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ANALYSIS

Report No. 1

KENYA

[illegible] LANDS

PRE-INVESTMENT INVENTORY

AID/afr-C-1275

ANALYSIS AND PROJECT IDENTIFICATION

KENYA
MARGINAL/SEMI-ARID LANDS
PRE-INVESTMENT INVENTORY

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Nairobi, Kenya
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FOREWORD

"...the earth (is) the 'mother' of the tribe, for the reason that the mother bears her burden for about eight or nine moons while the child is in her womb and then for a short period of suckling. But it is the soil that feeds the child through lifetime; and again after death it is the soil that nurses the spirits of the dead for eternity. Thus the earth is the most sacred thing above all that dwell in or on it." Jomo Kenyatta.

In April 1977 a group of eight Kenyans and eight Americans came together to carry out a Pre-Investment Resources Inventory of some of the Marginal/Semi-Arid Lands in the Eastern and Rift Valley Provinces of Kenya. During the following sixteen months they were joined by seven American and two Kenyan short-term consultants.

The Americans were provided by the United States Agency for International Development through contracts with the Consortium for International Development (a group of Western American universities) and the United States Department of Agriculture, Soil Conservation Service. The Kenyan professional, technical and support staff, totaling twenty-three people were supplied by the Ministries of Agriculture, Water Development, and Natural Resources. One short-term professional is a faculty member of the University of Nairobi.

The results of their labours are a series of reports recording the current status and future prospects for the development of the people and lands of the areas studied. The reports in this series are:

1. Analysis and Project Identification
2. Agronomy
3. Economics
4. Soil and Water Management (Engineering)
5. Forestry
6. Human Resources and Social Characteristics
7. Institutions
8. Livestock and Range Management
9. Seeds
10. Soil Science

Several of the short-term professionals' reports appear as sections in larger reports. Thus Dr. Bernard's report on population carrying capacity appears in Report No. 6; Mr. Taylor's report on ground water resources is in Report No. 4; Mr. Martin's report on Rangelands is in Report No. 8.

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Several of the working maps produced by the team have had to be so reduced to fit in the reports that some of the detail has been lost. Arrangements can be made through the Coordinator of the Marginal/Semi-Arid Lands Study Team, P. O. Box 30028, Nairobi, to supply full size copies of maps.

The team has received a great deal of willingly donated assistance from GOK, USAID officers and many others. Most of them have been identified in the lists of contacts in the inventory reports. However there are three individuals without whose support the project could not have functioned. They are G. M. Kimani, formerly Head of the Division of Land and Farm Management, Ministry of Agriculture, who was followed in that position by M. N. Maina, and Jerome Hulehan Project Manager in the Technical Services Section of the United States Agency for International Development. Only these three gentlemen know the many challenges that had to be met to organize, equip, transport, guide, liase, and prepare and publish these documents.

Finally a word of appreciation to the staff, the typists working under deadline pressures, the technicians, called on to do everything from field surveys to colouring maps and the drivers and subordinate staff who were in the right place at the right time and carried us over many miles of impossible roads. It has been a great experience in binational, interdiscliplinary cooperation.

Charles M. Gichohi
Byron C. Palmer

Project Coordinators

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Rapid population growth (on the order of 3 percent per annum), limited arable land and a shortage of employment opportunities in the industrial and service sectors have lead to a substantial growth in the number of small holders farming and ranching on Kenya's marginal lands. This trend is expected to continue into the twenty-first century. While increased settlement and exploitation of these lands provide a basis for the livelihood of small-scale farmers, the results are not an unmixed blessing. The soils, especially those on the steeper slopes are subject to serious erosion. Much of the natural coverings for the range lands has been overgrazed and the ground cover in some areas badly depleted. Also, rainfall for the areas under study is low 600 to 800 millimeters on average) and subject to considerable fluctuation. These factors when combined with traditional methods of farming and ranching have led to a low standard of living for much of the rural populace there. During times of rainfall deficiency the Government of Kenya has had to divert scarce treasury funds to famine relief for those most seriously affected. Moreover, the resulting depletion of the areas natural resources (forestry included) does not auger well for future generations who are expected to live on such marginal lands.

Recognizing both the opportunities afforded by the large amount of marginal and semi-arid lands (80 percent of arable land) and the dangers of erosion and desertification from indiscriminate use, the Government of Kenya has placed considerable emphasis on the proper development of these lands. Kenya's current Development Plan (1974-1978) in support for agriculture in general and small holders and the rural poor in particular, points to the need to pay greater attention to less developed agricultural and range areas.* The 1977 Budget Speech of the Minister for Finance and Planning singled out rural areas and medium and low potential lands for special attention.** Also discussions with various government officials indicate that even more emphasis will be placed on marginal and semi-arid lands in the 1979-1983 Development Plan.

