fertilizer requirement of food and cash crops under dryland conditions;

(vi) studies on rationalization of inputs in crop production under irrigated/assured rainfall;

(vii) testing of rock phosphates in acid soils;

(viii) studies on weed control;

(ix) monitoring the emerging nutrient deficiencies under different levels of input management and crop productivity.

Organization

The above studies would be coordinated within the framework of a nationally coordinated project of the kind presented in Volume I by a Chief Agronomist as a Program Coordinator, assisted by four principal investigators (Soil Chemist, Soil Survey Officer, Statistician, and Agronomist). This team would be responsible for program planning, monitoring of the field experiments, and documentation of the experimental results at the national level. The model agronomic experiments should preferably be conducted at eight locations in the country representing the most important cropping systems and agro-ecological zones, and in farmers' fields in these zones.

c) Location of sites

In order to fulfill the research needs for the most important soil-crop zones in the country, the following locations are proposed for the soil fertility network:

(i) coordination cell at NAL, Nairobi;

(ii) cooperating centers at -

* NRC, Kitale
* RRC, Kakamega
* NRC/RRC, Njoro
* NRC, Thika
* National Soil & Water Management Center, Katumani.
* RRC, Mtwapa
* NRC, Ahero/Garissa.

2.1.3.2 Strengthening Basic and Applied Research in Different Disciplines of Soil Science at NAL and the University of Nairobi

There are two experimental centers in the country which either in the past have done some good work in soil science research or currently have professionally qualified staff. These are NAL, Nairobi, and University of Nairobi, Kabete.

NAL, Nairobi has better-equipped laboratories in soil fertility/chemistry, soil physics, and pedology, but professional competence will have to be considerably strengthened. The section has a sufficiently large core staff which could be suitably trained for research in soil fertility, plant nutrition, soil chemistry, and soil physics. At NAL, a new building has been constructed for research on irrigation and drainage. In the opinion of the Mission, NAL is not a suitable center, and irrigation/drainage research should be relocated within a problem area for irrigation and drainage.

For meaningful research, manpower and equipment resources at NAL and Muguga should be pooled for research in soil science at NAL. Research programs should include soil physics/soil and water conservation.

Currently, the best qualified staff, representing most of the disciplines in soil science, are located at the University of Nairobi, but the faculty is mainly concerned with teaching. Including University of Nairobi staff in the national research stream could contribute to enrichment of research programs in soil and water sciences. This could be accomplished by joint advisorship for research officers registered for postgraduate programs at the University. After completion of course work, research workers could return to their parent organizations for completion of a research project relevant to the research mandate of the station.

At present, very good research work in biological nitrogen fixation, with special reference to isolaton, selection of various rhizobia for important legumes grown in the country, production of rhizobial inoculants, understanding of various soil factors affecting nitrogen fixation, maintenance of rhizobial culture collection, and phosphate solubilization in various soil types, is in progress within the Department of Soil Science and should be strengthened.

2.1.3.3 National Soil and Water Management Research Center (NSWMRC)*, Katumani

Kenya's land resources appear to be ample, with 27 persons per km^2 in 1979; however, when the land area capable of sustaining arable farming is considered, it is very limited. In some high-production areas with dependable rainfall, the population density is very high, with 294 and 395 persons per km^2 in Kakamega and Kisii Districts, respectively; the availability of good-quality land is getting extremely scarce. Therefore, to sustain the future population, projected at 30 - 40 million by the year 2000 and 70 million by 2030 A.D. (annual growth rate of 3.9%), the additional land likely to be available for agriculture is going to be in the arid and semi-arid areas.

Arid and semi-arid lands in Kenya account for over 72% of the land area, 20% of the total population, 35% of the total cattle, and over two-thirds of the total sheep and goats. Equally important, but not so often mentioned, is the role that these lands play as a major part of the watershed of the country. Therefore, the management and use of these lands greatly affect the extent and severity of droughts and floods and the rate of erosion and siltation of streams, rivers, irrigation dams, and reservoirs.

Taking into consideration the topography, low productivity, erratic rainfall pattern, and soil and water conservation problems in these semi-arid and arid areas, suitable technologies will have to be evolved for improving and stabilizing crop production through better techniques of soil and water conservation and crop management. There is, therefore, an urgent need for intensifying research in these areas. This should be achieved through the establishment of a National Soil and Water Management Research Center in agro-ecological zone IV at Katumani, with a sub-center at Perkerra and with collaboration with a number of Regional Research Centers.

Major objectives

The major objectives of establishing the NRC on soil/water management (or dryland farming) would be:

a) to develop techniques for rainfed farming and efficient rainwater management;

b) to identify crops, cropping systems, and sequences for efficient moisture utilization to increase and stabilize production per unit area;

c) to evolve farming techniques that increase *in situ* soil moisture conservation and the storage of runoff water to reduce moisture stress during crop growth;

d) to formulate plans to counter weather aberrations in order to minimize their effect;

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* or National Dryland Farming Research Center (used interchangeably).

e) to appraise erosion problems for conservation of land and water resources under different land-use systems;

f) to evaluate and identify suitable plant species for different land uses according to land capability;

g) to monitor changes in environment as affected by land use and management practices;

h) to evaluate the hydrological behavior and management of watersheds for reducing sediment discharge and improving the water regime;

i) to develop suitable technology for stabilizing and increasing biomass production in eroded and degraded lands;

j) to train soil and water conservation personnel at various levels so that the manpower resources for development programs can be effectively improved;

k) to demonstrate, using appropriate extension programs, soil and water conservation practices that improve production on cultivators' land;

l) monitor environmental changes on farmers' holdings as affected by integrated watershed management plans in operational research projects.

Organization

A proposed organization for the NRC in Soil/Water Management (Dryland Farming) is shown in Figure 2.2. The proposed objectives and research topics for each division are enumerated below.

a) Division of Crop Production
Objectives:

(i) identification of constraints responsible for low production and soil deterioration;

(ii) increasing and stabilizing production on a sustained basis by identification of crop varieties, cropping systems, and cropping sequences;

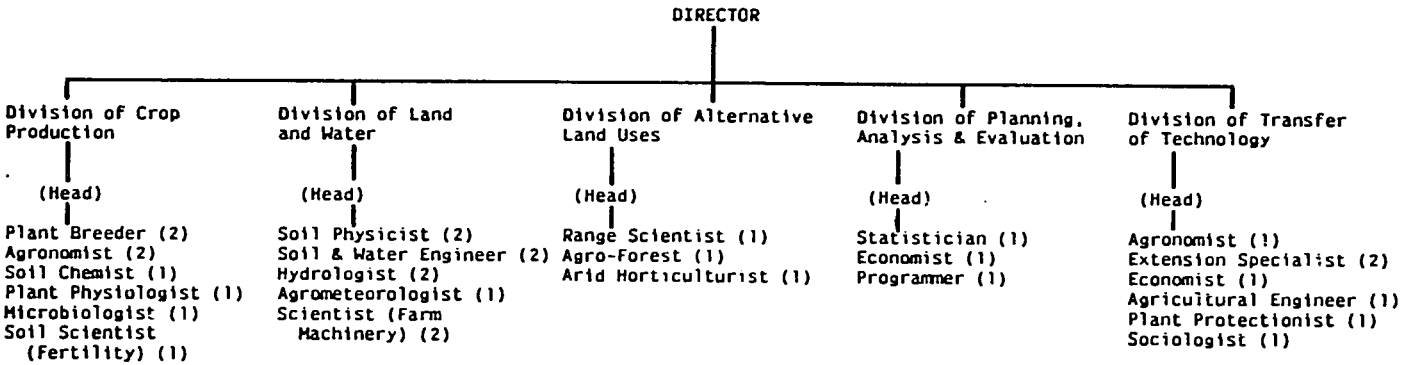
(iii) identifying production inputs and evolving packages of practices for a) higher production, b) soil and moisture conservation, and c) rainwater conservation and management;

(iv) evolving strategies and practices for various aberrant weather conditions;

(v) testing of various packages of practices on farmers' fields for improvement of crop production;

(vi) studying the inter-relation between climatic and crop growth parameters for evolving suitable cropping patterns.

Figure 2.2: Organization of the National Soil/Water Management Research Center*



* Cooperating centers should also have expertise in agronomy, soil chemistry, soil physics, statistics, soil/water engineering, extension and, where appropriate, in range management, horticulture, and agroforestry.

( ) Figures in parenthesis indicate the required number of scientists in each discipline.

Research topics

The following research topics are proposed:

(i) collection and correlation of available data on the following:

a. the weather in order to propose effective cropping seasons;

b. the probable duration of cyclic droughts;

c. soil information, such as depth, texture, soil moisture storage, etc.;

d. crops, their varieties and their phenology in order to identify critical stages of crop growth in respect of water requirements;

e. suitable cropping systems, conservation practices, and soil and crop management from national and international sources;

(ii) collection, testing, and screening of germplasm of various crops for their duration and phenology, growth characteristics (both shoot and root) in order to identify suitable varieties that would fit into cropping seasons and match stages and periods of growth in relation to available soil moisture regimes;

(iii) experiments on time of seeding in order to ensure that critical stages of crop growth demanding high water requirement coincide with relatively better moisture available periods and that those stages with low water requirements coincide with periods of low water availability;

(iv) studies on appropriate plant population and spacing that will suit available rainfall conditions and favor implementation of better soil and water conservation measures;

(v) studies on the rates, time and methods of fertilizer application for different water budgets and crop production systems;

(vi) studies on chemical and cultural practices for weed control;

(vii) studies on agronomic practices for erosion control and moisture conservation, such as inter-terrace land treatments and mulches to protect crops from effects of moisture stress at critical stages of growth in order to prolong the period available for cropping;

(viii) inter-cropping of deep rooted, long duration, drought tolerant crops with short duration, early canopy developing, shallow or medium rooted compatible crops so as to avoid complete crop failure in the worst years and also increase production and more effectively conserve soil and water in normal and above normal rainfall years;

(ix) research on possible cropping sequences for increased production in favorable years;

(x) formulation of package of practices for crops and cropping systems for stabilizing production and conservation of soil and moisture. Emphasis to be given to the use of non-monetary and low-monetary inputs;

(xi) testing of methodologies developed at research centers on farmers' fields in order to study, identify, and correct any deficiencies;

(xii) evolving alternative strategies for aberrant weather conditions from information collected from the above experimental programs.

b) Division of Land and Water Objectives:

(i) to survey and appraise soil erosion problems and the collection of soil data in collaboration with the Kenya Soil Survey and the Meteorological Department;

(ii) to predict soil erosion losses using climatic and soil data and to estimate various parameters of the Universal Soil Loss Equation (USLE);

(iii) to collect, collate, and interpret hydrometeorological data in order to evolve a strategy and methodology for efficient soil and water conservation and for improving and stabilizing crop production;

(iv) to evaluate hydrological behavior and management of small watersheds in order to reduce sediment discharge and improve rainwater use;

(v) to devise methods and implements for improving the intake rate of rainwater and the conservation of stored moisture in soil profiles in order to prolong the crop growth period;

(vi) to ameliorate surface encrustation problems in order to improve water intake rates and improve the germination of crops;

(vii) to evolve and test suitable mechanical measures for soil erosion control under different situations;

(viii) to develop suitable technology for rainwater harvesting, storing, and recycling for increasing crop productivity through supplemental irrigation at critical crop growth stages;

(ix) to reduce seepage and evaporation losses from water storage structures;

(x) to develop methods and techniques for in situ conservation of rainwater and for reducing soil erosion;

(xi) To study the interaction of soil moisture and soil fertility on crop yields.

Research topics

The following research topics are proposed:

(i) appraisal of soil erosion problems in Kenya, their causes, extent, distribution, and classification, etc.;

(ii) management of land prone to soil erosion for crop agriculture with regard to; a) preventive measures and b) corrective measures;

(iii) assessment of erosion hazards, runoff, and soil nutrient losses under different vegetative covers;

(iv) parameters of USEL with the establishment of standard runoff plots at the Center;

(v) improvement of soil physical properties for improved intake and storage of profile moisture;

(vi) monitoring of profile moisture at different crop growth periods and evolving strategy for growth of crops under limited moisture availability;

(vii) targeting desired production through interaction of limited water supply, efficient fertilizer use, and recycling of organic wastes;

(viii) techniques for increasing the crop growth period by augmenting profile moisture through mulches, tillage, and the use of fertilizers;

(ix) hydrometeorological data collection and analysis for the determination of; a) a rainfall erosion index, b) intensity-duration-frequency relationships, and c) daily, weekly, and monthly rainfall frequencies to be used for efficient crop planning;

(x) water balance studies (consumptive use rates) for rainfed crops;

(xi) studies on hydrological behavior of small watersheds under different land uses in order to establish relationships between catchment characteristics, rainfall, and sediment yield and runoff;

(xii) mechanical measures for erosion control and the conservation of rainwater;

(xiii) in situ conservation practices and measures, viz., contour-cropping, strip-cropping, broad bed and furrows, ridge and furrowing, conservation trenching, etc., in order to maximize utilization of rainwater for crop production;

(xiv) developing and testing methods of rainwater harvesting;

(xv) efficient methods for control of seepage and evaporation losses from harvested runoff;

(xvi) efficient methods for the application of stored water as supplemental irrigation to rainfed crops;

(xvii) development and testing of animal-drawn implements for seed bed preparation, planting, inter-culture, etc.;

(xviii) introduction and testing of threshers, winnowers;

(xix) efficient methods of post-harvest storage of grain and seed materials, etc.

c) Division of Alternative Land Uses

This division would conduct research in cooperation with other regional research centers and the Forestry Research Institute. It would primarily service, for soil and water conservation purposes, range research programs discussed elsewhere in this report and programs of the national forestry research institute.

d) Division of Planning, Analysis, and Evaluation
Objectives:

(i) collection, compilation, and interpretation of available statistical data;

(ii) statistical support to research on parameters related to agriculture-design and analysis of the data;

(iii) basic resources inventory and collection of diverse types of data for use in agriculture and soil and water conservation programs;

(iv) economic evaluation of crop, rangeland, and agro-forestry experiments;

(v) provide a national data bank of various soil and water conservation programs and a national index of field experiments.

Research topics

The following research topics are proposed:

(i) development of suitable statistical designs for crop, pasture, and agro-forestry system experiments;

(ii) development of statistical methodology for forecasting of crop yields;

(iii) analysis and interpretation of meteorological data for planning soil and water conservation measures and other agricultural operations;

(iv) development of models for estimation of runoff and peak discharge from small to medium-sized watersheds;

(v) development of crop response index and economic optima of various inputs;

(vi) research on economic factors relating to constraints in increasing yield from various farming systems;

(vii) research in the field of agricultural economics and related aspects having a bearing on rural development;

(viii) provide guidance and assistance to other center research projects with regard to economic analysis.

e) Division of Transfer of Technology

The major tasks of this division would be to develop programs for efficient dissemination of improved crop production technologies through organization of training programs for field staff and farmers, conduct of farm demonstrations and field days, and contribution to the publication of relevant literature.

Research topics

The research topics proposed are as follows:

(i) identification of constraints on production and problems of erosion in the farmers' fields;

(ii) selection of 100 small and large representative farms for study;

(iii) collection of base data on a) socio-economic conditions, b) production methods, c) cropping patterns, d) fertilizer use, e) cost of cultivation, and f) conservation methods used;

(iv) demonstration of packages of practices which include methods of soil and water conservation and crop management;

(v) providing alternative strategies to be adopted for aberrant weather conditions;

(vi) organizing farmer training programs in improved technology;

(vii) organizing field days to demonstrate the effect of improved technology to the farmers in the area;

(viii) collection of data on production and economics from the demonstrations annually, and monitoring the impact through changes in production and economic conditions;

(ix) study of the impact of technology on non-adopted farmers through sample plot harvesting and collecting data on increased production and its economics.

Cooperating research centers would undertake verification trials on the basis of the lead research conducted at Katumani. They will also undertake independent research programs unique to the climatic and soil needs of their region.

Thu following research programs are proposed for the cooperating centers:

a) selection of crops, varieties, and agronomic practices for increased production;

b) studies on the inter-relation between climatic parameters and crop growth evolving suitable cropping systems and cropping sequences;

c) development of fertilizer schedules for important crops and cropping systems in the region in order to optimize nutrient use efficiency and improve soil fertility;

d) development of technology a) to increase water intake rate of soil, b) to increase moisture storage capacity of soil, c) to increase efficiency of stored moisture for crop production;

e) studies on water harvesting and recycling techniques for improving the moisture regime and increasing cropping intensity by providing supplemental irrigation;

f) development of soil and water conservation measures for erosion control;

g) evaluation and testing of implements for various methods of soil tillage suitable for seed bed preparation, moisture conservation, seeding, and weed control.

Other research programs that should be conducted by the NSWMRC in other agro-ecological zones include:

(i) hydrological surveys to investigate the possibilities for water resource development;

(ii) feasibility studies on water harvesting techniques in selected situations;

(iii) monitoring of the process of desertification under different land and vegetation management systems.

2.1.3.4 National Irrigation and Drainage Research Center (NIDRC)

Out of a total land area of 57 million ha only about 10 million ha is under arable farming. About one million ha of unutilized and under-utilized land suffer from problems of waterlogging and impeded drainage and could be put to better agricultural use with proper reclamation measures. A part of the 72% of the land area that is semi-arid or arid might also be brought under cultivation, provided supplementary irrigation sources could be developed.

The total irrigation potential in Kenya has been estimated to be around 0.90 million ha, out of which only 0.54 million ha could be exploited. It is expected to create an irrigation potential of 0.16 million ha by the year 2000. The current irrigated area is only 40,000 ha. The major irrigation developments in future in Kenya will be in the Tana River basin (44%), Rift Valley basin (22%), and Lake Victoria region

(14%). The proposed irrigation developments in the Athi River basin and the Uasingishu region will account for the remaining areas. In the humid and sub-humid southwestern region, there is also a possibility of recycling swamp water for irrigation.

According to the National Water Master Plan of the GOK, irrigation development in the Tana River basin has been given the highest priority on account of the best prospects for hydro-power development. Of the total proposed irrigation development in this river basin, 75% will be in the lower region where the rainfall is low and Solonchak/Solonetz constitutes a major soil group; therefore the irrigation has to be based on sound scientific considerations; otherwise the soils may soon be degraded due to waterlogging and secondary salinization. In the upper catchment of Tana River, the soils possess high infiltration rates and the topography being undulating, the valley lands are prone to development of temporary waterlogging through excessive seepage from the uplands. Of the 1 million ha area with problems of drainage, 800,000 ha is in Nyanza and Western provinces where agricultural production can only be sustained through amelioration of drainage hazards.

At present the research programs on irrigation and drainage in Kenya are in their infancy, and different organizations dealing with water are working in isolation from one another. The biggest bottleneck in promoting this research program, at present, is dearth of trained professionals as members of multi-disciplinary teams.

Strategies

To find short- and long-term solutions to the problems of soil and water management and to provide scientific support to developmental programs on irrigation and drainage in Kenya, there is an urgent need to establish a National Center for Research on Irrigation and Drainage (NIDRC). In addition it is proposed that there should be three cooperating centers to cater for the following location-specific problems of irrigation and water management:

(i) drainage of agricultural lands in the southwest provinces in Yala swamp;

(ii) water management of red soils in the upper Tana basin, on a systems approach basis at Mwea Tebere;

(iii) water management in the lower Tana basin in soils with sub-soil salinity and/or sodicity at Hola.

The NIDRC should be established at Ahero or some other site in the Lake Basin area where about 60-80 ha could be provided for establishment of the experimental farm and other infrastructure to undertake research programs of an applied and basic nature and also coordinate research work on soil and water management that would be conducted at the three cooperating centers. The NIDRC should also perform the pivotal role of training field staff in irrigation, drainage, and land development.

The objectives and proposed research programs for the NIDRC are as follows:

a) Objectives:

(i) to conduct lead research (applied and basic) in various aspects of soil and water management for improving the efficiency of on-farm water management in order to ensure increased agricultural production;

(ii) to generate water management technology for transfer to the users;

(iii) to guide and coordinate the research activities of sub-centers on irrigation and drainage;

(iv) to impart training to scientific and technical staff in water management;

(v) to maintain a data bank of available information on soil and water management in the country and to make available the information to planners, researchers, and development agencies.

b) Research programs:

(i) design and evaluation of farm irrigation and drainage systems for improving on-farm water management efficiency;

(ii) studies to determine irrigation water needs of crops and cropping systems for irrigation optimization;

(iii) study of optimization techniques for crop water allocation under competitive demands and uncertainty;

(iv) development and compilation of yield response functions of various crops in relation to water and other inputs;

(v) crop management under excess moisture conditions;

(vi) comparative study of various equipment for land grading, shaping, and development;

(vii) prototype development and evaluation of irrigation water control, measurement, and regulating structures;

(viii) evaluation of socio-economic and environmental aspects of water management;

(ix) testing of improved water management technology under large-scale farmers' field conditions for technical feasibility and economic viability.

The objectives and proposed research programs for the three cooperating centers are as follows:

Cooperating Center for Drainage of Agricultural Lands

a) Objectives:

(i) to plan, design, and execute drainage investigations;

(ii) to conduct hydrological surveys to provide suitable criteria for surface and sub-surface drainage for reclamation of problem soils;

(iii) to test drainage materials for effectiveness, durability, and economy;

(iv) to evaluate the performance of different drainage systems;

(v) to study the inter-relationship of soil-water regimes and soil fertility in reclaimed soils;

(vi) to study the performance of different cropping systems under varying degrees of reclamation of waterlogged soils;

(vii) to develop technology for optimizing the productivity of reclaimed soils.

b) Research programs:

(i) statistical analysis of long-term rainfall data in order to determine excess and deficit periods, drainage requirements, and periods requiring supplemental irrigation;

(ii) studies on evaluation of drainage material for effectiveness, durability, and economy;

(iii) comparison of different drainage systems and their evaluation with respect to technical feasibility and economic viability;

(iv) studies on crop sequences under varying degrees of reclamation of waterlogged soils;

(v) determination of agronomic and cultural practices for different crops, including irrigation and fertilizer schedules for optimizing crop production;

(vi) studies on lime requirement of different crops on acidic soils;

(vii) study of physical and chemical changes in soil properties after drainage and their influence on crop production;

(viii) design of farm ponds for storage of excess rainwater and its recycling for irrigation in deficit periods.

Cooperating Center for Water Management of Red Soils in the Upper Tana Basin, Mwea-Tebere

a) Objectives:

(i) to characterize the physical properties of red soils in order to understand the factors causing high infiltration rates;

(ii) to design and evaluate both conventional and non-conventional irrigation systems, like sprinkler and drip irrigation, in order to reduce water losses and increase irrigation efficiency;

(iii) to study the efficiency of various practices/materials in reducing deep percolation losses;

(iv) to investigate the feasibility of storing seepage water in valley lands and recycling it through pumping for irrigation;

(v) to develop high-value cropping systems with low water requirement in the uplands and water-tolerant crops such as rice in the low-lying lands;

(vi) to determine the interactions between water and fertilizer use for different crops and quantify nutrient losses under varying water regimes.

b) Research topics:

(i) studies on quantification of deep percolation losses in red soils and ameliorative measures to the unproductive water losses;

(ii) studies on design and evaluation of surface irrigation methods with respect to reductions in water application rates;

(iii) comparative performance of drip and sprinkler irrigation systems in high-value vegetable and fruit crops on highly permeable soils;

(iv) studies on irrigation scheduling and water use by various crops in order to develop suitable cropping patterns for efficient water use;

(v) studies on nutrient losses under different water regimes in permeable uplands;

(vi) the evaluation of different lining materials for seepage control;

(vii) effect of surface drainage on crop growth in low-lying lands;

(viii) studies on re-use of drainage water for irrigation.

Cooperating Centers for Irrigation Water Management in Potentially Salt Affected Soils

a) Objectives:

(i) to undertake survey and pedo-chemical characterization of the nature of salinity/alkalinity in the sub-soil;

(ii) to study salt and water dynamics in irrigated agriculture;

(iii) to study the long-term effect of irrigation on a rise in water table and secondary salinization;

(iv) to design and evaluate surface irrigation methods and other practices in order to increase irrigation efficiency;

(v) to develop suitable cotton-based cropping systems for efficient use of irrigation water;

(vi) to investigate optimum agronomic and cultural practices, including irrigation and fertilizer schedules for different cropping systems;

(vii) to design and evaluate sub-surface drainage systems for regulating the rising trend in the water table as well as to ensure leaching of salts.

b) Research topics:

(i) characterization of physical and chemical properties of typical soil profiles with soil salinity/alkalinity in the sub-soil;

(ii) determination of different factors and their contribution to a rise in groundwater table and secondary salinization;

(iii) studies on evaluation of the effect of land treatment on irrigation efficiency and economic parameters;

(iv) conjunctive use of fresh canal and saline groundwater in crop production;

(v) design and evaluation of surface irrigation methods for efficient irrigation and higher water-use efficiency;

(vi) study of the response of cotton and other new crops to irrigation in order to develop cotton-based cropping systems for efficient water use;

(vii) determination of optimum agronomic and cultural practices, including fertilizer schedules for different crops;

(viii) screening of crops and varieties for salinity and alkali tolerance;

(ix) design and evaluation of surface and sub-surface drainage systems for regulating a rise in the water table and the leaching of salts.

Organization and staffing

It is proposed that the NIDRC should be organized in the following six sections:

(i) Hydrology and Agro-Meteorology

(ii) Irrigation Management

(iii) Agricultural Drainage

(iv) Soil Physics

(v) Cropping Systems

(vi) Agricultural Economics and Statistics and Transfer of Technology

together with a supporting unit of Plant Physiology/Plant Protection.

2.2 New Research Programs to Strengthen Soil/Water Management in Kenya

In order to strengthen soil/water management as an integral part of the national agricultural research strategy, it is proposed to establish a Division of Agricultural Engineering at KARI, Muguga, where a nucleus of agricultural engineering already exists.

2.2.1 Division of Agricultural Engineering at KARI, Muguga

It is important that agricultural research centers in Kenya should include agricultural engineering activities, together with some infrastructure in order to provide engineering research support for land and water resource development and tools, implements, and machines for crop cultivation, post-harvest technology, energy management, etc.

2.2.1.1 Farm machinery and power

Large areas in Kenya experience low rainfall with limited irrigation potential, and in the future dryland farming is likely to increase. In the absence of irrigation there is little control on soil moisture. Field operations, particularly seed bed preparation, need to be carried out in the limited time available between soil being too wet and too dry for good tilth. Inadequate machine capability prevents the farmer carrying out timely farm operations, which results in lower crop productivity. Operations carried out too early or too late need much more energy and effort, adding to the costs of production. Also, through precision metering and placement of seed and fertilizer, input costs can be reduced.

The majority of Kenyan farmers are smallholders. In order to improve the profitability of such farms, appropriate farm power and implement systems need to be evolved, produced, and distributed by indigenous entrepreneurs and an after-sales services network organized.

2.2.1.2 Post-harvest engineering and technology

Primary processing of agricultural produce and value-added products and by-products for on-farm consumption as well as marketable surpluses can increase the farmers' income to a great extent. The resulting by-products could provide cheap feed for livestock. Therefore it is only logical that at least primary processing of agricultural produce should be organized in rural districts.

Even more basic is the protection of agricultural produce and by-products from qualitative and quantitative damage, both those consumed on the farm and marketable surpluses. Growers of many commodities, particularly perishables, suffer on account of the commodity prices determined by demand and supply. During main harvest/market arrival seasons of a commodity and more so in the event of bumper crops, market prices slump, providing little gain to the farmer when there is a good harvest. Capability to retain produce with negligible losses on the farm or in the rural sector gives the farmer some capacity to negotiate with market forces. It is proposed that NAL should further develop its work in postharvest technology systems and collaborate with KARI in the engineering aspects.

2.2.1.3 Energy in agriculture

Crop production, post-harvest activity, as well as rural living, need direct or indirect commercial and non-commercial energy inputs. Total energy input is known to increase substantially with increased agricultural production. Non-commercial energy inputs in the form of seed, manure, animals, and humans might remained the same, but commercial energy inputs in the form of fertilizers, pesticides, machinery, diesel, and electricity often increase substantially. In crop production, lifting of irrigation water, seed bed preparation, harvesting, and threshing are directly energy intensive, while the use of fertilizer, pesticides, and machinery are indirectly energy intensive. In a village eco-system more than half of the total energy used is utilized for cooking food. In Kenya, as elsewhere, fuel wood needs have contributed to deforestation, causing ecological concern. Biogas technology can contribute to domestic fuel needs, and dependence on commercial fertilizer can be reduced by using livestock, human, and crop wastes. Similarly, where there are large quantities of surplus biomass in the form of wood, producer gas technology can be used to provide power and energy in remote areas where it is difficult to supply diesel fuel or electricity. Low-cost solar technologies have also been developed for cooking, drying, water heating, etc., and some of these have relevance for Kenyan situations. Wind turbines can be used in the regions where wind velocities are favorable. There is need for some carefully planned research activities in these areas.

2.2.1.4 Proposed research programs

Farm machinery:

a) study of crop rotations and field operations to be performed in different regions of the country;

b) study of the adequacies and inadequacies of traditional practices and of new implements and machinery that have been introduced;

c) evaluation of available designs of manual, animal-drawn, and small tractor-mounted tools for tillage, seeding, fertilizer application, weeding and intercultivation, pesticide application, lifting irrigation water, application of irrigation water, harvesting, threshing, and transport, adopting promising design of implements and evolving suitable packages of implements;

d) design of new tools, implements, and machines for operations for which there are no suitable designs available;

e) prototype fabrication for extensive field evaluation and first-line extension;

f) industrial liaison with small-scale manufacturers/entrepreneurs promoting indigenous manufacture and servicing;

g) training of fabricators and operators;

h) provision of information on demonstration and dissemination of proven implements.

Post-harvest engineering and technology:

a) study of harvest and post-harvest practices, primary processing of agricultural commodities, and marketing channels;

b) study of wastes and by-products, their current and alternative uses;

c) development of location/crop-specific drying, cleaning, grading, and primary milling processes and equipment;

d) development of storage structures, packaging, and management techniques for farm and community use;

e) study of production catchments and the development of agro-processing industrial models for farm consumption and marketed products;

f) field evaluation of crop conditions, storage, packaging, agro-processing, and by-product utilization technologies;

g) training, information dissemination, and front-line technology transfer.

Energy in agriculture:

a) study of farm power and energy requirement for crop production, post-harvest activities, and rural living on a unit area basis;

b) identifiying operations and activities involving wasteful use of energy and developing equipment or management techniques that minimize wastages;

c) studies with draft animals; traction farm power needs, harvesting, yoking, matching implements, and enhancement of their versatility;

d) evaluation and development of solar appliances for cooking, drying, water heating, desalination, etc.;

e) evaluation and development of windmill/turbine-operated equipment for farm operations and rural living;

f) adoptive studies on biogas technology, using livestock, crop, and human wastes as feed stock;

g) studies on producer gas technology and development of producer-gas-operated power units;

h) liaison with industry/users/extension organizations training and front line technology transfer.

Professional, workshop, and field staff in implements and machine engineering, postharvest and processing engineering, and in energy engineering will be required and have to be gradually built up.

CHAPTER 3: CROP PRODUCTION

3.0 The total land area of Kenya is 0.58 million km^2, of which about two thirds receives very little rain and therefore is only sparsely populated. In the other areas the population density is rather high; particularly in Central, Nyanza, and Western provinces, with a population density of about 200 people per km^2. The total population was, in mid-1981, 17.4 million, and the average annual growth rate of the population over the past decade was close to 4%.

Administratively the country is divided into seven provinces, excluding the city of Nairobi, and the provinces are further subdivided into districts (41), divisions, locations, and sublocations.

The Gross National Product per capita in 1981 was US$420. The shares of the major sectors in the Gross Domestic Product (GDP) in 1981 were: agriculture 32%, industry 21%, services 47%. However, not less than 78% of the labor force in 1981 was engaged in agriculture, as against 10% and 12% in industry and services respectively[1].

About 58% of total exports consist of agricultural and agro-industrial products, with coffee and tea being the major commodities, comprising 22% and 12% respectively, of total exports during the period 1980 to 1982[2].

Kenya is characterized by considerable contrasts in topography, climate and soils, and less than 30% of the total area has cropping potential. The altitude ranges from sea level to over 5,000m (Mount Kenya) and increases gradually from below 200m in the east to around 2,000m in the central and southwestern areas. Around Lake Victoria the altitude is between 1,200 and 1,600m.

The differences in altitude have a pronounced influence on the average annual temperatures, which are above 25°C in the eastern and northern parts of the country and below 20°C in the hilly and mountainous areas of the Rift Valley and Central Provinces.

The average annual rainfall follows a similar pattern, with less than 500mm in the north, in the east, and in some areas in the south, but with a small strip along the coast with more than 500mm and in some places more than 1,000mm. An average annual rainfall of more than 1,500mm is only found along the mountain ranges and in certain areas in Western Province.

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1) World Development Report.

2) IMF Statistics, 1983.

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Agricultural production is to a large extent concentrated in the higher altitude (above 1,500m) and higher rainfall (above 750mm) regions and the most populated areas.

In the Ministry of Agriculture's Farm Management Handbook of Kenya, agro-ecological zones are defined on the basis of temperatures (related to altitude) and rainfall characteristics (precipitation and evaporation). The main zones are based on the availability of water, while the zone groups are formed by temperature belts. The names of the zones refer to potentially leading crops and livestock activities. The first two main zones (I and II) constitute the humid and subhumid areas; zones III and IV are the semi-humid and transitional areas, while zones V and VI are characterized by semi-arid and arid conditions. The perarid zone VII is virtually desert.

In Table 3.1 the distribution of these categories of agro-ecological zones is shown in terms of agricultural land by district. The table also provides information on the average population density and the availability of agricultural land per person.

3.1 The agricultural sector and parameters to determine research priorities

The determination of agricultural research priorities, and consequently the allocation of resources, should, at the level of national commodity-based research centers, be based on national economic considerations on the one hand and on the feedback from regional centers on the other hand.

At RRCs' priorities should be largely oriented towards major crops and livestock in the region and should be directed towards the needs and circumstances of the respective target groups of farmers in the region.

Details are provided below of certain national economic factors of importance for the determination of agricultural research priorities.

3.1.1 Present status of production, imports and exports

One of the major objectives of the development policy in Kenya in the present decade is to meet the ever-increasing demand for food, resulting primarily from the rapidly expanding population. While the crude birth rate was already at the high level of about 53 per 1,000, the crude death rate decreased in the past few decades to reach 12.7 per 1,000 in 1979. The present population growth rate in Kenya, of over 4% per year, is among the highest in the world.

On the other hand, the agricultural sector must also be the major source of new jobs for the rapidly increasing labor force and must continue to generate foreign exchange earnings to pay for oil, capital equipment, and other imports.[1]

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[1] Sessional Paper No.4 of 1981 on National Food Policy.

Table 3.1: Categories of Agricultural Land and Population Density, by District

	Total Land Area (sq.km)	Agricultural Land[1] Humid & Sub-humid (Zones I & II)	Semi-humid & Transitional (Zones III & IV)	Semi-arid & Arid (Zones V & VI)	Population Density (1979) (sq.km)	Agricultural Land/Person
Western Province	8,196	4,055	1,834	0	223	0.48
Bungoma	3,074	1,210	782	-	163	0.46
Busia	1,626	927	422	-	183	0.57
Kakamega	3,495	1,918	630	-	294	0.42
Nyanza Province	12,526	5,537	4,148	395	211	0.42
Kisii	2,196	1,914	11	-	395	0.26
Kisumu	2,093	605	992	-	230	0.48
Siaya	2,522	985	1,054	20	188	0.39
S. Nyanza	5,714	2,033	2,091	375	143	0.56
Rift Valley	163,884	9,115	14,725	26,363	19	3.68
Baringo	9,885	207	1,769	5,209	20	3.81
Elgeyo M.	2,279	603	501	350	65	1.06
Kajiado[2]	19,605	3	308	3,019	7	8.40
Kericho	3,931	2,553	801	21	161	0.56
Laikipia	9,718	75	1,255	6,757	13	7.09
Nakuru	5,769	1,138	1,540	1,073	90	1.00
Nandi	2,745	1,136	790	-	109	0.65
Narok	16,115	2,179	3,256	6,438	13	5.93
Trans Nzoia	2,078	344	1,206	9	124	0.67
Uasin Gishu	3,378	328	2,453	-	89	1.11
West Pokot	9,090	522	846	3,487	17	3.64
Samburu/Turkana	79,289	-	-	N.A.	3	-
Central Province	13,173	3,482	3,892	485	178	0.44
Kiambu	2,448	778	470	174	280	0.23
Kirinyaga	1,437	285	665	5	202	0.34
Muranga	2,476	961	847	-	261	0.29
Nyandarua	3,528	763	1,225	97	66	0.95
Nyeri	3,284	695	685	209	148	0.35

Table 3.1 continued:

	Total Land Area (sq.km)	Agricultural Land[1] Humid & Sub-humid (Zones I & II)	Semi-humid & Transitional (Zones III & IV)	Semi-arid & Arid (Zones V & VI)	Population Density (1979) (sq.km)	Agricultural Land/Person
Eastern Province	155,759	1,035	9,194	28,438	17	5.06
Embu	2,714	161	639	1,213	96	0.82
Meru	9,922	743	2,127	2,447	83	0.71
Machakos	14,178	131	3,526	7,616	72	1.23
Kitui	29,388	-	2,902	17,162	15	4.43
Isiolo/Marsabit	99,557	-	-	N.A.	1	
Coast Province	83,040	275	9,359	24,701	16	N.A.
Taita/Taveta	16,959	40	663	5,139	8	4.23
Kivale	8,257	235	1,850	5,228	34	2.65
Kilifi	12,414	-	2,541	4,572	34	1.81
Tana River[3]	38,694	-	418	8,132	2	27.68
Lamu	6,506	-	3,887	1,630	6	16.27
N.E. Province	126,902	-	-	N.A.	2	N.A.
Total (Kenya)	563,480	23,500	43,152	80,382	27	

1) Zones I & II humid/sub-humid: tea, coffee, pyrethrum, horticulture, dairying.

Zones III & IV semi-humid/transitional: maize, wheat, pulses, oilseeds, cotton, dairying, cashew/coconut (coast).

Zones V & VI semi arid/arid: sorghum, millet, cotton, pulses, oilseeds; ranching cattle, sheep, and goats; wildlife resources.

2) Data on agricultural land only including the southeastern part of Kajiado.

3) Data on agricultural land only including the southeastern part of Tana River.

Source: Farm Management Handbook of Kenya Vol. II; Statistical Abstract 1983.

In the 1960s and the early 1970s agricultural production showed average annual growth rates of 4% and above. Food production was expanded, in particular through the introduction and efficient distribution of hybrid maize seed (accompanied by greater use of fertilizers), and an increase in the number of improved cattle. Coffee and tea production increased very rapidly, and both products fetched comparatively high prices on the world market.

In the late 1970s, however, the annual growth rate declined. As a result of marketing problems after the bumper crops of 1976/77, which led to a lowering of producer prices, and following adverse growing conditions, the national maize production in the period 1979-1981 was very low (Table 3.2). The production of wheat and milk also decreased in the late 1970s. As a result, the value of imports of food products (excluding oils and fats) tripled from K£ 13.7 million in the three-year period 1975/77 to K£ 39.3 million in the period 1980/82 (Table 3.3). The imports of oils and fats more than doubled over the same period, and vegetable oils and fats remained the single most important category of agricultural import. The average annual value of vegetable oils and fats imports of K£19.5 million (1980-82) is very large compared with the value of the marketed production of coconut products and other oil seeds of K£0.8 million in the same period. Given the stated objective to maintain a position of broad self-sufficiency in foodstuffs, there certainly appears to be urgent need for increased research and promotion efforts with regard to the production of oilseed crops such as sunflower, soybeans, and sesame.

Unfortunately, the world market prices of coffee fell in the same period from the record high levels of 1977/78, but this was to some extent compensated for by the positive trends shown by the tea and sugarcane subsectors. The production of tea more than doubled over the period 1970 to 1980 and export prices developed favorably. Kenyan tea generally is of high quality, and the country therefore exports most of its own production, and imports lower qualities for the domestic market.

Thanks to the expansion of the area under sugarcane and the considerable increases of yields, the production of sugar tripled over the period 1970 to 1980, and the imports of sugar were sharply reduced. The country now exports its 'plantation white' sugar to, among other countries, Sri Lanka and Sudan. To export to major markets such as the large mineral-oil-producing countries, Kenya would have to compete with the world's major exporters of sugar and would have to invest in refining capacity to produce refined white sugar.

Exports of meat declined in the late 1970s, while the exports of horticultural products increased (Table 3.4). Both these commodities require a regular refrigerated sea freight service, but the quantities were generally insufficient to justify frequent calls to Mombasa by the shipping lines, and because of the fall in beef exports, frequency of sailings has dropped even further.[1]

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[1] Schluter, M.: Constraints on Kenya's Food and Beverage Exports.

Table 3.2: Major crops in Kenya: development of area, yields and production, 1969/71 to 1979/81

Crops:	Area Harvested 1969/71	Area Harvested 1979/81	Yield 1969/71	Yield 1979/81	Production 1969/71	Production 1979/81
	1000 ha		kg/ha		100 MT	
Foodcrops:						
Maize	1,383	1,240	1,489	1,580	2,060	1,939
Wheat	133	119	1,678	1,779	223	212
Sorghum	201	210	1,070	994	215	209
Beans & peas(dry)	565	550	472	426	267	235
Rice[1]	5	8	5,100	4,700	25	38
Oilcrops:						
Coconut					77	90
Sesame	8	20	401	406	3	8
Sunflower	4	14	718	1,095	3	15
Trop. Beverages:						
Coffee (green)	85	122	668	694	57	84
Tea (made)	30	61	1,246	1,532	38	93
Other Crops:						
Cotton (lint)	74	124	215	293	16	36
Sugarcane [2]	26	38	5,692	11,316	148	430
Sisal [3]	52	44	888	1,025	46	44

1) NIB and Ministry of Agriculture.

2) Production of sugar (centrifugal and non-centrifugal).

3) In production.

Source: FAO Production Yearbooks.

Table 3.3: IMPORTS, Principal agricultural commodities and derived products

Three-year periods	1975/77 Quantity (tons)	1975/77 Value (KL'000)	1980/82 Quantity (tons)	1980/82 Value (KL'000)
Food Products:				
Milk (dry)	1,019	335	9,436	4,342
Fish (products)	1,734	524	451	170
Wheat (unmilled)	40,242	2,063	79,009	7,789
Maize (unmilled)	140	6	163,441	14,198
Rice	3,343	407	5,897	1,400
Fruit & Vegetables	5,042	1,023	1,969	1,645
Sugar (refined)	31,506	4,686	1,908	495
Sugar (confectionary)	15	11	6	7
Tea	4,304	3,188	8,192	4,333
Total Food Products		13,712		39,319
Oils & Fats:				
Animal oils & fats	13,391	2,580	14,103	4,237
Vegetable oils & fats	33,187	7,340	91,346	19,525
Oils & fats, processed	4,045	1,085	1,486	571
Total Oils & Fats		11,006		24,333
Natural Fibers:				
Cotton yarn & thread	270	266	19	24
Cotton piece goods('000sqm)	(2,381)	1,140	(730)	513
Jute (incl.cuttings,waste)	9,690	1,145	10,925	1,565
Jute bags & sacks (x1000)	(710)	124	-	-
Total Cotton & Jute Products		2,675		2,102
Farm Inputs:	1974/76			
Insecticides,funcicides,etc.	20,074	4,833	46,454	9,600
Manufactured fertilizers:				
Nitrogenous	56,375	4,531	65,210	6,534
Phosphatic	37,257	3,352	29,939	3,757
Other	34,107	3,012	60,829	8,216
Total Insecticides, Fertilizers, etc.		15,728		28,107
Sum of the above imports		43,121		93,861
TOTAL IMPORTS		343,541		930,580

Source: Central Bureau of Statistics; Statistical Abstract 1983.

Table 3.4: EXPORTS, Principal agricultural commodities, and derived products

Three-year periods	1975/77 Quantity (tons)	1975/77 Value (KL'000)	1980/82 Quantity (tons)	1980/82 Value (KL'000)
Food Products:				
Live animals (number x1000)	(1,625)	1,138	(340)	1,523
Meat & meat prep.	9,133	7,039	2,020	2,909
Milk & cream	802	1,504	45	57
Butter & ghee	1,119	586	558	595
Eggs (number x1000)	(2,363)	71	(1,742)	82
Fish & fish prep.	639	403	979	822
Maize (unmilled)	80,726	3,788	653	133
Cashew nuts	8,990	755	6,038	1,668
Pineapples, tinned	31,746	7,033	39,757	11,784
Beans, peas, etc.	17,513	2,239	18,304	3,248
Other fruits & vegetables	N.A.	6,268	N.A.	15,257
Total Food Products		30,824		38,078
Beverages:				
Coffee	79,825	110,948	89,047	120,688
Tea	60,679	42,158	76,854	65,567
Total Beverages		153,106		186,255
Oil & Fats:				
Oil seeds & nuts	5,965	939	7,965	1,512
Anim. & veg. oils & fats	1,728	769	1,035	487
Total Oils & Fats		1,708		1,999
Natural Fibers:				
Wool, raw	1,293	577	1,424	1,048
Cotton, raw	1,952	953	2,192	1,414
Sisal fiber & tow	32,339	5,246	39,061	9,483
Textile yarns, fabrics	N.A.	1,938	N.A.	1,801
Total Natural Fibers		8,714		13,746
Miscellaneous:				
Pyrethrum products (flowers & extract)		5,923		8,274
Animal feeds	20,193	1,066	8,234	477
Hides and skins, undressed	12,491	7,333	10,862	8,885
Total Miscellaneous		14,322		17,636
Sum of the above exports		208,674		257,714
TOTAL EXPORTS		343,541		515,748

Source: Central Bureau of Statistics; Statistical Abstract 1983.

Horticultural produce, largely consisting of the relatively low-value and bulky items: pineapples and mangoes, could also be transported by air, but the air freight space to new potential markets (Gulf States) is limited.

The export of fruits and vegetables is, however, mainly a matter of adequate and regular supply. The diversity of Kenya's agro-ecological conditions, covering both temperate and tropical zones, makes it possible to grow a wide variety of fruits and vegetables, and sustained research and promotion efforts in this sector certainly offer interesting prospects.

3.1.2 Relative importance of crop production

Of the total contribution of the agricultural sector to the GDP of around 32% in 1981, almost half could be attributed to the foodcrop sector and 20% to the export crops. Table 3.5 illustrates the relative importance of major crops.

Foodcrops

Maize is the staple food crop of the Kenyan diet and is extensively grown throughout the high- and medium-potential agricultural zones in the country. It is also grown in semi-arid areas, and the variability of maize production in those areas is largely responsible for the considerable fluctuations of national marketed maize production over the years. Droughts in 1973, 1979, and 1980 contributed to production declines, while 1976/77 and 1981/82 were years of large surpluses.

Maize hybrids were first introduced in 1964, and thanks to an efficient distribution network, were readily adopted: about one-third of the total maize acreage is presently planted in improved varieties.

While large-farm maize plantings are entirely pure stands, not less than 70% of the smallholder maize was estimated to be intercropped, mainly with beans [1].

Pulses, including beans, cowpeas, grams, and pigeonpeas, are the second most important category among the foodcrops, both with regard to acreage and production value (Table 3.5). A wide range of mainly traditional varieties is grown, giving rather low yields. Little incentive has been given to farmers to produce non-infested pulses of uniform size and color, which Kenya could produce for export. But improved Rosecoco and Canadian Wonder varieties were released recently, adoption of which is now increasing.

Wheat is the third major food crop in respect to area harvested, but it is surpassed by Irish potatoes, bananas, and sugarcane in respect to the value of the annual production (1981). Wheat is produced almost exclusively by large and medium-scale farmers, mainly in Uasin Gishu and Nakuru districts in Rift Valley Province. It is mostly grown using mechanized techniques, and contributes relatively little to employment generation. Improved wheat varieties are largely used, supplied by the

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[1] IRS Survey Data 1974/75.