Attention directed to marginal and semi-arid lands in agreement with the broader goals for the national economy. National goals have been specified by the GOK in the Development Plan 1974-78 and through its contributions to Kenya

* Development Plan 1974-1978, Part 1, page 18.
**Budget Speech for the Fiscal Year 1977-78 by the Hon. Mwai Kibaki, Minister For Finance and Planning, page 5.

into the Second Decade.* These goals emphasize the importance of continued economic growth, a greater sharing in the benefits of growth by the poorer segments of society, full control over the country's economy and broader participation by local organizations in government planning. Strong economic growth, as in the past will provide the resources and opportunities for the government to carry out its overall development objectives. When coupled with labour intensive technologies, such growth is expected to help provide the jobs needed for the growing labour force and for those only partially employed. Support for small holders, according to the World Bank Study, will not only benefit a broad, low-income segment of society but also tap a profitable potential. Small-scale farmers were identified in the study as an efficient converter of the country's land and labor resources into food, raw materials and foreign exchange earnings. Food production provides one of the basic needs while reducing the country's dependency on foreign sources. Production of raw materials, such as cotton, tobacco, and oil seeds provides industry with raw materials needed for its continued growth, offers an opportunity to earn and save foreign exchange and is one of the means for bringing small holders into the market economy. Overall such emphasis helps to assure continued economic growth, more employment opportunities, national self sufficiency and an improved standard of living in the rural areas. Of course, supportive action by the Government is also needed, such as appropriate price, wage, and tariff policies if small holder agriculture is to adequately benefit from increased production.

In short, the emphasis of the present study on marginal and semi-arid lands as well as on ways to improve small holder production and general quality of life in rural areas is seen as falling squarely within the country's goals and strategy for development. Yet, in directing increased attention to marginal and semi-arid lands the GOK is doing so partially out of necessity and partly out of faith. The necessity arises not only from the increasing overflow of population from the crowded high potential areas into the more arid, lesser potential areas but also from the need to better direct the development of this relatively fragile environment. The faith arises out of the belief that these lands can support a viable and durable agricultural activity without the GOK knowing the extent to which they can be used or the exact manner. It is with the intent of finding answers to these questions that the present study was undertaken.

1.2 STUDY OBJECTIVE

The primary objective of this project is to carry out a pre-investment survey that will identify, evaluate and quantify the developable agricultural resources of Kenya's marginal

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* Written by the World Bank and published by The Johns Hopkins University Press, Baltimore, Md., 1975.

and semi-arid lands. Due attention is to be paid to appropriate land management so as to conserve the natural resources of these areas. Moreover, the procedures are to be developed and applied in a manner that will allow the Kenyans to carry on after the expatriate team has completed its assignment. The end result of this effort is to provide the basis for the identification and design of development projects and policies appropriate for the country's marginal and semi-arid lands.

1.3 SCOPE OF THE STUDY

The Study is built around reconnaissance surveys of soils, vegetation, social, economic and related factors. The purpose of these surveys is to understand and prioritize the resource potential and problems of two areas. Because these are reconnaissance surveys, the analyses based on them will yield broad, generalized guidelines as to development possibilities. The understanding thus provided will serve to point the direction for further action rather than the specific route by which to attain the anticipated objectives. Such specifics require follow-up analysis and design, which lie beyond the scope of the present study.

The two study areas include portions of Machakos, Kitui, and Embu Districts in Eastern Province and portions of Laikipia, Baringo, Elgeyo Marakwet and Uasin Gishu Districts in Rift Valley Province. The combined areas comprise 2.5 million hectares, the boundaries of which are described in Chapter 4.

By means of the Mid-point review, held during December 1977, projects were to be tentatively identified for the Machakos-Kitui-Embu area. These project ideas were to be firmed up by the study team and included as part of the final report. Identification of projects for the Baringo-Kerio area is left for the Kenyan staff once the present contract has been concluded. The identification of projects is expected to flow logically from the evaluation of needs and opportunities resulting from the reconnaissance surveys.

Projects as herein defined include a breadth of opportunities ranging from single investments and operational activities to an integrated set of investments and activities, Project identification, which is included as part of this study, is distinguished from project evaluation and design, which is not part of this study, by the degree of detail involved. Projects are suitably identified if their nature and their relative significance and magnitudes can be sufficiently demonstrated to warrant further study. Project evaluation and design on the other hand, carry the analysis much further along. Such studies provide the basis for deciding whether or not an investment is to be made. They normally include such details as comparisons of alternative technologies, sites, products, policies, scale of activities, methods of finance, and so on.

Finally, the training provided under the contract has been informal and on-the-job. This was accomplished through close association between CID, US Soil Conservation Service and Kenyan personnel during the performance of daily activities. A test of success will be the extent that the Kenyan personnel assigned to this study will be able to apply to the Baringo-Kerio area the procedures of analysis developed for the Machakos-Kitui-Embu area.

1.4 METHOD OF APPROACH

The study method makes use of an interdisciplinary approach to the evaluation of resource potential and development possibilities. Procedures involved soil surveys, development and administration of socio-economic questionnaires, individual studies, analysis and synthesis of data, development of benefit - cost data on investment and operating activities, and suggestions for project and program development. Participants in the study included those with expertise in soil science, water resources, engineering, hydrogeology, agronomy, livestock and range management, agricultural economics, sociology, geography, demography, and political science. Integration of team activities was accomplished through regular staff meetings and work sessions and through jointly developing study concepts such as land suitability classifications, cropping packages, and technology levels.

The soil and socio-economic surveys required team members to spend considerable time in the field. This effort was augmented by contacts with government officials at the national and local levels and with others concerned with the various aspects of marginal and semi-arid land development. The soil survey followed approaches adapted by the Kenya Soil Survey which include techniques developed by the United Nations' Food and Agriculture Organization and the Soil Conservation Service of the United States. Assistance in developing and processing the socio-economic survey was received from the Central Bureau of Statistics. Other studies, as listed in the Foreward, were prepared by the resident team members and their Kenyan counterparts and by short-term consultants. In December 1977 the work to date was summarized and preliminary ideas for project proposals were presented in two volumes. These volumes served as the basis for a Mid-Point Review whereby government officials, expatriate advisors and other interested parties were able to evaluate and discuss preliminary study results and to offer suggestions for improvement. More specific information concerning the course of the study is provided in Chapter IV of this report. Details on the different topics are contained in the individual reports, which are listed in the Foreward.

These various reports, together with working documents and further analysis, formed the basis for the integrated approach presented in this final report. Soils and climatic data formed the basis for evaluating resource potential under alternative land uses. Alternative uses included rainfed

crops, irrigation, dairy cattle, ranching, and forestry. Large and small-scale activities were considered, as were alternative levels of technology. The latter included traditional, intermediate and advanced technologies. Effects of improved production techniques were compared with present conditions and in some cases a prediction of future conditions without corrective measures in land use and conservation.

The general approach to the identification of development possibilities was to select a production regime suitable to each type of activity for each soil type and ecozone. This regime is intended to give a representative value of the productive potential for a particular area under alternative conditions of use. For example, the net returns for a high quality soil in ecozone four was evaluated for each of the alternative uses mentioned earlier, e.g., rainfed traditional cropping, rainfed intermediate technology, ranching, irrigation, and so on. Each of these productive possibilities incorporate a set of improvements that call for government assistance and possibilities for technical and financial help from abroad. It needs to be noted that these productive possibilities represent approximations of suitable practices that are based on the professional judgement of the study team. As such, they serve to illustrate reasonable orders of magnitude concerning project feasibility. Refinement of cropping patterns, technical inputs, and other decisions through some form of optimation technique remains to be done once the initial level of profitability has become known.

The most profitable possibilities identified above were then recorded according to their characteristics, magnitudes, and locations. From this, requirements for economic infrastructure were identified according to rather general levels of need. The foregoing productive improvements are predicated on the ability to obtain credit and farm inputs, to receive instructions in new technologies, to market the ouput, and so on. Consequently, directly productive activities and economic infrastructure form an integrated package that must be developed as a unit, if the proposed program is to succeed as planned. Various conservation practices, forestry investments and social services round out the overall program of development. Further details on the evaluative procedures are contained in Appendix I entitled "A Note on Benefit - Cost Analysis".

The study was carried out by a resident team of eight expatriate and eight Kenyan specialists. Six short-term specialists prepared individual studies on various technical topics and two short-term specialists participated in the overall analysis and preparation of this final report. Staff from CRD Central Offices also participated in the Mid-Point Review.. Overall direction for the project was by Dr. Byron Palmer, who was assisted by Mr. Charles Gichohi as head of the Kenyan Staff.