Table 3.5: The importance of major crops, with regard to area harvested, production value, and employment generation (1981 figures)

Crop	Total Area Harvested ('000 ha)	Rank	Total Crop Production ('000 ton)	Total Production Value[2] (Million Kshs)	Rank	Estimated Total Annual Employment Generated (Million Manhours)	Rank	Gross Production Value per ha (Kshs/ha)	Labor Inputs[3] per ha (Manhour)
Maize	1,230	1	2,560	3,700	1	860	1	3,010	700
Beans[1]	456	2	370	1,360	4	230	4	2,980	500
Cotton	142	3	27	100	14	210	5	700	1,500
Wheat	124	4	233	505	8	50	12	4,070	400
Coffee	117	5	93	2,050	2	290	2	17,520	2,500
Sugarcane	113	6	4,400	750	7	140	6	6,640	1,250
Sisal	108	7	41	170	12	133	14	1,570	300
Sorghum	105	8	90	200	11	53	11	1,900	500
Millet	75	9	62	103	13	67	8	1,370	900
Tea	75	10	91	1,610	3	240	3	21,500	3,200
Pigeon pea	69	11	36	60	16	28	15	870	400
Bananas	61	12	665	860	6	61	10	14,100	1,000
Irish Potatoes	61	13	644	950	5	67	8	15,570	1,100
Cassava	47	14	672	300	9	42	13	6,380	900
Coconuts (copra)	34	15	33	20	18	7	19	590	200
Pyrethrum	31	16	17	290	10	87	7	9,350	2,800
Cashew	29	17	20	35	17	9	18	1,210	300
Sunflower	14	18	6	12	19	10	17	860	700
Rice	11	19	39	94	15	20	16	8,550	1,800
Other crops	(314)		-	-		-		-	-
Total	3,216		-	13,169		2,484			

[1] Also including cowpeas & grams; area harvested underestimated, more likely to be around 0.7 or 0.8 million ha.

[2] Valued at producer prices

[3] Average figures for small- and large-scale farming. (IDS discussion paper No.273).

Sources: Provincial Annual Reports, 1981, Ministry of Agriculture; Agricultural costs and prices 1982; IDS discussion paper No. 273, by W.M. Mwangi: Alternatives for improving production, employment and income distribution in Kenyan Agriculture.

Wheat Research Station at Njoro. Demand will probably rise, with increasing urbanization.[1]

Sorghum and millet have received insufficient development support to have major impact. These crops are widely grown, as subsistence crops in drought-prone areas, but since maize is preferred by consumers and maize production technology is better known, their production is likely to decline, unless higher-yielding, more-palatable varieties can be introduced.

Rice is mostly produced by tenant farmers on the few large irrigation schemes, managed by the parastatal National Irrigation Board. It is mainly an urban food of the Asian community, and demand will probably remain higher than the supply in the foreseeable future.

Sugarcane production in Kenya is concentrated in three regions: the Nyanza Sugar Belt, near Kisumu, some new schemes in western Kenya, and a small area at the coast. The production is organized around 'zones', which comprise a sugar factory, the factory's nucleus estate, and the outgrower farms (usually members of cooperatives). Despite a slow adoption by outgrowers of more advanced techniques, and rather low prices (below the estimated long-term world market equilibrium price) and as a result of considerable investment, Kenya's sugar production tripled between 1970 and 1980.

Irish potatoes, bananas, and cassava are other important food crops. While considerable attention has been given to the selection and introduction of high-yielding disease-resistant potato varieties and the marketing and storage thereof, the reverse is true for cassava and bananas. Some research has been undertaken on the epidemiology of cassava mosaic virus by the NHRS in Thika, in collaboration with the coastal research stations, which are mainly involved in the distribution (bulking) of selected cassava material.

Horticultural crops

Although they do not feature as such in Table 3.5, they constitute an important element in the national food production and in the long term offer considerable scope for increased export earnings, if the industry is given the necessary support for development. Horticulture includes such fruits as pineapple, mangoes, citrus, avocadoes, passion fruit, and temperate fruits, and such vegetables as tomatoes, onions, cabbages, sweet peppers, etc., and it also includes cut flowers. Horticultural crops are important for both the national food supply and for export. The value of exports of fruits and vegetables alone amounted in 1980 to about Kshs 470 million[2]. The national production is likely to be at

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[1] Although A.H. Jacobs, in his 1983 consultancy report: (An overview of Population Dynamics in Kenya Rangelands (1969-1979)), argues that the dominant flow of migration within Kenya is not rural to urban but within the rural sector itself, and mainly from rural arable lands to rural rangeland areas, which would stress the importance in the future of such crops as sorghum and millet.

[2] Source: Annual Trade Report 1976-80: derived from M. Schluter: Constraints on Kenya's food and beverage exports.

least twice as high, which would bring horticultural crops to fifth place with regard to the total value of production. Further details of the horticultural industry are provided in Chapter 5.

Oilseeds are still relatively unimportant, except for the production of copra along the coast, although recently efforts have been made to promote the production of sunflower. Other potentially important oilseed crops include soybeans, rapeseed (in the wheat/barley area), sesame, and groundnuts.

Major export crops

The two main export crops, coffee and tea, have developed very well over the last decade, with export earnings of coffee reaching record levels in the period 1976 to 1978, and those of tea increasing steadily. The coffee and tea industry provide almost 40% of total export earnings. Kenya's present quota under the International Coffee Agreement is, however, well below its production level, and because of its high quality Kenyan coffee is not readily sold on non-quota markets.

Once the new compact Catimor coffee varieties are released, the area under Arabica in the highlands (now including marginal zones), could be reduced. At the same time Robusta coffee could be further introduced in the lowland areas of western Kenya, to cater for lower-quality markets. Similarly the tea industry could consider producing again some orthodox teas for export to the Middle-East and for the local market. Tea and coffee show the highest gross production value per hectare.

Other traditionally important cash crops, in order of present importance are cotton, sisal, pyrethrum, and cashewnuts. While there exists, from an agro-ecological point of view, considerable scope for the expansion of the area under these crops (Table 3.11), their production is still at a rather low level. Both production value per hectare and labor inputs per hectare are quite low, except for pyrethrum. This last product, of which Kenya is one of the major producers, has only limited market potential.

In Table 3.6 actual average yields obtained in two provinces in Kenya are compared with potential yields, as obtained in fertilizer trials, on farms, and on research stations, respectively.

Table 3.6: Yield gaps

	Actual yields[A]			Potential yields[B]	
	Sub-humid zones Western Province	Semi-arid zones Eastern Province	National average (1981)	On farmers' fields (data from fertilizer trials)	On research stations (data from fertilizer trials)
Maize[1]	2,500	900	2,000	3,500 - 6,000	4,000 - 8,000
Sorghum	900	800	850	2,000 - 3,500	2,000 - 4,000
Wheat	1,950	1,150	1,700	-	2,500 - 3,500
Beans	900	500	700	800 - 1,500	1,500 - 2,000
Pigeon peas	-	500	500	-	- 2,000
Cassava	18,000	6,000	14,000	15,000 - 20,000	25,000 - 35,000
Irish Potatoes	14,000	8,000	10,000	10,000 - 20,000	20,000 - 30,000
Cotton	220	160	200	-	500 - 1,500
Sugarcane	40,000	-	40,000	-	100,000 - 200,000
Sunflower	500	500	500	1,000 - 1,750	1,500 - 2,500
Tea (green)	3,200	2,500	3,100	-	6,000 - 8,000
Coffee[2]	400	600	800	-	1,500 - 2,000

1) Actual yields concern all maize; potential yields concern hybrid maize mainly.

2) Actual yields in Western and Eastern provinces are well below national average, which is about 1100 kg/ha for estates and 700 kg/ha for smallholders. Potential yields do not include new Catimor varieties, of which yield potential is considerably higher.

Source: A) Provincial Annual Reports 1981, Ministry of Agriculture.
B) Information derived from Farm Management Handbook of Kenya, Vol II.

3.1.3 Nutritional status and demand for food

Although no specific food consumption surveys have been carried out in the last decade, a considerable amount of information on food consumption has been collected in the 1974/75 Integrated Rural Survey (rural areas, excluding pastoral zones) and in the 1977 Urban Food Purchasing Survey.

A detailed analysis of the food consumption pattern in Kenya, based in particular on the 1977 Urban Food Purchasing Survey, has been made [1]. Table 3.7 provides data on the estimated per capita consumption of the major food items, which can be translated into the 1975 demand for those commodities.

Projections for total food demand in 1990 and 2000, based on the 1975 demand, and for the total demand as estimated in the National Food Policy Paper of 1981 are also given in Table 3.8.

Table 3.8 gives the percentage distribution of average daily intake of calories, protein, and fats, for some major food products. Maize contributes more than 50% of the total calorie intake, and also to a high proportion of total protein and fat intake. Cassava, sorghum, and millet are also important suppliers of calories. Meat, milk, and vegetable oils are contributing considerably to the average daily intake of fats.

3.2 Agricultural Production and Agro-ecological Zones

In compiling extensive data by district on farming potential and actual land-use systems, and presenting these in the Farm Management Handbooks, the MOALD/German Agricultural Team has provided the country with a very useful data base for agricultural planning. The distribution of agro-ecological zones over the country should determine to a large extent the location of both NRCs and RRCs. In the past research efforts were greater in the large-farm areas, and therefore a disproportionate number of research stations are still located in those areas (e.g. Rift Valley Province).

The establishment of some regional stations in smallholder areas has only modified the situation to a limited extent, since these stations generally did not obtain adequate support to perform their role as independent regional stations.

Unfortunately, the agro-ecological zones in Kenya do not exist in the form of broad belts, but instead consist of narrow strips around the respective mountain ranges, the exception being formed by the extensive arid zones in the northern and northeastern part of the country covering about 75% of the total land area. Even the agro-ecological zones along the coast consist of relatively narrow strips, following each other at short distance and showing considerable differences in agricultural potential. It nevertheless is possible to distinguish a certain number of more or less homogeneous zones, accentuated by similar land-use patterns.

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[1] Derived from Shah, M.M. and Frohberg, H. Food consumption pattern. Rural and urban Kenya. IIASA: Laxenburg, Austria.

Table 3.7: Estimated per capita food consumption and projected demand

Selected Food Items:	Average annual per capita consumption Rural[1]	Urban[2]	Total	Total demand 1975	Projected food demand[3] 1990	2000	Estimated total demand National Food Policy Paper (1989)
	Kg			'000 MT			
Wheat - bread & flour	9.6	31.1	12.1	163	339	433	493
Rice	1.4	6.1	2.0	26	54	69	90
Maize - flour	114.2	70.2	113.3	1,508	3,137	4,004	3,514 (grain)
Other cereal - flour	18.5	5.9	16.8	230	478	610	563
Irish potatoes	20.6	14.7	19.9	270	562	717	828
Other roots	66.0	16.2	60.0	814	1,693	2,161	-
Sugar (raw & cane)	11.6	18.9	12.4	169	352	449	571
Pulses (beans)	11.3	10.5	11.2	151	314	401	344
Vegetables	17.8	52.6	22.0	298	620	791	-
Bananas	11.5	20.2	12.5	170	354	452	-
Other fruits	16.4	23.0	17.2	233	485	619	-
Vegetable oils	0.8	2.3	1.0	14	29	37	-
Animal fats & oils	0.1	1.9	0.4	5	10	13	-
Butter	0.1	1.7	0.3	4	8	10	-
Milk	48.7	41.7	47.8	649	1,350	1,723	2,058
Beef	6.8	11.9	7.4	100	208	265	314
Other meat	5.9	6.5	6.0	81	168	214	-
Eggs	0.8	2.1	0.9	12	25	32	-
Fish	1.7	7.9	2.5	33	69	88	-

Nutritional status:

Calories per day	2069	2051	2068
Protein per day (gms)	56.9	57.8	57.1
Fats per day (gms)	27.1	40.4	28.7

1) Total rural population (1975, excl. pastoralists) 11,936,000

2) Total urban population (1975) 1,634,000

3) On the basis of a universal 5% annual growth rate; see also Annex 4 to this report.

Source: Derived from Shah M.M. and Frohberg H.: Food consumption pattern - Rural and Urban Kenya: IIASA, Laxenburg

Table 3.8: Percentage distribution of average daily intake of calories, protein, and fats, by major food categories

	Calories	Protein	Fats
Maize	53	51[1]	41
Sorghum/Millets	8	8[1]	5
Irish potatoes	2	1[1]	0
Cassava/Sweet potatoes	9	3[1]	1
Beans	5	12[1]	2
Milk	4	7	16
Beef and other meat	3	9	18
Sugar	6	0	0
Vegetable oils	1	0	9
Total percentage	91%	91%	92%
Daily intake[2]	2,068	57.1	28.7

[1] These proteins lack essential amino acids and therefore require complementary (animal) proteins.

[2] This excludes certain pulses and other commodities: total estimated daily calorie intake in 1975 was 2,205.

Source: Derived from Shah M.M. and Frohberg H.: Food consumption pattern - Rural and Urban Kenya: IIASA, Laxenburg

From east to west there is first the coastal area, consisting of a narrow strip of sub-humid, tropical lowland, followed by the semi-arid hinterland. That area gradually turns into the arid pastoral rangelands stretching from there to the north and the northwest.

At around 300 km from the coast there is a large semi-arid zone, covering the southern part of Eastern Province, and including the districts of Kitui, most of Machakos, and the drier parts of Embu and Meru.

A very important high-potential sub-humid zone is formed by the wetter parts of Embu and Meru districts and practically the whole of Central Province. Two other high-potential humid zones are found in Western Kenya, one of which is formed by Western Province and neighboring areas north and east of that province, and farther south the area mainly consisting of Kisii and Kericho districts, important tea-growing areas.

Another relatively densely populated zone, because of lower rainfall (semi-humid), but only of medium potential, is found around Lake Victoria, comprising most of South Nyanza, Kisumu, and Siaya districts.

Rift Valley Province shows a wide range of agro-ecological conditions with small pockets of humid high-potential zones, some semi-humid medium-potential and semi-arid zones and dry rangeland in the north and in the extreme south. For agricultural purposes a major distinction could be made between predominantly semi-humid zones, in the center, stretching approximately from Naivasha to Eldoret (a wheat-producing area), and the semi-arid area, situated northeast of the previous zone, and comprising Baringo, Laikipia, and West Pokot districts. That zone resembles the semi-arid zone in the southern part of Eastern Province.

While livestock activities are to a lesser extent related to the agro-ecological conditions, dairy cattle, poultry, sheep, and goats being found in most humid and semi-humid zones, as well as in semi-arid zones, the distribution of crops varies considerably by zone. In Table 3.9 some details of the distribution of the principal crops over the major producing districts are provided.

Maize is grown throughout the country, but the most important surplus production areas are in the western sub-humid zones. Wheat is predominantly found in Rift Valley Province, in Uasin Gishu and Nakuru districts; while sorghum and millet are important crops in the drier areas around Lake Victoria and in Eastern Province.

South Nyanza is the major producing district for cassava and sweet potatoes, while almost half of the national Irish potato production is grown in Nyandarua district.

Sugarcane is grown mainly in the Lake Basin area, pyrethrum in Kisii district and parts of the Rift Valley, and sisal in the dry areas of Eastern Province, in Coastal Province, and in the Muranga district of Central Province.

Coffee and tea are grown in sub-humid and humid areas respectively, both east and west of the Rift Valley, but coffee mainly on the eastern side and tea predominantly in Western Kenya in Kericho, Nandi, and Kisii districts.

Table 3.9: Principal crops in major producing districts[1]
(and percentage distribution of 1981 production)

Cereals					
Maize	Kakamega (12%)	Kericho (9%)	Bungoma, S.Nyanza, Kisii, Tr. Nzoia (7%)	Nandi, Machakos (6%)	Uasin Gishu (5%)
Millet	Kitui (35%)	West Prov. (24%)	S. Nyanza (8%)	Kisii (7%)	Kericho, Embu (6%)
Rice	Kirinyaga (81%)	Tana River (8%)	Kisumu (4%)	S.Nyanza, Kilifi (3%)	
Sorghum	S. Nyanza (24%)	Kitui (20%)	Siaya (18%)	West Prov. (17%)	Embu (6%)
Wheat	Uasin Gishu (36%)	Nakuru (28%)	Narok (12%)	Tr. Nzoia (6%)	Meru (5%)
Pulses					
Beans/cowpeas	West Prov. (24%)	Embu (11%)	Machakos (9%)	Kiriny/Nyeri (7%)	Meru (6%)
Pigeon peas	Kitui (60%)	Machakos (18%)	Embu (14%)	Meru (5%)	
Tuber & Roots					
Cassava	S.Nyanza (44%)	Siaya (16%)	Kilifi (15%)	West Prov. (9%)	
Irish potatoes	Nyandarua (45%)	Meru (18%)	Nakuru (7%)	Nyeri (6%)	
Sweet potatoes	S. Nyanza (40%)	Muranga/Siaya (11%)	Kisii (9%)	Machakos (7%)	
Oilcrops					
Coconut	Kilifi (57%)	Kwale (32%)			
Groundnut	S. Nyanza (75%)	West Prov. (17%)	Kisumu, Siaya (4%)		
Sesame	Kilifi (90%)				
Sunflower	West Prov. (34%)	Tr. Nzoia (20%)	Meru (18%)	Machakos (13%)	Kirinyaga (8%)
Fruits & Nuts					
Banana	Kisii (29%)	Kiambu (8%)	Meru (7%)	S. Nyanza, Kirinyaga, Muranga, Nyeri (5%)	
Cashew	Kilifi (56%)	Kwale (32%)			
Citrus	Kwale (56%)	Meru (22%)	Machakos (6%)		
Pineapple	Muranga (85%)	Kilifi (9%)	Kiambu (5%)		
Fiber Crops					
Cotton	Busia (26%)	S. Nyanza (15%)	Machakos (14%)	Meru (10%)	Coast Prov. (10%)
Sisal	Taita/Tav. (37%)	Machakos (31%)	Muranga (26%)	Kitui (6%)	
Beverages					
Coffee	Kiambu (36%)	Muranga (17%)	Meru (14%)	Kirinyaga, Nyeri (7%)	Machakos (6%)
Tea	Kericho (36%)	Nandi (16%)	Kisii (15%)	Kiambu (9%)	Muranga (8%)
Misc. Crops					
Sugarcane	Kisumu (44%)	Kakamega (30%)	S. Nyanza (15%)	Nungoma (7%)	
Pyrethrum	Kisii (47%)	Nakuru (23%)	Nyandarna (8%)	Kericho, K.Marakwet (5%)	

[1] For most crops no district information was available for Western Province.

Source: Derived from Provincial Agricultural Reports, 1981.

Cotton is grown in several of the semi-humid and semi-arid areas, with Busia district showing the highest production.

Sunflower is grown both in Western Province and Trans Nzoia district and Eastern Province.

Some crops show a heavy concentration in one or two districts; bananas in Kisii, pineapple in Muranga, groundnuts in South Nyanza, and coconuts and cashew in Kilifi and Kwale districts.

In Table 3.10 the actual area under major crops is compared with their potential extent, from an ecological point of view. It shows that crops such as millet, sunflower, sisal, and cashewnuts are, for various reasons, relatively under-represented in those ecological zones to which they are suited. Maize, coffee, and sugarcane have expanded considerably in the ecological zones most suitable for them and also in less suitable zones.

3.3 The Producers

Although some 37% of the total farm land is still owned by large farmers, the great majority (98%) of the farms consists of smallholdings, that are generally below 10 ha in size, and in high-potential areas below 3 - 4 ha. About a third of these smallholdings are in fact less than 1 ha in area (Table 3.11).

In between the smallholdings and the large farms, there is also a category of so-called intermediate farms, ranging from 8 to 50 ha in area. The highest number of small farms is found in Nyanza Province, followed by Rift Valley and Central Provinces. The great majority of large-scale farms are also found in Rift Valley and Central Provinces.

While the smallholder sector can be characterized by an intensive use of land and labor resources for the production of a variety of crops and the rearing of some (dairy) cattle and small stock, the large-scale farms are to a considerable extent underutilized in respect to land use, and are mainly involved in the mechanized cultivation of such field crops as wheat, maize, and barley and in the rearing of beef and dairy cattle. Table 3.12 provides an impression of the importance of some major crops grown by smallholders in the respective provinces. It shows, among other matters, that hybrid maize has been adopted most completely in Rift Valley, Western, and Central Provinces.

Much of the expansion of the agricultural production in the 1960s and early 1970s originated from the smallholder sector, and from the subdivision of large farms and the opening up of new land by smallholders.

This increased production was, however, achieved to some extent at the expense of soil erosion and a depletion of the nutrient content of the soil, aggravated by a decrease in fertilizer consumption after successive dry periods and as a result of rising fertilizer prices. There is also the tendency in some densely populated areas towards zero grazing of dairy cattle, whereby only little manure is returned to the land.

Table 3.10: The area under major crops, in relation to the extent of ecological zones, suitable and highly suitable for such crops

CROPS	Actual Area (1000 ha; 1981)	Suitable Ecological zones[1]:	Extent 1000 ha	Actual area as % of suitable area	Highly Suitable Ecological Zones:	Extent 1000 ha	Actual area as % of suitable area
Maize	1,230	LH1-3 UM1-4 LM1-4 L2-4	5,828	21	LM2 UM1-2,4 L2	1,846	67
Wheat	124	UH2-3 LH2-4	1,663	7	UH3 LH3	707	18
Sorghum	105	UM4-5 LM4-5 L4-5	6,330	2	UM5	717	15
Millet	75	UM4 LM5 L4-5	4,804	2	LM5	2,354	3
Irish Potatoes	61	N.A.			LH1	325	19
Sunflower	14	UM1-4 LM1-4 L2-4	4,622	0.3	UM4	768	2
Cotton	142	LM3-4 L3-4	2,144	7	LM3 L3	681	21
Pyrethrum	31	UH2 LH2	595		UH2	290	11
Tea	75	LH1 UM1	662	11	LH1	325	22
Coffee	117	UM1-3	958	12	UM2	333	35
Sugarcane	113	LM1-2 L2	752	15	LM1 L2	368	31
Sisal	108	UM4-5 LM3-4 L4	3,410	3	UM4 LM4 L4	2,231	5
Coconuts	34	L2-3	242	14	L3	219	16
Cashew	29	L4	654	4	L4	654	4

[1] UH - Upper Highland; LH - Lower Highland; UM - Upper Midland; LM - Lower Midland; L - Lowland.
1 - Humid; 2 - Sub-humid; 3 - Semi-humid; 4 - Transitional; 5 - Semi-arid; 6 - Arid.

Source: Derived from Farm Management Handbook of Kenya Vol. II.

Table 3.11: Number of farms by category and by province, and their percentage distribution by size (1979)

Province	Western	Nyanza	Rift V.	Central	Eastern	Coast	National Total	Total area 1,000 ha
				SMALLHOLDINGS				
Farm size (ha)			(percentage distribution by size)					
0-1	63	74	66	69	60	58	67	
1-4	32	23	20	27	33	31	26	
4-8+	5	3	14	4	7	11	7	
	100	100	100	100	100	100	100	
No. of farms (x1,000)	342	708	527	501	456	160	2,694	(3,216)
				INTERMEDIATE FARMS				
8-50 ha No. of farms (x1,000)	4	5	29	4	10	1	53	(1,040)
				LARGE FARMS				
(ha)			(percentage distribution by size)					
below 200	36	78	44	75	46	49	54	(112)
200-2,000	45	18	51	22	23	35	48	(895)
over2,000	19	4	5	3	31	16	6	(1,652)
	100	100	100	100	100	100	100	
No. of farms	11	116	2,327	1,067	163	51	3,735	(2,569)
				ALL FARMS				
Total No. of farms (x1,000)	357	829	2,883	1,572	629	212	6,482	(6,915)

Source: Central Bureau of Statistics; The Integrated Rural Surveys (1976-1979); Agricultural Census of Large Farms (1979 & 1980).

Table 3.12: Percentage of smallholders growing selected crops by province (1974/75)

	Western	Nyanza	Rift Valley	Central	Eastern	Coast	Kenya
Local Maize	74	80	59	95	99	94	86
Hybrid Maize	73	36	92	67	30	19	50
Beans	79	39	22	98	86	28	69
Irish Potatoes	-	1	8	86	52	2	32
Sorghum	37	75	1	1	16	2	30
Coffee	5	21	5	45	44	1	27
Tea	4	-	15	18	11	-	12
Pyrethrum	-	18	16	8	7	-	9
Cotton	20	17	5	-	2	5	9

Source: Casley D.J. and Marchant, T. Derived from Integrated Rural Survey; 1974/75.

Although smallholders have gradually intruded into the former large-scale farming areas, through settlement schemes, subdivision of large farms, farm purchase societies and squatters, there still exists a great disparity between the land use in these areas (Rift Valley Province in particular) and the mixed farming activities of smallholders in the densely populated areas.

On account of subdivision and the declining importance of the remaining large farms[1], excluding the estates and some ranches, the distinction between large farms and small family farms is becoming less important, and the time has come to give it less emphasis, and to define instead agricultural regions based on major agro-ecological characteristics and potential and broadly defined actual farming systems.

3.4 Agricultural Regions, and Regional Research Centers

The delineation of broad agricultural regions should form the base on which to determine where the RRCs should be located. Each of these regions should have a RRC and some may need subcenters to cater for agro-ecologically different sub zones.

Because of important linkages, such as those between research and extension, it would be necessary to use, as far as possible, district boundaries for the delineation of these areas (not necessarily provincial boundaries[2].

A possible regrouping of agricultural regions is provided in map 3.1. This allows for the following regions:

a) The northern and northeastern pastoral lands with a small center in Marsabit and the specialized rangeland research station in Kiboko (total area has about 1 million inhabitants).

b) The coastal lowland region, with the Mtwapa agricultural research station as a regional center, serving Lamu, Kilifi, Kitale, and Taita Taveta districts (about 1 million inhabitants).

c) The eastern dry land farming region, comprising Kajiado, Machakos, and Kitui districts and the dry parts of Embu and Meru, with Katumani research station as the regional center (about 2 million inhabitants).

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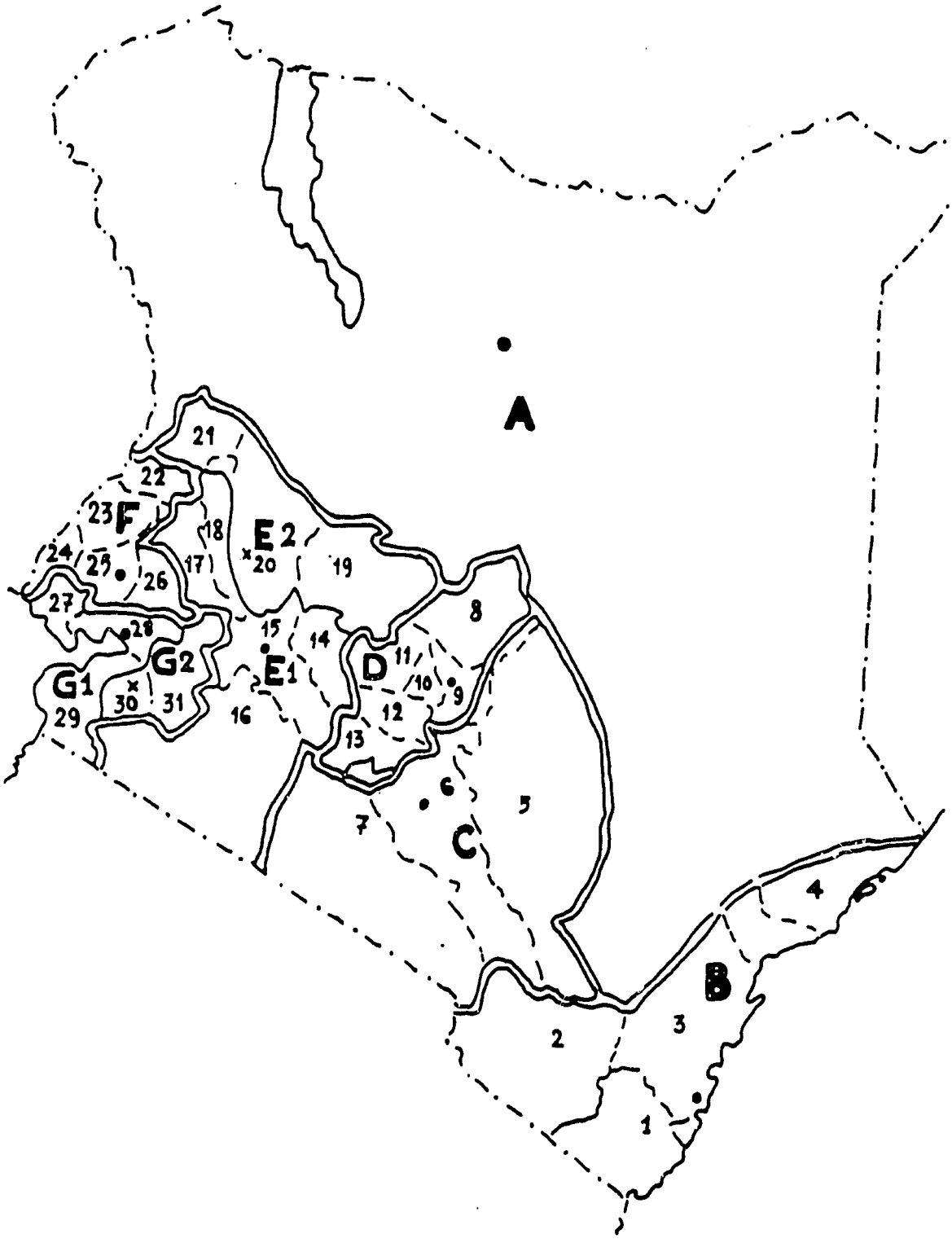
1) Number of large farms decreased to 3,700 in the period 1970 - 1980, while number of small farms increased to 2.7 million.

2) The IRS survey data showed that the classification by province does not give a clear picture of agricultural production. The classification by ecological zones defined for that survey gave a much better picture.

Fig. 3.1 Agricultural Regions



Legend to Map 3.1

Agricultural Regions and Districts Covered

		Total population (million)	Total land area sq. km.	Total agricultural area sq. km.
A -	Northern and northeastern pastoral lands.	1.0		
B -	Coastal lowland region. 1 - Kwale 2 - Taita 3 - Kilifi 4 - Lamu	1.0	44,136	25,785
C -	Eastern semi-arid region. 5 - Kitui 6 - Machakos 7 - Kajiado	2.0	67,383	37,110
D -	Central sub-humid region. 8 - Meru* 9 - Embu* 10 - Kirinyaga 11 - Nyeri 12 - Muranga 13 - Kiambu	2.8	18,069	10,661
E -	Rift Valley region.		31,069	22,009
	E1 Semi-humid sub-region 14 - Nyandarua 15 - Nakuru 16 - Narok 17 - Uasin Gishu 18 - K. Marakwet	1.7		
	E2 Semi-arid sub-region. 19 - Laikipia 20 - Baringo 21 - West Pokot		28,693	20,127
F -	Western (sub)humid region. 22 - Trans-Nzoia 23 - Bungoma 24 - Busia 25 - Kakamega 26 - Nandi	2.4	13,018	9,374
G -	South western region.		10,329	8,155
	G1 Semi-humid sub-region 27 - Siaya 28 - Kisumu 29 - South Nyanza	3.1		
	G2 (Sub) humid sub-region 30 - Kisii 31 - Kericho		6,127	5,300

* One third of Meru and Embu districts attributed to the Eastern semi-arid region.

d) The central sub-humid region, with high potential and a high population density, covering Central Province except for Nyandarua district, and the high-rainfall areas of Meru and Embu districts: regional center in Embu and/or Mwea Tebera (about 2.8 million inhabitants).

e) The medium potential semi-humid (wheat growing) and semi-arid regions in Rift Valley Province, including, respectively, the districts Uasin Gishu, Elgeyo Marakwet, Nakuru, Nyandarua, (part of) Narok, and the more northern situated districts Laikipia, Baringo, (Elgeyo Marakwet) and West Pokot. The latter sub-region should have a sub-center in Perkerra, which should maintain close scientific links with Katumani research center (in whole region about 1.7 million inhabitants).

f) The western high-potential sub-humid agricultural region, including the whole of Western Province and the adjacent districts Trans Nzoia and Nandi with the regional research center in Kakamega (about 2.4 million inhabitants).

g) The medium-potential semi-humid agricultural region surrounding Lake Victoria (South Nyanza, Kisumu, and Siaya districts) and the adjacent high-potential humid tea-producing districts Kisii and Kericho. The latter sub-region, with a sub-center in Kisii or somewhere between Kisii and Kericho, should maintain close scientific links with Kakamega research center. (In whole area about 3.1 million inhabitants.)

Taking into account the agricultural regions, as indicated above and shown in Map 3.1, a network of regional centers and regional mandates (district coverage) could be proposed, as shown in Table 3.13.

Table 3.13: Proposed regional stations, the major crops in the region, and the districts to cover

Main regional center	Important Crops[1]	Districts to cover[2]	Subcenter	Testing sites	Districts to cover[2]
1. Kakamega	Maize (33%)	Kakamega (LM1, UM1)			
	Beans (24%)	Bungoma (UM2-3, LM2)			
	Cotton (26%)	Nandi (wide range)			
	Sugercane (37%)	Busia (LM1-2)		(Alupe)	
	Sunflower (54%)	Trans Nzioa (UM4)		(Kitale)	
	Millet (24%)				
2. Kibos (presently cotton)	Maize (26%)	Kusumu (LM2-3)			
	Sorghum (48%)	Siaya (LM1-3)			
	Cassava (63%)				
	Groundnuts (79%)	South Nyanza (LM1-3)		(Homa Bay)	
	Sugarcane (62%)		Kisii		Kisii (UM1, LH1)
	Cotton (27%)				Kericho (LH1-2)
	Tea (64%)				
	Pyrethrum (52%)				
3. Njoro	Maize (18%)	Nakuru (wide range)			
	Wheat (85%)	Uasin Gishu (LH3)			
	Irish potatoes (62%)	Nyandarua (UH2-3)		(Ol' Jor Orok)	
	Pyrethrum (43%)	Narok (UM 5-6)[5]			
			Perkerra		Baringo (LM5-6)
					K. Marakwet (LM4-5)
					Laikipia (LM5, UM6)[5]
					W. Pokot (UM5, LM6)[5]
4. Embu	Maize (10%)[3]	Embu (LM4-5)			
	Beans (36%)	Meru (wide range)			
	Rice (81%)				
	Coffee (81%)	Nyeri (UM2, LK4)			
	Pineapple (85%)	Kirinyaga (LM4)			
	Cotton (10%)	Muranga (LM1, UM4)		(Thika)	
		Kiambu (UM2)			
5. Katumani	Maize (7%)[4]	Machakos (LM4-5)			
	Millet (36%)	Kitui (LM5, 1L6)			
	Sorghum (21%)				
	Pigeon pea (78%)	Kajiado (LM6)[5]			
	Cotton (16%)				
6. Mtwapa	Cashew (100%)	Kilifi (L4)			
	Coconut (100%)	Lamu (L4)[5]			
	Maize (4%)	Kwale (L4)		(Mariakani)	
	Cassava (18%)	Taita Taveta (LM4-5)		(Matuga)	
	Sesame (90%)				
	Rice (12%)				

Footnotes 1 In brackets percentage of national production
2 In brackets major agro-ecological zones; see table 11 for explanation of zonal categories
3 Including drier parts of Embu and Meru districts
4 Excluding drier parts of Embu and Meru districts
5 Only part of the district has agricultural potential

CHAPTER 4: PRIORITIES AND PROGRAM IN DRYLAND FARMING

4.0 Agroclimatic and Land Resources

4.1.1 Definition of dryland farming

The term dryland farming is to encompass farming of annual crops under natural rainfall conditions where seasonal moisture deficiencies cause significant restrictions to the length of growing seasons, to crop establishment and crop growth rates, and to harvestable yields. The constraints imposed by moisture deficits influence the choice of crop species and varieties, the husbandry of soils and crops and the strategies of the farming enterprise. The design of farming systems and research on systems and system components emphasizes suboptimal and uncertain water supply as a major factor limiting crop production.

4.1.2 Dryland farming environments

In general, the frequency, intensity, and duration of moisture deficits increase with increasing climatic aridity. Dryland farming environments tend to be synonymous with semihumid and semiarid climates and classified by rainfall and evaporation criteria. There are, however, no absolute geographic or climatic boundaries for dryland farming environments, and the principles and practices of dryland farming may also have important applications and affinities in regions with humid or arid climates.

In Kenya, dryland farming is primarily associated with those lands receiving 500-800 mm annual average rainfall.[1] There is an estimated area of 7.57 million ha (Table 4.1) which receives between 500 and 750 mm rainfall four years in five. This is approximately half of the total area in Kenya with potential for crop production.

Another classification of agroecological zones[2] interprets average rainfall, evaporation and temperature in a manner which essentially combines altitude and relative aridity (Table 4.2). Aridity classes 4 and 5 approximate both climatically and geographically the 500-700 mm rainfall zone of Table 4.1. The total area of agricultural land in these two zones is 7.12 million ha (Table 4.3).

On this basis, dryland farming lands occur in two main areas:

a) A narrow band parallel to the Indian Ocean coastline in the lowlands of Coast Province (1.52 m ha).

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1) Proc. of Symposium on Dryland Farming Research. E. Afr. agric. For. J. (1984), 44.
2) Farm Management Handbooks Vol. 3, IIA-IIC.

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Table 4.1. Area and percentage of total land areas receiving selected rainfall four years in five.

Rainfall (mm)	Area (m ha)	Percent
500	41.95	72
500-750	7.57	13
750-1,250	6.99	12
1,250	1.75	3
TOTAL	58.26	100

Source: Hargan (1964)

Table 4.2: Areas of Agricultural Land by Agroecological Zones and Provinces

Area in Sq. Km= 00 ha	NYANZA	WESTERN	RIFT[1] VALLEY	CENTRAL	EASTERN	COAST	TOTAL
Total area	12288	7037	70029	9960	44926	41932	
Agr. area	10129	5889	51497	7859	38674	34317	
TA 1			144		9		153
TA 2			67/211				67
							220
UH 1			880	271	34		1185
UH 2			2046	748	103		2897
UH 3			442	698	171		1311
UH 4					23		23
LH 1	623	140	1623	753	107		3246
LH 2	245	52	2460	129	131	40	3057
LH 3			5243	423	90		5756
LH 4			2802	645	159		3606
LH 5			3979	333	8		4320
UM 1	1144	725	693	566	249		3377
UM 2	328	221	1356	1015	411		3331
UM 3	299	315	809	621	714	118	2876
UM 4	23	807	4076	740	1930	103	7679
UM 5			6518	147	505		4170
UM 6			5972		1159		7131
LM 1	1653	1739	53				3445
LM 2	2347	1160	330				3837
LM 3	3677	607	139	109	1094		4626
LM 4	1175	114	988	451	4914	442	8084
LM 5	395		5414	9	16964	762	23544
LM 6						235	235
L 3						2187	2187
L 4					33	6509	6542
L 5"					1641"	8636	10277
L 6"			2372		7590"	13929	23891
Total TA 1 - L6	10909	5880	51484	7658	38672	34366	148969

[1]: Excl. Samburu District; northern and northwest parts of W. Pokot District.
": L5 + 1L 5, L 6 + 1L 6.
Agroecological Zones: TA-Tropical Alpine; UH-Upper Highlands; LH-Lower Highlands; L-Lowlands; 1-6 Aridity Classes

Source: Farm Management Handbook, Vols II A - II C.

Table 4.3: Areas of Agricultural Land by Agroecological Zones (km^2)

Aridity Class \ Altitude Class	Tropical Alpine (TA)	Upper Highlands (UH)	Lower Highlands (UH)	Upper Midlands (UM)	Lower Midlands (LM)	Lowlands (L)
1	153	1185	3246	3377	3445	
2	220	2897	3057	3331	3837	235
3		1311	5756	2876	4626	2187
4		23	3606	7679	8084	6542
5			4320	7170	23544	10277
6				7131	5116	23891

N.B. North and northeast Kenya excluded.

Source: Farm Management Handbook

b) A broad band of lower highland -- lower midlands which extends from Narok District in the southern part of Rift Valley Province, skirts the eastern slopes of the central highlands through the Machakos, Kitui, Embu, and Meru Districts of Eastern Province, and sweeps back through Laikipia, Baringo, and West Pokot Districts across the central and northwestern sectors of Rift Valley Province (5.36 million ha).

c) A third aggregate of discontinuous land areas occurs in the upper and lower midlands of Nyanza and Western Provinces (0.25 million ha).

4.1.3 Agroclimatic variability

The broad environmental classifications in para 4.1.2 conceal the substantial between-year and between-season climatic variability that is an important feature of dryland environments.

At one Kenyan location -- Katumani Research Station (UM4) -- mean annual rainfall has been 701 mm (27 years) and the range has been from 430 mm (1976) to 1,121 mm (1963).[1] The Katumani environment is one of bimodal rainfall (two wet seasons), yet the data indicate finite probabilities that the rainfall pattern in any one year may be effectively unimodal. Similar variability is indicated for a number of centers in Eastern Province.[2]

It appears likely that detailed analysis of agroclimatic variability throughout Kenya would reveal growing season characteristics that are more variable between years at specific locations in adjacent zones. This is certainly the case for rainfall; but variability in respect of other climatic parameters, such as maximum and minimum air temperatures, humidity, radiation, and evaporation may also be important agroecologically.

There is assumed to be a substantial overlap of zonal agroclimates in Kenya -- at least in terms of aridity. There will be significant moisture stress occurrences in many years in aridity class 3 and seasons of negligible stress in zones 4 and 5. There will be some years in aridity zone 6 when higher rainfall occurrences permit opportunistic crop production, and there will be run-on areas in zone 6 when some crop production can occur in most years. Differences between zones are assumed to be differences in the frequency of seasons in different aridity classes more than differences in the levels of aridity classes per se.

This variability has to be accommodated in farming systems and strategies and, of course, by dryland farming research. The matter will be discussed further in Section 3; but at this point it is noted that dryland farming research should not be rigidly constrained to agroclimatic zones, and that the principles and practices emerging from such research should have relevance to substantially larger areas than those lying only within 500-800 mm AAR zone.

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[1] Stewart and Faught, 1984. E. Afr. agr. For. J., 44.
[2] Stewart and Kashata (1984)

The scope of dryland farming research, while centered on zones 4 and 5, should therefore extend from zones 3 to 6. This broad definition of dryland areas is applied to subsequent discussion. In the classifications of Tables 4.2 and 4.3, the major dryland area of zones LH4 to L5 is extended -- in the cooler, more humid direction to UH3; in the hotter, more arid direction to L6. The total area of agricultural lands encompassed is then 12.4 million ha.[1]

The important implications of this definition are that:

- the winter cereal environment extend into drylands at high elevation (LH4/5) and overlap at least with the cooler more humid end of the main dryland environments (UM4);

- the main dryland environments of Eastern and Rift Valley Provinces have important affinities and continuities with environments of central Province; and

- specific emphasis in agricultural research is directed at crop technology for arid environments. This could have valuable repercussions on both crop genotypes and husbandry in semiarid environments.

4.1.4 Land suitability

Land suitability is a definition of the preferred land use for a particular area, based on interpretation of the climate, soil, and topography of that area. The agricultural land areas of Tables 4.2 and 4.3 include, without distinction, lands whose most appropriate uses range from continuous arable cropping to permanent rangeland.

Land suitability interpretations for Kenya are not available as area statistics for the defined agroclimatic zones within local government boundaries. Kenya Soil Survey is presently undertaking this work based on existing $1:10^6$ scale soil mapping.[2] More precise interpretations will be derived from 1:100,000 mapping of lands above 800 mm AAR and 1:250,000 mapping of 500-800 mm AAR zone, which have just commenced. At present, however, analyses of land suitability information cannot be used as a basis for establishing priorities for research related to different major land uses in the dryland farming regions of Kenya.

Land suitability information is very important for analyses of potential agricultural production related to national food policies. In section 4.3.1, an expansion of research directed at this objective is recommended.

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1) The pastoral areas of northern and northeastern Kenya are excluded.
2) Exploratory Soil Map and Agroclimatic Zone Map of Kenya, 1980; Exploratory Soil Survey Report No. E.1, Kenya Soil Survey, 1982.

For purposes of research planning and the formulation of priorities for dryland agriculture, the following are relevant:

- The Government's strategies[1] to provide food and employment for Kenya's increasing population are heavily dependent on increasing the area cultivated for field crops and on increasing production per hectare for all forms of land use throughout the dryland farming regions. The assumption that these can be achieved and that agricultural research will be a major agent for these changes establishes a high priority for dryland farming research.

- For the defined dryland farming regions the utilization of land to provide forage or fodder for livestock (cattle, sheep, goats -- milk, meat, fibre, and skins) or to produce food and fiber crops will all be major continuing requirements although their relative significance cannot be accurately predicted at this time.

- Horticultural plants (fruits and vegetables) will be significant contributors to the diversity of diets for farm families, but will not be major competitors for, or interactive users of, land resources other than in localized irrigation developments.

- The permanence of all agricultural land uses is dependent on the adoption of husbandry practices that will reduce soil erosion to acceptable rates and maintain soil fertility. The suitability of land for a particular use will therefore vary with the husbandry applied to that use. Husbandry in turn may be modified by research effort. This cyclic argument is an important justification for research if land use is to be intensified.

- Some of the semiarid and arid lands of dryland farming regions have been traditionally utilized by pastoralists. The extent to which these peoples will enter sedentary agriculture and there will be formal registrations of land titles is a major uncertainty in assessing realizable agricultural potentials. It also has a bearing on the controls that could be exercised over excessive grazing pressures on communal and open range.

4.1.5 Soils

The major agricultural soils of dryland farming areas are:

- Luvisols and Acrisols

  Widespread in semiarid areas. Poor structural stability of surface soil with tendency to surface seal, which leads to low infiltration and high erosion susceptibility. Subsoils have low porosity and water storage capacity.

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[1] National Food Policy, Sessional Paper No. 4, 1981;
Development Prospects and Policies, Sessional Paper No. 4, 1982.

- **Nitosols**

  Friable, porous red earths which occur in humid highlands. Favorable moisture storage, aeration, and structural stability with minimum erosion hazard.

- Ferrasols

  These are light-textured, strongly leached soils which are permeable and relatively resistant to erosion. They occur also as intergrades with luvisols and acrisols, and these intergrades tend to surface seal and are erosion susceptible.

- Vertisols

  Cracking clay soils with low profile permeability when saturated and erosion susceptible in this condition. Fertile soils of high moisture-holding capacity. Agriculturally undeveloped areas tend to be in aridity class 6, e.g., Athi Plains.

- Andasols

  Formed from recent volcanic materials. Fertility varies widely and some are extremely acid. Good physical characteristics but often occur on steep slopes.

- Planosols

  Imperfectly drained texture contrast soils on low-gradient country, e.g., Laikipia and Kajiado. Not considered suitable for arable agriculture, but significant agricultural settlement has already occurred.

Research that is soil-oriented or soil-related would logically be centered on the luvisols and acrisols, extending routinely to ferrasols and nitosols. A major factor in technology development is the degree of variability, both inherent and induced by different cultural histories within these groups, which must be encompassed to guide technology adoption at the farm level.

The research priorities for problems of vertisols, andasols, and planosols could be seen more clearly if land suitability and current use statistics were available for these soils.

The dryland potential of the vertisols deserves thorough exploration. The water retention properties of these soils may permit crop production in semiarid zones, provided husbandries are tailored specifically for them. Their resource potential is uncertain in that a significant proportion of undeveloped vertisols are in Masai lands.

The problems of the andasols are essentially related to mineral nutrition. Plant adaptation to acidity and heavy metal toxicities, pH amendment, and fertilization for nutrient deficiencies seem likely to be the component issues. These issues require a first stage of resolution by research to ascertain whether the costs of necessary inputs are feasible, before committing substantial research resources to them.

The problem of the planosols being primarily physical and secondarily nutrient infertility, it is difficult to conceive a rehabilitation technology which could be applicable to small dryland farms with limited cash and power available. The MOALD feels obliged to respond to pressures seeking improvement in the productivity of the planosols, but these responses should be very limited unless there are research options with reasonable probabilities of commercial success. Rehabilitation of these soils elsewhere in the world has usually been restricted to areas producing high-value irrigated commodities where the economy can carry the very high input costs of major physical and chemical amendments.