1.5 REPORT CONTENTS

The next Chapter contains a summary of this final report, along with conclusions from the analysis. Following that is a general discussion of the key issues and interrelationships affecting development in the marginal and semi-arid areas. The next Chapter gives a summary account, in more detail than in this introduction, of the several activities of the study. Included in this account is an evaluation of the effectiveness of the study approach. Chapter Five presents a synopsis of principal findings concerning present conditions in the Machakos-Kitui-Embu area. This is used to set the stage for project identification for that area (Chapter 7). Details of the situation in both areas are contained in the other reports of this series, Nos. 2-10. Problems associated with population pressures, erosion, range depletion and lowering production are predicted in the absence of a meaningful development program. The third part of this Chapter provides details of alternative productive activities. The economic and social infrastructure, as well as other activities supporting the productive activities are also described. This Chapter closes with a summary of activities and an estimate of the potential impact on the area. The final Chapter contains a discussion and recommendations on development projects for Machakos-Kitui and Embu. The Chapter also contains comments concerning follow-on activities.

1.6 ACKNOWLEDGEMENTS

Those contributing directly to this volume of the final report are Maynard Scilley and Robert Sketchley on basic soils data and their interpretation; Robert Sketchley on erosion hazards; Charles Hash and Bernard Mbatha on cropping packages, other production activities, and overall economic issues; James Wanjaiya on dairy and livestock production; Herbert Mann and I. Q. R. Kariuki on cropping packages and alternative technologies; Paul Njoroge on soil loss; Derrick Thom on carrying capacity and social factors; Gideon C. Mutiso on institutions and roads; Byron Palmer on irrigation, rural water supply, crop risk, summary and development programs; Bill Shaner on forestry, soil and water conservation, and procedures for benefit - cost analysis. Those taking the primary responsibility for planning the final report were Herbert Fullerton, Charles Hash, Byron Palmer and Bill Shaner. The actual writing of the report was divided among those having primary responsibility for the various topics. In addition, Charles Gichohi prepared Chapter Four. The foregoing were assisted by technicians who helped in preparing the maps, by the secretarial and typing pool for preparing the drafts, and by the administrative staff.

Technical advice and related assistance were obtained from a number of sources. These included Mr. N. M. Maina, Head of the Land and Farm Management Division; Mr. Larry Ngutter and Mr. Michael Nightingale of the Planning Unit, Ministry of Agriculture; Dr. C. D. Wenner and Mr. Lennart Bondesson, Soil Conservation Unit in Land and Farm Management;

Mr. Joseph Kiilu, Ministry of Commerce and Industry; Mr. L. L. Ljungman, World Bank Mission to Kenya; and by Mr. Jerome Hulehan and other members of the USAID staff.

CHAPTER 2

SUMMARY AND CONCLUSIONS

2.1 THE BROAD PICTURE

The principal theme running throughout this analysis is that a large investment in soil conservation works, farm production technology, and infrastructure is needed to reverse a rapid degredation in the quality of life and the physical environment in the Marginal/Semi-Arid Lands.

Livestock grazing is a steadily worsening livelihood. People are going to have to go into small hectarge, mixed farming with cash as well as subsistance crops, improved animal power, fertilizers, insect control systems, better on-farm crop storage facilities, better livestock, and more management know-how; otherwise famine relief will become a constant way of life.

Although there are a number of projects already in place which are assisting the subsistance farmer, their scale is in general not sufficiently large (with the possible exception of the relatively small area targetted by the Machakos, EEC supported project) to reverse the slide to less production in a degraded environment. As production drops, people will become more and more dependent on government assistance for famine relief. It seems that the GOK has to choose between a very major effort to boost agricultural production or accept the need to pass out larger and more frequent famine relief supplies.

The risk of crop failure is relatively high especially in ecozone V which has an annual average precipitation of 540 mm, enough to generate a net return of shs.540/ha/year on good land to about shs.250/ha/year on marginal land, under a reasonably advanced technology. However at least three years in ten, farm incomes will just balance expenses as farmers try to grow crops and graze too many cattle on a bimodal rainfall pattern in ecozone V of the Eastern Province of 387 mm.p.a. The bimodal pattern makes double cropping almost mandatory. Yet too often it is poorly distributed adding further to the risk.

A subsistance farmer is, in general, a risk averter. To move into a higher technology level he has to have cash to buy inputs, transport his produce to market and/or store it. Cash usually means credit and credit means a mortgage on his farm. A dry season or two in succession means a loss of his farm, a risk he is unwilling to take. All of which means that risk must be lowered. We are proposing a number of activities to do this.