4.2 Dryland Farming Systems and Analysis of Problems for Research

4.2.1 Types of land use

The land-use systems within the dryland farming agroclimatic regions are diverse.

4.2.1.1 Extensive areas of natural rangelands are traditionally utilized by the cattle, sheep, and goat herds of pastoralists with uncontrolled intrusions of game animals. The condition of these rangelands is one of severe and increasing degradation, with invasion of dense woody weed vegetation (Acacia spp.), reduced ground cover of perennial grasses (Panicum, Eragrostis, Themeda, Digitaria, etc.), and soil erosion, although in some cases Acacia may provide palatable feeds for camels and goats. The extensive rangelands are virtually restricted to the semiarid and arid climatic zones (zones 5 and 6).

4.2.1.2 In semi-humid areas (zones 3 and 4), intensive annual cropping systems predominate. More than 60% of farms are less than one ha and more than 90% are less than four ha. These small farms are almost entirely hand-cultivated to annual crops, and livestock are grazed on or hand-fed with crop residues. There is no range or sown pasture, although small areas of fodder may be grown for cut-and-carry feeding. Fruit trees and vegetables are grown on borders or small plots for domestic consumption.

4.1.2.3 Between the extremes of intensive cropping and extensive range there are mixed crop/livestock systems which vary in the relative importance of crop and livestock to the economy of the enterprise and in the proportions of land committed to crop and forage production. In broad terms, as climate grades from semi-humid to semi-arid:

- individual holdings increase in size and change from registered titles to the occupation of unregistered areas by squatters or by families with traditional rights;

- cattle numbers increase from single females used for milk and draft, to animals used solely for milk plus one or two draft oxen, to breeding herds maintained for milk, meat, and some cash sales;

- the area of range accessible to livestock changes from small areas within individual farms which are unsuitable for cultivation, through communal grazing areas within intensive farming districts, to the extensive areas of open range; and

- the cultivated area on each farm tends to be limited by family labor and draft power to less than five ha, expecting of course, on the large farms where tractor power is economic.

In Eastern Province, which is predominantly dryland farming, there were, in 1979 (see Chapter 3), 456,000 farms less than eight ha in total area, 10,000 between eight and 50 ha, and only 163 farms larger than 50 ha. These proportions are fairly representative of the dryland areas of other provinces also.

4.2.1.4 There is virtually no rotation of land between crops and pasture, and on properties where both occur the two are normally maintained on discrete areas. There are some exceptions to this, principally in Rift Valley Province, where grass leys were rotated with annual crops on large farms in past years. These rotations are disappearing as subdivision of large farms continues. There are also instances in intensive agricultural areas where degraded cultivation has been retired to self-regenerated range of very low productivity.

4.2.1.5 The interactions between crop and livestock production in mixed systems are very important. There is competition between the output interactions in such areas as the structure of family diets, relative contributions to cash flow and net farm income, and the degree of risk-spreading achieved by diversification. Research which seeks to manipulate one has to provide for repercussions on the other.

4.2.1.6 There is very little interaction between crops and livestock in respect to soil fertility. The extent of nutrient return to cultivated lands via livestock excreta is very limited and, as noted above, ley rotations are insignificant in Kenyan small-farm agriculture.

4.2.2 Field-crop production in dryland areas

4.2.2.1 There are five main elements of field-crop management that are vital to high and sustained dryland crop production. These elements match certain basic agronomic principles which are concerned with optimization of physical and biological responses.

Elements	Principles
- Genotypic adaptation	- Select crop species and varieties thereof with superior performance across range of environmental conditions prevailing.

Elements	Principles
- Crop moisture supply	- Minimize the occurrence and severity of moisture stresses in adapted varieties.
- Mineral nutrition	- Provide optimal nutrient supply relative to environmental conditions.
- Pests and diseases	- Eliminate yield reductions due to insects, diseases, birds, and other pests.
- Soil erosion	- Maintain soil loss rate below rates of soil formation.

Kenyan dryland agriculture and its research needs are discussed in relation to these elements.

4.2.2.2 In dryland agriculture, there are two important operational characteristics of productive systems -- timeliness and flexibility. Timeliness is a matter of timing and speed of cultural operations. Failure to complete key operations at the earliest opportunity may result in such things as delayed or missed plantings, heavy weed infestations, and uncontrollable insect populations. The economic consequences may be serious. Flexibility relates to the ability to make late-stage changes to crop selection and husbandry in response to climatic variability.

4.2.2.3 It is frequently stated that the technology developed for large-scale mechanized agriculture is inappropriate for smallholder agriculture in Kenya. This is true in the sense that for diverse reasons, which are discussed later, smallholders do not apply the basic husbandry principles and operationally they lack flexibility and timeliness. It is very important to recognize, however, that high productivity cannot be achieved without in some way applying the basic agronomic principles. It may seem self-evident, but there can be no highly productive technology that does not utilize adapted varieties, plant at the optimal time, and achieve optimal stands, control pests and diseases, and provide adequate mineral nutrition. This statement should be emphasized, because implicit in some non-professional statements on the charter of agricultural research in Kenya, and dryland research in particular, there are often inferences that scientists have to discover new or substitute principles. The scientific challenge is to find alternative ways to enable smallholders to apply the established principles.

4.2.2.4 **Genotypic adaptation of crop species and varieties.** The range of crop species to be considered for utilization in dryland areas is wide. Some are grown to significant extents in climatic zones in which they are not considered to be climatically well-adapted (e.g., maize in LM5) and others appear to be underutilized in zones where they are well-adapted (e.g., grain sorghum in UM/LM4). Whatever the causes, and food preferences are significant amongst these, the MOALD is obliged to assess the relative merits and to direct appropriate effort at the genetic improvement and husbandry of all of these species for a wide range of environmental conditions.

Species are:

Wheat[3-5]	Maize[3-5]	Drybeans (*Phaseolus*[3,4])	Sunflower[3,4]
Barley[3,4]	Sorghum[4-6]	Cowpea[4,5]	Soybeans[3,4]
Triticale[3-5]	Millets[4-6]	Pigeonpea[4,5]	Cassava[3-5]
	Finger[4]	Mungbean (Gram)[4,5]	Sweet potato[3-5]
	Bulrush (Pearl)[4,5]	Chickpea[4]	Cotton[3,4]
	Foxtail[4,5]		
	Proso[5,6]		

Superscripts refer to aridity classes of the agroecological range for each species within the defined dryland region. There are a number of other temperate grain legume species that might be considered (e.g., *Vicia faba*, lupins (*Lupinus* spp.), field peas (*Lens* spp.) for cool sub-humid environments (LH3/4).

For most of these species there has been recent selection for varietal superiority and adpatation for aridity zones 3 and 4 within reasonably diverse germplasm collections -- some from IARCs. In fewer species (winter cereals, maize, and drybeans) important commercial varieties (including F_1 hybrids) have derived from Kenyan breeding programs. The present agriculture is therefore operating with semi-improved and, in some cases, quite advanced genetic material. Even so, there is significant use of local varieties and the reasons are not solely the inability of smallholders to purchase pedigree seed. With maize, for example, there is substantial production, in Eastern Province, of local varieties whose yield is less stable, whose yield potential under good conditions is higher, and whose average yield is probably lower than the comparative parameters of Katumani Composite B -- the developed variety. In Baringo, X'Sandai maize is preferred for its very tight husks and excellent resistance to bird damage.

4.2.2.5 The husbandry of annual crops is dictated by complete dependence on growing-season rainfall. On average, this varies from strongly to weakly bimodal patterns in different areas of the dryland region. Rainfall dictates final land preparation, time of sowing, the occurrence of stress during the growing season, and the significance of grain weathering problems at maturity. It is important to note that under these circumstances, husbandry strategies can only be tuned for particular seasonal conditions to the degree that those conditions can be forecast early enough to allow husbandry adjustment.

Recent work in Kenya[1] has explored the predictability of growing-season rainfall in UM4-LM5 environments from the characteristics of the opening rains for both "short" and "long" rain seasons. This work has led to proposals that plant populations and nitrogen fertilizer inputs can be manipulated advantageously for maize.[2] In many other dryland environments, (e.g., subtropics of Australia, temperate drylands of USA, Turkey) soil moisture conservation by pre-crop fallowing permits some manipulation of crop husbandry and a degree of independence from the uncertainties of growing-season rainfall. This is not a feature of dryland farming practice in Kenya. The possibility of accumulating soil moisture before planting decisions are made has been investigated.[3] In particular, a strategy of fallowing partway through the short rain to conserve moisture has been explored. Plantings made late in the short rain may then utilize this moisture to link up with the long rain, thus creating one long growing season per year in lieu of two short growing seasons. Both approaches (Stewart/Whiteman) appear worthy of further exploration and development.

At this time, however, commercial agriculture is totally dependent on unpredictable and highly variable growing-season rainfall conditions. One consequence of this is that crop establishment is unreliable. Many crops are sown broadcast into dry soil to avoid delayed establishment when rains commence. Very few smallholder crops are sown with machines. The Rural Technology Development Unit has developed a punch planter for maize. Poor germination quality of farm-retained seed is another significant cause of unreliable establishment.

For the major crops and the important intercrop combinations there are husbandry guidelines on planting times, seeding rates, plant populations, and spatial geometries. Given the unpredictability of rainfall and the difficulties of achieving positive control on-farm, these guidelines appear adequate, and research in these specific areas has little scope for real improvement.

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1) Stewart and Kashasha (1984)
2) Stewart and Faught (1984)
3) Whiteman (1984)

In-crop weed control is very important to crop moisture supply. Again, this principle is well-understood in Kenya, and cultural and herbicide strategies are defined for most crop and weed species. Small farmers may have great difficulties in achieving timely control with tillage or handweeding, and in many instances selective herbicides are beyond their reach financially.

4.2.2.6 Mineral nutrition

Nutrient inputs to cropping soils from farmyard manure (FYM) and inorganic fertilizers are limited and the general trends of nutrient fertility of these soils are downwards.

There is probably enormous variability between the nutrient status of individual fields, but this has not been documented nor are there collaborated diagnostic systems to support field-specific strategies. Much of the available information has been derived from MOALD research stations, whose cultural histories and hence soil fertilities are unlikely to be representative of the smallholder situation.

For non-leguminous crops, nitrogen deficiency is widespread and becomes increasingly yield limiting as age of cultivation and the yield potential of particular growing seasons increases. For all crops, phosporus deficiency is largely unknown; but there is evidently no widespread occurrence of acute deficiency or toxicity disorders.

Grain legumes are common in intercrops and as sole crops in crop rotations. There are some data from Katumani available to quantify the significant contribution these can make to the nitrogen requirements of succeeding maize crops. At the present levels of utilization in rotations, these contributions are probably merely slowing the rate of soil organic matter and nitrogen depletion.

Data available on FYM, e.g., long-term experiments at Embu Research Station, indicate that crop nutrient requirements can be met this way. Enquiry suggests, however, that the quantity and quality of FYM available to smallholders and applied by them is much less than that required to meet crop needs, let alone to arrest soil fertility decline to any significant degree.

The current position is therefore very dependent on imported synthetic fertilizers which are expensive relative to commodity prices, and consequently utilized much below the levels necessary to meet crop requirements.

There is considerable ignorance of the actual soil fertility situation at the farm level in Kenya. It must be admitted that the preceding conclusions are largely speculative. They are justified by apparent agreement between what is known for Kenya, and the general principles of soil fertility decline. The fundamental conclusion is that

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[1] Nadar and Faught (1984)

mineral nutrient depletion, and particularly nitrogen depletion, are major limiting factors to the productivity of dryland agriculture now; and will, unless there is a huge increase in the use of grain or forage legumes in farming systems, or an equivalent large increase in nitrogen fertilizer usage, become increasingly limiting.

4.2.2.7 Pest and disease control

Pests and diseases cause major yield losses in most crops. Table 4.4 list the important species.

For some of the diseases, e.g., stem rust in wheat, complete control can be achieved by maintaining specific resistance. For others there are useful levels of field resistance (non-specific or generalized), and many crop varieties have very low levels of resistance or are completely susceptible. Hygiene with planting material is a useful strategy for the vegetatively propagated crops -- cassava and sweet potato -- for virus control. With the exception of inexpensive seed treatments for seed and seedling rots and smut diseases, there are virtually no chemicals used for in-crop disease control.

The situation with respect to insects is quite serious -- particularly for the pulses. Useful levels of field resistance are available for some species, but their use in established crop varieties is very limited, and their effectiveness is of limited value under high pest pressures. There is great need for reliance on chemical support, but insecticide costs and lack of water and spraying equipment are prohibitive obstacles for most smallholders. Economic population thresholds and economic injury levels have not been determined for most species. Pesticide resistances exist, e.g., Heliothis and Tetranychus to pyrethroids.

Biological control is not deliberately practised. It has been suggested that exotic parasites and predators might be introduced for cassava mealy bug and green mite, which are thought to be early 1970 arrivals from Latin America. All other insect species are long established, with matching suites of natural enemies. Manipulation of beneficial insects by integrated pest management (IPM) systems is being developed for irrigated cotton. Similar applications of IPM for dryland crops and smallholder agriculture should be investigated.

There are other very significant pest problems. Birds (e.g., Quelea spp.) cause serious losses from small grains (sorghum and millets). High tannin sorghum varieties have limited resistance, but bird scaring -- particularly by children -- has been the traditional protection, and one which is no longer practicable where compulsory school attendance is enforced. Birds are a major factor operating against the more extensive use of sorghum and millets in semiarid areas; and possibly for the excessive use of maize.

Striga spp. -- the root parasite of sorghum and millets -- is a serious problem necessitating wide rotation of infested areas. Some genetic resistance is available in sorghum.

Table 4.4: Diseases and Pests of Major Crops in Kenya

Crop	Diseases	Pests
Wheat, Triticale	Stem, leaf, and stripe rusts (Puccinia) Bunt, loose, and flag smuts Root rots (Fusarium, Helminthosporium)	
Maize	Charcoal rot (Macrophomina) Turcicum leaf blight (Helminthosporium); Rust (Puccinia), ear rots (Fusarium) Maize mosaic, maize stripe, and sugarcane mosaic viruses	Corn ear worm (Heliothis) Stem borers (Chilo, Busseola) Maize weevil (Sitophilus)
Sorghum	Charcoal rot (Macrophomina), covered kernel smut (Sphacelotheca), Anthracnose (Colletotrichum) Gray leaf spot (Cercospora); Downey mildew (Perenosclerospora); Grain moulds	Shoot fly (Atherigona) Head caterpillar (Heliothis) Stem borers (Chilo, Busseola) Cut worms (Agrotis), Wireworms (Elateridae)
Millets	Stalk rots (Macrophomina), Smut (Tolyposporium) Blast (Piricularia)	
Drybeans	Bacterial blights (Xanthomonas, Pseudomonas) Black node disease (Phoma); Scab (Elsinoe) Rust (Uromyces); Root rots (Fusarium rhizoctonia) Bean common mosaic virus	Stink bug (Nezara) Pod borers (Maruca, Cydia) Coreid bugs (Anoplocnemis) Bruchid (Callosobruchus)
Cowpea	Leaf spot (Septoria), Yellow mottle (Cercospora) (Ascochyta); Powdery mildew; Rust (Uromyces)	Thrips (Megalurathrips); Aphids; Pod sucking bugs (Clavigralla); Pod borers (Helicthis)
Pigeon pea	Wilt (Fusarium udum)	Pod-sucking bugs; Bean fly; Thrips; (Heliothis)
Soybean	Cowpea mild mottle, and peanut mottle viruses Bacterial pustule (Xanthomonas); Leaf spot (Cercospora)	Stink bug (Nezara), Aphids, Heliothis
Cassava	Bacterial blight (Xanthomonas), Cassava mosaic disease	Grassopper (Zononcerus); Red spider mite (Tetranychus) Green mite (Mononychellus); Mealy bug (Phenacoccus)
Sweet Potato	Sweet potato mild mottle virus Sweet potato virus B	Sweet potato weevil (Cylas)
Cotton	Bacterial blight (Xanthomonas) Leafspot (Alternaria)	Mites (Tetranychus); Cotton boll worms (Heliothis, Earias spp., Pectinophora); Jassids; Stainers; Shield bugs. Whitefly; Aphids.

The general position is one which places great emphasis on breeding for insect and disease resistance as the most viable approach to control in dryland agriculture. One should not be too optimistic about the degree of control that is likely to be achieved in this way; nor the time it will take to obtain tangible improvement. Reasonable crop protection and pest management techniques need to be developed and applied with crop improvement as a strategy.

4.2.2.8 Soil erosion

Many of the soils of dryland regions are highly susceptible to water erosion. Degradation of cultivated soils and overgrazed rangelands is serious already. It is believed to have reduced food production per millimeter of rainfall by over 50% in the cultivated areas of Machakos, Kitui, and Embu Districts from 1970 to 1976.[1]

The magnitude and significance of soil loss in Kenya was reviewed by Barber.[2] Qualified though his interpretations were, of data on soil loss rates and catchment sediment yields, there is little doubt that cultivation and grazing as currently practised in semiarid areas have accelerated soil loss rates by one or two orders of magnitude over natural erosion rates. It is also clear that the productive life of substantial areas of intensively utilized lands is limited to a few decades unless there are major changes in land use.

There is a comprehensive design base for construction of protective structures such as cut-off drains, steep back-slope bench terraces, and waterways in cultivated lands. There are some uncertainties because the approaches are adaptations of North American design principles, but there is no reason to believe that serious errors exist. The technolgy is therefore available to intercept run-off water and either pond it for infiltration or drain it at non-erosive velocities down stabilized drainage lines. Extensive areas of cultivation have protective structures in place. Structures are not used in grazing lands.

Mixed crop/livestock systems place heavy demands on crop residues (maize stover, pulse hay) for feeding cattle and goats, and much fibrous material is also used for domestic fuel. The result is that virtually no mulches can be retained for surface protection prior to and in the early stages of crop establishment, when soil erosivity is high. These covers would have ancillary advantages on crop water supply -- particularly on the surface-sealing soils -- by increasing infiltration and reducing evaporative losses.

The lack of protective mulches means that structures are virtually the only defence against erosion. This brings back into focus two issues, viz.:

- the standard of construction and maintenance of structures, the extent of their implementation by smallholders, and their effectiveness in erosion control; and

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1) Government of Kenya, 1978. Marginal/Semiarid Lands Pre-Investment Inventory Report No. 1 Analysis and Project Identification.

2) In "Soil and water Conservation in Kenya" Proceedings Second National Workshop, Nairobi, 1982 ed. D.B. Thomas, W.M. Senga, 1983.

- the matters of terrace design and tillage methods for virtually zero runoff strategies.

These are both areas requiring research including on-farm measurements of soil loss rates. Sound data would establish a baseline for whether erosion can be stabilized by structural approaches, or whether major changes in rotation and residue retention practices will be essential in the medium to long term.

The whole area of soil and water management is one involving important interactions with crop production under dryland conditions and is dealt with in detail in Chapter 2. Reduction in runoff must be advantageous to crop water supply and may enable extensions of crop production into lower rainfall areas.

Soil erosion from grazing lands is a direct result of reduced cover -- both basal ground cover of grass plants and leaf litter -- which results in turn from excessive grazing pressures. Stock trampling of exposed surfaces is an additional factor. There does not appear to be any technology to redeem this situation without reducing current grazing pressures. It is theoretically possible to increase pasture production by injecting legumes as a source of nitrogen and by controlling woody weeds. These are relevant research objectives provided some measure of grazing control can be envisaged. On those registered holdings which have a proportion of pasture or range land, increasing the productivity of that land may enable some livestock pressure to be removed from the cultivated portions. This could permit plant covers to be retained on the cultivation in the main erosive periods of the year.

4.2.3 Forage production and utilization in dryland areas

4.2.3.1 In the mixed crop/livestock systems which predominate in Kenyan dryland farming, it is essential to consider both crop and livestock components and their interactions, in any comprehensive treatment of dryland farming research. The trends of intensified land use are to decrease farm size and to increase the cultivated proportion of the farm. The immediate consequences are increased grazing pressures on residual grassland, and increased dependency on cut-and-carry fodders -- both fodder crops and stovers. Some of the implications of this to crop production have been discussed in section 4.2.2 in relation to soil fertility and soil erosion.

4.2.3.2 In this section, it is relevant to consider the existing forage situation and the forage production technology pertinent to the dryland areas. This may be covered under the following headings but are further discussed in the Chapter on Animal Production:

- Pasture conditions;
- Pasture species -- grasses and legumes;
- Forage crops;
- Pasture/crop rotation.

4.2.3.3 Pasture conditions

The term "pasture" is used to distinguish areas of natural range or sown pasture on mixed crop/livestock farms, from the more extensive areas of rangelands in group ranches or subject to nomadic pastoralism.

The natural grasslands of the semiarid areas were evidently fire disclimaxes. Infrequent, accidental, or deliberate burnings prevented bush encroachment from such species as Acacia hockii, A. brevispica, A. polyacantha, Solanum spp. Grazing pressures have generally prevented fuel accumulations in recent years, and periodic burning of pastures has virtually ceased. There has been substantial thicket development which has greatly reduced the seasonal grass growth. This creates a downward spiral in which bush density continues to increase, further reductions in basak grass cover occur, and the role of fires as ecologically "useful" agents is further reduced. Bush control with machinery or arboricides can be effective, but these controls are generally uneconomic and are not used.

The recovery of moderately degraded pasture can be quite rapid (one or two seasons). Natural regeneration of grasses in severely degraded pastures is very slow (many years) even with controlled grazing. Reseeding can be effective with some seedbed preparation, provided strict grazing controls are maintained after seedling establishment. Enquiry discovered no known instances of successful pasture rehabilitation on small farms in semiarid areas, even though the technology and adapted grass species have been available for at least 20 years.[1]

The situation is one where the smallholder is unable to reduce the grazing pressure on his pasture, and his limited uncommitted monies provide better returns purchasing inputs for cropping than they do if invested in pasture improvement or rehabilitation.

It should be implied that all pastures are severely degraded. It is concluded, however, that the trends are inevitably in that direction and that there are presently no practicable and acceptable interventions by which smallholders might reverse that trend.

4.2.3.4 Pasture species -- grasses and legumes

The natural flora of East Africa are rich in long-lived perennial grasses, and it is unlikely that these can be greatly improved upon. Selection within genera such as Cenchrus, Panicum, Cynodon, Digitaria, Eragrostis, and Chloris has identified useful ecotypes which have been developed as cultivated varieties for seed production and pasture sowings. In general terms, their production is limited by water and/or nitrogen supply. It seems unlikely that any major gains can be achieved by further effort in their genetic improvement.

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[1] van Rensburg, H.J. (1969). Management and Utilization of Pastures, East Africa. Pasture and Fodder Crop Studies No. 3. FAO: Rome.

The dominant indigenous legume flora are spiny trees and shrubs, e.g., Acacia spp., which can contribute significantly to the diet of goats but not to the same extent to the diet of cattle. The exotic legumes that have been selected (Desmodium, Glycine, Leucaena, Phaseolus, Clitoria) appear to be adapted to the subhumid rather than the semiarid areas of Kenya. In terms of persistence through droughts and heavy grazing, and in relation to known adaptations in other parts of the world, Stylosanthes seems a more likely genus for semiarid areas.

It is not clear whether legumes are required in pastures to provide seasonal protein supplementation to livestock, to provide nigher levels of total digestible nutrients, or to increase nitrogen supply to associated grasses. For example, it may not be true that animal performance on natural grass pastures, at least on those soils that are inherently nitrogen fertile, will respond to legume incorporation. Clarification of these questions by careful analysis of what factors limit livestock production appears to be a fundamental base for well-oriented forage research. Separate analyses are required for milk and meat production, reproduction, and for the major livestock breeds.

The potential role of legumes in improving soil nitrogen fertility -- particularly of soils depleted by periods of cropping -- was referred to earlier (section 4.2.2.6) and is deferred to section 4.2.3.6 for further discussion.

The need for drought fodder reserves is obvious, and many see edible shrubs and trees, particularly leguminous trees, as an important adjunct to pastures for this reason. There are ancillary values to be gained from such species as sources of fuel wood -- short and long term. A start has been made in this area, but there is as yet no robust technology.

4.2.3.5 Forage crops

The intensification pressures lead logically to high-growth-rate annual or short-term perennial forages such as the favored Pennisetum purpureum, Lablab spp, and to dual-purpose species such as pigeon pea for grain and forage.

The enthusiasm for Pennisetum is difficult to relate to the apparent difficulties of vegetatively propagating significant areas in dryland environments, its lack of persistence through droughts, and the necessity for significant nutrient inputs to maintain its productivity. The perspective gained was that there is tremendous scope for cultivars that can be established readily from seed, e.g., forage Sorghum spp., hybrid Pennisetum, and for further development of legumes to associate with these forages or to provide protein supplementation for natural grassland.

The use of forage crops is primarily for milk production. The lactating animal performs best when nutritional fluctuations are avoided. Both natural grasslands and forage crops provide a relatively high plane of nutrition (quality and quantity) during the rainfall periods. Forage crops therefore tend to accentuate the seasonality of forage availability, and render the limitations of the dry seasons even more acute. The emphasis must surely be on developing a feed-year

program and the development of options to improve dry-season nutrition and milk production. This appears to demand either dry-season deferral (stand over) of forages which retain nutritive value, or fodder conservation or both.

The pursuit of yield per se in gramineous forage crops, e.g., Pennisetum, needs very careful analysis by Kenyan researchers in terms of its real practical and economic significance. There is, in most areas of the world, a strong tendency for the nitrogen yields of forage grass cultivars to be fairly constant on a specific site. This tendency may not be apparent in the results of annual yields from single experiments. Furthermore, it is extremely difficult without conservation and feedback, to utilize bulky forages fully and efficiently. Both factors tend to reduce the end-effectiveness of yield objectives.

4.2.3.6 Pasture crop rotation

In section 4.2.2, the erosion and declining nutrient fertility of cropping soils were discussed. In some areas of the world (including more humid areas of Kenya in the recent past), pasture leys have been used in rotation with crops to control both problems. There is currently no application of such rotations by smallholders in Kenya's drylands. The concept appears to fit the Kenyan situation in many respects. It is:

- compatible with mixed crop/livestock enterprises;
- achieves soil fertility maintenance;
- avoids importation of nitrogenous fertilizer; and
- normally is a low cash input system.

For these reasons there must be a priority for developing ley options through research. There are, however, some aspects of ley systems which may make them unsuitable or unacceptable to smallholders. For example, per hectare income and human food production from pasture are often less than they are from annual crops. Economically, ley rotations are more likely to be viable on large properties than smallholdings.

It is desirable to be aware of the pros and cons, but final judgments must be reserved until the options have been fully explored. There can be interactive benefits whose magnitude cannot be predicted, which may lift the economic and practical performance of the whole system into viability for smallholders.

The most obvious limitation to progress in this area, and to improving the productivity of pastures generally, is the limited number of suitable legumes for the semiarid sector of dryland environments in Kenya. There is evidently scope for evaluating a wider and more extensive range of germplasm than has so far been screened. This research should also investigate legumes and systems for utilization in the semiarid areas.

4.2.4 Agroforestry

4.2.4.1 The term "agroforestry" is used here in the broadest sense of trees on farms, whereas it is more normally restricted to concurrent use of land for timber, fuelwood, and agricultural production. The broader definition is taken to permit brief examination of the need for trees in catchment management, control of groundwater hydrology and salinity, shade and fodder for livestock, as well as the more conventional implications.

4.2.4.2 The incidence of salinization and landslips in the dryland regions may in some cases pose less of a problem. Consequently, afforestation to manipulate ground water, and the complex and costly research related thereto may be of a low priority.

4.2.4.3 There are significant areas of the more erodible topographies in the drylands whose land use would most appropriately be restricted to full-density forest plantings for fuel or light pole production. The environment is mostly unfavorable for sawlog production. Such areas are unlikely to be utilized this way unless they are controlled either by Government or by local communities. No substantial interaction with dryland agriculture is perceived, beyond some reduction in water run-on to agricultural lands lower in the landscape, and some amelioration of siltation in streambeds and reservoirs. Where such areas exist in smallholdings they would have to be publicly resumed. Smallholders could not afford the long-term investment and lack of initial income.

4.2.4.4 The scope for trees on private lands is therefore:

- as plantings on external and internal property boundaries: substitution of the ubiquitous Euphorbia borders with more useful species has considerable merit; and

- as low-density spaced plantings in pastures.

For both applications there is real potential to provide fuel and forage. There are, of course, real practical problems to be overcome, e.g., damage by grazing animals during establishment. The presence of trees which could contribute to the nitrogen balance of the system, provide shade, supplement diets from pod and leaf fall, and constitute a standing drought fodder reserve, would justify considerable joint effort by foresters and pasture agronomists.

4.2.5 Some general research considerations

4.2.5.1 Strategically, there are two major forces converging on dryland agriculture in Kenya. One is the urgency to increase food production and provide vocation for a population growth which is outstripping food supply and employment opportunities. The other is the fragility of dryland agriculture in terms of soil

fertility, economic viability, and production reliability. This fragility is greater for smallholders and for drier climates. The trends of agricultural settlement are increasingly in these directions.

4.2.5.2 Urgency demands realistic consideration of the response times which are available to achieve agricultural production targets, in conjunction with the contribution that research can be expected to make to the achievement of those targets within the times defined. There is no objective basis on which this can be done for Kenyan dryland agriculture. The individual value judgments that are made vary from defeatist to optimistic.

It is optimistic to assume that the targets set by food policy can be achieved simply because those targets coincide reasonably well with potential yields determined from field research or top farm yields. No commercial agriculture anywhere in the world achieves average productivities approximating such potentials under dryland conditions. Some dryland agriculture operates on average between one-third and one-quarter of potential.

It is defeatist, however, to assume that productivity cannot be significantly increased.

The immediate question is to define the orientation of research which is most likely to make the greatest contribution to commercial production in the shortest time.

4.2.5.3 In this regard it is proposed that an adaptive research emphasis on field crops must be the highest priority. This research should build on the existing technological base and should be primarily concerned with assisting farmers to apply established husbandry methods as positively and efficiently as possible. In simplified terms this means:

- rapid increase and dissemination of the best-adapted genotypes available for each crop;
- provision of high-quality seeds;
- achieving reasonable standards of land preparation and reducing rainfall runoff and erosion;
- firm guidelines on crop combinations, sowing times, seeding rates, and population adjustments;
- positive fertilizer usage adjusted on particular field and crop basis; and
- positive weed, insect, and disease control strategies.

There is an essential research component in all of these methods, but there is also a need for support and incentive systems which require government interventions, e.g., community prices, fertilizer and pesticide subsidies.

This proposal is asserting that there is a viable technology which is not being applied, which will not be replaced with alternative technology in the short to medium term, and which requires adaptive research and incentive schemes to facilitate adoption.

It should be noted that forage research is not included. The reason is that such research is unlikely to achieve significant gains in commercial animal production in the short term.

4.2.5.4 Fragility has very important research connotations.

a) First, there is the critical issue of the GOK's policy of emphasizing agricultural intensification by smallholding in dryland regions. The research position should be one of providing data on which these policies can be examined objectively by the GOK. Such data should include land resource suitabilities and real-time commodity production estimates on a seasonal basis that reflect variations in climatic conditions. The other research implication is that some component of research effort should be directed at systems to utilize semiarid lands most reliably and efficiently for food production. Such direction must not be constrained by the socioeconomic boundaries of indigenous agriculture. This reflects the very real possibility that smallholder development of semiarid lands may prove to be economically and ecologically disastrous and immensely costly in terms of human life and suffering.

b) Second, if fragility cannot be overcome by adaptation of existing technology, the solutions must then lie in substantial changes to farming systems requiring innovative research. Such research (which includes genetic improvement of crop, forage, and livestock species, soil-water management, systems for increasing soil fertility, and development of effective field resistances to major insects and diseases) is inevitably medium to long term. It is an essential investment by Kenya and one whose benefit should start to flow before the momentum of short-term gains from adaptive research starts to diminish.

4.2.5.5 In section 4.3, an outline dryland farming research program is developed for the plant production sciences. This program is based on the problems and perspectives discussed in sections 4.1 and 4.2.

It is not the purpose of this review to offer recipes or solutions for the problems of Kenyan agriculture. Rather, it is required to propose a research coverage and orientation from which the necessary solutions might flow most quickly and efficiently from the resources available. Inevitably, research proposals will imply some value judgments on probable solutions. It is therefore stressed that the proposals in section 4.3 will be of greatest value if they are challenged by in-depth, discipline appraisals which lead to their replacement by superior approaches.

4.3 Dryland Farming Research Program

In section 4.2 the analysis of current dryland agriculture identified numerous areas where technological change should be pursued or where additional knowledge is required. These areas may be covered by a series of eight interacting programs, each with several sub-programs. They should also be seen as complimentary to the research programs in soil/water management presented and discussed in Chapter 2. There may also be the need, in implementation, to integrate some of them with the soil/water management programs.

The programs are treated as general for the whole dryland region as defined in section 4.1. In appropriate places comment is made on the scope of climatic or geographic coverage, and it will be recognized that a number of programs are parts of broader national programs with similar objectives.

It will be noted too, that there are many components that are not normally included within "dryland farming". It would be conventional treatment to emphasize improvement of the more drought-tolerant crop species and matters of soil and crop husbandry pertaining to water/rainfall utilization. To restrict treatment to such a narrow base would preclude attention to the many more important elements and their interactions that are critical to productive dryland farming.

4.3.1 Strategic analysis program: (Reference section 4.1.4, 4.2.5.4)

Objective: To provide probabilistic analyses of crop and livestock production in relation to current and potential land resource use in the dryland region.

Brief description: Climatic variability between years is a major factor in crop, pasture, and livestock production and influences strategic policies at all levels. This variablilty would be analyzed retrospectively, and stochastic projections would be made to examine repercussions of particular strategies. The program has a number of sub-programs.

4.3.1.1 Land suitability assessment (See Chapter 2)

A program based on soil, climate, and topographic information which makes agronomic interpretations of land suitabilities for a range of uses and defines possible areas for each use. This sub-program would have linkage with Kenya Soil Survey and district agricultural personnel.

4.3.1.2 Current land use

Current land-use statistics require compilation in terms of land suitability classifications. A resources-oriented program is required to interface with the Central Bureau of Statistics and a number of divisions in the MOALD currently involved with collection of statistical information.

4.3.1.3 Agroclimatology (See Chapter 2)

This sub-program is primarily concerned with agroclimatic classification and analysis of climatic variability in Kenya. It would maintain the meteorological data bank for use in all MOALD applications, and would negotiate with the Bureau of Meteorology for an adequate grid of weather recording stations for agricultural applications.

4.3.1.4 Production statistics and simulation

The core of strategic forecasting is a facility for converting climatic data to crop and pasture production, and hence to project availaibility of human foods and animal products. This facility would be a statistically calibrated set of relationships (including "state of the art" plant production and water balance models) which could input climatic data and output production estimates.

The sub-program draws on personnel and information from other sub-programs of 4.3.1. to undertake district, regional, and national analyses of agricultural production systems and the stochastic projection of system performances. A component would be a systems analysis group, able to analyze food, energy, labor, or finance flows at the micro (farm) or macro (industry or regional) levels. These persons would have direct linkages with regional socioeconomists in program 4.3.8., and with marketing personnel of MOALD.

Location: The core personnel of this program would be located in Nairobi (NAL/Muguga) with adequate computing facilities. These persons would provide in-depth support for regionally deployed scientists in respect of their special knowledge areas, and in turn would rely on regional personnel for data collection and component science. Commissioning of strategic studies might be from MOALD or from regional research centers.

4.3.2 Crop improvement program

(Reference sections 4.1.3.4 and 4.2.2.4/5/7)This program is discussed in more detail in Chapter 3. Coverage here is restricted to emphases required for dryland environments.

Objectives: To increase the productivity of crop plants by genetic improvement and by improved crop-specific husbandry practices, and to ensure that the quality of products meets market requirements.

Brief description: This is a very large program with a number of substantial sub-programs, each based on individual crops or crop groups (see Table 4.5).

Adaptation: The experimental approach to strain and cultivar evaluation needs to provide for:

- a wider environmental range than the traditional boundaries of crop adaptation;

Table 4.5: Crop Improvement Sub-Programs

A		B		C		CENTER LOCATION
4.3.2.1	Wheat	4.3.2.7	Triticale	4.3.2.16	Barley	
		4.3.2.8	Chickpea	4.3.2.17	Sunflower	Njoro
		4.3.2.9	Temperate grain legumes	4.3.2.18	Soybean	
4.3.2.2	Maize (late)	4.3.2.10	Pennisetum (grain and forage)			Kitale
	Maize (mid-early)					Embu
4.3.2.3	Cotton					Mwea Tebere
4.3.2.4	Drybeans (Phaseolus)					Thika
4.3.2.5	Sorgium (grain and forage)	4.3.2.11	Millets (except Pennisetum)			Katumani
4.3.2.6	Pigeon pea	4.3.2.12	Tropical grain legumes			
		4.3.2.13	Cassava			Mtwapa
		4.3.2.14	Sweet potato			
		4.3.2.15	New crops			Muguga

- selection within variable populations for adaptation to the extremes of the environmental range; and

- interpretation of cultivar adaptation in genotype x environment terms, rather than as discrete specific adaptations.

In practical terms, this means that all sub-programs, but particularly the breeding programs, must make provision in choice of parents and in choice of sites for early generation selection, so that there is a reasonable probability that adaptations will be extended to the most extreme environments where a crop species may be grown.

The temperate field crops (cereals and grain legumes, but particularly wheat and triticale) should be examined and developed for adaptation to drier and warmer environments, i.e., LH 4/5 and UM/LM 4. Some part of the maize program (mid-early) should retain a specific emphasis on aridity class 5 and the sorghum program should retain some pressure for adaptation to aridity class 3.

These objectives require careful consideration of experimental sites, so that broad adaptation is pursued. A component of farming systems research should be a comparison of production from alternative crop species, each grown according to their specific requirements.

Physiology

The physiology role should be directed at genotype x husbandry (planting time, population) combinations that may yield a better 'fit' of a crop to the variable environment. Some breeding may be required to create the genotypic diversity needed.

A complementary role is to develop the basic methods for relating weather conditions to crop yield. Such relationships become the framework for treating effects of climatic variability in many areas of field research and are the key to linkages with strategic analyses via sub-program 4.3.1.4.

Physiology should not be directed at basic studies of environmental response, stress reaction, and stress resistance. These approaches should remain the province of the IARCs and developed countries until they achieve advances of real applied value.

The physiology sub-program has important linkages with program 4.3.4.

Agronomy

The agronomy role in the crop improvement context is one which recognizes that there is a crop (and sometimes genotype) specific husbandry, which must be flexible in a disciplinary sense, but always integrating.

A priority task for agronomy in many crops is the development of on-farm strategies for fertilizer use. This has obvious interactions with soil chemistry and plant nutrition expertise in program 4.3.3 and in Chapter 2.

Both agronomy and physiology must cope with the breadth of environments discussed under "Adaptation", and the technology should be robust in respect to climatic and farm-to-farm variability.

Insect and disease resistance

It has been asserted that genetic resistances to insects and diseases must be the main thrust of control research for dryland crops because of the risks and the marginal profitabilities associated with the high costs of applied pesticides.

In pursuit of such resistances in breeding programs, there must be in-depth support from pathology and entomology to research the biology of particular organisms, to develop appropriate methods for screening for genetic resistance, to developing systems to utilize legumes. It should include documentation of the short- and long-term effects of grain and forage legumes on nitrogen accretion to soils and on the production of other crops in rotation sequences. It is research which, if done thoroughly, should not require intensive regional repetition. Regional research could then focus on the screening and development of integrated pest management approaches.

4.3.3.5 Specific soil problems

From time to time specific soil problems will arise which may require significant research effort beyond that covered by core programs. These problems require careful analysis and prioritization before research commitments are made. It is important that the momentum of major core programs is not impaired by engaging in such research. On the other hand, it is appreciated that MOALD cannot avoid its responsibilities to industry.

The usual approaches to such problems are at one of two levels:

a) For major problems:

- establishment of specific new projects with additional and/or redeployed personnel and resources already committed to core programs.

b) For minor problems:

- utilization of experts already committed to core programs as collaborators or consultants in problem analysis, design of research and interpretation of results with the main work executed by regional centers' agronomists and sometimes extension personnel.

In the course of this review two soil problems were proposed - those of andasols and planosols - and these appear to require further analysis. In-depth review would probably reveal others, and it would be an unusual agriculture if specific problems were not continually arising.

Planning for soil fertility research must, therefore, retain a contingency element, so that total research resources are not locked into core programs. Program 4.3.8. and those discussed in Chapter 2 provide some capacity to respond flexibly to emergent problems of this nature.

4.3.4 Soil and water management program

Objective: To develop soil surface husbandries for crop production systems that maximize the economic conversion of rainfall to crop product and minimize soil degradation via erosion or structural deterioration.

Brief Description: The subject is examined in broader context in Chapter 2. It will be apparent from the objective that this is another area of integrated disciplinary research.

4.3.4.1 Erosion and runoff assessment

The methodology of erosion and runoff measurement is complex, but it is basic to evaluation of the long-term effects of soil/crop husbandry systems. This sub-program requires in-depth expertise in this field, so that the limitations of the various methodologies are fully appreciated.

Given such expertise, the priority task is to establish a realistic picture of runoff and soil loss rates on smallholder properties. The performances of soil conservation structures should be analyzed for the range of designs and on-farm maintenance levels which exist. It will help to determine the relative emphases that should be given to implementation of soil conservation works programs, to structural design innovation and to the development of agronomic practices in support of structural works.

A core expertise should be centrally located, e.g., at NAL, but some expertise should be regionally deployed in regions of substantial erosion hazard (Embu, Katumani).

The assessments should be extrapolated from periods of runoff measurement to periods of rainfall record and must cater for the episodic nature of major erosion events. The regional scientists will have major consultative and collaborative inputs into sub-program 4.3.4.2.

4.3.4.2 Surface management

This sub-program provides for specialized research in the areas of:

- innovation in design of soil conservation and pondage structures;
- tillage practices (including residue management and fallow strategies); and
- crop establishment and seedbed conditions;

but is primarily an integrating program which recognizes the important interactions between these three areas in practice.

Structural design

A particular objective is the development of 'pondage terraces' designed to virtually eliminate runoff, and hence erosion. Unless this can be accomplished on soils of high erodibility, erosion cannot be stabilized without crop residue retention and possibly pasture ley rotations. If it can be accomplished, it has important secondary benefits to improving crop water supply. An important extension of pondage structures is that of run-off farming in low-gradient semi-arid lands, and research projects of this type in 55 mm AAR areas of Eastern and Rift Valley Provinces should be considered.

Tillage practices

There does not appear to be much room for manipulation of smallholder tillage systems. It is recommended that tillage research should be designed to characterize the water balances and crop water supply of current agricultural systems; and to explore and characterize other options for tillage methods, residue retention, fallow lengths, and crop and ley rotations in crop water-use-efficiency terms. The options should be unconstrained by convention and by the limitations of smallholder husbandries, but should cover those husbandries as well as those of fully mechanized systems. The work will necessitate some recourse to alternative crop genotypes - particularly if fallow lengths and planting times are being manipulated. This may seem somewhat undisciplined. It is, however, considered that the main opportunities to increase dryland crop production substantially lie in this area and that of fertilizer use. The potential of various options must be known before final judgements are passed on their practicability.

Crop establishment

As an adjunct to surface management research, crop establishment research is required because many tillage options affect seedbed conditions. Special attention to overcoming establishment problems may be required before an option can be properly evaluated. Expertise required may range from seed physiology to agricultural engineering.

Location: The surface management program envisaged is a flexible amalgam of those specialized areas which draw on many other disciplines (including plant pathology and entomology) as required. Since the program must infer long-term expectancies from short-term experimentation, it should utilize various levels of computer modelling for interpretations and evaluations of strategies. This implies a close liaison with personnel of sub-program 4.3.1.5. This may seem unnecessarily sophisticated, but the 'state of the art' is now such, that the power of applied research can be greatly increased by relatively simple models.

In the dryland farming context, one major program on luvisols/acrisols should be considered (Katumani), but two outlier programs are recommended in collaboration with Baringo District (LM5) and Mtwapa to access CL5 or LM5. The CL5 environment is preferred. A third but lesser program should be considered for vertisols (UM 5/6).

4.3.5 Forage improvement program
(Reference section 4.2.1.3/7, 4.2.3/4)

Objective: To increase livestock production by improving the continuity, quantity, and quality of forage available from forage crops, sown pasture, and natural rangelands; and at the same time increase the contribution of legume nitrogen and improve the supply of domestic fuel wood.

Brief Description: The boundary between this program and the livestock feeding systems program (4.3.6) is arbitrary, and in practice there must be no dysfunctional separations of plant and animal research. The two programs have a collaborative interface at the point where forages are utilized by animals, and consultation between the two in research planning is essential.

4.3.5.1 Forage crop selection

In programs 4.3.2.5 and 4.3.2.10 (*Sorghum* and *Pennisetum* respectively) it was proposed that forage objectives be included as a component of the crop breeding programs. The pigeonpea breeding program (4.3.2.6) could also have a forage component. The objectives are for annual or short-term perennial high-growth-rate forages (grasses and legumes) which are easy to establish on cultivated land, and which meet some part of feed-year requirements as defined by program 4.3.6. Temperate forages, such as oats and lupins, should not be overlooked.

This sub-program would be conducted by pasture agronomists interfacing directly with plant breeders for sorghum and pennisetum; and operating selection programs for other species. The agronomists could also undertake forage crop husbandry research as required. Superior lines would move quickly into joint feeding experiments with program 4.3.6. It is very unlikely that nitrogenous fertilizers for forage production and research in this area would be supported. Soil/water management research (4.3.4.2) should evaluate the reliability of or extending the growth period of annual forages.

4.3.5.2 Forage legume selection

Three morphological types of forage legumes are required, viz. herbage, shrubs and trees. This diversity indicates matching specialization in selection programs.

It is fundamental that legume adaptations are evaluated with effective rhizobium strains for host species x soil types combinations involved. This requires an applied legume bacteriologist for Kenya. Collaboration with the Department of Soil Science - University of Nairobi will be particularly useful in this regard. It is also desirable that the soil nutrient conditions under which legume selection is being conducted are known. These should, therefore, be linked with sub-program 4.3.3.1. If selection is seeking tolerance to soil mineral deficiencies,

e.g. phosphorus, it is necessary to anticipate problems of livestock nutrition which will have to be addressed in program 4.3.6, when adapted legumes of low mineral content become available.

It is not appropriate to develop selection objectives and criteria in this report. However, it is clear that legumes will have to be persistent and resistant to mismanagement - including heavy utilization pressures. If husbandry finess is requied to sustain a legume stand, that legume is unlikely to survive in commercial use.

Opinions vary considerably on genotype x environment considerations in the choice of experimental approaches for herbage plants. One extreme opinion stresses specificity of adaptation, and hence argues for a large number of soil and climatic combinations at a very early stage of screening diverse germplasm. The other exteme opinion stresses broad adaptation to be judged from a small number of locations covering the total environmental range. The situation in Kenya appears to require a compromise with the following features:

- primary screening programs examining wide botanical ranges of material for broad adaptation at three (or four) locations, e.g. Naivasha, Katumani, Kiboko, (Embu);

- secondary screening program with promising individual genera or species, using increased site replication to provide a more intensive soil x climatic coverage of the apparent adaptation range;

- tertiary programs, mostly cultivar-specific and agronomic in nature, to resolve such questions as seed production, establishment methods, suitability for particular utilization systems;

- development programs in collaboration with extension personnel to inject superior legumes into on-farm uses, to devise practicable ways of using these legumes and to obtain data on their performance and economics.

This implies a large total effort - larger than the priority relative to other programs may warrant. It is envisaged that the major effort will be in primary screening, and that secondary and tertiary programs will not be developed unless the potential for end-effective outcomes can be foreshadowed. The development phase is essential and may often be entered directly from primary screening without making a research program out of issues that can be handled more practically.

It is, therefore, important that the agronomic treatment and evaluation of entries in primary screening be very thorough, so that the potential value of lines is correctly and imaginatively assessed. Continual effort should be directed at germplasm collection, and direct linkages should be maintained between Kenyan agronomists and international workers in forage plant improvement.

4.3.5.3 Soil fertility trend in pasture

The priority for research in this area is lower than that for analogous work on arable land in sub-program 4.3.3.3. However, it is an area where knowledge could influence the direction of several areas of research, and some basic studies can be justified for that reason.

Studies might be considered on:

- the determination of seasonal dry-matter production and nitrogen yield of grasses by soil nitrogen mineralization;

- the significance of indigenous legumes to soil nitrogen accretion in grasslands and to the nitrogen supply of associated grasses;

- the nitrogen contribution of exotic legumes;

- the development of farming systems to utilize additional nitrogen from forage legumes to greatest economic advantage.

One small and specialized group (2-4 scientists) attached to sub-program 4.3.3.3 is required. The favored location for relationship with crop and pasture scientists and for a semi-arid emphasis is Katumani.

4.3.5.4 Bush control

Whether for eventual use by GOK-conducted programs, or by farmers, it is desirable to have up-to-date knowledge on methods of bush control and range rehabilitation, whether by arboricides, mechanical methods or by natural agents such as fire. The methods should encompass reseeding and natural grass regeneration.

The center for this work is logically Kiboko. It is mentioned in the dryland farming context, because bush encroachment is a problem for smallholders with natural pasture, and these farmers may be able to utilize control methods that are inappropriate for extensive rangelands.

This indicates a core program on bush control at Kiboko, with outreach programs in collaboration with other appropriate centers.

4.3.6 Livestock feeding systems
(Reference sections 4.14., 4.2.1.3/6, 4.2.3)

Objective: To increase productivity of the livestock component of mixed farming systems by improving the efficiency of utilization of concentrate feeds, fodders, forage crops, and pastures by cattle, goats, and sheep.

Brief Description: In mixed farming systems animals are maintained for meat, milk, fiber, draft power, and cash sale. They are grazed and hand fed, and they utilize natural pastures, forage crops, crop stovers and conserved feeds, grains, and concentrates. Their movement and management utilizes farm labor and influences the redistribution of nutrients on the farm. This program encompasses these factors and their interactions. Interactions between livestock breeds and feed sources are better studied in the context of breed evaluation.

The program is an integral part of the animal production program discussed in Chapter 6. It will be obvious from program 3.4.5. that the objectives of forage plant improvement must be defined with a knowledge of current feeding systems and livestock production objectives; and that the selection and development of new forages must involve research with those plants in the feeding systems context. As with crop research, while it is necessary to emphasize relevance to smallholders and to current livestock systems, the research must not be so constrained by this that valuable opportunities for change are not recognized.

There is no substitute for animal production experimentation in the field - whether on-farm or research station. This is costly, but it is the only way to ensure that realistic objectives are set and are practically assessed.

The sub-programs envisaged are as follows:

4.3.6.1. Evaluation of new forages

This sub-program undertakes animal production research in collaboration with plant scientists of sub-programs 4.3.5.1/2.

At the present time there do not appear to be many major opportunities for systems research, but the following are priority areas:

- utilization of Leucaena in semi-humid environments (800-1200 mm AAR): systems include planting on borders, and as widely spaced rows in crop land for supplementation of milking cows and oxen and for drought feeding;

- combination of Desmodium with Pennisetum in forage systems in semi-humid environments (nitosols);

- evaluation of Stylosanthes scabra and S. hamata under high grazing pressures in semi-arid grasslands.

On-farm development work in the same areas is warranted.

4.3.6.2 Analysis of current livestock feeding systems

There is a paucity of data on the diets of livestock (components, quantity, quality) run by smallholders, on the nutritional status and production of their livestock, and on the nutritive values of the various feed sources throughout the year. Good data of this type are an invaluable base from which to identify limiting factors and to seek productivity improvements. It should be collected in conjunction with agronomic data on levels of forage utilization, dry matter production, and quality-related parameters.

This is an introductory program of 4-6 years' term, which should incorporate the major variants of smallholder systems.

4.3.6.3 Feed-year systems

This program is directed at the design and testing of feeding systems to achieve particular production targets. It is essentially testing that the performance of systems can be estimated from knowledge of components and, in most instances, is not pursued by classical experimental methods with treatment comparisons.

An important smallholder enterprise throughout the dryland region is milk production for on-farm consumption, and feed-year designs for this should be given priority at a number of key locations (Naivasha, Embu, Katumani). It is envisaged that this project will have to address the scope for fodder conservation - possibly as a communal undertaking.

4.3.7 Farm mechanization and engineering
(Reference: section 4.2.2.2/3)

Objective: To innovate with the designs and applications of farm machinery, buildings, and other facilities on farms to increase the productive capacity of human labor and the quality of human life.

Brief Description: It is suggested that the terms of reference of the Agricultural Machinery Testing Unit should be broadened to encompass all areas of engineering that impinge on the farm and the farm family. This may be the intention for the proposed Rural Technology Development Unit (RDTU), but the impression was that this unit would be concerned with mechanization of agricultural operations only.

The RTDU should have some personnel in the farming systems program, making time and motion analyses of all labor applications, including those such as food preparation, water and fuel wood collection, which are regarded as domestic operations.

The aspects of this program (also discussed in Chapter 2), which are of particular importance to dryland agriculture, are those related to the extensiveness of agricultural production and to the climatic aridity. They include:

- mechanizaton to increase the speed and efficiency of cultural operations (land preparation, weed control, spraying, harvesting); this program must be collaborative with other programs, such as 4.3.4;
- low-traction positive-placement seeding and fertilizing implements;
- development of rainfall storage systems for domestic water supplies.

4.4 Institutional mandates and program management

This subject has been discussed in Volume 1 of the Report. In the context of dryland farming, it has been suggested that all program areas should not be location specific and, wherever possible, should be designed to develop technolgy and provide understanding which applies across a wide geographic and agroclimatic range.

The basic reasons for this suggestion are:

a) that dryland environments are variable, and that technology which fails to recognize and cope with this is almost invariably an inadequate technology at the farm level;

b) that it is generally more efficient than ad hoc repetition at a multiplicity of locations.

One should not, however, underestimate the difficulties in conducting research with such objectives. The professional skill and experience required is both considerable and uncommon; and the negotiation and management of collaborative programs across institutions and regions is

always difficult. The situation in Kenya is rendered more difficult by fund restrictions on the mobility of scientists and on special research equipment needs for this type of research. It has therefore been recommended that Dryland Farming and Soil/Water Management research be based at the National Research Center, Katumani, with sub-centers at Perkerra, Kitui, and Kampiyamawe. Katumani, in addition to being an NRC for dryland farming and soil/water management, will have regional research types of programs with strong emphasis in technology adaptation and on-farm research with a farming system perspective for the semi-arid areas.

Irrigation is an essential facility on dryland research stations

It has two particular uses: (a) to guarantee continuity of all research in which it is not essential to experience drought and crop failure as an extreme in sampling climatic variability, and (b) to increase the range of rainfall conditions which can be sampled within one season at one location.

These uses are valuable for increasing the rate of research progress, avoiding low staff productivity and morale during droughts, and generally increasing the return to research expenditure.

Particular attention must be directed at the main center station/sub-center network in cost-benefit terms.

It is considered that the current tendency to proliferate sub-centers is providing an intensive sampling of agroclimatic variability, which is more extension-related than technically based. The recommended network of NRCs and RRCs provides an extensive sampling of dryland conditions, which should permit robust technology development, and which should be fully utilized. The major stations in the dryland network are Njoro, Naivasha, Embu (including Mwea Tebere), Katumani, Kiboko, and Mtwapa.

Management of dryland farming research

This review has treated dryland farming as a broad-ranging field in terms of agroclimate, region, commodity, and scientific discipline.

The specific responsibility for providing the leadership in dryland farming and soil/water management research is assigned to the NRC, Katumani, on the understanding that through its cooperating centers it would be able to focus on the defined priorities in the broad-ranging field.

CHAPTER 5: HORTICULTURE

5.0 The Role of Government in Horticultural Development

The GOK pays much attention to horticultural development; more than most other governments. The main reason appears to be the importance of horticultural crop exports, which rank third after coffee and tea in value. Nevertheless, government efforts to develop horticulture have had a very limited impact to date. This is not surprising, because:

- the lead time to train competent staff and build effective institutions is quite long;
- the complex and dynamic nature of horticultural production for export demands extremely versatile government services;
- there is no clear definition of horticulture in the country, on which clear and consistent government policies can be based;
- self-sufficiency in food has top priority in government support for agricultural development.

Despite the importance of horticulture - there is surprisingly no good horticultural textbook in Kenya describing the centers of production, their ecology, the major crops, harvest seasons, market outlets, and development trends. In addition, the information in numerous reports is fragmentary and not easily accessible. Available data for the nine major production centers are presented in Table 5.1. Hopefully, analysis of the data collected in 1982 in the Rural Household Budget Survey will clarify consumption levels of fruits and vegetables and highlight the increments needed to meet nutritional requirements. Also, Volume 5 of the Farm Management Handbook of Kenya, which deals with horticulture and is to be published in 1985, should help to provide a more up-to-date picture of the state of horticulture in the country. The two main sectors of horticulture, home gardening and market gardening, are briefly discused in this report.

5.0.1 Home gardening

Home gardening has evolved as an integral part of traditional subsistence farming systems. Its main role is to provide the household, and to some extent local markets, with protective foods (vitamins, minerals, and some protein), which are essential to combat malnutrition. As such, promotion of home gardening should form part of the GOK strategy to attain food self-sufficiency.

Home gardening, as a component of subsistence farming, developed slowly. It is in fact lagging far behind overall agricultural development: home consumption of fruits and vegetables is said to be well below nutritional standards and a large proportion of the intake consists of leaves gathered from field crops and weeds, so that only a small fraction of the consumption by rural households is purposely produced in home gardens. Quantitative data on home production and consumption of fruits and vegetables is very scarce.

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Table 5.1: Supply and Demand Estimates in Horticultural Products for the Main Production Centers

Major Production Zones	1978 Estimated Demand (ton)	1977 Estimated Production (ton)	Area (ha) rainfed	Area (ha) irrigated	Type of growers
A NAIROBI AREA	209,932	72,781	21,981	163	
Kiambu District	(Nairobi: 145,378)	59,411	11,403	163	3/4<small
Machakos District		13,370	10,578	-	small
B CENTRAL RIFT AREA	22,422	31,593	6,077	906	
Nakuru District	(Nakuru: 10,136)	28,103	6,077	566	large
Baringo District		3,490	-	340	range + irrigated scheme
C MOUNT KENYA AREA	67,558	320,504	54,608	2,693	
Meru District		?	16,007	-	small
Nyeri District		95,983	9,936	54	small + estates
Muranga District		113,934	12,393	2,139	small
Kirinyaga District		27,819	4,231	50	small
Embu District		55,768	11,141	-	small
Laikipia District		27,000	900	450	large + range
D KISII AREA	43,543	53,525	8,038	-	
Kisii District		46,467	7,184	-	small
Homa Bay District		7,058	854	-	small
E KAKAMEGA AREA	60,005	21,716	4,895	211	
Kakamega District	(Kisumu: 24,270)	?	1,683	-	small
Siaya, Busia and Kisumu Districts		21,716	3,212	211	small
F KITALE AREA	10,969	n.d.	n.d.	n.d.	large
G COASTAL AREA	75,563	115,032	49,086	430	
Kwale District	(Mombasa: 62,910)	59,160	29,730	-	small
Kilifi District		45,331	16,931	-	small
H TAITA/TAVETA AREA	4,708	5,594	2,026	-	small + estates
I GARISSA AREA	876	370	-	101	very small
Totals	500,000 (4<main towns: 250,000)	625,000	150,000	4,500	

Source: Horticultural Development Study, Vol. 1. (1978).

5.0.2 Market gardening

Market gardening is an extremely varied and dynamic sector, in sharp contrast with home gardening and the production of field crops. It encompasses a large pineapple estate which has a substantial share of the European market for canned pineapples, as well as concentrations of small market gardeners whose products find their way to town markets.

Market gardening has been developing by leaps and bounds; and although many ventures have been short-lived, the overall trend shows an impressive expansion. This is particularly true for the export crops (Figure 5.1), the only ones for which reliable data on volume and value are readily available.

In market gardening, producing the crop is the lesser half of the job; post-harvest handling and marketing is the larger. The problems, the risks, and the consequent price increases in the marketing chain have attracted much, largely ineffectual, attention, as these factors have caused the collapse of many promising developments. For those who are discouraged by these intractable marketing problems it should be noted:

- that market gardening expands nevertheless;

- that the so-called marketing problems are for the most part 'produce problems', inherent in the perishable nature of the products; this means that they cannot be eliminated but have to be circumvented, mainly by producing outside the glut periods, which in fact is an essential theme in horticultural production.

It should be added that a high level of home consumption dampens market fluctuations as households adjust their intake of fruit and vegetables in response to current price levels. Presumably, low consumption levels of the rural millions contribute to the extremely volatile nature of the fruit and vegetable markets in Kenya.

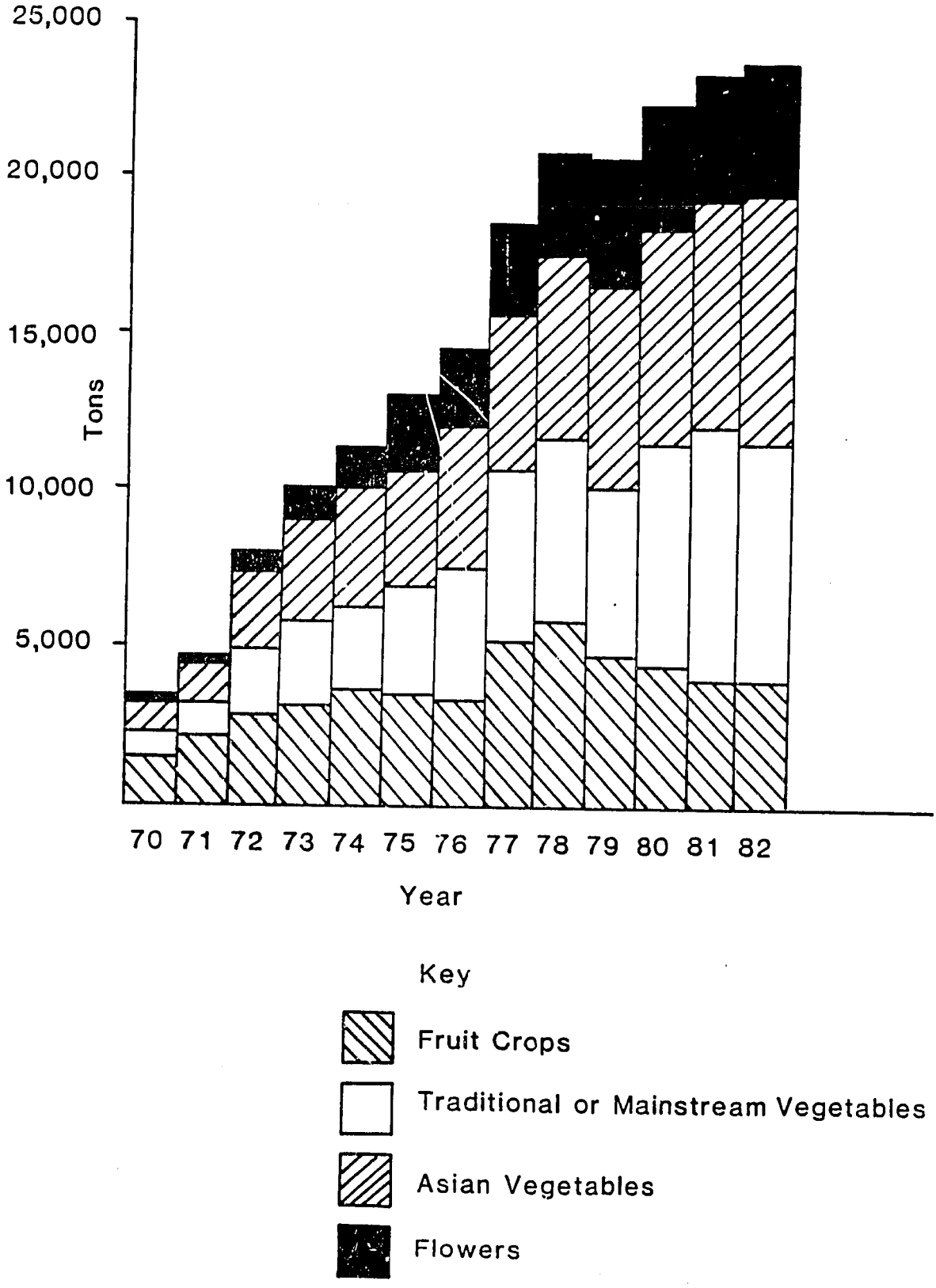
5.0.3 Government support for home and market gardening

Promotion of home gardening depends primarily on an increased awareness of the importance of fruits and vegetables for health. This is a slow process, requiring a long-term national nutrition education program, in which the Ministries of Health and Education should take the lead. MOALD can support the effort by introducing 'garden packages' for various agro-ecological zones, including handy planting materials (hedging plants, fruits, perennial vegetables, line stakes to support trailing plants, etc.) and train persons in appropriate skills (composting, watering, seed-bed preparation, garden hygiene, etc.), possibly using the Farmers Training Centers (FTCs). Long-term benefits of such a promotion program would be:

- contribution to self-sufficiency in food and impoved health;

- a stabilizing effect on the markets for fruits and vegetables through the introduction of greater elasticity in local comsumption.

Figure 5.1 Growth in Export Trade of Fruits and Vegetables (1970-1982)



Source: HCDA Statistics from Dixie (1984)

In promoting market gardening, the principal role of the government is to facilitate continuation of the spontaneous development which has been successful to date. Past experience shows that it is unrealistic to assume a more directional role in production or marketing, for instance through exercising the authority vested in the Horticultural Crops Development Authority (HCDA). The following specific contributions to the promotion of market gardening are recommended:

- Increasing local know-how, to be generated by specialized horticultural training at various levels for those engaged in market gardening. This can be achieved by directing the curricula of training institutions towards private rather than public employment. Training may in fact benefit from such a move, because public employment is approaching saturation levels, and the ability to attract students from or for the private sector is the ultimate proof of the quality of training.

- Making horticultural markets more accessible by (a) improving roads in the production centers; (b) providing wholesale/retail market facilities good enough to attract the bulk of the trade, thus bringing supply and demand together; (c) broadcasting daily market prices through bulletins; and (d) encouraging growers to pool their supplies. These measures should result in higher grower prices and lower consumer prices, and should stimulate expansion.

- Providing services which the industry cannot easily organize. Examples are existing services; such as quality control of export produce; the introduction and screening of collections of fruits, vegetables, and ornamental plants; the supply of a nucleus of seeds and healthy stock plants to seed firms and nurseries; the screening of chemicals for crop protection and crop regulation; and the organization of crop protection programs of national importance (e.g., greening control in citrus). Some of these services in fact constitute the core of the present activities of the National Horticultural Research Station (NHRS) at Thika.

5.1 Constraints in Horticultural Research

Current output of horticultural research appears to be hampered mainly by the following constraints:

- lack of competent staff, both in respect of horticulture and research methodology; upgrading of staff is now rapidly improving research capability, but the minimal horticultural content of training programs remains a severe handicap;

- high staff attrition rates: floricultural research work at Tigoni, for instance, has collapsed following the resignation of the two staff members assigned to this program;

- imbalance in staff disposition: whereas the NHRS Thika now has some 35 staff members trained at B.Sc. and M.Sc. level, other stations, with the exception of the Coastal Agricultural Research Station (CARS), Mtwapa, have to make do with two or three inexperienced horticulturists;

- lack of coordination in research programs: an inventory of all horticultural experiments would reveal a large number of unknown, out-dated, or overlapping trials;

- 'separatist' operation of externally aided projects: at NHRS Thika, for instance, some of these projects create their own little kingdoms, fragmenting rather than strengthening the station;

- over-extended outreach programs: the NHRS Thika is embarking on a number of multi-locational trials, extending as far as Kitale and to the coast: this approach is becoming prohibitively expensive in man days, travel cost, etc.;

- excessive land holdings: horticulturists typically farm small areas of prime land under great pressure; the large tracts of under-utilized land at stations and sub-stations provide an unrealistic setting for horticultural research.

5.2 Recommendations for Horticultural Research

The constraints can be grouped as concerned with (a) organization, (b) priorities, and (c) staff competence and motivation. The recommendations are grouped in the same manner, with the exception that issues related to motivation are discussed elsewhere in the Report.

5.2.1 Organization

Horticulture - with its great variety of crops ranging widely in ecological requirements and market destinations - repeats the great diversity of agriculture on a smaller scale. It follows that horticultural research is just as complex as agricultural research as a whole and that a single NHRS cannot adequately sustain horticultural development nationwide. It is common to distinguish nine major centers of horticultural production in the country; obviously it is impossible to provide each of these centers with its own full-fledged horticultural research station.

To resolve this dilemma it is proposed to make the best possible use of the existing research stations throughout the country. A two-tier network could be established with the core of research centered at the National Horticultural Research Center (NHRC) in Thika but with the rest of the horticultural research staff deployed as integral parts of research staff in RRCs and some NRCs located in major horticultural crops production areas.

The main implications of this recommendation are:

- a refocusing of the mandate for NHRC Thika;

- transfer of some staff from Thika to RRC and NRC programs at appropriate locations (cooperating centers);

- provision for the national coordination of horticultural crops research through NRC Thika and the cooperating centers.

The isolation, poor facilities, and under-utilization of the existing sub-stations visited render these stations ineffective. It is proposed to phase out these sub-stations and to utilize the services of appropriate RRCs for local adaptation trials in horticultural research and for linkages and training with extension personnel and farmers. The organization and execution of local adaptation trials at RRCs brings 'front line' horticultural research into close contact with the extension service and the farming systems perspective of research and extension at the regional level. It would also encourage the early application of research results.

5.2.2 Research priorities

As proposed, the principal task of the horticultural research system at this stage is to render services to the growers, rather than to contribute to the advancement of horticultural science.

Home gardening has been rather neglected. Research can serve this sector by formulating and testing the 'garden packages' suggested in Section 5.0 and by disseminating the planting materials and skills to RRCs and FTCs, but this is only likely to happen within the framework of a concerted government policy to combat malnutrition. Research services for market gardening have also been listed in Section 5.0. The NHRC Thika already renders these services. To sharpen the focus of these activities the following recommendations are made:

- research capacity should preferably be allocated to fruits, vegetables, and ornamentals in the ratio 3:3:1;

- priorities in respect of fruit research (which are long-term by nature) are listed in Table 5.2; fruits have been classified in five groups, within each group two priority crops have been identified, and a total of 16 high-priority research topics are proposed, including three new ones;

- research capability on post-harvest technology and marketing is negligible; therefore the current emphasis on production aspects is inevitable: the possibility of including post-harvest handling research for export produce under the HCDA, along with the marketing research for these products, should be considered. Post-harvest handling may also be considered as an integral part of the post-harvest technology mandate of NAL.

5.2.3 Training

Training is the way to improve staff competence; in effect, training is the cornerstone in the triangle, 'training-extension-research'. Agricultural training appears to be receiving attention in Kenya. However, the horticultural content in training programs is minimal and is believed to be the limiting factor for government support to horticultural development. The large increases in horticultural staff in both the extension service and research stations in recent years have not made much difference, presumably largely because most of the appointees are horticulturists only in name.

Table 5.2: Suggested Research Priorities for Fruit Crops

Category:	Single-stemmed	Tropical	Citrus spp.	Subtropical	Temperate
Priority crops:	banana coconut	cashew mango	orange mandarin	avocado macadamia	apple grape
RESEARCH TOPICS:					
Plant introduction (8)	x	x	x	x	x
Selection work (8)	xx	xx	-	-	-
Cultivar studies (8)	xx	xx	-	xx	xx
Rootstock studies (12)	-	x	x	x	-
Propagation methods (3)	x	xx	xx	xx	xx
Nutrient response studies (5)	xx	-	-	-	-
Water requirements (5)	x	-	-	-	-
Crop protection topics (3)	xx	x	xx	x	x
Growth rhythm studies (3)	-	xx	-	x	-
Regulation of crop cycles (5)	-	-	x	-	xx
Double-cropping (5)	-	x	-	-	xx
Fruit quality studies (0)	-	x	x	x	x
Post-harvest handling (0)	-	-	-	-	-

Notes: ( ) Expected number of years for treatments/observations to yield valid results.
- Low-priority research topics.
x Medium-priority research topics.
xx Top-priority research topics.

To upgrade the quality of the present staff, in-service training is provided under the National Horticultural Extension Training Program (NHETP). This type of training may be adequate for staff dealing with a single commodity such as coffee or tea. In horticulture, with its great diversity of crops, ecological requirements, and market destinations, short in-service courses are no substitute for specialized formal training. Intensive crop care (e.g., nursery techniques such as pruning, flower induction, pollination, etc.) with emphasis on differences between cultivars and a host of post-harvest problems, contribute to the complexity of horticultural technology. Specialized training is therefore a prerequisite for productive horticultural research and sustained horticultural development.

Formal training is provided by the government at four levels. These are: (a) farmers' training at FTCs, (b) certificate courses, (c) diploma courses and (d) university training.

Specialized horticultural training is offered only at the FTCs, often by staff who have not specialized in horticulture themselves, and at the diploma colleges, where the first horticulturists graduated at Egerton College in 1981. The horticultural content of the general agricultural certificate course is very modest and even at the University only 110 hour periods are devoted to horticulture in the B.Sc.-Agriculture curriculum (40 periods for plant propagation, 40 periods for tree crops and 30 periods for vegetable growing).

The diversity, dynamics, and complex technology of horticulture call for a special effort to provide relevant training, both for the private and the public sector. It is therefore strongly recommended that:

- station horticultural extension officers at selected FTCs should radically improve the horticultural courses through training and interaction with horticultural programs at NHRC Thika and cooperating RRCs;

- a Certificate Course in Horticulture be introduced in order to provide horticultural specialists for the extension front-line in selected districts;

- a further specialization be offered in the Horticultural Diploma through option courses in fruits or vegetables and flowers;

- a horticultural option be introduced in the B.Sc.-Agriculture program, to be followed as soon as possible by fully fledged B.Sc.-Horticulture and M.Sc.-Horticulture programs.

The preference for training of agricultural 'generalists' is understandable, but where lack of know-how becomes the limiting factor for development of a sector - as in horticulture - some degree of specialization is inevitable. In many instances (e.g., coffee, tea) in-service training can generate the know-how, but for the major sectors (e.g., field crops, horticulture, animal husbandry, forestry) specialized formal training appears to be the answer.

It will assist the recommendations on training and horticultural development as a whole if the existing information scattered in numerous reports and documents in Kenya could be compiled into an authoritative book on 'Horticulture in Kenya'.

CHAPTER 6: ANIMAL PRODUCTION

6.0 Animal Production Policies in Kenya

A national livestock development policy was published in 1980[1] listing overall policy objectives. These are:

a) the production of sufficient animal foodstuffs to satisfy the nutritional needs of a growing population and animal products other than foods to support resource-based agro-industries;

b) to adopt production systems that will conserve natural resources and sustain yields, particularly in semi-arid and arid areas;

c) to assist in the alleviation of poverty by improving employment opportunities throughout the livestock industry and in particular for smallholders and pastoralists;

d) the improvement of the overall productivity of livestock, particularly by intensification in high-potential areas and by more rational utilization of rangelands;

e) the export of surplus animal products, in so far as this objective does not conflict with that of domestic self-sufficiency, in order to improve foreign exchange resources.

These objectives are discussed in detail in Section 6.2 with reference to the future role of livestock in Kenyan agriculture.

6.1 Animal Production Resources and Resource Potential

Livestock are of particular importance in the farming economy of Kenya. Almost all farmers own livestock, and 73 percent of the total land area of the country, 412,000 km^2 in agro-ecological zones V and VI, can only be exploited by some form of livestock husbandry and/or by tourism. The livestock industry constitutes 7.7 percent of the GDP, and livestock products provide more than one third of total foods available in the country.

Resources available for the industry comprise: the genetic resource of existing livestock populations; the feed resource provided by pasture, cultivated fodder, and crop residues in the high- and medium-potential farming areas, together with the forage resources of the rangelands; the labor and managerial resource of farmers, ranchers, and pastoralists; and the technical services resource provided by GOK.

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[1] Ministry of Livestock Development (1980).
National Livestock Development Policy. MLD: Nairobi.

6.1.1 The numbers, distribution, and productivity of livestock

Available data on the numbers and distribution of livestock is based on estimates supplemented in rangeland areas by aerial surveys conducted by the Kenya Rangeland Ecological Monitoring Unit (KREMU). Estimates of the 1981 livestock populations listed by district and province are provided in Table 6.1. It will be seen that cattle, sheep, goats, and poultry are managed in all districts, though there are very few poultry in the pastoral districts. The husbandry of camels is restricted to the drier northern pastoral districts. Donkeys are only found in number in pastoral districts, half the national herd being in one district - Turkana - where they are eaten as well as being used for transport purposes. Small numbers of pigs are raised in many districts, but there are two concentrations of the pig population - one in Central Province and the higher potential districts of Eastern Province and the other in Western Kenya. A few rabbits are bred in many districts, but the only area of concentration is in Central Province.

Total numbers of livestock are not necessarily an accurate indication of the importance of a livestock species in the economy or of the demand of the species for feed and other resources. In Table 6.2 the numbers of grazing livestock have been converted into Livestock Units (LSU's) in order to make a more appropriate comparison of the importance of individual species. The data in Table 6.2 shows that cattle are unquestionably the most important grazing species, with camels, sheep, and goats of approximately equal numbers but much less importance. Camels are, however, only of importance to pastoralists, whereas sheep and goats are important throughout the country and are of particular importance to smallholders.

Data on the number of each type of livestock managed under smallholder, large-farm and pastoral conditions are provided in Table 6.3. It will be seen that approximately half of all cattle are managed on smallholdings, a quarter on large farms and a quarter by pastoralists. However, 80 percent of grade milking cows are to be found on smallholdings, while the reverse is the case with regard to grade beef cattle - 80 percent are on large farms. Almost half the total sheep and a high proportion of goats are owned by pastoralists, there being few goats or hair sheep and only one third of the total number of wool sheep on large farms; the remainder being managed by smallholders. Camels are exclusively managed by pastoralists. Three quarters of all pigs and 90 percent of poultry stocks are managed by smallholders, as are all rabbits.

Cattle

The total number of cattle in the national herd increased by 14 percent between 1978 and 1982 (from 9.2 to 10.6 million head) while at the same time the breed composition of the herd changed; the number of grade and indigenous zebu cattle increasing by 60 and 8 percent, respectively (Table 6.4). The increase in the number of grade cattle is entirely due to an increase in grade milking cattle, as the grade beef cattle population, mainly concentrated in Trans Nzoia, Uasin Gishu, and Nakuru Districts, has been steadily decreasing for at least a decade.

Table 6.1: Estimates of livestock numbers, 1981

PROVINCE District	Number of Livestock ('000 head) Camels	Cattle	Sheep	Goats	Donkeys	Pigs	Poultry	Rabbits
NAIROBI	-	3	0.6	0.8	0.2	3.3	40	5.6
CENTRAL								
Kiambu	-	117	27	17	1.2	13.0	441	7.1
Kirinyaga	-	80	43	36	0.2	4.9	191	14.0
Murang'a	-	189	63	60	0.2	11.6	474	5.8
Nyandarua	-	186	171	21	0.3	0.2	145	2.0
Nyeri	-	165	61	27	2.0	5.2	222	7.7
Provincial totals		737	365	161	3.9	34.9	1,473	36.6
COAST								
Kilifi	-	150	49	180	0.2	0.4	299	0.8
Kwale	-	120	58	160	0.3	-	208	0.2
Lamu	0.1	39	8	10	1.5	-	92	-
Mombasa	-	5	1	2	-	0.1	85	0.1
Taita Teveta	-	77	28	120	0.2	0.3	91	5.4
Tana River	43.0	346	20	130	5.0	-	40	0.1
Provincial totals	43.1	737	164	602	7.2	0.8	815	6.6
EASTERN								
Embu	-	71	24	73	0.5	5.0	231	1.6
Isiolo	17	235	295	300	15.0	-	7	-
Kitui	4	203	82	298	4.0	0.1	446	0.4
Machakos	-	423	220	528	4.6	0.2	998	3.7
Marsabit	147	152	337	500	44.0	-	5	-
Meru	-	382	197	130	10.0	4.5	717	4.4
Provincial totals	168	1466	1155	1829	78.1	9.8	2,399	10.1
NORTH EASTERN								
Garissa	36	431	368.2*		4.5	-	5	-
Mandera	111	92	394.2*		3.1	-	1	-
Wajir	145	163	282.7*		3.3	-	4	-
Provincial totals	292	686	1045.1*		10.9	-	10	-
NYANZA								
Kisii	-	414	120	98	0.3	0.1	950	0.6
Kisumu	-	164	82	91	0.1	0.2	766	0.2
Siaya	-	384	101	176	0.1	0.2	1,272	0.1
South Nyanza	-	549	196	244	7.4	0.2	1,272	1.2
Provincial totals	-	1511	499	609	7.9	0.7	4,260	2.1

Table 6.1 continued

PROVINCE District	Number of Livestock ('000 head) Camels	Cattle	Sheep	Goats	Donkeys	Pigs	Poultry	Rabbits
RIFT VALLEY								
Baringo	2.7	175	300	615	2.6	0.1	.87	0.2
Elgeyo Marakwet	-	125	140	92	0.2	-	107	0.2
Kajiado	-	644	272	326	14.0	2.0	122	1.0
Kericho	-	633	300	260	18.1	0.9	721	0.3
Laikipia	0.2	300	200	60	0.8	2.0	117	0.3
Nakuru	-	233	272	127	3.0	1.4	484	1.0
Nandi	-	330	43	34	11.0	0.4	300	0.2
Narok	-	700	703	890	11.0	-	152	-
Samburu	23.0	205	200	246	6.9	-	2	-
Trans Nzoia	-	100	18	10	0.5	10.4	29	0.8
Turkana	108.0	147	500	600	177.0	-	1	-
Uasin Gishu	-	200	36	38	0.5	1.0	110	0.7
West Pokot	1.0	68	121	150	4.0	-	21	0.2
Provincial totals	134.9	3860	3105	3448	249.6	18.2	2,253	4.9
WESTERN								
Bungoma	-	194	40	28	0.2	1.6	160	1.0
Busia	-	145	16	46	0.6	7.2	65	4.2
Kakamega	-	338	51	36	0.3	4.4	567	3.0
Provincial totals	-	677	107	110	1.1	13.2	792	8.2
Kenya totals	638.0	9671	5917.6	7282.8	358.9	80.9	12,042	74.1

Note: *Sheep and goats in Northeastern Province were counted together using aerial survey techniques; for the purpose of calculating national totals it was assumed that there were equal numbers of each species.

Source: Animal Production Branch (1982). Annual Report 1981. MLD: Nairobi.

Table 6.2: Grazing species livestock units by province, 1981

LSU's Province total	Camels	Cattle	Sheep	Goats	Donkeys	Totals	Province as %
			'000 LSU's*				
Nairobi	-	2.9	0.1	0.1	0.1	3.2	neg.
Central	-	643.7	45.2	16.1	2.0	257.0	8
Coast	43.1	523.2	16.4	60.2	3.7	646.6	7
Eastern	168.0	1047.5	115.5	182.9	39.1	1553.0	17
Northeastern	292.0	480.2	52.2	52.3	5.5	882.2	9
Nyanza	-	1071.3	31.0	60.9	4.0	1167.2	12
Rift Valley	133.9	2900.7	329.3	344.8	125.3	3834.0	41
Western	-	486.1	10.7	11.0	0.6	508.4	6
Totals	637.0	7205.6	600.4	728.3	180.3	9351.6	
Grazing species as % Total	7	79	6	8	2		

Notes: *1 LSU = 0.7 zebu cattle; 1.0 grade milking or beef cattle; 0.1 hair sheep; 0.15 wool sheep; 0.1 meat goat; 1.0 camel; and 0.5 donkey.

Source: Animal Production Branch (1982). Annual Report 1981. MLD: Nairobi.

Table 6.3: Number of livestock by type of management
('000 head)

Type of Livestock	Type of Management					
	Smallholder		Large Farm		Pastoralist	
	No.	as % total	No.	as % total	No.	as % total
GRAZING LIVESTOCK						
Cattle - zebu	3900	49	1500	19	2500	32
- grade milking	1200	82	270	18	-	-
- grade beef	90	18	400	82	-	-
- total	5190	53	2170	22	2500	25
Sheep - hair	2300	42	100	2	3100	56
- wool	400	67	200	33	-	-
- total	2700	44	300	5	3100	51
Goats - meat	4200	55	100	1	3400	44
Camels	-	-	-	-	640	100
Donkeys	20	9	-	-	200	91
NON-GRAZING LIVESTOCK						
Pigs	57	76	18	24	-	-
Poultry	10900	91	1000	8	100	1
Rabbits	70	100	-	-	-	-

Source: Animal Production Branch (1982). Annual Report 1981. MLD: Nairobi.

Table 6.4: Distribution of grade* and indigenous cattle by province, 1978 and 1982

Province	1978		1982		% Change between 1978 and 1982	
	Grade ('000 head)	Indigenous ('000 head)	Grade ('000 head)	Indigenous ('000 head)	Grade	Indigenous
Nairobi	2	1	2.4	0.5	+20	-50
Central	435	120	620.0	150.0	+43	+25
Coastal	13	360	22.0	694.0	+69	+93
Eastern	77	1598	115.0	1399.0	+49	-12
Northeastern	-	920	-	830.0	-	-10
Nyanza	33	1105	46.6	1534.0	+41	+39
Rift Valley	557	3444	947.0	3435.0	+70	no change
Western	11	559	56.0	708.0	+409	+27
Totals	1128	8107	1809.0	8750.5	+60	+8

Note: *The term 'grade' is used in Kenya to describe all exotic cattle and crosses of them with all other breeds.

Source: Animal Production Branch (1979-1983). Annual Reports 1978 and 1982. MLD: Nairobi.

There are probably several reasons for an increase in the demand for grade milking cattle. Milk production is more profitable than beef production, grade cows are much more productive than indigenous cows in high potential areas, and the majority of the increasing number of smallholders wish to produce milk, if only for family consumption. The increase in demand has stimulated increased production of grade milking cattle, partly by encouraging the insemination of a substantial number of indigenous zebu cows and heifers (46,000 in 1981) with European-type dairy bull semen.

As will be seen from Table 6.4, the majority of grade milking cattle are found in Central and Rift Valley Provinces; 34 and 53 percent of the national herd, respectively. Within these provinces grade cattle are concentrated in areas receiving 1000 mm rainfall per annum, so that 90 percent are in agro-ecological zones II and III and only 10 percent in zone IV. The most rapid increase in grade dairy cattle numbers during the 1978-82 period occurred in Western Province, though from a very low base, while above-average increases were also registered in Rift Valley and Central Provinces.

The breed composition of the national grade dairy herd at the present time is approximately 27, 23, 16 and 8 percent high grade or purebred Ayrshire, Friesian, Guernsey or Jersey, respectively. The remainder are F_1, F_2, etc. crossbreds.

The herd structure in the national grade dairy herd is as follows:

Females	as % total herd
Cows	46
Heifers (all ages)	17
Heifer calves	14
Total	77
Males	
Bulls	2
Steers	10
Bull calves	11
Total	23

In 1981 the distribution of grade dairy cattle between small (20 ha) and large farms and the average size of herds was as follows:

Type of Farm	Number of farms	Number of cattle ('000 head)	Number of cattle per farm
small (20 ha)	250,000	1200	4.8
large (> 20 ha)	1,800	270	150.0

Estimates of the present distribution of grade and indigenous cattle by agro-ecological zone are:

Agro-ecological zone	Grade cattle (as % total grade cattle)	Indigenous cattle (as % total indigenous cattle)
II & III	90	51
IV	10	24
V		22
VI		3

Apart from the grade milking and beef cattle and improved zebu breeds such as the Boran, the cattle of Kenya are a mixture of Large and Small East African Zebu. In general the improved indigenous herds and cattle in the northern pastoral areas are of the Large East African Zebu type, while unimproved cattle in the wetter areas, the dryland farming areas, and the southwestern rangelands, are of the Small East African Zebu type. The major proportion are Small East African Zebu, and within this breed there are considerable regional variations in type.

Milk production

It is estimated that, excluding the quantity consumed by suckling young, 1566 million litres of milk were produced in Kenya in 1982 by all types of milk-producing livestock (Table 6.5). Of this total it is estimated that 70, 8, and 22 percent were produced by smallholders, large farms and pastoralists, respectively.

Milk sales were estimated to be 600 million litres in 1982 or 38 percent of the total production, so that the major proportion of the milk produced was consumed by producers' families. Smallholders produced 70 percent or 420 million litres of the milk sold; large-scale producers selling 120 million litres, mainly through the Kenya Cooperative Creameries (KCC). Smallholders sold their milk, partly through the KCC, partly through local cooperatives, and the remainder directly to consumers.

Milk production increased from an estimated 841 million litres in 1977 to 1566 million litres in 1982. The major factor involved in this dramatic improvement in milk production between 1977 and 1982 has probably been the rapid increase in the number of grade milking cows, but assistance has also been provided by three dairy development programs. The National Dairy Development Program (NDDP), partially funded by the Netherlands, has been concerned with increasing milk production and has established a small research project at the NAHRS at Naivasha in order to investigate the optimal use of Napier grass (Pennisetum purpureum), simple silage-making techniques, and the storage and utilization of cattle manure. The Rural Milk Collection and Cooling Centers Program, partially funded by the Finnish Government, has been concerned with improving the collection and processing of milk produced by smallholders while the Livestock Recording Center at Naivasha, formerly receiving West German support, has conducted milk recording and the progeny testing of dairy sires. The production data from 19,000 cows in 191 herds was recorded in 1982.

Table 6.5: Estimated total milk production in Kenya in 1982[1]

Type of Animal	Av. milk yield[2] (litres/year)	Lactating females ('000 head)	Estimated milk production (million litres)	Milk production as % Kenya production
Grade milking cows	875	954	835	53
Indigenous cows	100	4162	416	27
Camels	750	400	300	19
Ewes/does[3]	50	300	15	1
Totals		5816	1566	100

Notes: 1) The estimate excludes milk consumed by suckling young stock.

2) Yields vary from area to area, the data provided being estimated averages.

3) There are 12,700 dairy goats in Kenya, the remainder of the milk being produced by sheep and goats owned by pastoralists.

Source: Based on data in Annual Production Branch (1983). Annual Report 1982. MLD: Nairobi.

Beef production

The estimated total beef production in Kenya in 1982 is shown in Table 6.6. At present about seven percent of beef is produced from grade dairy cattle farms and 17 percent from large-scale farms and ranches on which are managed grade beef cattle and improved indigenous cattle. The grade beef cattle population has been declining as large farms have been subdivided and at present mainly comprise Hereford, Charolais, and their crossbreds with Boran, though small numbers of some other European-type beef breeds such as the Galloway, and stabilized crossbreds such as the Santa Gertrudis, also form part of the grade beef cattle population.

The breeding of beef cattle was a concern of large-scale ranchers in the past and one result has been a major improvement in the genetic merit of one of the indigenous beef breeds - the Boran. This breed is a major Kenyan asset, with high-quality breeding stock in demand throughout Africa and elsewhere. The Sahiwal herd at Naivasha is another breed asset, as it is the only source of Sahiwal breeding stock in Africa, where the demand for the Sahiwal as a dual-purpose breed (beef and milk) is high.

As shown in Table 6.6, apart from the beef produced from dairy herds and large farms and ranches, approximately half the total is produced on small farms and the remainder from pastoral herds. A decade or more ago it was considered that a beef industry could be established based on the purchase of young unfinished cattle from the pastoral regions and the fattening of them on forage crops, grains, and crop by-products in the high-potential areas. The idea was particularly attractive, as the system would have assisted in the reduction of stocking rates in the pastoral areas and produced high-quality beef, some proportion of which would have been available for export. On the basis of a series of investigations as to the viability of the system, a feedlot industry was established. The system, however, did not prove to be stable. Feed prices rose, beef prices did not inflate at the same rate and, owing to the imposition of quarantine restrictions in the pastoral districts, the supply of unfinished cattle from the pastoral regions rapidly declined. As a consequence all commercial feedlots ceased operations.

Sheep and goats

Estimates of total sheep and goat populations have fluctuated during the period 1978-82 (Table 6.7), and the concensus of opinion is that, unlike the cattle population, sheep and goat populations are not increasing very rapidly at the present time. There have, however, been some changes within populations. The number of wool-type sheep on large farms has declined from 250,000 in 1974 to 191,000 in 1981, but the total number in the country has slightly increased. There has also been a rapid increase in the number of milking goats, though the population is still very small compared with the total meat goat population.

Details of the distribution of different types of sheep and goats by province are provided in Table 6.8. Wool sheep are concentrated in Central and Rift Valley Provinces (99 percent of the total). Within Central Province 80 percent of wool sheep are in Nyandarua District, while in Rift Valley Province 90 percent are found in Kericho and

Table 6.6: Estimated total beef production in Kenya, 1982

Agro-ecological zone	Livestock system	Type of cattle	No. of cattle ('000 head)	Estimated offtake (%)	Estimated av. carcass weight (kg)	Estimated beef production (m.t.)	as % total
II	Dairy farming	Grade milking	295	25	140	10,325	7
II, III, IV	Small holder mixed farms	Grade	1514	20	110	33,308	24
		Indigenous	3986	13	80	41,454	30
III, IV	Large scale farms and ranches	Grade beef and improved zebu	390	33	180	23,166	17
IV, V, VI	Pastoral	Indigenous	3375	11	80	29,700	22
Total			9560			137,953	

Source: Animal Production Branch (1983) Annual Report 1982. MLD: Nairobi.

Table 6.7: Sheep and goat populations, 1978-1982

Year	Population ('000 head)					
	Sheep			Goats		
	Wool-type	Hair-type	Total	Meat-type	Milk-type	Total
1978	500	6000	6500	8500.0	2.0	8502.0
1979	480	4594	5074	7064.0	2.0	7066.0
1980	483	5546	6029	7759.0	3.1	7762.1
1981	629	4980	5609	6996.0	6.1	7002.1
1982	564	5574	6138	7203.0	7.5	7210.5

Source: Animal Production Branch (1979-1983). Annual Reports 1978-1982. MLD: Nairobi.

Table 6.8: Distribution of sheep and goats by province, 1982

Province	Number ('000 head)					
	Sheep			Goats		
	Wool-type	Hair-type	Total	Meat-type	Milk-type	Total
Nairobi	0.4	0.3	0.7	1.5	0.8	2.3
Central	182.6	198.0	380.6	187.0	3.5	190.5
Coast	-	247.0	247.0	545.0	1.0	546.0
Eastern	3.5	1217.0	1220.5	1537.5	0.2	1537.7
Northeastern	-	453.0	453.0	610.0	-	610.0
Nyanza	1.5	450.0	451.5	607.0	0.2	607.2
Rift Valley	375.0	2909.0	3284.0	3602.0	1.8	3603.8
Western	1.0	99.7	100.7	113.0	-	113.0
Totals	564.0	5574.0	6138.0	7203.0	7.5	7210.5

Source: Animal Production Branch (1983). Annual Report 1982. MLD: Nairobi.

Laikipia Districts and in the higher-altitude areas of Nakuru, West Pokot, and Elgeyo Marakwet Districts. Approximately half of all the small population of milking goats are to be found in Nairobi and Central Provinces.

Data on the approximate distribution of sheep and goats by ecological zone are shown in Table 6.9. As might be expected, all wool-type sheep and milk-type goats are managed in agro-ecological zone II.

The most common wool-sheep breeds are Romney Marsh, Hampshire Down, and Corriedales, and the major part of the national wool-sheep flock comprises sheep of these breeds, and their crosses, together with a small number of Merino sheep. There are two major indigenous sheep breeds, the Blackhead Persian, extant throughout the northern rangelands, and the Red Maasai, found mainly in the southwestern rangelands. In addition, there are a large number of crossbreds of these two breeds and crossbreds between them and the wool breeds. The Dorper breed of sheep has been introduced and Dorpers are increasing in number. They are very popular in the ranching and dryland farming areas.