Better seeds, more fertilizers, more chemicals, all mean higher production and will lower his long-term risk. He can still have a crop failure and lose everything. For this reason we have endorsed the concept of drought insurance as described in the MDIDP program for Machakos. Without some such mechanism, farmers will not go into debt if they have to put up their land as collateral. Unsecured supervised credit is another alternative which then raises the problem of how to deal with high default rates.

2.2 OTHER KEY ISSUES

2.2.1 Production Issues

Soil conservation works must be speeded up. Every year the losses are lowering production and causing greater difficulties downstream. This requires better structures layout, more tools, and in some areas, more secure land titles.

Rangelands still have a capacity to revegetate although this will require removing livestock for one and one-half to two years. However on the average only one hectare in five in the grazing lands needs to be destocked the first two years. With proper attention to stocking rates on the revegetated hectares most, if not all,the cattle can be held on that hectare while the other four are allowed to revegetate.

Seed supplies adapted to the marginal lands must be increased. Energy for farm operations must be improved or farmers will not be able to cultivate the five to nine hectares they need to make a living. We are proposing dual purpose dairy animals for draught power and milk wherever bana grass to feed them can be grown.

The soils are very low in nutrients. A major fertilizer supply program is essential. Crop pests and diseases are serious production obstacles and must be controlled. Chemicals are needed in a timely manner. Farm tools, especially a substitute for the mold board plow are in very short supply.

Access roads must be installed or upgraded. People will need to get their inputs in and their produce to market.

Agricultural research needs to be accelerated even above the levels currently planned at the Katumani station. Besides the need for improved varieties of the well known crops, a number of crops little known to the areas could be introduced but need local research. Farming systems, both rainfed and irrigated, require more research.

The agricultural pricing structure will be a determining factor in a farmer's decision to go into higher technologies. It may be that the government will have to choose between high farm subsidies and a more or less uncontrolled market.

Farm labour is scarce during peak periods. However this does not appear to be caused by too few people. Rather there is not enough cash to pay a working wage.

2.2.2 Quality of Life

Most residents in the study areas see water, roads, transport, health, schools as the things they need most. The relationships between production increases and improved quality of life are not always perceived. There is a tendency among some to let the government solve all the problems. Massive government intervention should be done in such a way as to avoid increasing this attitude.

Training of farmers must be upgraded in both quantity and quality. Current training activities are helpful but too limited to have much of an impact.

Population increase has often been called a nation's time bomb. The semi-arid lands are doubling in population every twenty years. Unless this is decreased or the food production increased famine will become an annual event, and soon.

Finally, we raise the issue of how much help an area can effectively use over a fixed period. For example does the Machakos Integrated Development Programme "saturate" the district's development capabilities over the five years of its funding program, or can even more resources be put in?

2.3 THE SURVEY PROGRAM

A soil survey at a scale of 1: 250,000 has provided the basis for our analysis of land use activities. This covered an area of about 2.3 million hectares in Eastern and Rift Valley Provinces. The survey was carried out on 15 minute grids to tie into KSS survey activities.

The ground water resources of the two areas were surveyed and significant amounts were found but not enough for large scale irrigation

The range resources survey found that most of the rangeland is in fair to poor condition but that given two years of rest, much of it still has the capacity to rebuild its productive capacity.

The agronomy survey found low production levels, inadequate tools and power, frequent crop failure, prices not keeping up with inflation, unavailability of certified seed, and insect and disease problems.

The livestock survey highlighted over-grazing of the range lands and the poor quality of the cattle in Eastern Province.

The engineers detailed rural water supplies, irrigation, and soil conservation.

In the dry season people are walking on the average 5 kilometers to carry water which is usually of poor quality. Irrigation is not extensive and that practiced in the study areas has not been an outstanding success. Many soil conservation self help groups are functioning in the Machakos and Kitui areas. They need more tools and help in structures' layout.

An inventory of the forest lands detailed the species grown and productive possibilities.

A socio-economic survey secured data from over 3000 farmers on their farming and ranching activities, incomes, expenses, family composition, and their perceptions of their problems.

Institutions of importance to the semi-arid lands were surveyed and suggestions made for increasing their effectiveness.

2.4 EVALUATION OF PRESENT CONDITIONS

People in the study area have to rely on off-farm income to make ends meet. Current average family income is about shs.3,500 per year including that from off-farm sources.