There are two major breeds of indigenous goats. The Galla, found throughout the dry northern pastoral districts, and the Small East African, bred in all other districts. Galla goats are rather uniform in type, while there is very great variation in type within the Small East African breed. There have been small importations of meat-type goats, particularly of the Boer breed, and of wool-producing Angora goats. Temperate-type milking goats of the Anglo-Nubian, Saanen, and Toggenburg breeds have also been imported, and although there is a small number of purebred herds, the imported goats have been mainly used to produce crossbred milking goats for use by smallholders and women's groups.

At present, breeding and some other aspects of sheep and goat research are conducted by the Sheep and Goat Development Project, supported by FAO/UNDP. This project is administered by the Animal Production Branch of MOALD and not by SRD, although use is made of some experimental stations, including Naivasha. In addition, the Small Ruminant Collaborative Research Support Program (CRSP), funded by USAID, is also using facilities at Naivasha, where an attempt is being made to breed a dual-purpose (meat/milk) goat.

Wool production

Wool production was estimated to be 1,230,760 kg in 1982, with the Kenya Farmers Association (KFA) purchasing about 75 percent of the crop. Mature sheep produce on average approximately 4 kg of wool per annum.

Meat and skins production

Estimates of the production of meat and the total number of skins from sheep and goats are provided in Table 6.10. These are likely to be underestimates, as the slaughter of many sheep and goats is unrecorded, particularly in the pastoral areas. Nevertheless, the comparative data suggest that the production of meat from sheep and goats fluctuates considerably from year to year, that there is a higher offtake from goats than from sheep, and that goat meat is possibly more popular with consumers than mutton and lamb.

Table 6.9: Distribution of sheep and goats by agro-ecological zone, 1982

Agro-ecological zone	Sheep		Goats	
	Wool-type ('000 head)	Hair-type ('000 head)	Wool-type ('000 head)	Hair-type ('000 head)
II	564	750	753	7.5
III	-	1200	1250	-
IV	-	1350	2150	-
V	-	1774	2330	-
VI	-	500	720	-
Totals	564	5574	7203	7.5

Source: Animal Production Branch (1983). Annual Report 1982. MLD: Nairobi.

Table 6.10: Estimates of the production of skins and meat from sheep and goats in 1978 and 1982

	1978	1982
Sheep population ('000 head)	6,560	6,138
Number of skins ('000)	1,645	1,251
Estimated % offtake[1]	25.0	20.4
Estimated meat production (m.t.)[2]	13,818	10,509
Goat population ('000 head)	8,502	7,210
Number of skins ('000)	2,612	1,786
Estimated % offtake[1]	30.7	24.8
Estimated meat production (m.t.)[2]	21,941	15,003
Estimated total number of skins ('000)	4,257	3,037
Estimated total meat production (m.t.)	35,759	25,511

Notes: [1] The offtake is estimated to be 40, 40, and 20 percent from large farms, smallholdings, and pastoral areas, respectively.

[2] Estimated liveweights of sheep and goats on large farms, smallholdings, and in pastoral districts are 17, 18, and 14 kg, respectively; carcass weights are approximately 50 percent of liveweights.

Source: Annual reports of the Animal Production Branch, MLD.

Camels

Information on the camel population of Kenya and of the productivity of camels is very limited.

Estimates of the camel population for the years 1977-82, partly based on data provided by KREMU and partly on estimates from the Animal Production Branch of the Ministry of Livestock Production (MLD) are:

Year	Number of camels ('000 head)
1977	607
1978	680
1979	790
1980	n.d.
1981	638
1982	825

Although there are major fluctuations from year to year, the general trend appears to suggest an increase in the camel population. It is possible that this is a real trend, as the camel population is likely to increase as the rangeland condition deteriorates, and there are persistent reports that camel ownership is spreading to pastoralists who never used camels in the past.

All pastoralists manage camels for milk production, and the majority use them for transport and for meat production. It is estimated that adult female camels produce on average 750 litres of milk per annum (Table 6.5) in addition to milk taken by their suckling calves and that the live weight of adult camels in Kenya varies from 250 to 400 kg.

Pigs

Data on the number and distribution of pigs by province between 1977 and 1982 are provided in Table 6.11. Pig numbers increased by 35 percent between 1977 and 1982, but there have been large fluctuations in numbers from year to year. More than 80 percent of all pigs are reared in Nairobi, Central, and Rift Valley Provinces, approximately half the total pig population being found in Central Province, where the main pig-farming districts are Kiambu, Nyeri, and Murang'a.

There is evidence that the pig industry is developing into a smallholding industry, as the number of pigs raised on large farms is decreasing at the rate of about 500 per annum. Unfortunately, data on the structure of herds shown below suggests that small farms are less efficient than large farms at pig production.

Class of pig	Class of pig as a % of total pigs	
	Smallholdings	Large farms
Breeding sows and gilts	20	18
Breeding boars	10	2
Piglets	23	31
Porkers/baconers	45	48
Others	2	1

Table 6.11: The number and distribution of pigs by province, 1977-1982

Province	Number of pigs 1977	1978	1979	1980	1981	1982	% change between 1977 and 1982
Nairobi	3,100	4,200	4,300	4,300	3,300	4,280	+38
Central	31,120	36,400	37,100	41,799	34,900	47,700	+53
Coast	800	992	800	581	800	600	-25
Eastern	3,476	5,109	5,700	5,109	9,700	9,160	+164
North Eastern	-	-	-	-	-	-	-
Nyanza	953	660	1,000	600	700	1,000	+5
Rift Valley	15,498	13,230	11,940	15,287	18,200	21,050	+36
Western	5,714	6,195	7,000	6,400	7,200	8,300	+45
Totals	67,652	66,789	67,840	74,096	74,800	91,090	+35

Source: Annual reports of the Animal Production Branch, MLD.

These data show that there are less breeding females and boars but more piglets and fattening pigs on large farms, suggesting that breeding is more efficient and/or piglet mortality less than on smallholdings. Evidence of declining efficiency in the pig industry is also provided by the slaughter data shown below:

Year	Estimated number of pigs slaughtered	Total number of pigs
1978	80,000	66,800
1979	80,000	67,800
1980	57,600	74,100
1981	57,700	74,800
1982	64,800	91,100

As the total number of pigs on farms has increased, the number slaughtered has fallen. This is probably due to the fact that piglets are growing slowly and have to be retained on the farm for longer periods. If, as the available evidence suggests, there are approximately 17,000 breeding sows at any one time on the farms, then under good average pig farming conditions, each sow should produce some 16 live piglets weaned and fattened per annum. The slaughter data suggests that Kenya pig farmers are only producing 5+ piglets. On the assumption that the average liveweight of slaughtered pigs is 100kg and that the killing out percentage is 75, approximately 4900 m.t. of pig meat were produced in 1982.

Poultry

The estimated numbers of exotic egg-laying, broiler, and indigenous poultry in the years from 1977 to 1982 are provided in Table 6.12. These estimates suggest that the exotic egg-laying poultry population has expanded faster than the indigenous poultry population but that in 1982 the exotic poultry population still accounted for only 20 percent of the total poultry population. The exotic broiler population has fluctuated from year to year, with a major increase in numbers in 1982. It should be noted that the estimate for poultry numbers in 1981 (Table 6.12) is somewhat different from the estimate in Table 6.1, demonstrating the rather arbitrary nature of the estimates of poultry populations and the degree of error involved.

In Table 6.13 estimated numbers of exotic and indigenous poultry by province are shown. The modern sector of the egg industry is mainly concentrated in Central and Coast Provinces (75 percent of total exotic layers), while the modern broiler industry is concentrated in and around Nairobi. The largest concentrations of indigenous poultry are in Western Kenya, more than 50 percent of total indigenous poultry being found in Western and Nyanza Provinces.

There is a National Poultry Development Plan, assisted by the Government of the Netherlands, and as a part of this plan a National Poultry Research Unit has been established at Naivasha. This unit is at present testing commercial feeds and conducting random hybrid poultry sample and broiler density investigations.

Table 6.12: Estimated indigenous and exotic poultry populations, 1977 to 1982

Year	Poultry populations ('000 head)			
	Indigenous	Exotic egg layers	Exotic broilers	Totals
1977	12,000	906	1,093	13,999
1978	12,820	1,730	460	15,010
1979	13,320	1,900	500	15,720
1980	13,349	1,799	500	15,648
1981	13,890	1,946	534	16,370
1982	15,300	1,570	2,726	19,596

Source: Annual reports of the Animal Production Branch, MLD.

Table 6.13: Estimated indigenous and exotic poultry populations in 1982, by province

Province	Poultry populations ('000 head)				
	Indigenous	Exotic egg layers	Exotic broilers	Totals	as % national total
Nairobi	11	60	1,766	1,837	9
Central	1,177	820	280	2,277	12
Coast	1,275	360	130	1,765	9
Eastern	2,928	153	330	3,411	17
North Eastern	22	-	-	22	neg.
Nyanza	4,793	39	24	4,856	25
Rift Valley	2,050	96	170	2,316	12
Western	3,044	42	26	3,112	16
	15,300	1,570	2,726	19,596	

Source: Animal Production Branch (1983). Annual Report 1982. MLD: Nairobi.

Egg and poultry meat production

Estimates of the number of eggs produced in Kenya in 1982 are provided below:

	Poultry population ('000 head)	No. eggs laid ('000)	% of eggs laid that are sold
Indigenous	15,329	306,380	10
Exotic	1,570	334,000	99
Totals	16,899	640,380	

Of the estimated 640 million eggs produced in 1982 52 percent were produced by exotic poultry that comprised 9 percent of the national poultry stock.

Details of the number of poultry estimated to be slaughtered and the production of poultry meat in 1982 are as follows:

	Number of poultry slaughtered ('000 head)	Average slaughter weight (kg)	Poultry meat production (m.t.)	as % total production
Indigenous	15,329	1.7	26,059	82
Broilers	2,726	1.8	4,907	15
Culled exotic layers	501	1.9	952	3
Totals	18,556		31,918	

Thus although exotic poultry provide at least half of all eggs produced in the country, indigenous poultry provide the major proportion of the poultry meat produced.

Rabbits

Details of the domestic rabbit population by province for the years 1979 to 1982 are shown in Table 6.14. The population has more than doubled in four years and almost half is concentrated in Central Province. In 1982 it was estimated that there were 150-200 semi-intensive and 40-60 intensive rabbit units in the country.

There is a National Rabbit Production Program administered by the Animal Production Branch of MOALD, and this includes breeding investigations and the establishment of a National Rabbit Stud Flock.

Estimates of the number of rabbits slaughtered and the total production of rabbit meat between 1978 and 1982 are provided below. It is estimated that the average rabbit carcass weighs one kilogram.

Table 6.14: Domestic rabbit population by province, 1979 to 1982

Province	Domestic rabbit population 1979	1980	1981	1982	1982 population as % national total
Nairobi	5,000	5,500	5,600	7,000	8
Central	16,800	36,300	36,600	41,700	46
Coast	3,800	4,000	6,600	7,900	9
Eastern	8,200	9,700	10,100	15,500	17
North Eastern	-	-	-	-	-
Nyanza	2,600	2,600	2,600	6,700	8
Rift Valley	3,200	3,400	4,300	6,560	7
Western	2,000	2,000	4,200	4,800	5
Totals	41,600	63,500	70,000	90,160	

Source: Annual reports of the Animal Production Branch. MLD.

Year	Rabbit population	Number rabbits slaughtered	Rabbit meat production (m.t.)
1978	36,100	52,000	52
1979	41,600	80,000	82
1980	63,500	100,000	100
1981	70,000	110,000	110
1982	90,200	360,000	360

As the number of rabbits slaughtered is increasing more rapidly than the rabbit population, it is assumed that the industry is increasing in efficiency. Generally, rabbit pelts are not utilized.

6.1.2 Wildlife resources

Wildlife are comparatively numerous and an important economic asset in Kenya; at present mainly as a tourist attraction, but also to a lesser degree as a source of game meat for local inhabitants and live game for export. If hunting is recommenced, wildlife will provide additional revenue in the form of hunting licenses and game trophies.

On rangelands outside the National Parks, game and domestic livestock compete directly for feed and water resources, and it is necessary to aquire some knowledge of the number or game animals in order to be able to estimate the overall grazing pressures on the rangelands of game and domestic livestock. There are also animal health problems associated with the intermingling of wild and domestic grazing species, as wild species may act as reservoirs of domestic livestock parasites and diseases. These problems are dealt with in Chapter 7.

Since 1977 KREMU has been conducting inventories of game and domestic animals in the rangelands, using aerial survey techniques. The individual game species population totals have been converted into Tropical Livestock Units (TLUs) and KREMU has published data on the total number of wildlife TLUs in each rangeland district[1]. Data on the number of wildlife TLUs in rangeland districts and wildlife densities are provided in Table 6.15. It will be seen that the major concentrations of wildlife are to be found in Lamu and Taita Taveta Districts in Coast Province and Kajiado, Laikipia, and Narok Districts in Rift Valley Province.

6.1.3 Land and forage resources

Estimates can be made of the livestock carrying capacity of unit areas of cultivated forages, planted and natural pastures, and rangelands, but data are not available on the areas to be found in each district. The situation in the high-potential farming areas is complicated on account of the major changes that have taken place in land tenure within the last two decades. The original large-scale farming system has been transformed into a mainly smallholder system. This has meant that planted pastures, suitable for large-scale ley farming systems, are no longer of the same importance, while cultivated forage crops suited to zero-grazing systems are more important, as they are

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[1] Peden (1984). For full reference see Table 6.15.

Table 6.15: Wildlife in rangeland districts

PROVINCE District	Number of wildlife TLU[1)]	Wildlife density (TLUs/km^2)
COAST		
Kilifi	15,983	1.29
Kwale	4,603	0.56
Lamu	61,508	9.45
Taita Teveta	149,189	8.80
Tana River	79,313	2.05
EASTERN		
Isiolo	36,802	1.44
Kitui	33,804	1.15
Marsabit	45,014	0.61
NORTH EASTERN		
Garissa	102,696	2.34
Mandera	11,803	0.45
Wajir	38,136	0.67
RIFT VALLEY		
Baringo	1,639	0.17
Kajiado	97,582	4.98
Laikipia	86,054	8.86
Narok	344,834	21.40
Samburu	35,165	2.00
Turkana	17,067	0.28
West Pokot	817	0.09

Note: [1)] 1 TLU is equivalent to 250 kg animal liveweight.

Source: Peden, D.G. (1984). Livestock and wildlife inventories by district in Kenya (1977-1983) KREMU: Nairobi.

required by smallholders. At the same time crop agriculture has expanded in both high-potential and semi-arid districts, with consequent reduction in the area of planted and/or natural pastures available for grazing and an increase in the availability of crop by-product feeds.

Cultivated forages

The major forage crop cultivated in the high-potential areas is Napier grass (Pennisetum purpureum). There are a large number of different varieties, and the variety Bana is recommended for use in both high-potential and dryland farming districts. Investigational work has demonstrated that the average dry-matter (DM) yield of Bana is of the order of 14 m.t. per annum per ha[1]. If it is assumed that average yields on smallholdings are of the order of half the average yield on experimental sites and that one LSU consumes approximately 2.2 m.t. DM per annum, then one hectare of Bana grass will provide sufficient feed year-round for 3 LSU's. In practice, as the zero-grazing system is very labor intensive, most smallholders do not plant a sufficient area of Napier grass to ensure a year-round supply of forage, but depend upon natural pasture and crop by-products as supplementary feeds. There has been some attempt to introduce legume forage crops into smallholdings in high-potential areas, and to date Desmodium spp. are the most successful. There are no estimates of the total area of cultivated forage crops grown.

Planted and natural pastures

One of the most successful grass species planted in leys is Rhodes grass (Chloris gayana). The average DM yield of Boma Rhodes, one of the more popular varieties, at experimental sites is 4 m.t. per ha per annum[1]. Allowing for wastage under field grazing conditions, Boma Rhodes leys should carry one LSU per ha year-round.

The average DM yield of star grass (Cynodon dactylon), one of the most productive of natural pasture grasses, is 4 m.t. per ha per annum under experimental conditions[1]. The carrying capacity of a good average star grass pasture is therefore 1 LSU per 1.5 to 2 ha. In practice many natural pastures are overgrazed and full of weeds and grasses inferior in feeding value to star grass so that their carrying capacity is likely to be far less. At Naivasha the carrying capacity of the mixed star grass pasture is estimated to be 1 LSU to 4 ha.

Available grazing lands in the high (agro-ecological zone II) and moderate (agro-ecological zone III) potential grazing lands are estimated to be less than two million ha and four million ha, respectively.

Range resources

On account of wide variations in climatic, edaphic, and socio-economic conditions, forage resources in the rangelands vary widely from district to district, with livestock carrying capacities of from 1 LSU to 5 ha to 1 LSU to more than 25 ha.

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[1] Jaetzold, R. and Schmidt, H. (1982).
Farm Management Handbook of Kenya. MLD: Nairobi.

The total area of rangeland is 44.4 million ha or 79 percent of the total land area of Kenya. The distribution of this rangeland by agro-ecological zone is as follows:

Agro-ecological zone	Area of rangeland (million ha)	Area of zones as % total area
IV	13.0	29
V	26.0	59
VI	5.4	12

Information on estimated stocking rates and managerial systems in rangeland districts is provided in Table 6.16. Stocking rates were estimated by deducting the area of crops grown from the total land area in districts and dividing the resulting rangeland area by the estimated number of LSUs in the district. As the area of rangeland must include some land that cannot be grazed, the area available per LSU is overestimated, but the resulting data are useful for comparative purposes.

When the grazing pressure of both wildlife and domestic livestock is considered, it can be stated quite categorically that all rangeland districts are overgrazed. In North Eastern Province, Marsabit in Eastern Province, and Turkana in Rift Valley Province, stocking rates that would provide stability and ultimately some improvement in rangeland forage resources are probably of the order of 15 to 25 ha per LSU, while in Coast Province and Isiolo, Baringo, and Samburu Districts they are likely to be of the order of 10 to 15 ha per LSU. Kajiado, Laikipia, and Narok Districts, where the rangelands have a relatively high carrying capacity, are also overstocked.

The overall situation with regard to stocking rates

Details of stocking rates and the density of grazing livestock in the high- and medium-potential agricultural districts are provided in Table 3.17. All land in the districts except the area cropped is included in the area estimated to be available for grazing, but some part of this area will not be available. However, in districts where there is a high proportion of cropped land, such as Kisii, there will be crop by-products available as animal feeds. Nevertheless, in a district such as Kisii, where it is estimated that there are 3.36 LSUs for every hectare of uncropped land, there must be limits on any further expansion of livestock numbers.

Throughout the high agricultural potential districts, stocking rates are relatively high, and it is doubtful whether existing stocking rates are sustainable in dryland farming districts such as Machakos.

Crop by-products resource

There are large quantities of crop by-product livestock feeds available in Kenya, and some details of the area grown and current production of the major crops that provide by-products are provided in Table 6.18.

Table 6.16: Estimated stocking rates and managerial systems in rangeland districts, 1981

PROVINCE District	Stocking rates ha/LSU		Number of cattle ('000 head) Managerial system					
	Domestic livestock	Domestic[1] livestock and game	Individual company	Cooperative ranch	Group ranch	Grazing block	Traditional	Total
COAST								
Kilifi	8.7	7.7	18	-	18	-	24	60
Kwale	7.2	6.9	17	7	24	-	-	48
Lamu	21.4	7.0	13	2	-	-	2	17
Taita Taveta	23.9	7.5	54	8	15	-	-	77
Tana River	12.8	10.1	86	35	138	87	-	346
			188	52	195	87	26	548
EASTERN								
Isiolo	10.3	9.0	12	-	-	223[2]	-	235
Marsabit	20.6	18.3	-	-	-	31[2]	121	152
			12	-	-	254	121	387
NORTH EASTERN								
Garissa	11.7	9.2	-	-	-	200[3]	231	431
Mandera	12.2	11.6	-	-	-	46[3]	46	92
Wajir	19.5	17.3	-	-	-	98[3]	65	163
						344	342	686
RIFT VALLEY								
Baringo	4.2	4.1	18	-	157	-	-	175
Kajiado	3.8	3.2	64	-	580	-	-	644
Laikipia	4.0	3.0	180	75	45	-	-	300
Narok	2.4	1.6	70	-	630	-	-	700
Samburu	8.2	7.0	31	-	82	-	92	205
Turkana	15.1	14.5	-	-	-	30[2]	117	147
West Pokot	10.6	10.5	7	10	17	-	34	68
			370	85	1511	30	243	2239

Notes:

1) Includes all grazing species, domestic and wild.
2) Grazing blocks planned but not fully established.
3) In North eastern Province districts some grazing blocks have been completed, others not; some difficulty now in distinguishing the grazing block and traditional areas.

Source: Ronco Consulting Corporation (1984). Evaluation: Agricultural Systems Support Project (ASSP), No.615.0169 Kenya. Ronco Consulting Corporation: Washington.

Table 6.17: Estimates of stocking rates and of the density of grazing livestock in the high- and medium-potential agricultural districts

PROVINCE District	Total land area (km^2)	Area not cropped[1] (km^2)	Total domestic[2] livestock LSU's ('000)	Hectares available per LSU	Density of grazing livestock (LSU per ha)
CENTRAL					
Kiambu	2448	1850	115.6	1.6	0.63
Kirinyaga	1437	710	84.2	0.3	1.12
Muranga	2476	1450	192.5	0.8	1.33
Nyandarua	3528	3100	198.3	1.6	0.64
Nyeri	3284	2410	166.4	1.4	0.69
EASTERN					
Embu	2714	1730	59.8	2.9	0.35
Kitui	29388	27268	190.4	12.2	0.08
Machakos	14178	10900	382.1	2.9	0.35
Meru	9922	7810	313.1	2.5	0.40
NYANZA					
Kisii	2196	940	315.4	0.3	3.36
Kisumu	2093	1340	129.6	1.0	0.97
Siaya	2522	1500	295.0	0.5	1.97
South Nyanza	5714	3610	427.2	0.8	1.18
RIFT VALLEY					
Elgeyo Marakwet	2279	1940	124.3	1.6	0.64
Kericho	3931	2971	591.5	5.0	0.20
Nakuru	5769	4820	231.5	2.1	0.48
Nandi	2745	2050	280.1	0.7	1.37
Trans-Nzoia	2078	1440	84.0	1.7	0.58
Uasin Gishu	3378	2310	169.5	1.4	0.73
WESTERN					
Bungoma	3074	1930	146.2	1.3	0.76
Busia	1626	840	110.6	0.8	1.32
Kakamega	3495	1510	251.6	0.6	1.67

Notes: [1] The area not cropped is calculated by deducting the total crop area from the total land area; it is not necessarily grazing land, although the major part of it will be.
[2] The total LSUs in each district were calculated from the 1981 livestock population estimates.

Sources: Central Bureau of Statistics (1983) Statistical Abstracts. Ministry of Economic Planning and Development: Nairobi.
Annual Reports of the Animal Production Branch. MLD:Nairobi.

Table 6.18: Major crops that could provide by-product livestock feeds

Crop	Area harvested ('000 ha)	Production ('000 m.t.)	By-product that can be used as animal feed
Maize	1230	2550	Stover (straw); grain; milling by-products
Beans	456	370	haulm (stalk)
Cotton	142	27	cottonseed; cottonseed cake
Wheat	124	233	straw; milling by-products
Sugarcane	113	4400	molasses; bagasse; sugarcane tops
Sisal	108	41	sisal waste
Sorghum	105	90	stover; grain
Millet	75	62	stover; grain
Pigeon pea	61	36	haulm
Bananas	61	665	stem; leaves; waste green bananas
Cassava	47	672	tops; roots
Coconuts	34	33	copra; coconut meal
Cashew	29	20	cashew waste
Rice	11	39	straw; bran

6.2 The Role of Livestock in Kenya Agriculture

Livestock are a major factor in Kenya agriculture, whether it be in the rangelands, where pastoralism is the dominant way of life, or in the high- and medium-potential areas, where the majority of Kenyan farmers own some grazing livestock, even if their holdings are very small.

The industry comprises a mosaic of modern, cash/subsistence, and subsistence sectors and includes a multiplicity of livestock systems. This is well illustrated by the overall milk production scenario. There was an estimated total milk production in the country of 1566 million litres in 1982 (Table 6.5), but only 600 million litres or 38 percent of the total production was estimated to be sold and to enter into the milk distribution system. It is estimated that large farmers sold 96 percent of the 125 million litres produced by their grade dairy cattle, while smallholders only sold 44 percent of the 1096 million litres produced by their grade dairy and indigenous cattle. The pastoralists consumed all of their estimated production of 345 million litres.

Because the industry is heterogeneous, livestock play a variety of roles, some of which are described below.

In high-potential areas livestock are usually an integral part of the farming system. On large farms, grade dairy and/or beef cattle or wool sheep are grazed on grass/legume leys and are considered as a cash crop. The grazing leys are rotated with cash crops, usually barley, wheat, or potatoes. On smallholdings, cattle provide milk for sale and home consumption, work oxen, and manure. Increasingly, the cattle are grade dairy cattle, managed under zero grazing conditions. In addition, smallholders usually maintain a few sheep and/or goats that are sold for cash or provide meat for home consumption. They are usually grazed on natural pasture, roadways, etc. The smallholder may also have a pig or an exotic poultry enterprise. There will certainly be some indigenous poultry around the holding. The cash income of the smallholder is derived from both crops and livestock.

In the drier ranching areas, large herds of cattle, usually Boran or Boran crossbreds, are grazed on fenced and watered natural pastures. Inputs are relatively low and slaughter cattle are the major cash crop. Large flocks of hair sheep and meat goats are also being managed on these ranches as the advantages of mixed grazing and browzing species is increasingly recognized.

Crop yields are generally lower in the dryland farming areas than in the high-potential districts, and a higher proportion of the crops is consumed on the farm. Consequently, ruminant livestock, particularly sheep and goats, are the major cash crop for smallholders. A survey in Machakos District, a major dryland farming district, has shown that livestock provide some 60 percent of total farm income. There is an increasing demand for acclimatized dairy cattle in the dryland farming districts, and zero-grazing managerial systems are being introduced. There will also be some indigenous poultry on the smallholdings.

In the pastoral areas that occupy about threequarters of the total area of the country, milk is the major crop and the principal food of the pastoralists. Cattle, camels, and sometimes sheep and goats, are milked, and the annual per capita consumption of milk by the pastoralists is at least three times as high as that of the rural population elsewhere.

Although milk is the subsistence crop, live animals are the cash crop. Cattle, sheep, goats, and sometimes camels, are sold to livestock traders, as and when quarantines and other circumstances allow.

At present the livestock industry could be described as an industry in transition, but not all sectors are moving in the same direction or changing at the same pace. The increase in the number of milking cattle and in the production of milk is very marked (Table 6.4), as is the increase in the number of exotic poultry (Table 6.12) that now lay more than half of all the eggs that are produced, but the productivity of the pig industry has apparently declined as it has developed into a smallholder industry.

6.2.1 The effect of national policy objectives on the future role of the livestock industry

National policy objectives, as listed in Section 6.0, are discussed below with respect to their effect on the future role of the livestock industry.

a) The first objective is to produce sufficient animal foodstuffs, specifically milk and meat, to satisfy the nutritional needs of a growing population.
Milk. As it is estimated that only about half the cow's milk produced in 1982 was sold and that the number of grade milking cattle is increasing (Table 6.4), it should not be too difficult to satisfy the demand for milk by 1990 if the government pursues a milk pricing policy that encourages farmers to sell a higher proportion of the milk that they produce, artificial insemination and other services are improved so that there is a continuous upgrading of zebu to grade milking cattle, and there is a breeding program that will produce acclimatized milking cattle for the dryland farming areas. Given these assumptions, milk production and sales should increase at least as rapidly as demand.
Meat. Unfortunately, the above optimistic scenario does not apply in the case of beef. Estimated demand by 1990 is 228,000 m.t. while total production in 1982 was only 138,000 m.t. (Table 6.6). Beef production may in fact decline as pasture in higher- and medium-potential areas is replaced by crops and the rangelands continue to deteriorate, unless there is a rapid increase in production from the grade dairy herds. It is also unlikely that shortfalls in the supply of beef can be balanced by substantial increases in pig and poultry meat production, as both classes of livestock are in direct competition with humans for feed grains. There could, however, given a suitable research and development policy, be an increase in the quantity of meat produced by sheep and goats.

b) The second objective is to adopt production systems that will conserve natural resources and sustain yields.
High-potential areas. There is no reason why the substitution of grade dairy for zebu cattle should endanger natural resources, and intensification could increase overall fertility.
Dryland farming areas. Stocking rates are already high (Table 6.17), and a major research effort is required to provide drought-resistant forage and acclimatized livestock for these areas.
Rangelands. These are already overgrazed. The systems should be studied, but a major development effort is required to prevent further deterioration.

c) The third objective is to improve employment opportunities. The proliferation of smallholdings will increase employment opportunities, as will an increase in zero-grazing dairy farming systems. The provision of alternative employment to pastoralism in or outside the pastoral districts would help to decrease overgrazing, as there is a direct relationship between the number of pastoralists and the number of grazing livestock.

d) An improvement in the overall production of livestock is the fourth objective. This is an attainable objective in many sectors of the industry, but it will require a major research and development effort.

e) The fifth objective of exporting any animal products surplus to domestic consumption requirements will have to be accorded a low priority, but there will always be some animal products available for export.

6.2.2 Research needs of the livestock industry

If the government is to achieve the objectives set forth in the National Livestock Development Policy, then a meaningful national animal production research policy is essential.

The detailed research programs and priorities for research programs are discussed in Section 6.4; only the basic needs for animal production research are listed here. These include:

a) A network of research centers providing a comprehensive cover of the major agro-ecological zones and stocked with the principal classes of livestock that are to be studied.

b) Staff with both a general training in agriculture or veterinary science and specialized training in animal breeding, animal physiology, nutrition, etc. Animal production research often requires interdisciplinary teams.

c) Adequate land, livestock, laboratory, and other resources at the research centers or elsewhere. Most animal breeding work will have to be conducted outside research centers.

d) An element of coordinated direction of programs. Continuity of effort is important, as many animal production investigations will last for several or many seasons. Animal breeding studies usually last for many years.

6.3 The Current Status of Animal Production Research

The components of animal production are: animal breeding; animal nutrition, including many aspects of pasture and range management, production and utilization, animal physiology, specifically climatic adaptation, and reproductive behavior; animal management that is part applied sciences and part intuitive skills; and animal health, a component that is considered separately in Chapter 7. In addition, partly on account of the number of agro-ecological zones in Kenya, many different types of livestock are used, including exotic and indigenous dairy and beef cattle, wool and hair sheep, meat and dairy goats, pigs,

indigenous and exotic poultry, rabbits, camels, and donkeys. Wildlife species are also important in the rangelands. The combinations of different components in animal production and the different types of livestock utilized create formidable animal production research problems, particularly with regard to the establishment of priorities and the provison of sufficient resources for a priority program. These problems have been intensified as animal production research has been relatively neglected during the last two decades, while responsibility for its administration has been shuttled backwards and forwards between one authority and another, sometimes in the same ministry and at other times in different ministries.

The result has been limited and constantly changing direction with regard to priority research programs and the status of stations, together with staff demoralization and an insufficient output of meaningful research data.

6.3.1 Current animal production research programs

Stations with facilities for pasture, range management, animal production, or veterinary research are listed in Table 6.19. Current research projects at the individual stations will be discussed as components of the pasture, range, animal breeding, animal nutrition, animal physiology, and animal management research programs.

Pasture and forage research

The NARS, Kitale, holds a mandate for national pasture research management and administers research sections concerned with forage collection and evaluation, forage breeding, forage agronomy, forage microbiology, and pasture chemistry. The station has also established a forage species gene bank. Evaluation of pasture and forage species is partly conducted using livestock. Forage breeding investigations are mainly concerned with the evaluation of *Pennisetum* spp. hybrids. Varieties of Napier grass, fodder sorghum, lucerne, and lupins are major forage plants investigated in the agronomy program. The critical level of nitrogen in nitrogen fixation is being investigated by the forage microbiologists, and the screening of forage plants for nitrates and oxalates is being conducted by the forage chemists.

Forage investigations, particularly studies of the management and utilization of Napier grass, are also being conducted at Kakamega and its sub-station Alupe, Lanet, Naivasha, Muguga, Embu, Katumani, Garissa, Mariakani, Mtwapa, and possibly elsewhere, but this nationwide program is not in practice properly coordinated from Kitale. There are major constraints on coordination efforts by Kitale staff, primarily imposed by lack of resources, but it is also doubtful whether Kitale is now the most suitable center from which a nationwide pasture and forage program should be coordinated. Kitale was originally established primarily to conduct research on the establishment and maintenance of planted pastures essential for the ley farming systems practiced on large farms. Planted pastures may still be important on the remaining large farms in Trans-Nzoia, Uasin Gishu, and Nakuru Districts, but of more immediate priority for a national pasture and forage research program are the problems of forage production and utilization in zero-grazing systems on small farms in high-potential areas and of forage production in dry-land farming districts and in Coastal Province.

Table 6.19: Stations with facilities for pasture, range, animal production, or veterinary research

Province District	Station (Substation)	Area (ha)	AEZ	Altitude (m)	Av. ann. rainfall (mm)	Mean ann. temperature (°C)
CENTRAL						
Nyandarua	Nyandarua Agric. Exp. Station, Ol' Jor Orok	405	II & III	2371	977	13.8
	Mandate: pig research (Landrace); wool sheep, Hampshire Down (mutton) and Corriedale (dual purpose); dairy cattle for medium-potential areas; leys, pure legume stands and agronomy and utilisation of fodders in frost susceptible areas.					
Kiambu	Veterinary Research Laboratories, Kabete					
	Mandate: virology; bacteriology; parasitology; pathology; chemistry (biochemistry); wildlife disease; veterinary epidemiology; economics.					
	KARI, Muguga	1174	III	2095	954	15.8
	Animal Production Research Department: Mandate: fodder production and utilization in central Kenya; *in vivo* digestibility trials; animal physiology; reproductive efficiency of beef cattle. Veterinary Research Department: Mandate: virology; protozoology; helminthology; bacteriology; vaccine production.					
	Univ. Nairobi, Kabete Limuru Substation		II	2300	1320	16.5
Kirinyaga	Karatina Veterinary Investigation Laboratory					
NAIROBI	Foot-and-Mouth Disease Laboratory, Embakasi					
	A substation of the Veterinary Research Laboratories, Kabete.					

Province District	Station (Substation)	Area (ha)	AEZ	Altitude (m)	Av. ann. rainfall (mm)	Mean ann. temperature (°C)
EASTERN						
Embu	Embu Agric. Res. Station, Embu	68	II & III	1450	1065	19.6
	Mandate: evaluation and utilization of forage by dairy cattle.					
Machakos	KARI ranch Athi River	1619	V			
	This is a substation of the Animal Production Research Department, KARI.					
	National Dryland Farming Res. Station, Katumani	500	IV	1600	717	19.3
	Mandate: integrated crop/fodder nutritional research and development of suitable systems of feeding and management of cattle, sheep, and goats; screening of grass and fodder legume varieties for suitability.					
	National Range Res. Station, Kiboko	30,000	V	975	595	
	Mandate: grazing behavior of animals on range; management of range for sustained production; domestic animal/wildlife relationships; carrying capacity of range vegetation; extensive sheep and goat production; establishment of a National Boran Stud.					
COAST						
Taita-Teveta	Buchuma Range Res. Station, Buchuma	2000	VI	396	500	24.8
	A substation of the National Range Research Station, Kiboko.					
	Mandate: as Kiboko					
Kilifi	Coastal Agric. Res. Station, Mtwapa	242	III		1258	
	Mandate: integrated tree crop/fodder/livestock research; comparative study of dairy breeds; processing and utilization of byproducts (cassava chips and meal, copra cake, cashew nut siftings, maize, bran); conservation of fodder; utilization of natural pasture.					
	Substations at: Msabaha, Malindi, Mpeketoni, Lamu, and Ngerenyi (Taita/Taveta).					

Province District	Station (Substation)	Area (ha)	AEZ	Altitude (m)	Av. ann. rainfall (mm)	Mean ann. temperature (°C)
	Msabaha Substation	40.5				
	This substation has a small herd of Jersey cattle; used to provide milk locally; no animal production research.					
Kwale Kilifi	Animal Hus. Res. Station, Mariakani	400	IV & V	204	856	26.0
	Part of this station is in Kwale and part in Kilifi districts.					
	Mandate: extensive ranching (local zebu and exotic crossbred) for milk and immatures for finishing on coastal strip; screening of grasses and legumes; role of fodder shrubs; conservation of fodder; role of small ruminants and rabbits; trekking experiment.					
	Substation at Bamba, Kilifi district	20				
	Mariakani Veterinary Investigation Laboratory					
	Satellites at Garissa and Lamu					
Kwale	Matuga Agric. Res. Station	(1250) 35 utilized	III	120	1100	
	This station was established in 1948 on 4000 ha; moved to Mtwapa in 1960; since 1979 rejuvenated; considered substation of Mtwapa in past but now has a separate budget. There is no animal work at present on this station, but there is ample room for livestock.					
NORTH EASTERN Garissa	Agricultural Res. Station, Garissa	(40,500) 8 utilized (leased)	VII			
	This is a research station in name only. There are said to be approx. 60 crossbred cattle (Sahiwal x Ayrshire and S x Boran), and a small herd of camels has been kept at Griftu, Wajir at the FTC.					

Province District	Station (Substation)	Area (ha)	AEZ	Altitude (m)	Av. ann. rainfall (mm)	Mean ann. temperature (°C)
EASTERN						
Marsabit	IPAL Project	-	VII			
	The headquarters of the project is in Marsabit town. Research is conducted on the surrounding rangelands in cooperation with the pastoralists. At present the project is funded by UNESCO and the West German Government.					
WESTERN						
Kakamega	Western Agric. Res. Station, Kakamega	101	I	1585	1918	20.0
	Mandate: integrated crop/forage animal nutrition research; zero-grazing for dairy cattle; supplements for Napier grass; byproducts (bagasse, molasses, etc.) utilization.					
Busia	Alupe Agric. Substation	223	I	1220	1766	21.9
	Mandate: program as for Kakamega.					
NYANZA						
Kisii	Nyanza Agric. Station Kisii	100	I	1765	2677	19.2
	The future of this station is uncertain at the present time.					
	Mandate: as Kakamega.					
RIFT VALLEY						
Trans-Nzoia	National Agric. Res. Station, Kitale	912	II & III	1890	1182	18.2
	Mandate: pasture and related research under high uni-modal rainfall, including forage introduction and evaluation, breeding, agronomy, analysis; forage pasture utilization on medium/large-scale farms; nutritional factors limiting meat and milk production.					

Province District	Station (Substation)	Area (ha)	AEZ	Altitude (m)	Av. ann. rainfall (mm)	Mean ann. temperature (°C)
Baringo	Chemerone Range Substation (Egerton College)	23	V		700	
Uasin Gishu	Eldoret Veterinary Investigation Laboratories					
Uasin Gishu	Eldoret Exp. Farm It is not known whether this station is used for experimental work.		III	2180	1100	15.5
Kericho	Kericho Veterinary Investigation Laboratories					
Nandi	Animal Husbandry Substation, Baraton			1981	1539	17.4
Nakuru	National Potato and Horticultural Res. Station, Marindas	266	II	2804	1209	12.4
	Mandate: to study wool sheep and dairy goats.					
	Beef Research Station, Lanet	1632	III & IV			
	Mandate: intensive and semi-intensive finishing of beef animals; conservation and utilization of forage by beef cattle; performance testing of beef animals.					
	Nakuru Veterinary Investigation Laboratories					
Nakuru	Egerton College		II & III	2238	1012	14.9
Nakuru	National Animal Hus. Res. Station, Naivasha This consists of two major properties: Olmagogo (1457 ha) and Naivasha (2560 ha).	4017	III, IV, V	1829	729	16.8
	Mandate: maintenance and genetic improvement of the Sahiwal Stud; crossbreeding of cattle for milk production; intensive (medium-scale) dairying; all aspects of pig and poultry research; boar performance testing unit; genetic studies on dairy and beef cattle.					

An investigational program concerned with the problems of forage production and utilization in zero-grazing systems on small farms in those areas of Kenya west of the Rift Valley can and possibly should be coordinated from Kitale, but investigations of the problems of forage production and utilization in the dryland farming areas and the coastal strip are probably more easily coordinated elsewhere.

Rangeland research

Rangelands occupy some 80 percent of the total area of Kenya and are the home of approximately three million people. Some 73 percent of the total land area, or 412,000 km^2, comprises rangelands in agro-ecological zones V and VI that can only be exploited by some form of livestock husbandry and/or by tourism.

As the NRRS at Kiboko holds the national mandate for range research, its investigational program is of considerable national inportance. An ambitious program (53 listed projects) includes such varied studies as: the management of rangeland, particularly by using the techniques of burning and rotational grazing; the influence of wildlife on rangeland productivity and management; soil/water relationships with regard to forage production; livestock management on rangelands; the economic justification for controlling ticks; mineral inputs and possible deficiencies; and the influence of burning on feed selection by livestock.

At the present time this investigational program is only meaningful for those parts of the rangelands that are managed as individual or cooperative ranches (Table 6.16), and to a lesser extent for those areas managed as group ranches. It does not relate in any meaningful manner to the problems in the northern pastoral districts, i.e., Garissa, Wajir, Mandera, Isiolo, Marsabit, Samburu, and Turkana, the major proportion of the rangelands of the country.

The staff at Kiboko are not totally unaware of this situation, and it is proposed that in future investigational programs they should place increased emphasis on socio-economic research concerned with the dynamics of the livestock systems in the northern pastoral areas and on such relevant problems as the impact of infrequent watering on livestock productivity and the development of strategies to alleviate the impact of drought. A considerable number of staff are being trained in the United States in rangeland research techniques, but although advanced training is very desirable, there must be some doubt as to whether their orientation will be such as to enable them to easily and realistically appraise the problems and constraints in the northern rangelands that are occupied by pastoralists.

Animal breeding studies

To date there have been few major animal breeding studies. The reason for this situation is partly historical. With the exception of ranchers in rangeland districts, the large-scale farmers were usually only interested in exotic dairy and beef cattle breeds and in wool sheep breeds. A small number of enthusiastic ranchers developed the Boran breed, a Large East African Zebu, because exotic beef cattle were not viable on their properties, but they were not at that time interested in hair sheep or meat goats.

Thus the breeding of exotic dairy and beef cattle and wool sheep was left to private enterprise and there were a sufficient number of skilled large-scale farmers interested in breeding these classes of livestock to ensure an adequate supply of breeding stock in the country.

The situation has now changed dramatically. With a majority of the large farms subdivided, there are less breeders of exotic livestock while the demand by smallholders for exotic and grade dairy cattle and wool sheep has increased. The Government, recognizing the gravity of the situation, charged the Agricultural Development Corporation (ADC) with the task of conserving the nation's pedigree herds and the ADC has now become the major owner of pedigree dairy and beef cattle herds, wool sheep flocks, and of the National Boran Stud at Mutara Ranch in Laikipia District. However, no national breeding plans have yet been proposed for the conservation and improvement of either the exotic or the indigenous livestock breeds of Kenya.

The most important and the longest lasting breeding study has been that in the Sahiwal herd at Naivasha. This herd was established in 1963, being assembled from the descendents of Sahiwal cattle imported in 1939 and 1945. The objectives of the study were to improve the genetic merit of the herd by progeny testing all bulls used for breeding, to provide progeny-tested bulls for use by the Central Artificial Insemination Station (CAIS) at Kabete, and to sell breeding stock to farmers. Since 1963, 200 bulls have been progeny tested, 22 used by CAIS to produce semen, and some 60-70 selected but untested bulls sold each year to farmers. The Sahiwal herd at Naivasha is certainly of high genetic merit and is a national asset. There is a considerable export demand for breeding cattle from this herd and for Sahiwal semen from CAIS. The herd numbers about 2,000 head at the present time, and the management is beset with problems, as the area of grazing land available has decreased as the herd has increased in number.

There have been investigations in which attempts have been made to produce crossbred dairy cattle suitable for different agro-ecological zones. These have been undertaken at Naivasha, Lanet, Katumani, Mariakani, Garissa, and possibly elsewhere, but the program has not been completely coordinated. There is some doubt as to whether at some centers the planned crossbreds were the most suitable cattle for local conditions, and there are still no firm data published as to which type of crossbred cattle is best acclimatized to which ecological zone.

Another facet of the breeding program is that a pedigree Boran herd has been established at Kiboko, and performance testing on bulls from Kiboko is conducted at Lanet.

Sheep and goat breeding studies have been conducted since 1972 at Naivasha and elsewhere by the FAO/UNDP 'Sheep and Goat Project', but this project has been administered by the Animal Production Branch of MOALD and not by SRD. Little progress has been made in these breeding studies.

Two purebred pig herds are maintained by MOALD, a Large White herd at Naivasha and a Landrace herd at Ol' Jor Orok. New boars of both breeds are imported at intervals, there is continuous recording, and selection pressures are exerted within these herds in order to improve productivity

No known poultry breeding has been undertaken to date.

Animal nutrition studies

The present density of stocking (Tables 6.16 and 6.17; Map 6.1) is such that there is probably some underfeeding of livestock even in high-potential areas. For example there is less than one hectare of uncropped land available per LSU in six districts in Western Kenya and in two districts in Central Province. In dryland farming districts such as Machakos, the present stocking rate is certainly unsustainable during very dry seasons, and throughout the pastoral areas the rangeland is continuously overstocked. Thus a major nutritional problem is the production of sufficient feed to support the present livestock population. This is primarily a forage, pasture, and rangeland vegetation production problem.

There are also the problems concerned with utilizing crop and other by-product feeds and as to whether their feeding value can be enhanced by some form of physical or chemical treatment. Investigations of the feeding value of by-products are being made at a number of stations, including Mariakani, Katumani, Muguga, Lanet, and Kakamega, and investigations on attempting to improve the feeding value of straw by chemical treatment are being conducted at Mariakani and Katumani. However, these studies do not appear to be coordinated in any manner.

The feeding of forage to dairy cattle in zero-grazing systems presents a number of nutritional problems, and one or more of these have been studied at Muguga, Naivasha, Katumani, and Kitale, but without a coordinated approach.

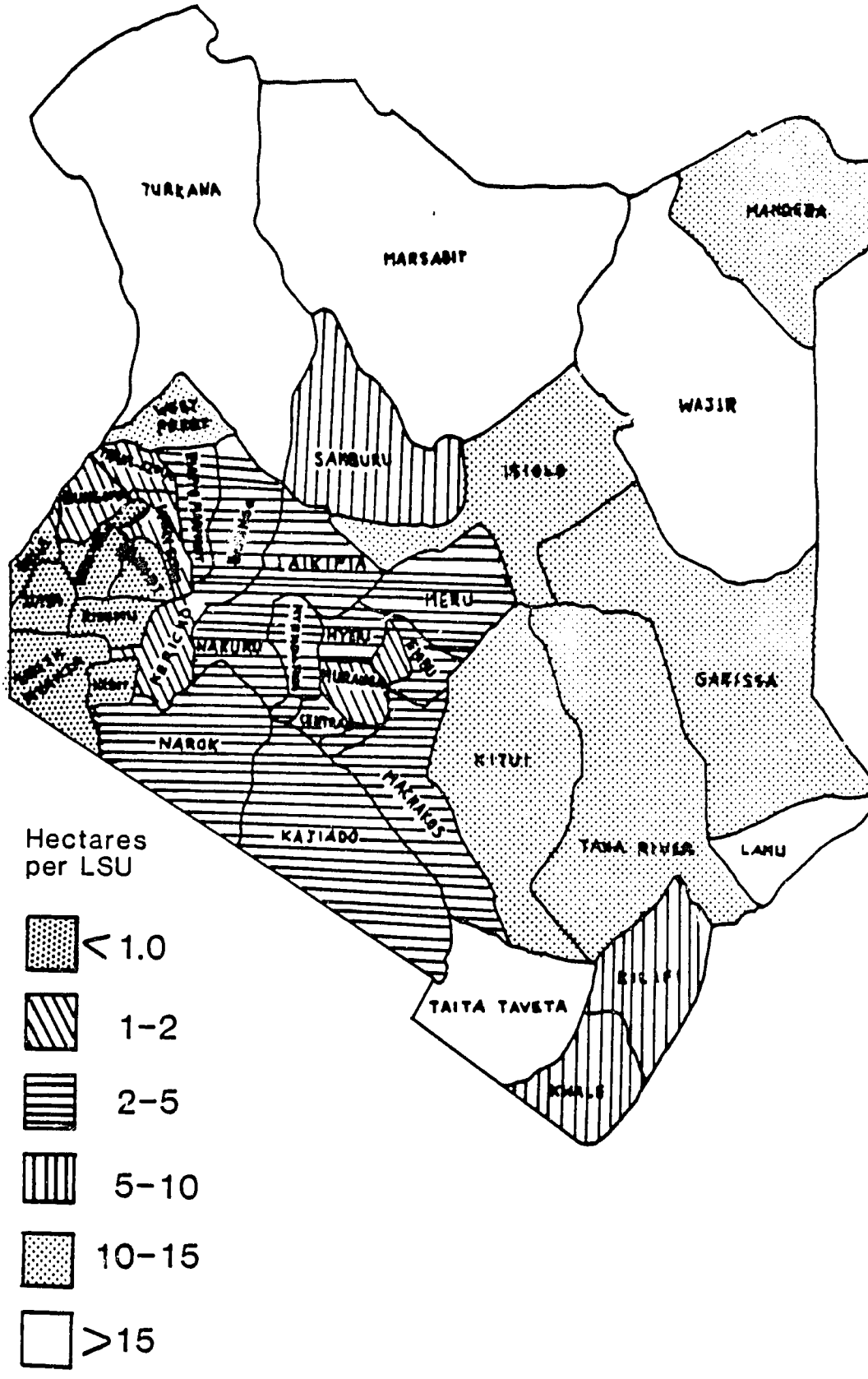
A very large number of investigations concerned with the husbandry of dairy cattle have been conducted at Naivasha and associated stations since the establishment of the Dairy Cattle Research Unit in 1969. Nutritional studies include: feeding experiments using pasture, by-product supplementary feeds, and concentrates with Guernsey, Friesian, and Sahiwal cattle; the effect of 'steaming-up' on milk production; methods of conserving feeds for dairy cattle; and the use of milk replacers and restricted feeding in dairy calf nutrition. At Lanet experiments are still being conducted on the composition of rations for the feedlot finishing of beef steers, despite the fact that feedlot finishing of steers has been uneconomic for a number of years and there are no commercial feedlots now operational in Kenya.

A limited number of investigations have been made on the nutritional requirements of sheep and goats. These include studies on the effect of feeding supplements on the production of Red Maasai sheep and dairy goats that have been conducted at Naivasha.

Some pig nutrition studies have been conducted at Naivasha, mainly in an effort to solve local problems, including verification of the quality of purchased feeds.

Poultry nutrition investigations at Naivasha have included evaluation of optimum energy requirements for broilers under Kenyan conditions, the value of different rations for broiler production, efforts to improve feed conversion efficiency, the effect of feed restriction during the growth period on egg production and verification of the quality of purchased feeds.

Fig. 6.1 Density of stocking in districts (ha/lsu)



Animal physiology research

There has been no planned physiological research on such important topics as acclimatization and water deprivation during the last two decades. Fertility in dairy cattle has, however, been the subject of a major investigational program based at Naivasha during the 1970s, and reproductive disorders in various classes of livestock have been investigated by Kabete Veterinary Research Laboratories and provincial Veterinary Investigation Laboratories on an ad hoc basis.

Animal management studies

Some management studies have been conducted at most stations, usually in an effort to solve local problems. At Naivasha there has been some concentration of studies on the management of cattle. These include investigations of calf rearing, the early weaning of calves, the effect of housing on the performance of cattle, and a study of calf mortality in the Naivasha Friesian herd during the period 1975-83.

Livestock systems research

Studies of livestock systems have been severely constrained in recent times by lack of resources, particularly vehicles and fuel. Some very useful surveys were, however, conducted in the past, such as the survey of fertility in Kenyan dairy cattle. Two recent studies are a diagnostic survey of farming systems in South Nyandarua completed in 1982 by Ministry of Livestock Development (MLD) staff and a study of the traditional livestock production systems of smallholder farms in the dryland areas of Eastern Province (Machakos, Kitui, and the lower-altitude areas of Embu District), completed but not yet analyzed by staff at Katumani.

6.3.2 Research assisted by external donors

Research assisted by external donors has been included in descriptions and discussions of the overall program without special reference. Some details of this assistance are as follows.

Pasture and forage research. The FAO/UNDP 'Forage Plant Development and Seed Production Project', with headquarters at the NARS, Kitale, is essentially an extension project, but valuable data are being obtained on the dry-matter (DM) yields of forage crops and the milk yield of dairy cows in different agro-ecological zones in Western Kenya and on forage crop seed yields. The project has organized eight forage multiplication centers, 94 first-generation forage pre-extension demonstration plots in Western Kenya, and established nine hectares for forage legume seed production at Kitale and Alupe.

Rangeland research. The NRRS at Kiboko was originally established in 1970 with FAO/UNDP assistance, and since 1969 it has received USAID assistance, with Winrock International Livestock Research and Training Center as the operational agency. Winrock International staff are assisting in the development of the station infrastructure, the research program, and the training of Kenyan staff, 18 of whom are studying at U.S. universities. Some doubts can be expressed as to whether the current research and training programs are completely relevant to the problems in the rangelands occupied by pastoralists, a major part of the total area of rangeland in the country.

Animal breeding studies. With the exception of the CRSP project all sheep and goat breeding, studies are at present being conducted by the FAO/UNDP 'Sheep and Goat Project' administered by the Animal Production Branch of MOALD. As there has been very limited progress since 1972, and the project is utilizing large areas of land on some SRD stations, particularly Naivasha, the present situation is unsatisfactory, and a new approach to the problems of sheep and goat breeding is required. In addition, through a Title XII SR-CRSP funded by USAID, Winrock International, three U.S. universities, and MOALD are collaborating in a long-term breeding program to produce a dual-purpose goat breed.

Animal nutrition studies. Dairy research, including nutritional research, at Naivasha, was originally assisted by the Netherlands Government. It is also assisting the NDDP, currently engaged in studying the problems of dairy zero-grazing managerial systems at Naivasha. The Overseas Development Administration of the U.K. (ODA) may also support studies of these systems at Muguga. In addition, the Netherlands Government has supported the establishment of the National Poultry Research Unit at Naivasha, where some nutritional studies have been conducted.

Livestock systems research. The International Livestock Centre for Africa (ILCA) commenced collaborative work with the GOK in 1976 with monitoring of Kenya's livestock development projects, and since 1980 intensive research has been conducted on three group ranches in the Maasai rangelands. It has now been agreed that ILCA should assist in the analysis of the results of the dryland livestock systems survey that has been conducted at Katumani and assisted by FAO/UNDP. Once the analysis of the results has been completed, a decision will be made as to whether ILCA will assist in the design and testing of appropriate interventions into dryland farming livestock systems.

6.3.3 Research-related services

At present national and regional SRD stations are producing purebred and/or crossbred livestock for sale to farmers. This is not a research activity, but it is a service valued by farmers, and it is in the national interest. Also, at many stations there are areas of land that are not at present farmed due to restricted station budgets and inadequate resources. Land that is not farmed attracts squatters or at least adverse local comment, and as future demands of research on land resources is unknown, it would be imprudent to relinquish possession of any station land. One alternative is to have it farmed, and methods of achieving this objective should be investigated.

6.3.4 Present management of animal production research

The managerial shortcomings of the present system have been listed elsewhere, but in addition to these, the animal production research program has lacked an identity and has been shuttled between one authority and another within the same or even different Ministries. The rightful position for it is within an integrated research system in which animal scientists can work in equal cooperation with plant and veterinary scientists.

6.3.5 Animal production research-extension linkages

The linkages have been fragile. Their form has changed according to whether the animal production research program has been administered within a veterinary or an agriculturally focused authority. When the program has been administered by agriculturists the linkage with the district agricultural extension service has been direct, but only a minority of district agricultural staff are well trained in animal husbandry, while when the program has been administered by veterinarians, understanding of the problems has improved but the veterinary extension staff have been very limited in number compared with the agricultural extension staff. In summary, the situation has been very unsatisfactory.

6.4 A Future Animal Production Research Strategy

6.4.1 Program priorities

Some general principles must be observed with regard to program priorities.

On a livestock type basis the highest priority should be accorded to investigation of the problems of cattle production, as almost 80 percent of all grazing livestock units in the country are derived from cattle (Table 6.2), cattle are managed in all except the most arid districts, and milk and beef are the two most important animal protein foods. Although camels, sheep, and goats provide almost equal numbers of grazing livestock units (Table 6.2), investigation of the problems of sheep and goat production must be given priority over investigation of the problems of camel production, because these two species are managed in every climatic zone and district, whereas camels are only managed by pastoralists in the drier pastoral districts. Pig and poultry research must be given a lower priority than research on ruminant livestock, as ruminants can convert roughages into human foods, whereas pigs and poultry are to a limited extent competitors for some foods. As poultry are reared by all farmers, with the exception of the majority of pastoralists, (Table 6.1) and pig production is concentrated in two regions (Table 6.11), investigation of the problems of poultry production should be granted some priority over the problems of pig production. Rabbit research would have the lowest priority on a livestock type basis.

On an animal production component basis, animal breeding research is different both in the time scales involved and in locations at which it should be organized. Animal nutrition, physiology, and management research can be conducted almost entirely at research centers, whereas animal breeding research will have to be organized both at research centers and on parastatal and private farms. Livestock systems research should be organized from RRCs, and animal health research that will be considered separately in Chapter 7, would be conducted at research centers and in cooperation with the provincial and district veterinary services.

It is not usually possible to allocate priorities between the different components of animal production research. However, program priorities can and should be accorded within specific components. As between components, it should be noted that improvements within one

component often depend upon improvements within other components. For example, it would be of little use conducting breeding, nutrition, physiology, and management studies if major epidemic diseases are not controlled. Similarly, it is of no use breeding livestock of high genetic merit for production if insufficient feed is available.

The types of program required and their relative priorities in an overall animal production research program are considered below.

Pasture and forage research

Kitale would be designated the lead center for pasture and forage research.

With a high density of ruminant livestock in high- and medium-potential districts (Table 6.17; Map 6.1), shortage of adequate feed, particularly in the dry season, is a constraint on achieving high productivity in grade dairy cattle, wool sheep, and dairy goats.

Priority programs at Kitale would be:

a) to continue to assemble, maintain, and evaluate grasses and legumes and any other forage crops suitable for use in the agro-ecological zones of Western Kenya;

b) to continue investigations into the most suitable methods of propagating, managing, and utilizing forage grasses and legumes that can be used for the feeding of grade dairy cattle and other classes of livestock in zero-grazing managerial systems.

Of a lower priority at Kitale would be the continuation of forage breeding and ley pasture investigations. Forage breeding investigations should ultimately be terminated, as resources are not adequate for all types of pasture and forage research, and new varieties of forages can be imported from other breeding centers. With regard to ley pasture investigations, there is considerable information already available, and the situation is changing with ley pastures being confined to the larger farms.

Program a) should be replicated at Naivasha (grasses and legumes suitable for natural pastures in ranching areas, Katumani (grasses, legumes, legume shrubs, and trees suitable for browsing and lopping in the dryland farming districts) and Mtwapa (grasses and legumes suitable for pastures in the high-rainfall coastal strip).

At Katumani there should be two other priority investigational programs:

c) To investigate the management and utilization of the most suitable grasses and legumes for natural pastures in the dryland farming districts;

d) to study the most suitable methods of propagating and utilizing legume bushes that can be browsed and legume trees that can be lopped in the dry season to provide livestock feed.

Rangeland research

Kiboko would be designated the lead center for rangeland research. Priority programs would be:

a) investigation of the dynamics of livestock systems in the pastoral districts;

b) the development of possible drought strategies that could ultimately be used by government;

c) investigation of the effect of stress (feed and water shortages and trekking long distances) on the productivity of range livestock (cattle, camels, sheep, goats);

d) investigation of the effect of grazing different proportions of range livestock together on the productivity of the rangeland and the livestock. The interactions when wildlife are introduced would also be studied.

At the present time program a) would be the only priority program that could be organized in the northern pastoralist districts. The first phase would be to assemble information that is already available on the dynamics of pastoral livestock systems. A great deal of information is available on Maasai livestock systems in Narok and Kajiado Districts and from the Integrated Project for Arid Lands (IPAL) on livestock systems in a major part of Marsabit District. Some studies of the Turkana livestock systems have also been conducted by NORAD and a group of American anthropologists.

Programs c) and d) would provide information for program b), and program c) should be conducted in cooperation with the animal physiologist from NARC, Muguga.

All other existing programs would have a lower priority, as interventions into rangeland systems that might be made as a result of the investigations could not yet be made in the northern pastoralist districts that constitute the major proportion of the rangelands of Kenya.

Animal breeding studies

Naivasha would be designated the lead center for animal breeding studies.

For reasons previously discussed, national breeding plans are now essential for the conservation and improvement of specific exotic and indigenous livestock breeds.

It is proposed that a National Animal Breeding Council (NABC) be established by government. The membership of NABC should include representatives of the national agricultural research organization and the Animal Production Branch of MOALD, ADC, the livestock breed societies, and prominent private livestock breeders. The coordinator of animal breeding programs in the national agricultural research organization should act as secretary to the Council. NABC would be charged with ensuring that programs are organized for the conservation and development of valuable exotic and indigenous livestock breeds on ADC properties, private farms and ranches, and MOALD research centers.

Details of the proposed national breeding plan are provided in Table 6.20.

Table 6.20: Proposed breeding programs

Type of livestock	Breed	Possible organization(s) conducting breeding program and site(s)
Dairy cattle	Friesian	ADC and private farmers
	Ayrshire	ADC and private farmers
	Guernsey	ADC and private farmers
	Jersey	ADC and private farmers
	Crossbreds for specific agro-ecological zones	MOALD and ADC Coordinated from Naivasha Kibos; Kakamega; Katumani; Athi Plains (Muguga); Mtwapa
Dual-purpose cattle	Sahiwal	MOALD and ADC MOALD at Naivasha ADC at Ol' Jorrai
	Small East African Zebu	MOALD at Kiboko
Beef cattle	Hereford	ADC and private farms and ranches
	Charolais	ADC and private farms and ranches
	Boran	ADC at Mutara Ranch, Laikipia (National Boran Stud), Nai and at other private ranches
Wool sheep	Romney Marsh	ADC and private farmers
	Hampshire	
	Corriedale	
Hair sheep	Red Maasai	ADC at Mutura ranch Laikipia
	Blackhead Persian	MOALD at Buchuma
	Dorper	ADC and private farmers and ranchers
Meat goats	Galla	MOALD at Kiboko ADC at Astra/Munyeti, Manyangola and Kulalu ranches
Milking goats	Temperate-type breeds & crossbreds	MOALD at Naivasha and Molo Private farmers
Dual-purpose goats	CRSP Mosaic	CRSP Program (USAID aided) MOALD at Naivasha or Lanet and Maseno
Pigs	Large White	MOALD at Naivasha
	Landrace	MOALD at Ol' Jor Orok
	Duroc	ADC?
	Hampshire	ADC?

The breeding programs at MOALD research centers are listed below according to priority.

High-priority programs

a) The breeding of acclimatized and productive dairy cattle suitable for smallholder management in five specific livestock systems, using purebred or crossbred cattle.

Livestock system	Research center
*Zero-grazing High stocking density on high-potential land	Kakamega
*Zero-grazing High stocking density at medium altitude on high-potential land	Kibos
*Zero-grazing High stocking density in a dryland farming district	Katumani
*Dairy ranching Low density on natural pasture	Athi Plains (NARC, Muguga) Mariakani
*Zero-grazing High density on the higher rainfall coastal strip	Mtwapa

b) Continuation of the existing breeding program for the Sahiwal, with the possibility of dividing the herd into two groups, one group remaining at Naivasha and the other being transferred to Ol' Jor Orok (ADC).

c) Continuation of the program of importing pedigree boars from time to time and selecting the most productive breeding stock at Naivasha (Large White) and at Ol' Jor Orok (Landrace).

Lower-priority programs

d) The establishment of a Galla goat herd at Kiboko with selection for fertility and liveweight gain.

e) The establishment of a dual-purpose Small East African Zebu cattle herd at Kiboko, with selection for milk production and liveweight gain.

f) The establishment of an indigenous Blackhead Persian sheep flock at Buchuma Sub-Center, with selection for fertility and liveweight gain.

g) Crossbreeding of temperate-type goat breeds (Saanen; Toggenburg; Anglo-Nubian) with Galla goats at NAHRS, Naivasha and Small East African goats at Molo, with selection for milk production and hardiness.

Only one new high-priority program is proposed, but it is an extremely important one if total milk production in the country is to continue to increase in the future.

There is at present insufficient grazing land at Naivasha for the Sahiwal herd, and so a part of it must be moved out. ADC has already commenced the establishment of a Sahiwal herd at Ol' Jor Orok, a property close to Naivasha, and would be willing to accept Sahiwal cattle and continue the breeding policy adopted at NAHRS, Naivasha.

At present there is a small herd of Boran cattle at Kiboko, but there is a national stud at Mutara ranch (ADC) and several other pedigree herds, so there is no reason why Boran breeding should be located at Kiboko. There is no breeding and selection of the Small East African Zebu anywhere, although there were selected herds in the past. It is important that this dual-purpose indigenous breed should be evaluated, as should the indigenous Blackhead Persian sheep and the Galla goat. Both Kiboko and Buchuma, a subcenter of Kiboko, own a sufficient area of land to undertake the proposed breeding programs.

Although the USAID-supported CRSP project is attempting to breed a mosaic dual-purpose goat, the time-scale is very long, and there is a present demand for milking goats in higher-potential areas. There are already temperate-type breeds of goat at Naivasha and Molo, and these could be used in crossbreeding studies.

Animal nutrition studies

NARC, Muguga would be designated the lead center for animal nutrition studies.

Some of the priority programs would be linked to priority projects in the pasture and forage research and animal breeding programs.

High-priority programs

a) Investigations as to how far the nutritional demands of grade milking cattle can be satisfied so that they can express their full milking potential, with and without the use of concentrates and/or by-product feeds in:
   (i) zero-grazing systems based on planted forages;
   (ii) semi-intensive systems based on ley and/or natural pastures in high potential areas;
   (iii) extensive dairy ranching systems based on natural grazing in medium-potential areas.

b) Investigations on the nutrition of work oxen during the dry season and during work periods at Katumani and Kakamega.

c) The organization of a survey on the potential total production and availability of by-product feeds and determination of:
   (i) their suitability for feeding to different classes of livestock;
   (ii) the districts in which it will be economic to use them;
   (iii) their safety as feeds.

Programs with a somewhat lower priority would be

d) The possible use of by-product feeds in:
   (i) feeding sheep and/or goats during the dry season in dryland farming districts;
   (ii) pig rations;
   (iii) poultry rations.

e) Investigations on the possibility of improving the digestibility and hence nutritional value of roughages using physical, chemical, and microbiological techniques.

f) A survey of mineral deficiencies in Kenya livestock.

Investigations a) on the nutritional requirements of dairy cattle managed in a zero-grazing system should be conducted at all regional research centers, while that on dairy cattle managed on leys or natural pasture should be conducted at Kitale and in dairy cattle managed under ranching conditions at the Athi River (Muguga) ranch and at Mariakani. Program d) would be conducted at Kakamega, Katumani, and Naivasha, while programs e) and f) should be conducted at Muguga. There is the possibility for some quite basic research at Muguga on the use of microbiological methods; particularly the possibility that livestock that survive under very poor feeding conditions, such as Small East African Zebu cattle, may include in their rumen flora and fauna organisms that are capable of digesting cellulose outside the rumen. The survey of possible mineral deficiencies would be centered in Muguga.

Animal physiology research

Muguga would be designated the lead center for acclimatization investigations and the climatic physiologist would work very closely with the animal breeders at Naivasha and the range scientists at Kiboko.

Naivasha would be designated as the lead center for reproductive behavior research.

The priority program would be to:

a) survey the extent and the causes of infertility in dairy cattle, particularly those in smallholder livestock systems;

b) investigate whether the provision of AI, or bulls from a local bull center, would be the most suitable and economic method of satisfying the requirements of smallholders for cattle breeding services.

Two lead centers are required in animal physiology because acclimatization and reproductive behavior are specialized subjects. While at Muguga there are unused facilities for climatological and metabolic studies that could be used by the climatic physiologist, at Naivasha there are many cattle that can be used in studies of reproductive behavior.

Animal management and livestock systems studies

Animal management studies would be conducted on an ad hoc basis in order to provide solutions for current managerial problems. Present studies at Naivasha on the provision of cheap and utilitarian housing and feeding equipment for pigs and poultry should continue.

Livestock systems studies will be conducted at all RRCs.

6.4.2 Rationalization of animal production research facilities

Research center locations and research requirements are determined in large part by the nature and contents of the research programs. The location of existing stations, their infrastructure and past research activities must also be taken into account, as must the need to develop laboratory and other research-related services and the diversity of livestock systems in different agro-ecological regions.

Rationalization is required at all levels if a truly integrated research system is to be established. The proposals that follow are based on the assumptions that both NRCs and RRCs are required, that they will be equal in status and that generally research sub-centers will be administered from RRCs.

Headquarters

At headquarters a Deputy Director of the integrated research organization would be responsible for all animal production and veterinary research programs. This would ensure coordination of the respective programs at the highest level. Responsible to this Deputy Director would be two Assistant Directors, one in charge of animal production and the other of veterinary research.

National Animal Production Research Centers

Three national centers are required. These are the:

* National Animal Production Research Center, Naivasha;
* National Agricultural Research Center, Muguga;
* National Range Research Center, Kiboko.

National Animal Production Research Center, Naivasha

Rationale. Naivasha is a large (4017 ha) station located at an altitude of 1800 m in agro-ecological zones IV and V and with an average annual rainfall of 730 mm. There are natural and irrigated pastures, and grazing livestock comprise the national Sahiwal stud herd, a dairy herd that includes Friesians and other breeds on irrigated pastures, and large flocks of sheep and herds of goats. The station is also the site of national facilities for pig and poultry research. It houses national records for progeny-tested dairy cattle and the records of the Sahiwal stud herd. It has a long history of animal production research. Given all these circumstances, it is considered to be a suitable site for a National Animal Production Research Center.

Mandates and functions. The Center would exercise national mandates for all livestock breeding studies, all reproductive physiology studies, and for all aspects of pig and poultry research. (See Volume I).

A coordinator of animal breeding studies would be stationed at Naivasha and, in addition to responsibility for the coordination of livestock breeding programs at all Research Centers, he would also act as Secretary to the National Animal Breeding Council charged with the coordination of all livestock breeding programs in Kenya. A central system for the analysis of all records generated by livestock breeding

programs at Research Centers would be established at Naivasha, though Research Centers would retain duplicates of all records for their own livestock recording systems.

The coordinator of reproductive physiology studies would also be stationed at Naivasha, with access to large herds and flocks of breeding livestock.

The scientists in charge of pig and poultry research at Naivasha would not have the same coordinating functions, as all pig and poultry research would be conducted at Naivasha.

National Agricultural Research Center, Muguga

Rationale. In the past, Muguga was an East African center for research in agriculture, forestry, animal nutrition, animal physiology, and veterinary science. It is located in an atypical area of Central Province in agro-ecological zone IV and is not a suitable site for a RRC. Muguga does, however, possess an excellent library, extensive and well equipped laboratories, animal nutrition and physiology experimental facilities, and a considerable area of grazing land. Under these circumstances it is considered to be a suitable site for a NRC from which ruminant livestock nutrition and animal physiology investigational programs can be coordinated. Muguga would also exercise other roles as a NRC, and these are considered in other chapters of this Report.

Mandate and functions. The Center would exercise two national mandates in animal production research. One for all ruminant livestock nutrition studies and the other for all climatic physiology studies.

A coordinator of ruminant livestock nutrition studies would be stationed at Muguga and would be responsible for the coordination of all ruminant livestock nutrition studies in Kenya, as well as for conducting nutritional investigations at Muguga.

The climate physiologist would have no separate animal physiology programs to coordinate. What would be required is a cooperative program with the livestock breeding coordinator in the breeding of acclimatized dairy cattle for different agro-ecological zones, and a second program with staff at Kiboko concerned with the stress problems of livestock in the rangelands. In addition, the climatic physiologist would conduct investigations related to the breeding of acclimatized dairy cattle and stress problems, using existing facilities at Muguga.

National Range Research Center, Kiboko

Rationale. The fact that 80 percent of the total land area of Kenya is rangeland, with 73 percent (412,000 km^2) in agro-ecological zones V and VI, is sufficient justification for the establishment of a NRRC. In addition, some 16 percent of the total human population and 25, 51, 44, 100, and 91 percent of the total population of cattle, sheep, goats, camels, and donkeys are to be found in the pastoral areas (Table 6.3).

Mandate and functions. Kiboko would exercise a national mandate for rangeland research, but unlike the situation in the other NRCs, there are no RRCs through which the national mandate can be exercised. Therefore, Kiboko should be the exception and establish research sub-centers. At

the present time there is a sub-station at Buchuma, and this should be retained. But Buchuma is not in an area inhabited by pastoralists; if Kiboko is to exercise its national mandate and conduct a comprehensive range experimental program, it requires a sub-center in a pastoralist district. The most suitable sub-center could be KARLS at Marsabit. This is a research and development station, at present funded by UNESCO and the West German government, but it will ultimately revert to MOALD. It is possible to conduct camel husbandry research at KARLS, Marsabit, and although it has not been suggested in this report that camel breeding, nutrition, physiology, or management studies should be conducted, it is considered that the first phase of any camel research program should be animal health studies. This subject is considered in Chapter 7.

The coordinator of range research at Kiboko should be a scientist not only with training in range management and/or animal husbandry but also with an interest in socio-economics and anthropology. One of the major tasks of the coordinator will be to coordinate investigations of the livestock systems in the pastoralist districts.

Regional Research Centers

Of the RRCs proposed for crop research, Njoro would not be required for animal production investigations, as for certain research programs Naivasha could provide facilities in the same region. The National Maize Research Center at Kitale would, however, have to provide facilities for a forage and pasture research program. As this center undertook this role in the past, some basic facilities are available and should be rehabilitated.

The RRCs required for an animal production research program are listed below, together with some details of the major animal production investigations that will be carried out at these centers and the districts that the centers will serve.

* Regional Research Center, Kakamega

Livestock systems research; selection of acclimatized livestock breeds; forage trials; by-product feed trials, grade dairy cattle nutrition trials; work oxen nutrition trials; etc.

Districts: Kakamega, Nandi, part of Bungoma, part of Busia.

* Regional Research Center, Kisii

Livestock systems research; selection of acclimatized livestock breeds; forage trials; grade dairy cattle nutrition trials; by-product feed trials; etc.

Districts: Kisumu, Siaya, part of Busia, and South Nyanza.

* Regional Research Center, Embu

Livestock systems research; forage trials; grade dairy cattle nutrition trials; by-product feed trials; etc.

Districts: Higher-altitude regions of Embu and Meru, Nyeri, Murang'a, Kiambu, Kirinyaga.

* Regional Research Center Programs at Katumani

Livestock systems research; selection of acclimatized livestock breeds; forage trials; dairy cattle, sheep, and goat nutritional trials; work oxen nutritional trials; by-product feed trials; propagation and utilization of shrubs and trees; grasses and legumes for natural pastures; etc.

Districts: Lower-altitude regions of Embu and Meru, Machakos, Kitui, part of Kajiado.

* Regional Research Center, Mtwapa

Livestock systems research; selection of acclimatized livestock breeds; forage under tree crops trials; dairy cattle nutrition trials; by-product feed trials; etc.

Districts: Higher rainfall areas of Kwale, Kilifi, Tana River, and Lamu.

* National Maize and Pastures Research Center, Kitale

Livestock systems research; pasture and cultivated forage trials; etc.

Districts: Trans Nzoia, Uasin Gishu, and high-altitude areas of West Pokot, Elgeyo Marakwet, and Baringo.

CHAPTER 7: VETERINARY RESEARCH

7.0 Introduction

Veterinary research has a long and distinguished history in Kenya. Devastating epidemics of rinderpest at the turn of the century and the susceptibility of imported stock to a wide range of diseases led to great emphasis being placed on livestock disease research and control. Although many of these diseases were widespread in Africa and elsewhere, research in Kenya has played a leading role in identifying control measures. Highlights include the development of a greatly improved vaccine against rinderpest, and of a vaccine against contagious bovine pleuropneumonia (CBPP) in the 1960s. More recently, introduction of a chemotherapeutic against East Coast Fever (ECF) followed many years of effort in Kenya, and the infection and treatment method which shows promise for the control of the same disease was pioneered and subsequently developed.

Successful implementation of research findings has contributed to the development of a modern livestock industry and an animal health situation more favorable than in neighboring countries.

7.1 Veterinary Research in Kenya

Veterinary research is conducted at national, international, and commercial institutions and is to some extent already coordinated.

7.1.1 National institutions

Kenya Agricultural Research Institute, Veterinary Research Department (KARI, VRD)

Situated at Muguga, VRD took over many of the functions of the East African Veterinary Research Organization (EAVRO) as they related to Kenya. It carries out research into diseases of major importance, and due to its origins, these are often of regional importance. The department also manufactures rinderpest tissue culture vaccine and plans to commence production of vaccine against contagious abortion of cattle (Brucella Strain 19 vaccine).

VRD includes the following sections: virology, bacteriology, protozoology, helminthology, biochemistry, and pathology. There is also a collaborative unit within protozoology, working with the International Centre of Insect Physiology and Ecology (ICIPE).

VRD has extensive laboratories and isolation facilities for work on infectious diseases. It has no sub-centers but has built up fruitful relations with cooperating farmers over the years. An excellent library is shared with the Agricultural Research Division (ARD). It houses over 50,000 bound journals and in 1979 had 470 subscriptions to journals, with a further 180 on exchange, and 120 free periodicals. There is a bindery and a Scientific Literature Service which is benefiting from the easing of regional tensions.

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In 1982 there were 86 scientific and technical staff, compared with 49 in 1979. The distribution of the staff by degree and section is shown in Table 7.1.

Table 7.1: Staff composition: KARI Veterinary Research Department 1982

Division	Ph.D	MSc	BSc [1]	Technologists	Technicians
Bacteriology	2	5	2	3	9
Helminthology	1	3	1	0	3
Pathology	1	2	0	0	1
Protozoology	2	3	3	2	13
Virology	4	1	1	9	
Biochemistry	2	1	3	1	3
Totals	10	18	10	7	38

Notes [1] Includes Bachelors of Veterinary Science.

The emphasis in the virology division is on rinderpest and rinderpest-like diseases. VRD is to be a regional center for rinderpest under the proposed Pan African Rinderpest Campaign. Kenya is currently free of the disease, but the section will have an important role to play in rinderpest control on a regional basis through its long experience and facilities.

The objectives include the improvement of diagnostic techniques, particularly to distinguish between strains of rinderpest virus and the improvement of differential diagnosis of the many conditions which are clinically similar to rinderpest. There is considerable interest in the epidemiology of these diseases in the region.

Rinderpest vaccine is produced for use in Kenya and for export, with close to 8 million doses produced in 1979. Demand has increased markedly following the resurgance of rinderpest in many countries in sub-Saharan Africa, and new equipment has been delivered but has not been

commissioned. It is understood that a decision has recently been made at a high level concerning the future financing of rinderpest vaccine production, which had formerly placed an undue strain on research activities.

The bacteriology division is the strongest in terms of staff. It has a particular interest in the mycoplasma which cause pleuropneumonia of cattle and goats, and vaccine is produced against CBPP (over 1 million doses in 1979) and on an experimental basis against contagious caprine pleuropneumonia (CCPP). A new project is investigating new approaches to the control of CBPP.

External funding has been made available equipment for the production of Brucella S 19 vaccine. For reasons not entirely clear, vaccine is still not available after a period of several years.

The control of ECF has been and continues to be a major interest of the protozoology division in four main areas: epidemiology, tick control and ecology, chemotherapy, and immunization. Considerable field research is undertaken by a very experienced team which is making major contributions in the control of this important disease.

The helminthology division has paid particular attention to bovine cysticercosis (the intermediate stage of the human tapeworm Taenia saginata) and to fascioliasis (liver fluke), but is not very active at present.

The division of pathology has an important service role to the other divisions through the operation of the postmortem facilities.

VRD is experiencing the same problem as most other research bodies; most of the recurrent budget has to be allocated to salaries, leaving inadequate resources for the implementation of research. External funding eases the situation to some extent, and ODA continues to provide support to the virology, bacteriology, protozoology, and biochemistry divisions. USAID also supports the biochemistry division. Research in many cases is proceeding at a very modest level and many research officers are clearly under-employed. This is very wasteful of human and physical resources in the face of the existing need for animal health research.

There is a considerable inventory of obsolete and defunct equipment which requires replacement. VRD has clearly suffered from the unsatisfactory situation in KARI. However, management of the department could be strengthened as evidenced by the unsatisfactory situation regarding Brucella vaccine production.

The existing effective research activities relate to clearly important problems, but it is unclear whether this is a result of policy determined by VRD or by other objectives.

Kenya Veterinary Research Laboratories of MOALD

The laboratories at Kabete are generally referred to locally as "Vet. Labs". The term Vet. Labs, Kabete, is adopted here. They were founded in 1906 and form the major technical support to the Veterinary Services

Department of MOALD and are headed by the Deputy Director of Veterinary Services (Research). Despite the use of the term 'research', the present function of the laboratories is mainly service-orientated. An extensive range of buildings houses the sections of virology, bacteriology, protozoology, parasitology (including immunology), chemistry, diseases of wildlife, and the epidemiology and economics research unit. These sections play a national role in laboratory disease diagnosis, although this has been reduced by the advent of four regional veterinary investigation laboratories (VIL). Vet. Labs., Kabete, continues to provide back-up facilities and retains primary responsibility for an extensive area of South Central Kenya. Laboratory diagnosis of viral diseases of livestock for the whole country is also undertaken, with the exception of foot-and-mouth disease (Embakasi) and rinderpest (Muguga).

The laboratory has an important function in monitoring large-scale health interventions. An example is in tick control. Dip wash samples are tested for acaricide concentration from all over Kenya although Wellcome (Kenya) monitors its own products and decentralization has occurred in the case of Steladon (Ciba-Geigy), for which a kit test is operated by the VILs. Acaricide resistance testing is another aspect of this work.

A range of other services may be briefly listed. These are: hides and skins inspection; meat inspection (including other products); the artificial insemination (AI) service; and vaccine production. A number of important research activities are generated by these services. The diagnosis of complex obscure or novel diseases can readily be seen to involve a research component, as does the testing and evaluation of new therapeutic agents and vaccines. Data generated by service activities and from field operations flow into Vet. Labs, Kabete, which also has an important administrative function. The pioneering activities of the epidemiology and economics research unit are of particular importance and demonstrate the close link which exists at Kabete between service and research in the veterinary field.

More fundamental research has been undertaken at Vet. Labs. and will continue to be appropriate as determined by the nature of the problem and the availability of manpower and other resources. This is particularly manifest in the virology section, where very useful research has followed the identification of unusual field situations.

The laboratories suffer from important constraints. Water supply is from local bore holes and can be inadequate. Limited recurrent budget largely spent on salaries and slow procurement processes have caused a reduction in capabilities. This is particularly noticeable in vaccine production, where a minor failure may result in loss of an entire batch. Section heads vary in their ability to overcome such difficulties; some could do more but may be poorly motivated.

There are few experienced Kenyan scientists who can act as effective section heads or team leaders. A high level of competence and confidence are required to identify and perform useful research against the background of difficulties presently encountered.

At Kabete effective research is largely dependent on external funding: including investigation of CCPP vaccine (GTZ and others), virus diseases (ODA); epidemiology and economics unit (GTZ); and chemotherapy of trypanosomiasis (GTZ). The Walter Reid project of the U.S. Army, investigating human and animal trypanosomiasis, is also based at Kabete, and multilateral funding is represented in the FAO/UNDP tick control project.

The laboratory serves as a reference laboratory for a number of viral pathogens, including bluetongue and Rift Valley fever.

The University Veterinary Faculty

The Faculty of Veterinary Medicine, College of Agriculture and Veterinary Medicine of the University of Nairobi, is one of the university's oldest faculties, having been constituted as a degree-granting faculty in 1962. The pre-clinical departments of Anatomy and Histology, Physiology, and Biochemistry are located at the Chiromo campus, while the departments of Veterinary Pathology and Microbiology, Animal Production, and Public Health Pharmacology and Toxicology are at Kabete, adjacent to MOALD Vet. Labs.

The teaching staff are expected to spend 40% of their time on research as there is considerable investment in buildings and equipment (including an electron microscope). Much of the equipment is now aging. The staff structure is shown in Table 7.3.

Table 7.2: Kenyan Staff at Veterinary Faculty, University of Nairobi 1980/1984

DEPARTMENT	PhD.	DVM.	MSc.	BSc/DVM	TOTAL
Veterinary Anatomy	1	1	-	2	4
Veterinary Physiology	4	-	1	3	8
Veterinary Pathology	5	1	1	2	9
Animal Production	11	-	1	1	13
Animal Studies	3	1	10	8	22
Public Health	1	-	7	3	11
Totals	25	3	20	19	67

This represents an extremely valuable resource of trained manpower and has been further increased as a number of vacancies have been filled and further qualifications have been obtained. There are very few expatriate staff members. The academic staff is supported by a strong technical staff, with the desirable ratio of 1 academic: 3 technical staff.

Severe financial restriction over the last four years has led to a severe curtailment in research activities. It is estimated that only 20% of academic staff time is now spent on research, which represents a considerable waste of resources. The University should be filling a complementary role to the other institutions, being less constrained by the immediate needs of the industry and thus able to pursue more path-breaking and speculative research.

Opportunities for research may be further reduced by the expansion of the veterinary curriculum from four years to five, with the intake of students remaining the same, representing a 25% increase in the student body.

The physical proximity of the Faculty to Vet. Labs. provides the opportunity for considerable research cooperation, but this is limited. Veterinary students do, however, spend a short period at Vet. Labs, gaining experience of routine laboratory diagnostic procedures.

Kenya Trypanosomiasis Research Institute (KETRI)

This institute took over the functions relevant to Kenya and some regional functions from the defunct East African Trypanosomiasis Research Organization (EATRO) at Tororo, Uganda, after the break-up of the East African Community.

KETRI is constituted as a parastatal under the Ministry of Health, but much of its work relates to animal trypanosomiasis. Considerable success in attracting support has enabled the construction of extensive new laboratories at Muguga which are nearing completion.

The research program is extensive, and only major veterinary elements are mentioned:

Protozoology
- a trypanosome bank is maintained as a World Health Organization (WHO) world reference center
- *in vivo* culture of trypanosomes
- development of trypanosomes in tsetse flies
- development of laboratory animal models using immunosuppression and strain selection
- drug resistance

Immunology
- development of serum bank
- immune response of infection with trypanosomes
- immunosuppression of infection with trypanosomes

Biochemistry
- biochemistry of antigenic variation
- biosynthesis and structure of antigens
- biochemistry of tsetse development

Ecology
- development of techniques for large-scale breeding of tsetse flies
- host attraction mechanisms
- mechanical transmission of trypanosomes by flies, including studies of Trypanosoma evansi
- social and economic factors of trypanosomiasis
- tsetse ecology in relation to modern control methods

Diagnosis
- development of better diagnostic methods
- development of in vitro tests for drug resistance
- evaluation of therapy

Pathology
- role of immune response in pathogenesis of disease
- physiological change in cattle infections

Others
- response of small ruminants to tsetse challenge
- economics of chemotherapy in beef ranching

7.1.2 International institutions

Nairobi has proved to be a popular location for international institutions, and animal health research is no exception. The activities of each institute are discussed below.

International Laboratory for Research on Animal Diseases (ILRAD)

Established in 1973, ILRAD is sponsored by the Consultative Group on International Agricultural Research (CGIAR). The mandate is wide: to develop effective control measures for livestock diseases which seriously limit world food production, but the research program focuses on two major African and Kenyan problems: animal trypanosomiasis and ECF, a form of theileriosis. ILRAD has a 28-ha site with an extensive laboratory complex, equipped to high standards and complementary services, library, conference and residential facilities. ILRAD's Kapiti ranch provides an assured supply of Boran cattle.

Research is on a multidisciplinary basis, with emphasis on immunological approaches. Much of the work is basic research and results for application cannot be expected quickly. Progress has been made in the following areas:

Theileriosis

- epidemiology of ECF
- characterization of Theileria parva strains
- characterization of T. parva antigens

Trypanosomiasis

- immunological characterization of trypanosomes
- quantification of tsetse challenge and improved blood meal analysis.
- trypanotolerance
- trypanosome culture systems
- genetic basis of antigen variation
- life cycle studies in the mammalian host

ILRAD has a high-quality internationally recruited staff. In 1983, 36 manyears of senior scientific staff were supported by 10 manyears of senior administrative staff. The total budget was US$ 9.3 million.

The prestigious nature of any CGIAR institute makes it a target for much criticism, some justified, some based on misconceptions. An example of this is in the training of Kenyans, where the balance between ILRAD's primary research function and secondary training function would be struck at different points by different commentators. Degree-related and specialized training has built up from 1979, as shown in Table 7.4.

Table 7.3: ILRAD Summary Table of Training: Kenyans

Year	DEGREE-RELATED	SPECIALIZED	TOTAL
1979	1	-	1
1980	2	-	2
1981	5	4	9
1982	8	5	13
1983	9	8	17
1984 (to June)	7	9	16

A plan for ILRAD's second decade 1984-1983 has been published. Much of this is of direct relevance to Kenyan problems and embraces field programs in Kenya. Major areas of activity include:

Theileriosis:
- identification of Theileria strains for use in the infection and treatment control method
- development of non-infectious vaccines
- quantification of importance of other tick-borne Theileria spp.

Trypanosomiasis:
- integrated control systems based on trypanotolerance and chemotherapy
- provision of services for better epidemiological study
- identification of biological, biochemical, and immunological characteristics for improved control

International Centre of Insect Physiology and Ecology (ICIPE)

ICIPE was registered under Kenyan law in 1970 as a non-profit-making company limited by guarantee.

It has an international governing board, and its international funding is coordinated by the Sponsoring Group for ICIPE.

ICIPE is accommodated on the campus of the University of Nairobi, has residential accomodation elsewhere in the city and also makes use of facilities at KARI, Muguga. A recently completed field station at Mbita Point on the shores of lake Victoria provides a valuable research resource, and includes laboratories, farm buildings, field plots, a library, workshops, housing, a clinic, and a school. Plans for a headquarters building in Nairobi are advancing.

The prime concern is research in integrated control methodologies for crop pests and arthropod vectors; and two of the current programs are of veterinary significance: the livestock ticks research program and the tsetse research program, both of major significance in Kenya.

Livestock Ticks Research Program

The goal of this program is to develop biological methods for the control of ticks on livestock which, together with vaccines and drugs, will result in the development of integrated methods for the control of ticks and tick-borne diseases. The research areas are broadly complementary to those of ILRAD. They are:

- investigation of the immune mechanisms of mammalian hosts to the ticks themselves
- ability of tick-resistant cattle to reduce tick pasture-infestation
- concentration on Rhipicephalus appendiculatus, the vector of ECF

Five international staff are involved in this program, with a 1984 approved budget of just over US$ 300,000.

Tsetse Research Program

The objective is to develop new strategies to reduce trypanosome challenge to animals through vector control. Again the complementarity to ILRAD's activities lies in concentration on the vectors, through work on:

- field-based research on trapping and the use of attractants
- effectiveness of insecticide-impregnated screens
- Glossina pallidipes, an under-researched species important in Kenya
- development of a tsetse population model

Six international staff are involved in the program, with an approved 1984 budget of US$ 435,000.

International Livestock Centre for Africa (ILCA)

Animal health has been of interest in farming systems research conducted by ILCA in Kenya. The major involvement has been on the role of trypanotolerant cattle, and this is being studied at Kwale in Coast Province. A health component was included in studies in Maasailand under the Kenyan Rangelands Program, but the serious drought has disrupted much of this work.

Inter-African Bureau for Animal Resources (IBAR)

IBAR is a bureau of the Scientific and Technical Research Commission of the OAU, based in Nairobi. The Animal Health section is concerned with the collection, analysis, and dissemination of information on animal health and productivity. IBAR could provide a commentary on international aspects of animal health control in so far as they affect Kenya and provide an input with a strong statistical base into the establishment of research priorities in animal health.

A second role of IBAR is in the coordination of international disease-control campaigns. The research required in the preparation and implementation of these makes IBAR a customer for Kenyan veterinary research findings but may, and should, also involve it in its own research which would be of relevance at national level.

7.1.3 Other externally funded veterinary research

German Technical Assistance (GTZ) has a project in Trans-Mara investigating the health and productivity of local livestock. Long-term investigations of field situations are expected to give much-needed information on which to base discussions on the need for and design of control activities.

The Small Ruminant Project of the Collaborative Research Support Program (SR - CRSP) funded by USAID has encountered significant health problems in its crossbred goats and is paying considerable attention to this area with a view to devising appropriate health packages.

The FAO/UNDP Sheep and Goat project has also paid some attention to veterinary research, particularly intestinal helminthiasis.

7.1.4 Research in the commercial sector

The Wellcome Group has a long history of the provision of veterinary and animal health products in East Africa and has combined with Coopers, another company with long experience in the same field.

There are a number of related companies, and locally based staff are exclusively Kenyan. The group has an important research capability firmly orientated to developing commercial products.

A research team of three veterinarians and one entomologist is based at Kabete. Major recent emphasis has been on the development of chemotherapy against ECF, and work in the U.K. and in Kenya has resulted in the licensing of the first highly effective drug - parvoquone (Clexon, Wellcome).

There are extensive facilities for work on acaricides and tick ecology, including six experimental paddocks. Acaricides are a major product and a free advisory and testing service is available. Research and development in this area is a continuous process.

A number of products are manufactured locally (Twiga Chemical Industries). In several important product areas, e.g., anthelminthics, no local research is considered appropriate.

The other major research and production activity is at Embakasi Foot-and-Mouth Disease Laboratory. Here vaccine is produced by Wellcome for use in Kenya and is exported to many countries in Africa and the Middle East. The associated MOALD laboratory screens field samples and cooperates with Wellcome in vaccine quality control.

7.1.5 Coordination of research into animal disease

Concern about the increasing number of institutions engaged in research into animal disease in Kenya led in September 1981 to the formation of "The Nairobi Cluster of Institutes in Kenya cooperating in research on tick-borne diseases, trypanosomiasis, and their vectors". The memorandum of understanding signed by twelve institutes has as its purpose, "to create a forum and framework for the exchange of ideas and information, to promote collaboration between scientists, to maximise utilization of resources and expertise, to facilitate training programs and to avoid duplication of effort". It is specifically stated that there is no intention to impose coordination on institutions or to influence their policies, structures or funding.

Directors of institutes meet twice a year as do scientists' groups. There are also ad hoc meetings and field meetings. Although, inevitably, some institutions are more active in the affairs of the "Nairobi Cluster" than others, there is general satisfaction that the defined objectives are being met. This is a considerable achievement when the potential areas for disagreement between national and international organizations and between government and non-government agencies are considered and resolved.

7.2 Veterinary Research Strategy and Plans

7.2.1 Objectives

The major role of veterinary research is to develop new technologies to improve the health and productivity of livestock. It has other roles, including the direct protection of human health through better understanding of zoonoses and also improving the management of health and productivity of wild game. Research into the health of companion animals and into the welfare of domestic animals is presently accorded low priority but may be considered appropriate in the medium term.

It is clear that the animal health situation in Kenya is deteriorating due to reduced funding of field services by government. Research is clearly not justified if mechanisms for applying existing knowledge are weak, and new methods of financing animal health services must be developed.