Thirty-two percent of the land is moderately suitable, 57 percent marginally suitable, and 32 percent unsuitable for traditional agriculture. About 18 percent of Machakos, 6 percent of Kitui and 9 percent of lower Embu are currently being cropped. Little of the area is forested, the bulk of the remainder is in range land. Returns to farming are running at about shs.1,320/ha/year in the high rainfall areas of ecozone II to shs.200/ha on class C soils in ecozone V. Net annual returns to livestock are less than shs.30/ha/year in ecozones IV and V. The family labour constraint limits the cropped area to less than 3 ha/family; hence the need for livestock and off-farm employment.

A lack of abundant low-cost water supply has inhibited irrigation development. Water for small irrigation schemes, domestic and livestock uses is available from underground reservoirs, ephemeral streams, rock catchments and a number of subsurface and surface dams. However many of the latter have been breeched or have silted up.

The roads system is, except for the main roads servicing Machakos and Kitui towns inadequate to meet even the present marketing needs.

Lack of adequate storage, marketing, credit and other facilities is constraining development.

2.5 FUTURE CONDITIONS WITHOUT A DEVELOPMENT PROGRAM

By 1985 the M/K/E area's population will have reached 1.5 million from its present 1.14 million. Population movement to the less densely populated Eastern Kitui (ecozone V and VI) will bring about a lowering in per capita yields forcing people off the land and into more intensive livestock efforts. This will further degrade the range lands.

An estimate of the economic implications of soil erosion puts it at about shs.12.7 million per year under traditional technology. The present-worth of this annual loss at an interest rate of 8 percent is shs.160 million or shs.350 per hectare of cropped land. By the year 2000 the loss rate will have risen to shs.23 million per year. These estimates consider production losses due to soil loss but not nutrient depletion from the remaining soil. This is thought to be a greater cause of production loss than even the soil erosion.

2.6 PRODUCTIVE POSSIBILITIES

Eight production alternatives were investigated.

Small-holder rainfed traditional, intermediate, and advanced technology; large scale farming, advanced technology; small and large scale irrigated farming; livestock grazing; forestry for fuel and building poles production.

Using the soil unit descriptions developed by the soil scientists, each soil unit was classified for its suitability under seven of the productive units. Range management is reported separately in the Livestock and Range Management Report No. 8. Four categories were established:

A - Highly suitable
B - Moderately suitable
C - Marginally suitable
D - Unsuitable

Criteria used for their selection were, for the rainfed alternatives, drainage, ecozone, slope, soil texture, soil depth,and stoniness. Where a soil units was classified as a complex it was cropped a class.

The irrigated technology classifications did not consider water availability, only soil suitability, nor was ecozone considered. Soil moisture holding capacity was added.

An important feature of the analysis was to estimate crop yields for each of the A,B, and C land suitabilities for each ecozone and technology. These assume median rainfalls and good average husbandry by farmers. Emperical data supporting these figures is limited. We therefore strongly recommend acceleration of research now under way at Muguga, Katumani, and Kampiya Mawe to verify and/or improve them. They form the basis, when combined with costs and prices of generating net returns-rainfall relationships with which the government can make policy decisions on what technologies to encourage in the various regions of the study area.

These production functions were not developed in a frivolous manner. Many days of field observations, discussions with farmers and agricultural officers, reviewing literature and drawing on the experience of the staff, especially the agronomists went into this exercise. But they can and should be improved upon by careful, extensive field plot research.

Net returns were estimated for traditional, intermediate and advanced technologies, including for the intermediate level, forestry and grazing returns. These estimates were based on the hectarages and crop mixes in each ecozone as displayed in the farm budgets of Appendix VI. Farm sizes of 5,7, and 9 hectares were assumed for ecozones III, IV, and V respectively. These showed an increase from the current traditional agriculture of shs.118 million per year to shs.419 for intermediate and shs.766 for advanced rainfed technology. Returns from grazing were estimated to increase from shs.9 million to shs. 41 as technology moves from traditional to intermediate. There is an expected annual return from forestry of shs.39 million which is based on getting about 78,000 ha planted to balance supply with demand for fuel and building poles.

We suggest that an ambitious but possible target is to have a technology mix by 1990 about as follows:

	Percent of Land
Large scale irrigated	2
Small scale irrigated	10
Small-holder rainfed advanced	58
Small-holder rainfed intermediate	20
Small-holder rainfed traditional	10

There should then be a surplus in production on an average rainfall year.

Low rainfall years will still result in crop failures so improved storage facilities are needed to carry food supplies over at least one year, preferably more.