7.2.2 Issues affecting the demand for research

The demand for veterinary research is influenced by several major issues. These include:

- the need to increase productivity to satisfy the demand for livestock products from a rapidly increasing human population;

- the knowledge that disease is an important constraint on livestock production, particularly in East Africa;

- the fact that livestock production systems have changed markedly over the last four decades, but our understanding of disease processes in existing and emerging systems is deficient;

- the need to develop more cost-effective interventions, particularly in the light of financial constraints on subsidized government services.

7.2.3 Research, investigation, and production

The term 'research' has been used rather loosely in the veterinary field in Kenya, and the nature of different activities should be more clearly understood. Clinical diagnosis is performed by a field veterinarian or, frequently, by the producer, at the animal's side. He may seek laboratory confirmation of his diagnosis and submit specimens or the carcass to a VIL. This diagnostic process is not in itself research, but where problems are obscure, novel or on a large scale, the process of investigations can readily be seen to include research elements. This is clearly recognized and desirable. The term "veterinary investigation" is most useful, indicating a process of diagnosis and its associated research aspects. Generally, it has not been found to be entirely satisfactory to combine veterinary investigation and research functions as a matter of policy, since one function inevitably prospers at the expense of the other.

There is, however, one very important area of research, of great significance in the present context, which should be closely related to the investigational function. This is research into the epidemiology and economics of livestock disease where survey research, disease monitoring and surveillance, and the evaluation of field implementation play important roles. This area of applied research overlaps significantly with veterinary investigation and other field services and has a commonality of interest in the information system required. The special skills and information technology required for such work also tend to bring such endeavors into the field of management. This research is also closely related to livestock systems research.

A distinction must also be made between research and production, particularly in relation to work on veterinary vaccines. Research and production activities require different skills and management environments.

Veterinary Research Laboratories, Kabete

Veterinary investigation and other activities performed at or administered by Kabete and the activities of the regional VILs are key service functions of MOALD and are central to the proper functioning of many of the responsibilities of the Director of Veterinary Services (DVS): implementation of official animal health control measures (notifiable disease, import and export, meat inspection), service to livestock producers (laboratory diagnosis, investigation in the field, monitoring of veterinary inputs). As such, these functions must remain under the direct and immediate control of the DVS and the appropriate Deputy Director of Veterinary Services (DDVS).

It is clear that the National headquarters for Veterinary Investigation should remain at Kabete. Vet. Labs., Kabete, will continue to have an important research role in the area of epidemiology and economics, as discussed above. Limited research of a less applied nature will also be performed as merited by circumstances and available facilities and manpower. Over-compartmentalization of investigation and research is counter-productive and should be avoided. The Kabete laboratory and the regional laboratories also have a service function for research performed elsewhere, and this should be considerably strengthened. It will be necessary to clearly separate the funding for research and for services at Kabete, with funding for research coming from the reorganized KARI and for services from the Department of Veterinary Services.

Wherever possible, vaccine production should be handed over to the commercial sector. Where government remains the major purchaser, realistic agreements on price structures must be made. Economic realism must also prevail when deciding whether to continue local low-volume production or whether to import. Some specialized low-volume production could remain at Kabete.

Veterinary Research Department, KARI, Muguga

Longer-term and more fundamental research should be the function of the VRD, Muguga. Veterinary Laboratories, Kabete will have an important role in contributing to the determination of research priorities for Muguga, as it is they who will be quantifying the magnitude of health and production problems.

Veterinary research at Muguga will have two major interdependent aspects: laboratory-based research at Muguga and field trials.

The management of the laboratory-based research is straight-forward within the existing sectional structure if adequate resources are available. Field trials, however, require extensive collaboration with private livestock producers and with government livestock units. There are clear advantages in performing pilot studies on stock in other government stations, and a close relationship should be fostered with livestock stations representative of the major agro-ecological zones. Patterns of disease are much affected by agro-ecological determinants, obvious in the case of vector-borne conditions, such as tsetse-transmitted trypanosomiasis, but also in the case of contagious diseases such as foot-and-mouth disease. Although some of this work will be collaborative exercises which can be carried out mostly by staff on the station, there will also be a requirement for secondment of central

staff and also, on occasion, for complete control of livestock on experimental stations. This allocation of resources must be within the power of general or specialist committees.

Muguga has a good record for cooperation with private producers. This could be expanded through cooperation with VILs who would be able to identify farms within their areas and assist in first-stage laboratory processing.

The complex structure of veterinary research in Kenya with government, international, and donor activity requires coordination. This is already operating for tick-borne disease and trypanosomiasis through the 'Nairobi Cluster'. Potential for unnecessary duplication is less with other disciplines, but the need for coordination arises with related activities performed by different agencies in separate geographical areas. An agent-related example is gastrointestinal nematodiasis in small ruminants; a syndrome-related example is infertility in dairy cattle; and a methodological example is farming systems research where there is a strong livestock component. An important part of the overall research strategy must be for the creation of a mechanism for MOALD to obtain an overview of all activities in a given field to plan and coordinate research efforts. This could be achieved by including in the job description of section heads at Muguga requirements that they keep themselves informed of all activities in their field and report at appropriate intervals to specialist committees and the director.

In summary, the overall veterinary research strategy should be as follows:

a) Need for research to be established by the appropriate Muguga committee, with a major input from Vet. Labs., Kabete, particularly through information generated by the Epidemiology and Economics Research Unit. Research undertaken by government will be complementary to that undertaken by other agencies within Kenya (International Institutes, commercial) or outside Kenya.

b) Longer-term research program to be performed by the VRD of KARI at the Muguga laboratory, with collaborative field programs involving the National Animal Production Research Center, the VILs, and appropriate RRCs, international organizations and bilateral donors and farmers. Where appropriate, this national role may be expanded to a regional role for East Africa.

c) MOALD veterinary services department should continue to have research capabilities at Veterinary Laboratories, Kabete, and elsewhere, deriving from its primary service function in the more applied areas of diagnosis, survey, quality control, health management planning, and implementation.

Veterinary research, to have an effective role in improving the health and productivity of livestock, must address itself to a wider range of issues than has traditionally been the case. These include:

- quantification of disease-related production losses, in physical and economic terms;

- identification of technically feasible, epidemiologically appropriate and economically attractive interventions;

- determination of methods for bringing existing and new knowledge to the livestock producers;

- development of new technologies for disease control, their testing and adaption for the wide range of production systems;

- maintenance of communication between Muguga and other research organizations to facilitate coordination and planning of research.

7.3 Research Priorities and Programs

Priorities for veterinary research should be largely determined by the nature of the livestock production systems and the health constraints which they encounter. The objectives of livestock production were formulated in the National Livestock Development Policy and are summarized in Chapter 6 The policy was well-conceived and will remain appropriate for the next ten years. The aspirations of livestock producers are largely consistent with these policy objectives, but the increased production and productivity required to meet the policy objectives of self-sufficiency in livestock products will result in continuing adoption of production systems. No revolutionary change is anticipated; rather, research must recognize that trends towards greater intensification and zero-grazing in the high-potential areas and movement towards diversification of pastoral systems may have important animal health consequences.

A starting point in setting priorities for veterinary research is clearly to quantify the economic contribution made by species, breeds, and different classes of livestock in the whole range of production systems which exist today and also to anticipate how these contributions may change over the planning period.

The second stage is to examine our understanding of the health and production constraints operating in these systems, to quantify losses due to disease, and to examine which control measures exist and the costs and benefits of employing them. Where solutions exist which are of proven value in benefit-cost terms, research would only be justified if either greater disease challenge was anticipated or major improvements in technical efficiency were expected. In many cases, solutions appropriate to local conditions do not exist. We must clearly distinguish between the availability of a prophylactic or therapeutic measure which works in the West European or North American environment and our ability to recommend systems for the use of the measure in the Kenyan environment. As a general principle it can be stated that research has already generated much knowledge relevant to the control of diseases in livestock but that more applied research is needed to convert this into practical, economic disease-control systems. For a relatively minor group of disease problems no obvious control or treatment interventions are available, and research may be required to identify these. Research requirements will also be generated by the emergence of new conditions, which continue today as management systems create new relationships between hosts and disease agents.

A third stage is to identify projects or research opportunities and to assess how likely a proposed piece of research is to generate knowledge which may be of practical use for the livestock producer. This is clearly a case for expert judgement, but there are some ground rules. It is important, for example, to judge not only if a project is likely to be successful in a technical sense, but also if the technology to be generated thereby is likely to be robust enough to be effective in the field. At this stage the decision will be affected by consideration of what type of research is appropriate at the present stage of development. Clearly, some research is highly speculative but, if successful, has a high return. This is often research demanding access to high levels of technology and a wide range of services. An extreme example here is the search, via genetic engineering techniques, for new vaccines against foot-and-mouth disease which would be more heat stable and more effective. In this case the research is proceeding outside Kenya, but results would be of high applicability. There is clearly no need to duplicate this effort. The decision may be more difficult in less extreme cases, but the questions "Is this being done elsewhere?" and "Can Kenya benefit from what is being done elsewhere?" are always relevant.

Information for stage one appears in physical terms in Chapter 6 and in financial terms in Volume I of the Report. Rather limited data is available for stage two; this itself is one appropriate area for veterinary research which is being pursued at the Veterinary Laboratories, Kabete. It is perhaps surprising that major investment in disease control schemes can be approved with only the sketchiest information on the benefits likely to accrue.

It is not possible to examine veterinary research in a more exhaustive way, discussing all diseases of economic significance. Rather, an attempt is made to highlight major avenues of importance.

7.3.1 Cattle

Study of the diseases of cattle has always accounted for the major proportion of funds available for veterinary research, reflecting their economic and social importance. It is noted in Table 6.2 that cattle, in terms of LSU, comprise 79% of the national livestock resource of grazing species. Much of the emphasis of this work has been directed to the problems of the European commercial farmer with exotic cattle kept in fairly large herds grazed on managed pastures. Solutions appropriate to him may not be relevant to the small-holder keeping a few cross-breds on zero-grazing or East African Shorthorn Zebu on communal land.

Despite the major epidemiological and economic differences between these two systems, there has been, and continues to be, an assumption that what was considered beneficial for the one must also be beneficial for the other, the only constraint being the ability of government to continue to heavily subsidize an ever-increasing service.

An example of this is in the control of tick-borne disease and, particularly, ECF. A universal recommendation for close-interval dipping is inappropriate since:

- the vector tick is absent from drier areas or inactive in the dry season;

- in undipped zebu populations in endemic areas, mortality rates from ECF are minimal;

- the effective dipping of zebu cattle results in the population becoming highly susceptible to tick-borne disease.

In the event of failure of the dipping program, for whatever reason, epidemic disease will ensue.

The need is for the determination of strategies for the control of ticks and tick-borne disease specific to the production system, with major determinants being:

- genotype of cattle;
- tick challenge in terms of species and numbers;
- husbandry practices;
- contact with other stock.

Ultimately, the need for control will depend on price-ratios, livestock products, acaricide, labor. This illustrates well the need for one type of research - how existing techniques can be used in a given system to achieve economic or financial benefits.

Cattle production system priorities

Smallholder dairying

This is an increasingly important system, with 1.2 million grade cattle representing 82% of the total (Table 6.3). The producers are innovative, the system is dynamic and adaptable, and new health problems will inevitably follow change. Major aspects of change include the increasing role of zero-grazing and shift in balance from government disease control measures to private initiatives. The small holder will be prepared to protect his cash income by expenditure on medicine and perhaps less willingly, on service and advice. The role of research in this more intensive use of health inputs must be examined.

Indigenous cattle in Zones II and III

The Small East African Zebu in these zones are generally communally grazed. They total 4.1 million cattle and 51% of the total indigenous cattle. Although maintained in low input/low output systems, they are an important resource, are accessible to services, are subject to forces of change, and are very important epidemiologically because of contact with grade dairy animals.

Indigenous cattle in pastoral systems

These account for 25% of the national herd and are mostly in Zones IV and V. The provision of health services is expected to remain mostly in official herds. Since there may be less feedback from livestock keepers, it is particularly important here to positively monitor the impact of health inputs. Research will also have an important survey and surveillance role in the pastoral areas, and cost-effective ways of doing this must be developed. However, there is also evidence that once convinced of the benefits of a disease control, pastoralists will willingly purchase inputs. This is widely observed in trypanosomiasis prophylaxis, and research planners should note this.

Commercial beef production

Close to two million cattle are kept on large farms and account for a high proportion of marketed beef. Their viability depends on adequate health management, and grade cattle are less than 25% of the total.

Cattle health research priorities

The epidemiology and economics unit is beginning to develop data bases for the quantification of disease losses, but decision-making at present largely depends on expert judgement to ascribe priorities to different diseases.

Epidemic diseases of national importance

Rinderpest is again widespread in Africa and represents the single greatest disease threat to Kenya's cattle herds, although experience has been much more favorable than in neighboring states. Effective control measures exist and are well understood. There is some room for survey research - monitoring antibody levels in unvaccinated small ruminants and game species would indicate active infection which might remain obscure in partially immune cattle. The development of techniques to identify strains of virus would provide a useful epidemiological tool and a rapid 'cow-side' test a useful control tool. Modelling techniques to improve epidemiological understanding are also worthy of development.

There are several other viral diseases where control has been highly effective in the past but is now reduced due to diminished field capability. The major example in cattle is foot-and-mouth disease. This disease costs the industry over ksh 200 million per year, but studies[1] have shown its control, even allowing for difficulties of fighting a multiplicity of sub-types, to be economically attractive. Again, the only relevant research is epidemiological in nature, and the capability of the Embakasi laboratory to perform this should be strengthened.

CBPP has been brought under considerable control and is thought to be absent from the vast southern and northwestern pastoral areas which, because of the possibility for introduction across the border, remain under quarantine. Recent problems with the disease followed introduction from Uganda. The unsatisfactory situation in neighboring countries and the insidious nature of the disease justify continued surveillance and a limited investment in research on improved vaccines.

Tick and tick-borne diseases

The control of ticks and tick-borne disease has attracted very great support for research, and theileriosis, babesiosis, anaplasmosis, and heartwater can, under certain circumstances, cause major loss in cattle populations. To take the case of ECF, the distribution of the vector tick Rhipicephalus appendiculatus includes major cattle-rearing areas, particularly in the high potential dairy areas. Recent research developments include:

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[1] Ellis, P.R. and Putt, S.N.H. (1981). Epidemiologic and economic implications of the foot-and-mouth disease vaccination program in Kenya. Mimeo. GOK: Nairobi.

- further development of the infection and treatment method for ECF;
- the commercial launch of a chemotherapy against clinical ECF;
- development of vaccinial techniques against ticks.

The present research spectrum and spread of institutional involvement is wide, and coordination of activities was discussed above. Research into integrated control systems to develop economic and financially viable and robust solutions is essential. It is unlikely that pharmaceutical companies will be able to justify large research and development budgets in the search for more cost-effective remedies for theileriosis, as the market is small by the standards of multinational manufacturers.

If ECF is successfully controlled, new emphasis will be placed on other tick-transmitted diseases. It may be that other conditions previously overshadowed by and even misdiagnosed as ECF will emerge, particularly in smallholders' grade cattle. For some, solutions are available, for others, e.g., heartwater, research opportunities will arise and should be addressed.

With the prospect of vaccination or chemotherapy being available for theileriosis, new attention must be paid to the direct effects of the ticks themselves. Few data are available on the impact of mixed infestations on different genotypes of cattle in East Africa. The research goal should be to develop models which will form the basis for advice on strategic tick control in relation to agro-ecological zones, production systems, and meteorological conditions.

Close contact with the veterinary investigation service is required, as it is the VILs who will monitor tick-control measures routinely. The determination of acaricide-resistance patterns in ticks will provide essential data for the devising of integrated strategies, and analysis of problems and testing solutions will require close collaboration.

Trypanosomiasis

The role for VRD, Muguga, in trypanosomiasis research is limited. Basic research of high relevance to Kenya is conducted at ILRAD and elsewhere. ICIPE is concerned with the vector. KETRI examines Kenyan problems through a multidisciplinary approach.

Diseases of breeding

Breeding systems for grade dairy cattle are changing due to the inadequacy of the AI service. If a change to the use of bulls shared by a number of farmers occurs, this will carry disease risks. The problems can largely be dealt with using existing knowledge, but research will be needed to determine the best control strategies.

More survey and investigational research is needed to determine causes of infertility in grade cattle. Here a close relationship is essential with animal production (see Chapter 6), as the problems are generally multifactorial with nutritional, management as well as disease components.

Mastitis in dairy cattle is frequently investigated by VILs. Survey and investigational work is required to determine the frequency of mastitis and its causes. Research may be required to develop control systems of wide applicability if application of hygiene and antibiotic treatment methods developed elsewhere prove inadequate.

Disease of calves

Concern has been expressed about high calf mortality rates, and this may become worse if major efforts are made to increase the proportion of milk sold, since calf nutrition may suffer. Research into the cause and prevention of calf mortality in traditional systems is proceeding in several localities. Major reduction in mortality will, however, only be beneficial if the resources are available to grow-out the increased numbers of survivors, particularly the males. Again veterinary and animal husbandry scientists must cooperate. A simple intervention such as protecting young stock from rain may, for example, have a much more dramatic effect on survival than vaccination. Helminthiasis can be a major problem, and zero-grazing techniques have obvious advantages.

Other conditions

Further research is required on the following diseases of cattle:

- Rift Valley fever;
- malignant catarrhal fever;
- bovine petechial fever;
- ephemeral fever.

7.3.2 Sheep and goats

Sheep account for 6% and goats for 7% of the L.S.U. of the national livestock population, but their role in socio-economic terms is greater than this suggests. The decision to dispose of a bovine is a major one, but comsumption or sale of a small ruminant can provide a high-quality addition to diet or a sum of money sufficient for many needs.

Diseases of small ruminants have been under-researched and merit greater attention, particularly since they are being forced into new production systems. An example of this is the significant losses which occur when attempting to rear the apparently hardy goat in an environment different to that in which it is traditionally kept. Work with crossbred goats has also experienced health problems.

It is dangerous to generalize for the two species, but the following diseases demanding research may be discussed together.

Helminthiasis

Parasitic nematode worms of the stomach and intestine are a major cause of morbidity and mortality in small ruminants. In high-potential areas the environment allows development of the infectious larval stages of worms all the year round, and the challenge is high. Modern anthelmintics are effective but costly and must be used at three- or four-week intervals in crossbred goats. It may be that the apparent resistance of goats to helminths is simply that their browsing behavior reduces exposure to infectious larvae. More intensive systems often

demand that goats graze, and problems then arise. Research is required to devise control strategies based on the combined use of grazing management and anthelmintics on developed farms. Where communal grazing of indigenous breeds is practiced, epidemiological investigation may reveal possibilities for control, based on treatment of the highly susceptible young animals at key times of the year.

Skin diseases

The etiology and classification of sheep and goat pox and related diseases is poorly understood and should be further investigated. Mange, particularly of goats, is an important condition, but better information on prevalence, economic significance, and practical approaches to control is needed. Pneumonia is important in both species, with CCPP being more important in goats. The production of vaccine is at the field trial stage and should be continued. Non-specific pheumonia is a problem in both species and should be further investigated.

Tick-transmitted diseases (including Nairobi sheep disease) need greater emphasis; also trypanosomiasis, among arthropod-transmitted diseases, Rift Valley fever, and bluetongue affect sheep and have been discussed in the section on cattle.

Of the specific diseases of sheep, agents causing abortion are of research interest. Methods for their control are, in some cases, poorly developed, and a new agent has recently been identified in Kenya.

Gaseous lymmphadenitis of goats requires more study.

7.3.3 The camel

Data presented in Chapter 6 indicate an increasingly important role for the camel in the northern pastoral areas, with numbers at an historic high and perhaps approaching one million. The value of the species in drought conditions is self-evident. There is a new interest in the species by scientists, and a number of significant disease problems exist; others doubtless will be discovered.

Progress requires diligent field work with fairly limited local facilities and the submission of material to distant laboratories. It is more appropriate to use existing facilities in Nairobi than develop special capabilities in the production area.

Conditions requiring research may be briefly listed:

- trypanosomiasis, especially *Trypanosoma evansi*;
- septicemias, including anthrax blackquarter;
- skin diseases, particularly skin necrosis and mange;
- brucellosis and salmonellosis.

7.3.4 Non-grazing species

Poultry and pigs which are intensively kept are considerably protected from the natural environment, and the disease spectrum observed is much more uniform between countries than is the case with the grazed species. Research elsewhere is thus much more relevant, and control systems evolved in Europe or USA may be applied with little or no modification in Kenya.

In poultry, good control methods exist for major disease. Newcastle disease, fowl typhoid, and pox should present no problem if vaccines are available and properly applied. Conditions which arise are frequently more management-related, particularly where improperly constituted rations are fed.

7.3.5 Wildlife

With its declining, but still significant, numbers of game animals, Kenya has special problems with wildlife in relation to disease. The aspect which attracts most attention is the extent to which wild ungulate populations act as reservoirs for disease in livestock but, increasingly, conservationists must pay attention to the significance of disease in the game populations themselves. Major change is taking place in the extent and nature of available habitat and in the population dynamics of the individual species, and this will have disease consequences. Disturbance of endemic situations where the game and their parasite fauna are in balance may occur with resulting mortality of particular significance to the smaller populations. In a number of areas, game populations are maintained at very high densities, which may adversely affect their disease experience. There are many possibilities for research in this area, requiring cooperation between MOALD, KARI, and the Ministry of Tourism and Wildlife.

Research into the importance of wildlife as potential reservoirs is proceeding in a number of areas. Their role in foot-and-mouth disease, malignant cattarhal fever, and theileriosis has been and should continue to be examined. The recrudescence of rabies has stimulated interest and may require prevention and control attention.

7.4 Proposals for Research at VRD, KARI, and Veterinary Laboratories, Kabete

The circumstances of the Mission and the limited time available did not permit the development of detailed research programs or projects. The Deputy Director of Veterinary Services (Research) was available only informally, and there was no opportunity for technical discussion. Visits to Kabete and Muguga, although useful, were limited in scope. Much more detailed planning and coordination is required to further define priorities and determine approaches over the next ten years.

The general roles of the two laboratories have been discussed in section 7.1, and a number of areas of research interests are listed by system and species in section 7.3. The following annotated lists should be treated as indicating some useful areas for research activity. They are by no means comprehensive, and no attempt to indicate final priorities is made. Allocation of work between the two institutes is based on the premise that longer-term research will be conducted at Muguga and that research at Kabete will be shorter-term and more service-oriented. However, some divergence is allowable in terms of the existing interests and skills of existing research teams.

7.4.1 VRD, KARI, Muguga

Virology:

Rinderpest:
Survey research (antibody titres in vaccinated and unvaccinated cattle, small ruminants, game.
Development of diagnostic tests for field use.
Consolidation of laboratory tests for rinderpest-like diseases.
Development of tests to distinguish between strains of rinderpest virus.
Vaccine production to be put on more commercial basis and financially independent of research program.

Malignant catarrhal-fever epidemiology and control.

Pox-viruses - etiology and classifaction of sheep and goat pox and related diseases.

Bacteriology:

Bacterial diseases of breeding (all spp.).

Caseous lymphadenitis of goats.

Bacterial diseases of the camel - anthrax, salmonellosis, skin necrosis.

CBPP - vaccine development.

Protozoology:

Continuing development of infection and treatment method for the control of ECF, with emphasis on field trials.

Protozoal diseases of small ruminants.

Helminthology:

Parasitic intestinal gastritis in cattle, sheep, and goats.

Epidemiological studies to determine loss in different agro-ecological zones and to develop appropriate control methods.

Problems requiring an interdisciplinary approach:

Diseases of wildlife (significance for wildlife *per se* and to determine significance of wildlife reservoirs of livestock and human diseases).

Longitudinal studies of livestock populations to determine mortality and morbidity rates.

7.4.2 Veterinary Laboratories, Kabete

Epidemiology and economics research unit:

Play a lead role in the design and implementation of animal health and production surveys.

Develop data-processing methods to generate appropriate information for decision makers.

Design and examine alternative approaches to disease control and determine their utility in economic terms.

These activities will be important in the allocation of priorities to veterinary research.

Virology:

Foot-and-mouth disease (Embakasi). Strengthening of epidemiological capability.

Arthropod-borne viral diseases - Rift Valley fever, Nairobi sheep disease, bovine petichial fever, ephemeral fever, Thogoto virus - epidemiological studies with objective of improving productive models and control methods.

Bacteriology:

Diseases of breeding, with strong survey component.
Mastitis in cattle, with strong survey component.
CCPP vaccine development.
Leptospirosis epidemiology and control.

Parasitology:

Mange, particularly in camels and goats.

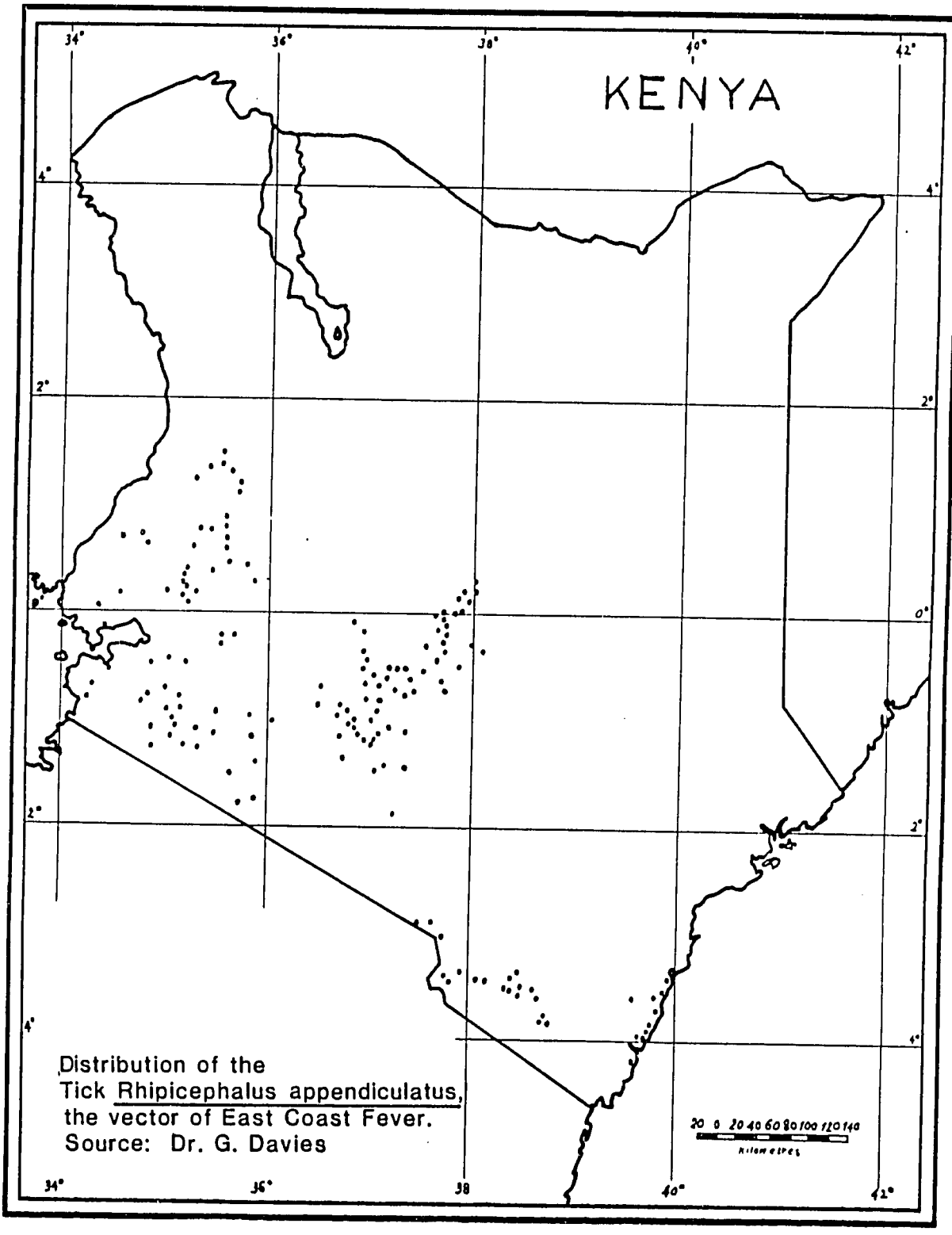
Chemistry:

Acaricide resistance in ticks and other arthropods.
Survey of livestock poisoning.
Consolidation of information on mineral deficiency and toxicity in Kenya in association with the animal nutritionists (Chapter 6).

Disease syndromes requiring interdisciplinary approach:

Diseases of neonatal cattle, sheep, and goats.
Pneumonias of sheep and goats.

Fig. 7.1



Distribution of the
Tick Rhipicephalus appendiculatus,
the vector of East Coast Fever.
Source: Dr. G. Davies

CHAPTER 8: SOCIO-ECONOMIC AND FARMING SYSTEMS RESEARCH

8.0 Present Situation

The Kenyan agricultural research system has not accorded great priority to socio-economic research. This was recognized in the 1979-83 Plan which sought to strengthen this component, mainly in context of research on farming systems. There is a senior position of economist at headquarters (now vacant), and positions of farming systems economists have been created at several research stations.

Outside the GOK agricultural research system, socio-economic research in agriculture has been carried out at the Institute of Development Studies (University of Nairobi) and some in the Agricultural Economics Department at the University of Nairobi. The former has addressed some broad macro-economic issues, and the latter has concentrated on micro-level studies on production and marketing problems. On the whole, these studies have had a very limited impact.

The Farm Management Unit in MOALD has done some valuable work on defining cropping systems for different agro-ecological zones over large parts of Kenya. This work has provided much-needed benchmark data on cropping patterns, labor use, disposal of crops, farm size and soil in relation to climatic conditions. It continues to provide data on costs and returns for important enterprises on a year-to-year basis.

These are the beginnings of socio-economics research covering the agricultural sector. A program for socio-economic research in the agricultural research system is now proposed which aims at creating capacity (considering that skill levels in socio-economic research will continue to be weak for some time) and directing very scarce resources towards priority areas.

It should be noted that the Coffee Research Foundation (CRF) has initiated a well-conceived program covering the smallholder coffee sector. Similar work covering other commercial crops (tea, sugarcane, pyrethrum, cotton, tobacco, fruits, and vegetables) would help in a better understanding of constraints facing the smallholder sector and in formulating technical and economic policy measures to alleviate them.

8.1 Priorities in Socio-economic Research

8.1.1 Studies on evaluation of technical packages and farming systems

At the level of RRCs, this should be a priority area. The economists should, on a routine basis, undertake economic evaluation of technical packages in terms of profitability, risk (both yield and price risks), capital needs, and interaction with existing farming systems. This calls for active cooperation between economists and agro-biological scientists. In most developing countries, this area is weak because economists have not approached the problem in a cooperative context; they have usually taken a critical stand which has led to their isolation from

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the mainstream of agricultural research workers. Since the Kenyan system is just beginning to station economists at research stations, it would be worthwhile to take note of this potential inter-disciplinary conflict and take measures to avoid it. One way of ensuring this is to insist that all such work should be jointly carried out by economists and concerned scientists and not by economists alone. This rather obvious point has been emphasized at some length because, if it is not explicitly recognized the discipline will fail to integrate with the mainstream research effort, and the very purpose of such work will be defeated. Details on farming systems research, together with a proposed research program, are provided in section 8.3.

8.1.2 Farm management studies

The need for reliable data on inputs and outputs per various enterprises, prices and marketing, cannot be over-emphasized. The Farm Management Unit in MOALD is expected to provide this information on a regular basis. Nevertheless, there is an urgent need for in-depth studies based on small samples which will provide reliable information not only on farm inputs and outputs but also on changes in farming systems, cost structure, etc., over time. For this purpose, all NRCs and RRCs should select a small sample (about 30) of smallholders in areas surrounding the centers, so as not to create logistic problems in monitoring these farms, and collect data on resource inventories, enterprise patterns, input use, output levels, marketing of inputs and outputs, etc. Production and input data should be collected on a plot basis.

These farms should be used as intensive observation units and should be visited at fortnightly intervals to obtain reliable information. In order to provide a broader coverage, the sample should be changed every three years; after three years another sample of 30 farmers should be chosen, and after three years of observations, the observers should revert back to the original sample. In this way, each research center will have a sample of 60 farmers who are constantly monitored, and over time this will provide valuable information on changes in farming structure and practices.

For logistic reasons, the sample farms should be chosen from two to three conveniently located villages. These will not be representative of the entire mandated area of the research center, and this should be clearly understood. The basic purpose is to provide in-depth information which is useful for researchers, such as time and depth of planting, method of planting, weeding practices, intercropping practices, time, method, and kinds of fertilizer used, use of varieties, unorthodox practices, etc., which are crucial for deciding research priorities. As a by-product, information will be generated on cost of cultivation, etc.

As mentioned previously, this should be a routine activity at all NRCs and RRCs and should be the primary responsibility of the economist. The Agricultural Economics Department of the University of Nairobi should assist in designing a suitable set of simple questionnaires for this survey. At the end of each year there should be a report from each center providing summary results. The Senior Economist at headquarters could compile these data. The data could also be made available to M.Sc. students for dissertation work.

8.1.3 Studies on macro-economic policies

Over a period of time, as the discipline establishes itself and skill levels improve, socio-economic analysts will move from micro-economic to macro-policy areas. At present, it would be premature to indicate areas of policy research. The priority is clearly on strengthening capacity for micro-economic analysis in Kenyan agriculture, and supporting the two broad areas outlined above would set this process in motion. Economic analysis has been emphasized at this stage, and this is based on a perception of immediate priorities. Eventually, sociologists and anthropologists should play a role, but at present their work would be extremely marginal. However, one area in which their role is clear is pastoral systems.

8.2 Organization of Socio-economic Research

An organizational setup which links farming systems research at experimental centers and the headquarters is proposed in section 8.4. In order to implement farming systems research and other priorities, each RRC would need at least two economists and each NRC at least one. These economists will need to be adequately supported by technical assistants (at least two to three per economist) and travel grants.

The concept of a disciplinary critical mass of professional manpower has not yet been discussed. Ideally, this is achieved by concentrating socio-economic disciplines at one place. Clearly, at this stage, it would be inappropriate to suggest the creation of such a center - it can only be considered a long-term goal. However, there is obviously a case for the greater involvement of centers like the Institute of Development Studies and the Postgraduate Department of Agricultural Economics at the University of Nairobi. The Senior Economist at the headquarters of the research organization should make all possible efforts to draw in these professionals. There should be provision for an annual conference of all the center economists to discuss: (a) the results of their farming systems research and (b) to present the results of their farm management surveys analysis. There should be a provision for publishing the papers presented at these meetings.

In summary, it needs to be stated that the research system needs to be particularly aware of the special needs of socio-economic research, as distinct from agro-biological research. These pertain to support for data collection, travel, computation needs, and a greater need for stationery. These mundane needs are stated because social science units are created in agricultural research institutions with inadequate appreciation of the special needs of socio-economic scientists.

Finally, there is an urgent need for training. In fact, placement of economists at research centers should be planned in such a manner that, in five to six years, all of them are able to obtain higher qualifications. The University of Nairobi offers postgraduate courses, and full advantage should be taken of this facility in training farm economists in the field of farm management and production economics. In view of the problem of staff attrition, the system would do well to plan for some excess capacity in training.

8.3 Farming Systems Research

In the Report much attention has been given to the establishment of strong RRCs. These centers should play an important role with regard to interactions between technical research, a large part of which will be carried out at the NRCs, and the on-farm adaptive research, to be carried out by teams of farming systems specialists from the RRCs in collaboration with the national extension service.

While the NRCs will be mainly involved in looking for new materials and methods that are technically feasible in the major agro-ecological and/or production zones, the RRCs should lay emphasis on identifying materials and methods that are most relevant to the respective target groups of farmers in the region, and the RRCs should then give a feedback to the NRCs for the further orientation of their research activities.

In the past, many of the so-called regional stations were too often regarded by the national stations as well-staffed testing sites; this should not be so.

As opposed to the national stations that had a clear mandate and were sometimes well equipped, the role of the regional stations was not clearly defined, and therefore they were quite willing to carry out (purely technical) experiments on behalf of the national stations.

But in a few regions farmers and officials had already put pressure on the regional research stations to become involved in the direct provision to farmers of relevant recommendations, technology packages, and services. However, to play this role, RRCs should, in collaboration with the extension service, follow careful procedures, including the identification of farmer target groups, diagnostic surveys and on-farm technology testing and experimentation, the methods of which have already been introduced in the country since 1976.

8.3.1 Past experience

In 1975 an agreement was reached between the GOK and CIMMYT's Eastern Africa Economics Program to introduce farming systems research and demonstrate its procedures in Kenya. The first demonstrations of an interdisciplinary approach to planning adaptive agricultural research programs were undertaken in Siaya and Kwale districts, and a formal report was written up about the experiences in Siaya.

These first demonstrations were undertaken by biologists from the research services and, in the absence of those specialists in the research system, by economists from Egerton College.

As a result of these activities, an economic advisor was appointed to the Director of Research, who cooperated with CIMMYT in developing an in-service training program, and in 1978/79 about 12 agriculture graduates were recruited who, while posted on several national and regional research stations, received in-service training in farming systems research. Those with a B.Sc. degree were subsequently sent for master's degree training in Agricultural Economics.

Most trainees became well-acquainted with various methods of data collection, they made some interesting exploratory surveys (section 8.4.2), and they were able to contribute to improving the planning and interpretation of experiments. But these efforts did not lead automatically to the establishment of farming systems teams or units at the respective stations.

A setback followed in 1979, when a reorganization divided the Ministry of Agriculture into two ministries; one responsible for agriculture and one for livestock development. This made it even more difficult to bring crop scientists, livestock specialists, and agricultural economists together to carry out farming systems research. Besides, since 1980 there was no longer an economist within the SRD to coordinate the farming systems research.

However, in Kenya's fourth Five-Year Development Plan, published in 1979, the need for a farming systems perspective in agricultural research was clearly stated to be as follows:

> "Research must be of increasing relevance to the farmers' situation. This includes not only the physical environment that confronts him, but also the socio-economic setting of his farm activities."

The development plan also stressed the need for "integrating the semi-arid lands into the mainstream of national economic activity and for evolving well-developed and less-risky farming systems making semi-arid lands self-reliant for food requirements." In the past, agricultural research had been focussed mainly on the high- and medium-potential areas, but through the strengthening of the Katumani National Dryland Farming Research Station in 1969, more attention was paid to improving the agricultural productivity in the dryland farming areas of Kenya. With assistance of a FAO/UNDP Project, the Katumani Research Station in the period 1980-1983 placed substantial emphasis on the identification of on-farm problems to determine research needs, on pre-extension trials under real farm conditions, and on monitoring the effectiveness of research recommendations. In their farm surveys and in both their "unit farm program" (testing under controlled conditions) and their "pre-extension trials program" (under farmers' conditions) they generally followed a whole-farm analysis approach.

Following these activities, Katumani is now embarking on a so-called "whole-farm research program", for which 24 farms were selected in three different districts.

By the end of 1983 MOA and MLD merged again, at a time when new impetus had already been given to the nationwide promotion of adaptive research, as a result of the newly established National Extension Program. In this program provisions were made to involve research officers in the training of extension staff and to establish and carry out on-farm trials.

In anticipation of the introduction of this new program, commonly known as the 'Training and Visits' (T&V) system, in some coastal districts, a team from the Coastal Research Station, composed of an agronomist, a livestock specialist, and a farm economist, was asked to carry out exploratory surveys. These were undertaken with a view to identifying farmers' priorities and constraints and to understanding the reasons for non, partial, or slow adoption of recommendations.

Meanwhile, seminars on farming systems research were organized in 1983/84, under the CIMMYT Economics Training Program, with all station directors, the Provincial Agricultural Directors (PDAs), and Provincial Extension Coordinators. And this was followed in 1984 by two workshops for farming systems researchers, including agronomists, farm economists, and extension officers. Both workshops included a three-week teaching period, a two-week practical training in conducting a diagnostic study, and a one-week evaluation session following a period of practical involvement in farming systems research at the participants own duty stations. The first workshop included 21 participants from the western part of Kenya, and the second involved a similar number of participants from the eastern part of Kenya.

8.3.2 Some features of selected farming systems in Kenya

In order to give some idea about the resource endowments of farmers and their cropping systems in different ecological zones in the country, and to illustrate the sort of constraints they encounter, a very brief description of some features of five selected farming systems in different zones is provided.

The information is derived from some of the farming systems survey reports prepared in the past five years by farm economists and other officers from three different agricultural research stations (Kakamega, Katumani, and Mtwapa).

These examples show, first of all, how diverse smallholder farming systems in Kenya are, ranging from intensively cropped one-hectare farms with tea or coffee in high-potential humid zones, to more extensive crop/livestock systems on 10-15 ha farms in the low-potential semi-arid areas.

They also show, however, a few similarities between the different systems: maize is grown universally, and cattle are predominantly kept for milk. Cattle, sheep, and goats are usually also kept to provide cash in periods following a crop failure, and this constitutes the main purpose of livestock husbandry in the semi-arid farming areas.

Some information is provided with regard to cultivation practices, major constraints and food preferences, and other reasons why farmers prefer certain crops and varieties.

The five selected farming systems are as follows:

A high-potential humid zone in the southern part of Kakamega district[1)]

Ecology:

Altitude:	1,600 m
Average annual rainfall:	1,900 mm
Lowest average monthly rainfall in:	January: 60 mm
Soils:	Well-drained red sandy clay
Zone:	UM1: Tea, coffee

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1) Source: Pre-survey report of Vihiga-Hamis Central Divisions of Kakamega district, by Mrs. S.M.M. Wangia. 1980 Westerm Agric. Research Station.

Farm size:

Average size of holding, one ha: population density 500 persons per km^2.

Crops:

In long rains: hybrid maize (H 623 C) mixed with beans; also sweet potatoes.
In short rains: local maize, mainly pure stand.
Permanent crops: bananas, coffee, and/or tea, sugarcane (mainly sold to factories).
In April and November, critical food shortages, with high consumption of green maize, bean leaves and pods.

Livestock:

Local and crossbred cattle (only 3% grade): two-three-head farm unit for milk, bull calves sold early. Also poultry, sheep, and goats. Shortage of grazing in December to February; in that period semi-zero-grazing near homestead, using maize, banana leaves, and roughages.

Notes

- Hoe cultivation; some farmyard manure applied at planting but little top dressing (due to costs of fertilizer).
- Local maize in short rains; believed to be hardy, early-maturing, and more tasty.
- Napier grass on benches for soil conservation and fodder.
- Broadcasting of beans, sorghum, and millet (in maize stand) to save time.
- Per holding three-four indigenous zebu can be kept against one-two grade cattle.

A medium-potential sub/semi-humid zone in Busia district[1)]

Ecology:

Altitude:	1,200 m
Average annual rainfall:	1,400 mm
Lowest average monthly rainfall in:	January: 40 mm
Soils:	Well-drained, red-brown sandy clay
Zone:	LM2-LM3 sugarcane-cotton

Farm size:

Average size of holding three ha; population density 200 persons per km^2.

Crops:

In long rains: finger millet and sorghum (several varieties); maize (H622; H511 - unreliable)
In short rains: Cotton (BPA 75)

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1) Pre-survey report of transitional zone in Busia district, by Isaac Rep. 1980 - Western Agric. Research Station.

Perennial crops: Cassava, sugarcane (outgrowers of Mumias, or sold to factories): striga is a major problem for cereals: the inclusion of cotton in the rotation led to a reduction in striga incidence.

Livestock:

Oxen most important, followed by other cattle (milk and cash); also sheep, goats, and poultry. Shortage of grazing in December - February: in that period grazing in distant places and/or supplementary feeding with leaves, stover, etc.

Notes:

- Ox-ploughing followed by hoe-cultivation.
- Since maize can not be kept long, ugali is often prepared from a mixture of finger millet or sorghum with cassava.
- Less-preferred finger millet and sorghum varieties can be stored best.
- Current cotton varieties are developed for the long rains, which are not compatible with farming systems in target area (cotton is the cleaning crop for finger millet).
- Simsim and Bambara groundnuts are disappearing because of marketing problems.
- Early bird-resistant varieties of finger millet and sorghum are required; these crops are now grown close to homestead to scare birds.

A medium- to low-potential transitional zone in Machakos district[1)]

Ecology:

Altitude:	1,200 m
Average annual rainfall:	780 mm (452-1,177)[2)]
Lowest average 3-monthly rainfall:	June-Sept: 40 mm
Soils:	Sandy with patches of black cotton soil
Zone:	LM4, Marginal cotton

Farm size:

Average size 7.5 ha, median 5.1 ha; population density 70 per km^2.

Crops:

About two ha cropped: maize, cowpeas, beans (in both seasons); pigeon peas, pumpkin, cassava, cotton. Foodcrops mainly in mixtures. Most farmers buy food at some time (Oct.-Dec.) in the year. Main dishes: Isyo (mixture whole maize and peas/beans); ugali/uji (from maize or finger millet).

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1) Source: The farming systems of Lowland Machakos District, 1981 by Rukandema, M., Marua, J.K., Audi, P.O. - Katumani Research Station.

2) Lowest and highest average annual rainfall in past ten years.

Livestock:

Some 80% of farmers have an average seven head of cattle, mainly for milk and ready cash income. Also 10 goats and three sheep (cash income and meat). Mainly open grazing, complemented with maize stover and pigeon pea threshings.

Notes:

- 72% of farms own oxen, mainly used for ploughing; not trained to perform inter-row weeding; lack of ox-carts for haulage.
- Mainly local maize seed used. Reportedly Katumani maize not available and/or not better.
- Late planting, because land too hard to plough.
- Since schools are built, sorghum and millet are less popular, because of bird damage and unavailability of children for bird scaring.

A low-potential, semi-arid zone in Kitui district[1)]

Ecology:

Altitude:	900 m
Average annual rainfall:	530 mm (119-885)[2)]
Lowest average 3-monthly rainfall:	June-September: 28 mm
Soils:	Sandy, erosion prone
Zone:	LM5, livestock-millet

Farm size:

Median size, 10-15 ha; population density 30 per km^2.

Crops:

About 2.5 ha cropped: in order of importance: maize, cowpeas, pigeon peas, sorghum, bulrush millet, green gram, pumpkin, gourds, pawpaws, castor. Usually crop mixtures; beans, sorghum, and bulrush millet also in pure stand. Only occasionally marketable surpluses of cereals and pulses; high proportion of families buy maize in hungry season (Oct.-Dec.). This is period when weeding is required. Most important cash crop is green gram.

Livestock

On average, farmers keep 12 head of cattle (milk, cash, tradition). Ownership of goats and sheep, averaging 10 and four respectively, more widespread than cattle. Most families also keep chickens. Communal grazing and crop residues grazed in the fields. During the whole of the dry season, animals trekked to distant areas (transhumance).

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1) Source: The farming systems of semi-arid Southern Kitui, 1983, by Rukandema, M., Muhammed, L., Jeza, A., - Katumani Research Station.

2) Lowest and highest average annual rainfall in past ten years

Notes:

- Only 32% of farmers use ox-plough; handhoes and pangas widely used.
- No fertilizers used and hardly any manure.
- Water for livestock and human consumption extremely scarce during the dry season.
- Katumani seed reportedly not used because of lack of cash, non-availability and susceptibility to insect attack.
- Field insect pests pose major problem.

A semi-humid/transitional coastal zone in Kwale district[1)]

Ecology:

Altitude:	1-300 m
Average annual rainfall:	1,100 mm
Lowest average monthly rainfall:	Feb (20 mm)
Soils:	Well-drained red/brown, sandy clay (loam)
Zone:	L3, coconut/cassava, L4, cashew nut/cassava

Farm size:

Average size about five ha; population density 70 per km^2.

Crops:

Maize (local and Coast composite), cassava, cowpeas, green gram, coconut, rice, beans, simsim, bananas, cotton. Maize, either as sole crop, intercropped, or relay cropped (simsim).

Livestock:

Grazing of zebu and some grade cattle (milk), sheep and goats (meat, cash, tradition) in natural pastures; no supplementary feeds. Disease problems; dips not well located. Poultry and beehives also important.

Notes:

- 55% of farmers use hand hoe, 17% ox-plough, and 16% tractor.
- Little fertilizer used, but some manure.
- Interplanting of maize with rice in valley bottoms; depending on rainfall, at least one crop will be successful.
- AI services unreliable due to transport problems. Besides, farmers prefer the bull-schemes and argue that with AI "the calving is difficult and gives a high percentage of bull calves".