There are over one million hectares of land suitable for irrigation out of a total hectarage of 1.8 million. Water is the major constraint. The Athi, Thua and Ikoo rivers may have irrigation potential for developing fairly large scale irrigation projects. However small scale irrigation from

surface dams, springs, rock catchments, boreholes and sub-surface dams will probably result in more land being irrigated than large scale projects.

Because of the difficulty of avoiding crop failures even under advanced technology, in seasons of low rainfall, irrigation should be actively promoted. Even farm ponds, sufficient to irrigate small vegetable gardens or a few fruit trees will be a definite asset.

Large scale irrigated farming is a high technology, high labour enterprise. The existing irrigation projects in the study areas are still not producing well for a variety of reasons. Nevertheless, increased hectarages under irrigation ought to be encouraged.

Livestock can be upgraded. Grade animals are needed to serve as dual purpose draught animals and milkers. This can be done in ecozones III and IV where bana grass for forage can be grown. It probably cannot be successfully grown in ecozone V but improved range grasses there should make it possible to build up livestock quality for beef and draught power.

In spite of moving to higher technology levels, there is going to be a surplus of people who, if they wish to work and stay in the area will have to move to Kitui. Using a target family income of shs.4,500 p.a., under intermediate technology, by 1985 there will be a surplus in the Machakos portion of the study area of 400 thousand people and in the Kitui area of 25 thousand. If all the suitable land were put into rain-fed advanced technology there would still be a surplus of 107 thousand in Machakos but a deficit of 169 thousand in Kitui and 35 thousand in lower Embu. These figures are rather sobering and again speak for the need to use every available drop of water for crop production.

We looked at risk and concluded that once every ten years, under intermediate technology there will be a food deficit, expressed in maize units of 440 million kg even though on the average year there may be a slight surplus. There will be a deficit of 90 million kilograms or more, at least four years out of ten. This is based on 60% of net returns going to maize, 20% spoiled and 20% being used for non food essentials.

2.7 INFRASTRUCTURE

We looked at rural domestic/livestock water supplies and concluded that if GOK supply and quality objectives are to be met, reticulated systems may be the most economic in those locations with a current population density in excess of $72/km^2$ when compared with the only other major safe source of water, boreholes. There is a good possibility of lowering rural water supply costs if a cheap effective cistern for storing rain water collected on the farmstead can be developed.

Small earth dams could serve as dual purpose water supplies (small irrigation/domestic water) but they are high technology structures subject to washout and silting. They may seriously increase the incidence of bilharziasis in the area. Their use seems to be justified only in ecozone V for supplemental irrigation. Boreholes, although expensive to operate and maintain, seem to be the best answer for domestic/ livestock water in the more sparsely populated areas.

Roads are inadequate for developing a market economy. We are suggesting a contruction programme of about 1100 km tarmac, 645 km new murram, 468 km upgrading and 25 new bridges for the study area.

Credit access and marketing structures will have to gear up to a much higher level of operation. Our "order of magnitude" credit estimate is for shs.622 million per year for the crop programme. Soil conservation structures will need shs.800 million but that need not all be credit and can be phased.

Rural health programmmes have been included; mobile health clinics, improved supplies procurement, more rural health centers, water pollution control and disease prevention programmes.

Finally, we have given attention to the need for institutional adjustments (See Institution Report No.7) and proposed a project to assist GOK supervisors meet the increased burden which any government sponsored new programme will place upon them.

2.8 CONCLUSIONS

1. The productive capabilities of the study areas are being depleted.
2. It is not too late to reverse the downward trend but it has a good deal of momentum and massive infusions of money, equipment, supplies, and know-how, programmed in an integrated manner are needed to get the trend reversed.
3. Except for the health and domestic/livestock water supply programmes which have an indirect effect on production, all other programmes proposed are necessary and interrelated. Only an integrated programme has any chance of success.
4. GOK with donor agency support will have to take the initiative. There are no other institutions who can operate and coordinate at the level needed.
5. For the Machakos/Kitui/Embu study area of some 1.8 million hectares an investment of some shs.1,500 million programmed over twelve years could result in an annual increase of production worth over shs.700 million for an annual net return of over 40%. The economics look good but the job is a big one.

CHAPTER 3

KEY ISSUES

3.1 FOOD PRODUCTION

The key issue in the study areas is the increasing difficulty of feeding the inhabitants. Population is doubling every twenty years at about 3% per annum, possibly more. Table 3.1 indicates what is happening in Machakos to food production (calculated by combining Tables 2.1; 2.7; 2.9; 2.10; from the Agronomy Report No.2).