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1) Source: Farming Systems in Kwale district (1984) by: Koech L.C.A., Kamau; G.W.M. and Mureithi J.G. Farm Economist, Agronomist and Animal Production Scientist respectively, at Coast Agricultural Research Station, Mtwapa.

8.3.3 Proposed national farming systems research program

In the past eight years a start has been made with introducing a farming systems perspective in crop and livestock research in Kenya, through the conduct of some diagnostic farm surveys and livestock systems studies, and through the formal and in-service training of farming systems research specialists.

The National Extension Program made important contributions in recent years to a farmer-oriented approach to research, through the formalization of certain research-extension linkages and through the introduction of an on-farm trial network.

The diagnostic farm surveys made so far show interesting results, of importance for adaptive research, but these studies were generally carried out on an ad hoc basis, and did not form part of a comprehensive regional or national program of on-farm research, with the possible exception of the regional activities undertaken by the Katumani National Dryland Research Station.

There is now a need for the country-wide adoption of a farming systems perspective in the agricultural research undertaken by the network of RRCs, in close collaboration with the national extension program. Coordination at the national level is also required.

National coordination

Within the reorganized KARI (see Chapter 9, Volume I), the main responsibility for the coordination of farming systems research should rest with the Assistant Director, Regional Research Centers, who should be assisted in this task by the Assistant Director, Planning (economics), the Assistant Director, Animal Production, and the Assistant Director, Veterinary Research.

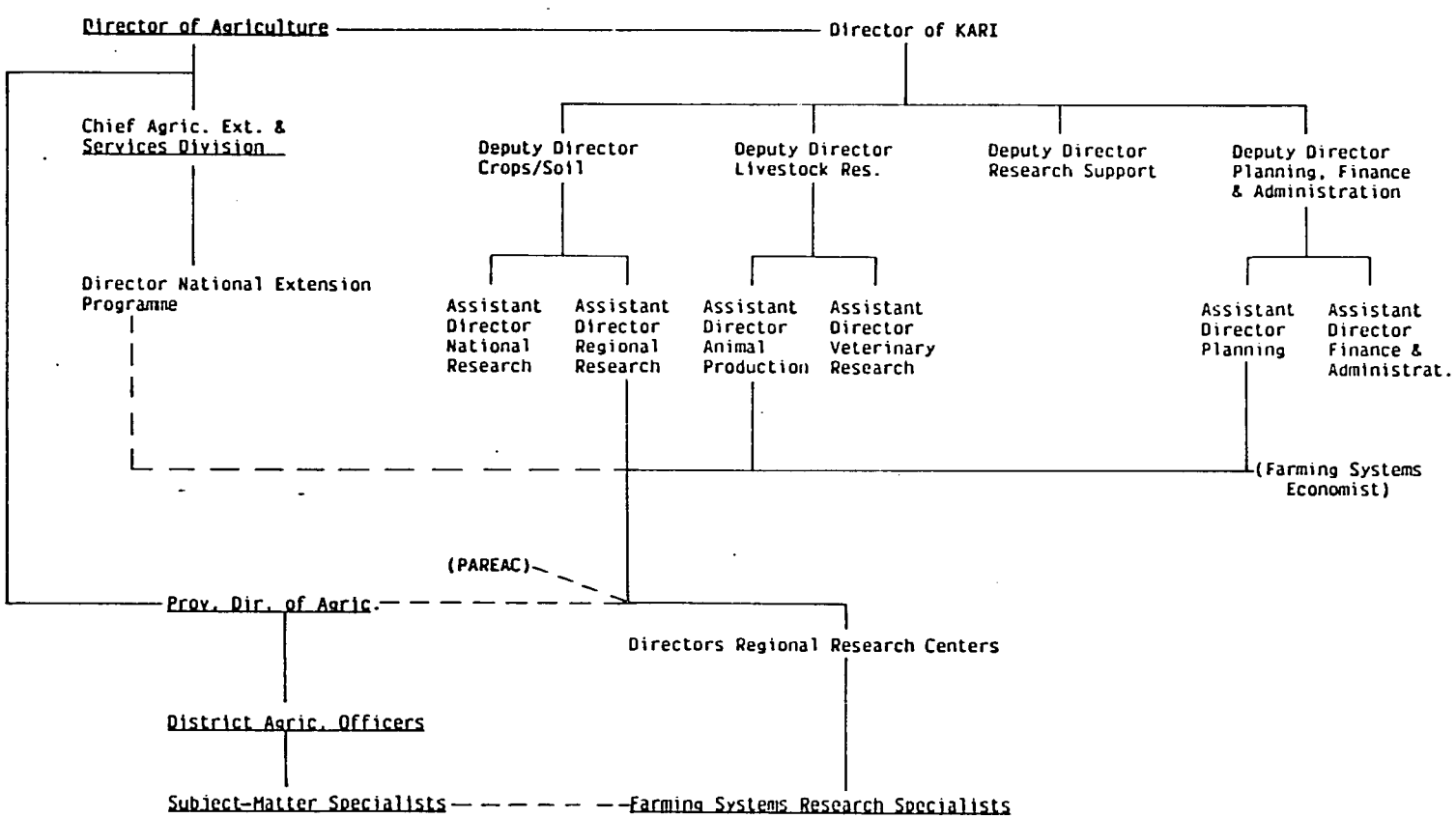
They should liaise closely with the Director of the National Extension Program (see Figure 8.1). Regular contacts should also be established with several branches within different divisions of MOALD, such as the Agricultural Information Service and the Agricultural Credit and Farm Management Branches of the Agricultural Extension and Services Division, and the Agricultural Mechanisation, Soil, and Water Conservation and Agroforestry Branches in the Land Development and Soil and Water Conservation Divisions.

It is proposed that a Senior Farming Systems Economist should be recruited, with a long-term experience in farming systems research and research-extension linkages to assist in the coordination of farming systems research in the regions and in the training of farming systems specialists (research officers and subject-matter specialists). He should liaise closely with CIMMYT's Eastern Africa Economics Program (see the Terms of Reference in Annex 2).

The above-mentioned Assistant Directors of KARI and the specialist should have the following responsibilities with regard to farming systems research:

- to identify training requirements and to organize training sessions for the farming systems research staff;

Figure 8.1: Coordination of Farming Systems Research



- to assist the RRCs with regard to methodological issues of on-farm research such as determination of target groups, organization of diagnostic surveys, design of survey forms, and establishment and statistical analysis of on-farm trials;

- to assist the RRCs in the documentation of results from adaptive research and in the communication thereof to the NRCs and to the extension service;

- to organize seminars for high-level MOALD staff and research staff from the NRCs;

- to initiate and coordinate sociological studies of livestock farming systems in the rangeland areas.

At the regional level, farming systems research activities will be coordinated by the Directors of the RRCs, while policy matters will be handled by the Provincial Agricultural Research and Extension Advisory Committee (PAREAC).

Regional program and activities

An important part of the crop and livestock research activities of the RRCs should be carried out on farmers' fields, and allowance for this, in terms of travel expenses, etc., should be made in the budget for the RRCs under the heading 'farming systems research'.

The staff at the RRCs to a much larger extent than at NRCs, should be composed of general agronomists, and should also include animal husbandry specialists and veterinarians. Each RRC should have at least one farm economist.

In the regional on-farm research program, clearly defined procedures should be followed, including the identification of target groups, the diagnosis of farmers' circumstances, the design and management of on-farm experiments, the analysis of experimental results, and the presentation, through the extension service, of recommendations to farmers.

At each of the RRCs one or more teams should be formed for on-farm research, generally composed of an agronomist and a farm economist, and in some cases a livestock specialist and/or a veterinarian. During the respective stages of the adaptive research cycle they will team up with crops, farm management, and/or other extension officers in the respective districts.

Once a decision has been made at the regional level, by PAREAC, to initiate farming systems research in a certain area, the farming systems research team will begin to collect general information on the natural and socio-economic conditions in the area that affect farming.

Following this general orientation, a preliminary assessment will be made, with assistance from the district extension coordinator and local extension agents, of the respective target groups of farmers, or recommendation domains (groups of farmers within an agro-climatic zone who have similar farms and use similar practices).

This distinction will be refined at a later stage, after the diagnostic studies. The final recommendation domains can include several groups of farmers in different locations in the region.

The next step will be an informal exploratory survey, to be undertaken by the agronomist, farm economist, and livestock specialist in order to obtain a clear idea about the significance of the respective enterprises to the farmer, about how he decides upon the use of his resources, about the external constraints he faces, and (given these factors) about the possible ways and means of improving his production systems and integral farming system. They also should identify what new materials and practices could make major contributions towards better and more suitable farming systems. A short list of possible solutions could be prepared, to be screened on their agronomic potential and socio-economic relevance.

The informal exploratory surveys should be followed up by the formal verification survey in the respective recommendation domains.

These surveys should be carried out by the farm economist of the RRC, in collaboration with the subject-matter specialist(s)/farm management officer(s) in the district(s) involved. These surveys will serve to verify the homogeneity of the recommendation domains, and to quantify the major characteristics of the farms and agricultural production systems identified within the domain, e.g., cropping patterns, seasonal labor requirements for crops and livestock enterprises, cash requirements throughout the production cycle, yields and yield-variability, etc. While information on resource endowments can easily be obtained during a single visit, a second visit might be required to obtain detailed information on resource use (labor requirements). These surveys should also focus on improved practices already adopted by innovators. Since the surveys are normally covering homogeneous populations (recommendation domains), a sample size of about 30 - 50 farmers would suffice, which allows for a tabulation and analysis by head.

On the basis of the general findings from the informal survey and the quantative data from the formal survey, conclusions can be drawn as to which enterprise(s) should be given emphasis first and which management changes are most likely to benefit the farmer. This will lead to the planning of a number of on-farm experiments that are believed to have a high biological potential and to be economically viable and socially acceptable to farmers. In all cases where there exists a considerable element of risk, the experiments should first be undertaken at the RRC, or at one of its experimental sites.

A schedule of proposed activities in the on-farm research cycle is shown below.

Activities	Participants	Time required
- General orientation on natural and socio-economic conditions of the sub-region	Research team	2 months
- Identification of recommendation domains in the sub-region	Research team and extension officers	2 months
- Informal diagnostic survey	- do -	1 month
- Formal survey - preparation & fieldwork - analysis	Farm Economist & SMS (Farm Mgt)	2 months 1 month
- Data interpretation & experiment planning	Agronomist (Livest. spec.) & SMS crops (Livest.)	1 month
- On-farm experiments* - fieldwork - analysis	- do - (TAs & farmers) Research team	whole crop cycle

* to be repeated over a period of at least 3 years.

The major responsibility for the on-farm trials will rest with the (farming systems) agronomists from the RRC, or a livestock specialist when animal husbandry is the dominant agricultural activity. In collaboration with a crops (or livestock) officer from the district agricultural office, suitable sites will be chosen, and participating farmers will be selected.

The agronomists of the RRCs should at regular intervals receive training in the organization and statistical analysis of experiments, to be given by the biometricians within the national agricultural research network.

Each region served by a RRC covers on average about five districts and some 25 locations, and is, because of the ecologically rather complex situation in most areas, likely to contain up to about 15 recommendation domains.

One team could at the maximum operate about 30 on-farm experiments at a time and since at least six experiments would have to be undertaken for each recommendation domain, such a team could cover every three years about five target groups and would need about ten years to cover the whole region. It would therefore be necessary to aim at a minimum of two teams in every region.

This would in fact mean that a total of 12 farm economists need to be posted to the RRCs, (a number of whom have already received the necessary training), and that a total of about 18 scientists of different specialization would be involved full-time in the farming systems program, or half-time for 36 of them.

The program would require the services of about 5% of the professional agricultural research staff and the assistance of a relatively small number of extension officers. This would, however, be the absolute minimum staff requirements for the program to have some impact, and assumes that it will receive all necessary support.

Because of the limited number of experienced farm economists presently attached to the RRCs, and the few agronomists already made familiar with farming systems research, it is proposed to recruit two experts; one farming systems economist and one farming systems agronomist to be attached to one of the two RRCs in Western Kenya (Kakamega or Kibos). They could also give some support to the other center (see their 'Terms of Reference' in Annex 2). If required, a similar team could at a later stage be recruited for a center in Eastern/Central Kenya (e.g., Embu).

At the same time considerable infrastructural support should be given to the RRCs so that they can conduct an on-farm research program. In particular this would require the provision of transport facilities and a travel vote for all research staff engaged in the program, and where required, also for extension staff. Allowance should also be made for the (free-of-charge) supply and distribution of considerable quantities of material inputs (seeds, fertilizers, etc.) and tools, to be used in the on-farm experiments.

Financial assistance is also required for the various training activities in the farming systems research program.

ANNEX 1

Costs Estimates

Farming Systems Research Program (first 3-year period)

	Cost/Year U.S.$	No. of Years	Total
1. Specialist - Farming Systems Economist - KARI	100,000	3	300,000
2. Two Experts: Western RRLs - Farming Systems Agronomy & Farming Systems Economics	150,000	3	450,000
3. Travel vote. Regional Research Centers for On-farm Research Program	30,000	3	90,000
4. On-farm experimentation - expenses - material inputs - tools, etc.	20,000	3	60,000
5. Training activities - farming systems specialists & subject-matter specialists - high-level staff & staff national research centers	20,000	3	60,000
	Total		960,000

(These are mere approximations: details should be worked out during the Projects Preparation Phase).

ANNEX 2

Terms of Reference

1. Senior Farming Systems Economist
Duty Station: Nairobi - KARI - Headquarters

- To assist the RRCs, with regard to methodological issues and organizational aspects of farming systems research.

- To assist the RRCs in the documentation of results from adaptive research and in the communication thereof to the NRCs and to the extension service.

- To identify training requirements and organize training sessions for farming systems research specialists.

- To organize seminars for high-level MOALD staff and research staff from the NRCs.

- To initiate and coordinate socio-economic studies of livestock farming systems in the rangeland areas.

- To promote mechanisms for maintaining a close relationship between technology-generating research and adaptive research undertaken by the various institutions and centers, and for strengthening extension-research linkages.

- To assess, periodically, the scientific staff and infrastructural requirements, for the involvement of socio-economics in the implementation of the programs of both the NRCs and RRCs.

- To undertake any other duties, aimed at strengthening the national farming systems research capability.

Terms of Reference

2. Farming Systems Economist
Duty Station: Kisumu (Kibos) or Kakamega - Regional Research Center

- To collect secondary data on the natural and socio-economic conditions in the region.

- To establish, in collaboration with the extension staff the various types of farming systems prevailing in the respective agro-ecological zones of the region.

- To identify, in collaboration with the (farming systems) agronomists and the extension staff the different target groups of farmers in the respective sub-regions.

- To determine, by means of informal surveys and in collaboration with the agronomist and the extension staff, farm-level constraints for the different farm enterprises and the farm as a whole, for the respective target groups.

- To carry out, in collaboration with the District Farm Management Officer, formal verification surveys; analyze survey results and prepare concise survey reports.

- To collaborate in the preparation of solutions and in the design and analysis of on-farm experiments.

- To carry out an economic analysis for various technological packages and prepare partial budgets for minor interventions in farming systems.

- To engage in the training of research and extension staff in farming systems research methodologies and activities.

- To undertake any other duties, aimed at strengthening the regional farming systems research capability.

Terms of Reference

3. Farming Systems Agronomist
Duty station: Kisumu (Kibos) or Kakamaga - Regional Research Center

- On the basis of research findings from the NRCs, to identify relevant research activities for the RRCs.
- To plan and carry out on-station experiments relevant to the farming community in the region.
- To collect secondary data on the natural conditions and farming practices in the region.
- To establish, in collaboration with the extension staff, the various types of farming systems prevailing in the respective agro-ecological zones of the region.
- To identify, in collaboration with the (farming systems) economists and the extension staff, the different target groups of farmers in the respective sub-regions.
- To determine, by means of informal surveys, and in collaboration with the economist and the extension staff, farm-level constraints for the different farm enterprises and the farm as a whole, for the respective target groups.
- On the basis of the findings from farm surveys and their interpretation, to plan, undertake, and analyze on-farm experiments.
- To engage in the training of research and extension staff in farming systems research methodologies and activities.
- To undertake any other duties aimed at strengthening the regional farming systems research capability.

CHAPTER 9: AGRIBUSINESS

9.0 The agricultural research system is characterized by four different mechanisms for coordinating agricultural research between the GOK research system and the agribusiness sectors. These four mechanisms are:

a) Assignment of principal research responsibility to a private firm. Example: With well-proven expertise in tobacco technology, British American Tobacco (BAT) Ltd. was assigned exclusive responsibility for tobacco research and extension in Kenya. Kenya tobacco production has increased from 170 m.t. in 1974 to 6628 m.t. in 1983.

b) Creation of commodity boards encompassing all private estate and smallholder producers of that commodity to fund research. Example: The successes in tea and coffee are well documented, with tea production increasing from 36.3 million kg in 1971 to 96.0 million kg in 1982, and coffee production increasing from 59.9 million kg in 1970/71 to 86.1 million kg in 1982/83.

c) Permission for a flow of public-sector personnel and technology to the national private sector. Example: In 1975/76 Kenya Breweries Ltd. began recruiting public-sector barley breeders, who brought with them the varieties and experiences they had accumulated at the Njoro National Plant Breeding Station. These researchers are now successfully developing barley malting varieties for Kenya Breweries.

d) Assistance in the coordination of public-sector research, private-sector production, and international investment, essentially, the Government being a broker of contract research. Example: The Kenya Nut Company Ltd. in Thika provides a partnership through which Japan is providing financing and technology. The Thika research station is conducting research and providing planting material for macadamia nut production, and the Kenya Nut Company Ltd. is purchasing the macadamia nuts from farmers, processing the nuts, and exporting, mostly to Japan.

A number of agribusiness concerns are involved in agricultural research in Kenya. These research activities include fairly sophisticated research programs, such as the tea and coffee research stations, to one-man efforts limited simply to testing imported materials for adaptability. Some firms encompass the whole spectrum; for example, Brook Bond has a sophisticated tea research program, and a one-man program selecting carnation varieties suitable for export. The high rise in the price of energy in the 1970s has induced several processing companies (e.g., BAT, Kenya Canners, Brook Bond) to focus roughly half of their research efforts on improving processing efficiencies. The agribusiness concerns involved in agricultural research in Kenya include the following:

Tea Research Foundation
Coffee Research Foundation
Kenya Seed Company Ltd. (maize, oilseeds, etc.)
BAT Ltd. (tobacco)
Kenya Breweries Ltd. (barley)
Kenya Canners Ltd. (pineapple)
East Africa Industries Ltd. (oilseeds)
Brooke Bond Ltd. (tea, carnations, sincona)
Kenya Nut Company Ltd. (macadamia)
MEA Ltd. (soil-testing)
Twiga Chemicals Ltd. (agro-chemicals)
FMC Ltd. (agro-chemicals)
Wellcome Ltd. (pharmaceuticals)
Dawa Pharmaceuticals (pharmaceuticals)
Nightingale Farms (poultry)
Delamere Estates (livestock)

While all farmers can be considered de facto agricultural researchers, some private farmers are very consciously pursuing improved lines in livestock, french haricot beans, and jojoba.

9.1 Utilizing Linkages with Agribusiness for the Agricultural Research System

Each of the linkage mechanisms with agribusiness can be utilized to strengthen the national agricultural research system.

The first, assigning principal research responsibility to a private firm, has the potential of: preventing the duplication of research activities between the public and private sectors; preventing the scattering of scarce public-sector research resources over a great range of crops; preventing the siphoning of scarce public-sector resources to research areas where the private sector has a comparative advantage; and reducing friction between public- and private-sector research staff.

Several of the private companies conducting agricultural research in Kenya have access to extensive resources and outside technology, which can have an impact on agricultural development in Kenya in a relatively short time. Some of these companies have created new industries and new export crops where none existed before. These companies are willing to invest in agricultural research, and ask that they be allowed to do their research without interference. Indeed, some consider that public-sector mechanisms, such as quarantine regulations, slow down the importation and utilization of improved varieties. However, there is much apprehension among many public-sector agricultural researchers that these companies will use their economic power and technological advantage to exploit farmers. Furthermore, public-sector researchers consider that while some private sector firms may have a comparative advantage in undertaking research in certain crops, the public sector must as a minimum effort maintain viable germplasm in that crop to assure an alternative supply of germplasm.

Recommendations on private-sector responsibility for agricultural research are that:

- The public agricultural research sector husband scarce resources by limiting research efforts in areas which duplicate private-sector research initiatives with significant research resources and/or access to outside technology. Specifically, the following companies might be assigned principal research responsibility in Kenya for the following crops:

  BAT (tobacco)
  Kenya Canners (pineapple)
  Kenya Breweries (malting barley, hops)
  Brooke Bond (carnations)

- The public-sector research in the above-mentioned crops be limited to maintaining a viable collection of germplasm.

- The Njoro National Plant Breeding Station and East African Industries Ltd. design a joint plan to share the research effort in sunflower and other oilseed crops to take greater advantage of a large-scale investment in oilseeds research being contemplated by East African Industries Ltd.

- The Department of Planning Economics and Department of Statistics in MOALD be strengthened in order that they better protect Kenyan farmers from potential exploitation by being able to measure the benefits being derived by farmers from their relationship with private sector companies, and being able to alert and document abuses to policymakers.

- The private companies doing agricultural research be requested to organize annual field days on their research activities in order to keep public-sector agricultural researchers and the public fully informed of the technological advances being made in the private sector.

- That the public sector maintains its vigilance in such matters as quarantine regulations to prevent the importation of harmful diseases, pests, or weeds in the name of expediency.

The second linkage mechanism between agribusiness and the national research system, the commodity boards, have proved very successful in tea and coffee. The Tea and Coffee Commodity Boards have done extremely well in coordinating the interests of Government, smallholder farm representatives, and the private estates. A significant part of their success is due to their efforts to explain their activities and finances to their membership. The Coffee Board provides an excellent model on the clarity with which its finances and activities are reported.

A commodity board's long-term viability is determined by how clearly the membership appreciates the services they provide. The Tea Board is facing difficulties raising the cess it collects to finance agricultural research, with particular resistance among smallholder farmers. The Tea Board must do more to explain the services it offers directly to the smallholder farmers, for otherwise, smallholders will see the cess as a burden on them, and not as an investment. Furthermore, in view of the fact that private estates are conducting some of their own research, the research of the Tea Research Foundation (TRF) should continue to focus on smallholder production.

The coffee industry is continually being threatened by outbreaks of disease. The Coffee Board may want to consider investing research resources in developing resistant varieties and early disease-detection methods.

Duplicating the success of the tea and coffee boards in other commodities in Kenya will be very difficult. Large crop volumes are required in order that a small cess on production will raise enough money to finance an adequate research program. A large cess, like a large tax, may merely decrease production. Furthermore, commodity boards in export markets must master what are often complex marketing rules and practices.

A vegetable commodity board would be difficult to organize due to the multitude of crops involved, the relatively small volumes grown in Kenya, and the complexity and precision of the marketing demands. The HCDA has tried to fulfill this role, and failed, though certainly not due to lack of entrepreneurial talent. Kenya Canners Ltd. has succeeded in canned pineapples because they can control marketing up to the supermarket door, and because canned pineapples are not easily liable to spoilage.

A Sugar Commodity Board may have to face the daunting tasks of struggling in a world market where world production continues to increase, and world demand for sugar continues to plummet as other sweetners replace sugar. Kenya's policy of self-sufficiency in sugar production should, however, be able to sustain the industry and the research required.

A Cotton Commodity Board cess to finance research would be crippled by the structure of the Kenyan cotton processing industry. The large number of government-owned, money-losing, cotton processing mills suggests that it would not be possible to set aside a significant and dependable amount of financing for cotton research. Cotton research should therefore continue as a public-sector research effort and service to farmers.

A Maize Commodity Board that could collect a small cess to finance maize research seems a viable alternative. The volume is high enough that a small cess will not impact on production, and the National Cereals & Produce Board and the Kenya Seed Company could provide a mechanism for collecting the cess on marketed consumer maize as well as seed maize. Nevertheless, to assure the long-term viability of this mechanism, the link between the cess to maize research for increased productivity must be clearly established in the minds of the producers and the researchers.

Based on an assessment of the existing and potential linkages in the agribusiness sector, the following recommendations concerning the linkage mechanisms of commodity boards are suggested:

- that the reporting and information procedures of the Coffee Board be used as a model for financial and operational reports by similar organizations in Kenya,

- that the Tea Board initiate an intensive campaign to explain its functions to the smallholder farmers,

- that the TRF continue to focus more of its research effort on smallholder production,

- that the Coffee Research Foundation (CRF) consider strengthening the development of pest and disease monitoring systems so as to anticipate outbreaks,

- that the GOK consider the application of a small cess on maize production to be used exclusively to finance continuing research in maize and associated crops and cropping systems.

The third linkage mechanism between agribusiness and the national research system is permitting the flow of personnel and technology from the public sector to the private sector. While the departure of researchers from public service is often seen as a loss, the contribution of the individual researcher to the development of the country may actually increase. These researchers who have left the public sector may become more productive in the private sector; because they have more adequate resources at their disposal or because they have very specific objectives to work for, and because they are being evaluated on the applicability of their work. Sometimes, the researchers who have moved have tended to maintain close relationships with their former colleagues, and thus an informal but highly effective communication link is maintained between the research being conducted in the public and private sectors. Nevertheless, it is undeniable that the departure of experienced staff from public service can seriously disrupt the public research program.

Private-sector companies have mentioned a frustration with not being able to get documentation of the research being conducted in the public sector. When reports are available, the private-sector companies indicate frustration that conclusions are presented without supporting data. This is particularly true of Kenyan companies having limited access to outside technology, and of agrochemical importers. Some private companies have mentioned a willingness to help finance publications on experiments on crops or chemical inputs, in which public-sector researchers could publish their results.

It is recommended in respect to the flow of personnel and technology from the public sector to the private sector that:

- Public-sector researchers be required to publish their research results in a timely manner, and encouraged to publish in some cases in trade journals or magazines. It is important that these publications include relevant data that support the analysis and conclusions reached.

- Private companies hiring public-sector researchers be encouraged to provide scholarships to Kenyan students or agricultural technicians to help repair the loss to public-sector research programs.

The fourth linkage mechanism that has been identified is the GOK coordinating third-party funding, public-sector research, and private-firm production; essentially, the GOK serving as a broker of "contract research". For contract research to be a viable mechanism, the research objective must be very specific and tangible. It would most often have to lead to the delivery of a specific input, such as an

improved seed. The link between the funding and the research result must be very clear. The funding of research by a third party is an investment, and the funding must be directly accountable to specific research activities.

Third-party-financed contract research is an alternative that becomes possible through the expressed interest of donor agency funds to support agricultural research on problems being faced by the private sector in Kenya. This alternative presents the opportunity of bringing incremental funding to work on national agricultural constraints, but care must be taken that these funds do not seriously skew national research priorities. Incremental funding must be considered a welcome development in a national agricultural research system facing resource scarcities. The problem arises in that the only available talent to actually do the research is in the public sector and the universities. Since this talent has few operational funds at its command, it would be very tempted to pursue the incremental funding made available by third-party-financed contract research to the detriment of their normal and under-financed responsibilities.

It is recommended that:

- MOALD seek from the GOK Treasury permission to pursue direct project funding for potential third-party support (both national and international) of specific research projects. This mechanism has already been used with some foreign donor project funding.

- Third-party-funded contract research be encouraged, with the clear understanding that the projects to be funded must be of a size and scope that do not impair the ability of the public sector and the universities to concentrate on national priorities.

CHAPTER 10: RESEARCH AND EXTENSION LINKAGES

10.0 Agricultural Extension in Kenya

Agriculture in Kenya grew at the impressive rate of 4.6% per annum in the period 1964-72, because of the break-up of well-managed larger holdings and rapid adoption by smallholders of tea, coffee, dairying, and hybrid maize. With the intrusion of smallholders into new areas, the annual growth rate fell to 2% in the period 1972-78. The production of foodcrops stagnated in 1979, and Kenya has had to import considerable quantities of food to feed its fast-growing population since then.

The 1981 National Food Policy Paper estimated that the production of major food crops would need to grow at annual rates of 10% and more to attain self-sufficiency by the end of the 1980s. These targets will be difficult to achieve, since there is not much new land of good quality available, and similar increases in yields as were obtained through the first introduction of hybrid maize, fertilizers, and improved agronomic practices are not likely to be obtained. There is, however, considerable scope for increased productivity by the timely use of improved techniques and inputs in both food and export crops.

Since the large-scale farming sector has become less important, the country has had to rely on the further intensification of smallholder agriculture to realize these production targets. Specific technologies need to be developed for smallholder agriculture. In doing so, it will first of all be necessary to fully understand what farmers and their families are doing now and why they do it, and how the impact of recommended new technologies is likely to affect the farmer and his family. This is a joint function of the research and extension services, and the exercise of this function should be strengthened.

Increasing agricultural productivity on small farms is a complex activity which requires collaborative efforts by research, extension, input supply, credit, and marketing and other supporting services; these efforts must be combined with the necessary price incentives.

A crucial role will have to be played by the extension services of MOALD, but the role of the other services and policies are no less important.

10.0.1 The organization of MOALD extension

Within MOALD, the Department of Agriculture is responsible for agricultural extension and the Department of Veterinary Services for veterinary and animal health extension and services.

Under the Director of Agriculture, the Department of Agriculture is divided into seven divisions. These are:

- The Scientific Research Division (Research)
- Agricultural Extension and Services Division (Extension)
- Crop Production Division)
- Livestock Development Division)
- Range Management Division) (Development)
- Land Development Division)
- Soil and Water Conservation Division)

MOALD also has its 'Project and Program Development Unit' and 'Central Resource Support Unit'.

The actual field and extension operations are directed at the provincial level through the Provincial Director of Agriculture (PDA) and the Provincial Director of Veterinary Services (PDVS) and coordinated on a district basis.

The districts are headed by a District Agricultural officer (DAO), who is assisted by a certain number of Subject Matter Specialists (SMS), and each district is divided into an average of five divisions: each headed by a Divisional Extension Officer (DEO), who directly supervises the work of the front-line staff: the Technical Assistants (TA) and Junior Technical Assistants.

Excluding the rangeland districts, there were in 1981 about 3,500 front-line workers covering some 1.7 million farm families. This ratio of one field extension officer to every 480 farm families is better than that for many African countries and compares favorably with those in the more advanced developing countries in Africa and Asia; the population density in many areas in Rift Valley and Coast Provinces, and in Machakos and Kitui districts, makes such a ratio desirable.

At the provincial level, PAREACs have been established, which are composed of regional and national researchers, provincial and district officers, and selected farmers. The responsibility of PAREAC is to develop an overview of all agricultural activities in the province, and it controls the Provincial Commodity Research Sub-Committtees, which have to propose priorities for extension recommendations, field trials, and regional research in the form of detailed plans. At district level the DAO and his subject-matter specialists are required to prepare District Technical Work Plans to guide extension recommendations for the year. At the central level, the Agricultural Information Center (AIC) is responsible for the production and dissemination of agricultural information.

In the past, agricultural extension in Kenya has generally followed the innovation-centered approach[1]. Rather than starting from the farmers' conditions and taking into account the constraints involved, new technological packages developed and tested on the national and regional stations were being 'sold' to the farmers without reference to existing socio-economic conditions and the ability of farmers to utilize these packages.

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[1] Pickering D.C.: The role of agricultural extension and some issues concerning current methodologies in Sub-Saharan Africa; Eldoret 1984.

In some cases, farmers adopted parts of the packages, which for example has been the case with the adoption of hybrid maize, which in certain areas proved moderately successful without the recommended dosage of fertilizers. In such cases the full potential of hybrid maize, fertilizers, and good management was never realized.

Because of lack of funds, research officers were generally unable to carry out testing on farmers' fields in different zones on different farms, and the extension agents were unable to visit large numbers of farmers.

To redress this situation, a new country-wide National Extension Program was introduced in 1982, mainly based on the T&V system. This is a farmer-focused approach, whereby emphasis is laid on the specialization of extension agents, on regular visits to farmers and on well researched key impact points, on the inclusion of home economics agents who work primarily with women, and on feedback from farmers.

In addition to the National T&V Extension Program and the general MOALD extension, extension activities are carried out through Farmers' Training Centers (FTCs) and the Agricultural Information Center (AIC), which has the national mandate to produce and disseminate agricultural recommendations through publications, radio, films, and other audiovisual aids.

Other agencies or institutions that perform extension functions include:

(1) The parastatal boards, such as the Coffee, Tea, and National Irrigation Boards. These train personnel in the demonstration and promotion of new recommendations, improved techniques, and husbandry practices among farmers who grow the particular commodities or engage in the particular type of activity for which they are responsible.

(2) National and Regional Research stations and laboratories of the Scientific Research Division of MOALD. These produce brief guidelines and handouts for distribution to farmers during agricultural shows, field days, and other demonstrations. They also provide training for extension personnel and some farmers through the FTCs, the T&V program, or on their own stations.

(3) Private companies, such as Kenya Canners (pineapples), Kenya Breweries (barley, pawpaw) BAT (tobacco), Hortiequip (French beans for export), etc. These companies supply seed, other planting materials, other production inputs, as well as information on proper production and husbandry techniques. They backstop the farmers' activities with regular visits and advice to ensure good results and improved-quality products.

(4) Missionary groups which assist farmers and other rural people in the organization of production and rural development activities. These cover a wide range of crop production activities, soil fertility maintenance and soil conservation, fuelwood production, and tillage practices using ox-drawn implements and other improved practices. They also assist the famers in the organization of input supplies and, in some cases, marketing.

The value to Kenyan farmers of the national and other programs of extension services depends largely on the availability of sound, relevant, and adoptable recommendations on improved farming techniques; the efficiency of the network of extension services in delivering these recommendations to them; and effective and rapid spread and communication of these recommendations among farmers. These requirements call for very close collaboration between the research services which generate and adapt these technologies and the extension and other services which introduce and demonstrate these to farmers, and are in a good position to provide constant feedback to the research services.

Current Status and Quality of Extension Material

The messages on appropriate and improved farming techniques for Kenya can be obtained mainly from the technical handbooks produced by AIC, handouts and circulars from the research stations and boards, and the lecture notes of station researchers and SMSs used for training workshops and courses. Private companies provide husbandry instructions and recommendations for their specific crops. Radio programs in English and Ki-Swahili are organized by AIC and the Coffee Board.

In general, it can be said that the sharper the focus on a single crop, and the tighter the organization of production and marketing of a commodity, the more valid, useful, and effective the recommendations on crop husbandry are likely to be. Thus, the recommendations for the tea or coffee growers, the contract-grower of French beans, or the tobacco grower are usually adequate and site specific, generating substantial yield increases and improved incomes. The situation in respect to crops such as food grains (except hybrid maize and commercial wheat), pulses, roots and tubers, green bananas, and of livestock (dairy and beef cattle, sheep, and goats) is markedly different. These crops and livestock, because of their very nature and their production systems, lack such clearly defined foci for increased production and productivity. The impact of applied improved technologies therefore seem to be limited in respect of these crops and livestock and is only likely to improve if research and extension can focus on defining the major research-related limitations to increased production and on resolving these through the development of appropriate packages of technology.

Some Shortcomings of Extension Material in Foodcrops and Livestock Production

A few weaknesses of the existing instruction materials of the Extension and Research Divisions of MOALD were observed by the Mission as follows:

- The nature of texts and presentation is frequently too academic or general, written by a researcher rather than by a good extension-educator or farm manager.

- Research results are usually not simplified or translated into straightforward recommendations on how, when, and what to do.

- Recommendations are seldom site-specific; e.g., recommendations for plant density and fertilizer application seem to vary widely in similar agro-ecological zones and soil types and conditions.

- Grass-root messages to be used in the weekly courses for farmers in the FTCs are inadequate or almost lacking. Training at FTCs is too formal and classroom oriented; simple illustrative or demonstrative material is mostly not available.

- Messages from research stations are mostly developed for high-potential zones, where farmers' husbandry practices are more or less well-established. Very limited valid recommendations exist for the newlysettled areas in the semi-arid regions, or for smallholder farmers in the more marginal areas where good advice on crop and livestock production is most required. In fact, the danger exists that inappropriate recommendations may be disseminated in such zones.

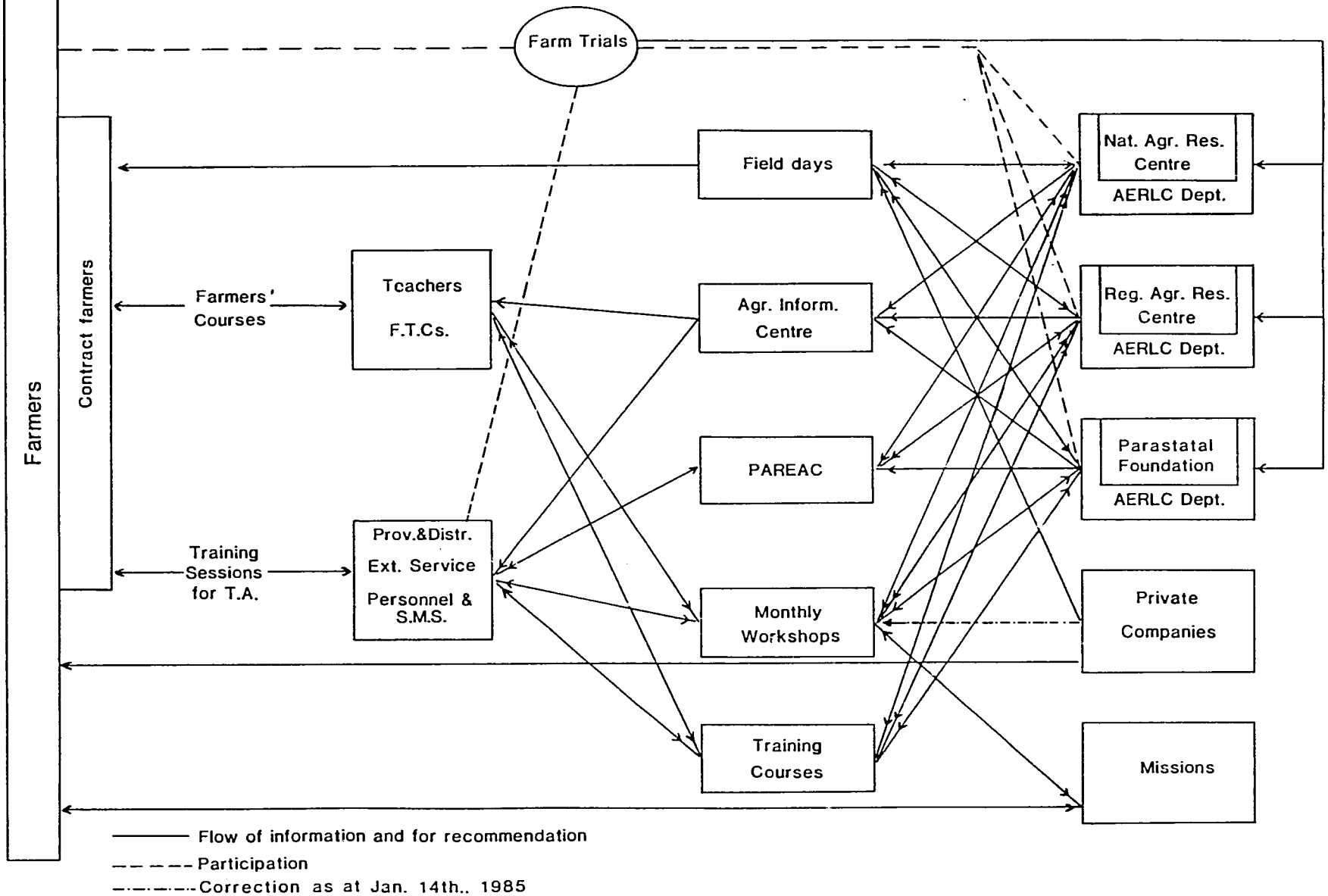
Improvement in the Standards and Relevance of Extension Material

In the light of the observed weaknesses in the present research/extension linkages and extension materials, the Mission recommends that:

- Research efforts should be devoted to relevant subjects identified as genuine farmer constraints by diagnostic surveys carried out in the different agro-ecological zones. To carry out these surveys and provide effective organizational and field liaison with extension, it is recommended that an Agricultural Extension/Research Liaison and Communication Department (AERLC) be created within the reorganized KARI. This department will be comparable to the one existing within the CRF and will be a suitable model for strengthening research/extension linkages. This department should integrate the Agricultural Information Center (AIC) and the Kenya Agricultural Documentation Center into an effective extension/research communication and information service. In addition to headquarters staff of subject-matter, communication, and information specialists, it should have assigned agronomists and subject-matter specialists who will function as integral parts of the on-farm research teams at RRCs. The work of the AERLC Department should be organized and coordinated by the Assistant Directorate RRCs, as proposed in Figure 9.1. of Volume I. The position and relationships of the AERLC are schematically illustrated in Figure 10.1 and emphasize the need for it to interact with national, regional, and parastatals research centers, as well as in training, information, and demonstrations right down to the level of farmers. The diagnostic surveys to be undertaken by the unit and in cooperation with RRCs should be carried out by agricultural economists, farm managers, farming systems economists, and agronomists to ensure that constraints are seen from both managerial and production systems' points of view, rather than from a purely technical perspective.

- Research efforts of any well-defined program or project should be coordinated and headed by a Project Coordinator; this is to avoid the generation of conflicting recommendations and the duplication of research and extension efforts, and to ensure that trials are laid out at appropriate locations or zones.

Figure 10.1 Suggested model for strengthening research / extension linkages



- Formal and informal contacts between researchers of national and regional centers and extension personnel of divisional, district, and provincial levels in T&V workshops should be continued and strengthened. Even if the logistics of these workshops ask for a less frequent encounter than a monthly workshop, the courses on specific subjects, as being held at research stations, should not entirely replace the regional T&V workshops in the districts. Research officers of the stations should carefully record the criticisms and feedback as generated during such workshops and associated field trips, to be able to provide relevant research subjects when preparing the annual work program proposal. As far as possible, the choice of subjects should be more in consultation with the AERLC Department and the on-farm research teams at RRCs and NRCs.

- Arrangements should be made to involve the communication specialists from AERLC to translate and simplify the outcome of field trials into advisory messages and recommendations for farmers and target groups at different levels, e.g., contact farmers in the T&V scheme, farmers at FTCs, and extension officers at the division or district levels.

- Provision should be made for improved facilities for researchers and AERLC personnel to use the AIC and other appropriate channels to produce and disseminate the latest research results nationwide.

- Provision should be made for simple on-farm trials or pre-extension trials, in the different agro-ecological zones, by RRC on-farm research teams in close cooperation with the AERLC department. The farm trials should be as simple as possible, without replications (the farmers' sites act as replications), and should preferably be farmer managed. The diamond trials, as carried out on hybrid maize in the 1960s, are a good model for these field trials. Centrally edited guidelines on the layout and monitoring of the trials, with strong inputs from a biometrician and the relevant coordinator, will be necessary.

Extension Network in Kenya: Personnel and Communication Channels

The successful linkages between research and the farmer through extension personnel in Kenya parastatals, such as the Coffee or Tea Boards, are widely reported and extensively cited in the world literature. Successes are also known from companies, such as BAT and Hortiequip, where adaptive research, inputs supply, and extension are all centrally organized and focused on the production of a crop or commodity. Research in food crop and livestock production is undertaken by the public sector through MOALD and associated institutions, and should focus on many smallholders throughout the nation. This is often more problematic, even where an extensive network of extension centers and personnel exists, as is the case in Kenya. The three legs of the Kenyan extension apparatus of MOALD, the extension services at the district level, the FTCs, and the AIC can only perform well if support from other services and industries are strong and fully integrated. The teaching at FTCs was observed to lack basic communication and technical skills, and the presentations often lacked adequate audiovisual aids and are ineffective. Demonstration fields and livestock units around the facilities were seldom satisfactorily organized. Fieldworkers and staff of the extension services at district and provincial levels exhibited a too-general knowledge of farming to be of much practical help to most

farmers. AIC certainly does not exploit its potential to print and distribute accurate and up-to-date messages needed by the farming community, although some commendable materials, relevant for the smallholder farming situation, have been produced.

One of the few occasions where researchers, extension personnel, and farmers can meet and discuss are meetings of the Provincial Agricultural Research and Extension Advisory Committees (PAREAC). These meetings are scheduled to be held yearly, but often are not held for many consecutive years. PAREAC meetings, even when they are held, do not seem to adequately reflect the needs of farmers for relevant research and researchable problems.

The Training & Visit Extension Scheme of MOALD

As indicated earlier, MOALD, aware of some of the weaknesses of its extension services, decided in the early 1980s to introduce the Training & Visit (T&V) extension model, as conceptualized by Mr. Benor and widely adopted by the World Bank as a successful extension formula for developing nations. The general thrust of the T&V extension system is the strengthening of research/extension linkages through a disciplined, systematic scheme of farm visits and the regular training of field extension workers on relevant topics. Funding of the Kenyan T&V scheme is mainly through a World Bank loan to the Kenyan Government. The T&V system was started in a few pioneer districts in Western Kenya in 1982 and, after some successes were recorded there, it is now firmly establishing itself in the majority of the Kenyan districts of importance in national agricultural and livestock production. The systematic and disciplined approach involved in this scheme has certainly made its impact: researchers from the stations and extension officers from the districts discuss regularly, at monthly workshops, and current research findings are passed on without delay to the frontline extension workers. The regular visits of these front-line workers to their contact farmers should ensure that new technologies are passed on to contact farmers, other farmers associated with them, and the farming community in general. A few suggestions are provided below on pitfalls to avoid and recommendations to consider when introducing T&V into other districts and agro-ecological zones.

Recommendations and suggestions for increasing the efficiency of the T&V approach

- Front-line workers, already involved in useful extension work at the time of initiating the T&V system in their division, should preferably not be taken away from this work.

- Researchers should not be asked to repeat their lectures more than once per year; instead, they should be asked to prepare a handout on the relevant crop and/or livestock husbandry recommendations to serve as a basis for discussions at workshops. This handout should be prepared in collaboration with an officer of the AERLC Department or with the on-farm research teams at RRCs.

- Messages as provided at present by researchers are not always relevant and site-specific, especially not for the semi-arid and marginal zones where so many new settlements are being initiated.

- Recommendations in respect of labor requirements, crop arrangements (pure or mixed cropping), fertilizer application, and plant density, and the breeding, feeding, and health care of livestock, should always be related to farmers' management conditions. This may mean that compromises should be found at the field level, and after consultation and discussion with researchers and AERLC officers.

- Subject Matter Specialists (SMS) and the extension officers trained by researchers at a station should be involved as much as possible in the training of the FTC teachers. They should also assist in the organization of demonstration plots around the FTCs and on farmers' fields.

- Provincial Extension Coordinators should invite FTC teachers to monthly workshops or courses at RRCs, when relevant topics for the region are dealt with.

- The choice of contact farmers, to be visited by the front-line workers, should not be left to the front-line workers themselves, but, to ensure a better dissemination of information, the local chiefs or respected elders should be involved in the selection.

- The monitoring of the impact of the introduction of T&V in a certain district can best be performed by an independent body, such as IDS, the Crop Science Department of the Faculty of Agriculture, or the farming systems economists in the CIMMYT economics program.

- Training in extension and communication occurs at all educational levels in Kenya. It would be worthwhile to concentrate less on the theory of communication, and to collect Kenyan cases of success, or lack of adoption of certain recommendations in the field, and to use them as practical teaching materials. Field examples could be surveyed by IDS, or other organizations. In-service training of this type in practical extension techniques could be given by AERLC officers at courses in research stations or at monthly T&V workshops.

- The regular fortnightly farm visits of the front-line workers is a splendid opportunity to derive more information on existing farming systems, crop and/or livestock production and management constraints, farmers' needs, and reasons for lack of adoption of new improved technologies. These surveys should be done in a professional way, using trained personnel and properly designed questionnaires and analytical techniques.

The consistent implementation of the T&V extension scheme and close collaboration with research services in these efforts will go a long way in strengthening research/extension linkages in Kenya. The ultimate beneficiary of this improved linkage will be the Kenya farmer.