Table 3.1 FOOD PRODUCTION TREND - MACHAKOS
(Kgs. x 10^6 per year)

Crop	1970	1971	1972	1973	1974	1975	1976
Maize	453	526	468	201	206	238	162
Beans	56	68	56	50	46	64	36
Cowpeas and Pigeon peas	12	10	15	20	22	20	13
Totals	521	604	539	271	274	322	211

These do not represent all the food grown but they do represent the bulk of the staple food of the area.

One might look to rainfall as the major reason for the annual variations. Table 3.2 gives the average of the long and short rains for several representative stations in each ecozone in the study area.

Table 3.2 AVERAGE PRECIPITATION FROM LONG AND SHORT RAINS IN THE MACHAKOS, KITUI, EMBU STUDY AREA

Ecozone	1970	1971	1972	1973	1974	1975	1976
III	942	948	1097	557	743	884	700
IV	617	842	852	292[1]	566[1]	513	465
V	385	526	546	355	632	314	413
Weighed Averages (2)	478	633	659	351	621	400	444

Notes: (1) Interestingly in 1973 and 1974 the precipitation stations in Ecozone IV registered less rainfall than those in Ecozone V.

(2) Weighting based on the areas in each ecological zone as follows: Zone III 6%; Zone IV 26%; Zone V 68%.

Dividing the production of Table 3.1 by the precipitation of Table 3.2 provides an index of the relationship of food production in the study area to rainfall. (Table 3.3)

Table 3.3 FOOD PRODUCTION - RAINFALL INDEX: MILLION KILOGRAMS PER YEAR PER MILLIMETRE OF PRECIPTATION

1970	1971	1972	1973	1974	1975	1976
1.09	0.95	0.82	0.77	0.44	0.81	0.48

Except for 1975 there is a fairly smooth downward trend in production per mm of rainfall. One would expect some fluctuations in the index due to several factors affecting production. This strong trend if extrapolated linearly forecasts zero yield by 1980. It is more likely going to flatten out. Nevertheless the trend is alarming - even more so when the high rate of population increase is factored into the issue.

The message of Table 3.3 is that the lowering rates of production are not just because of low rainfall years. Most agrometeorologists are convinced that the moisture-production curve is linear throughout most of its range, or in other words that the ratio of production to rainfall is a constant all other factors being equal. Here, obviously all other factors are not equal.

A millimetre of rainfall in 1976 produced only half as much food as it did in 1970. The most probable reason is land depletion, probably by both soil loss and nutrient depletion. Although losses are thought to be less in Kitui, the data in the Agronomy Report do not separate the Machakos and Kitui yields. We suggest that MOA staff review these figures, going back a few more years to better establish trends. One can question the accuracy of the data but if errors in data collection are of a random nature one would expect more scatter, i.e. less strong a trend.

The downward trend is not because of fewer hectares of maize, beans, cowpeas and pigeon peas planted. According to Table 2.1 in the Agronomy Report, maize hectarage has remained about the same from 1970-1976 while hectarages of beans, cowpeas and pigeon peas have all increased. These four crops accounted for 80% of all food crops grown in the project area last year. (Table 2.2 Agronomy Report No. 2).

There is no more important issue in the marginal lands! Expressed another way, using Machakos district figures - the 1969 census put the population at 707,000 people. Using an annual growth rate of 3% the 1976 population was about 870,000 people. If the above cited yield and hectarage figures are accurate, the food produced per capita that year was:

$$\frac{221 \times 10^6}{870 \times 10^3 \cdot 0.8^*} = 318 \text{ kg}$$

*The four crops included represented 80% of total production.

Allowing 3200 calories per kg of cereals and 2400 calories/capita per day as an acceptable nutritional level, the annual per capita requirement is 274 kg or 86% of that actually produced.

3.2 COST OF SOIL DEPLETION

Estimates appear in Chapter 6 on the costs of soil conservation works. Are these works worthwhile? Referring back to Table 3.3 the slope of a best fit straight line through the data is about 100,000 kg/mm/year. The average precipitation over the six data years was 464 mm. So the average annual production loss has been 46 million kg. This six year trend means that each year the area is able to support 200,000 fewer people. This is an incredible figure! It may not be accepted because the mind almost automatically looks for less pessimistic conclusions. Our identification of the magnitude of this trend has come too late to search out and get separate corroboration of the yield and production data which came from the Eastern Province Annual Reports. Again we urge MOA staff to reevaluate the validity of the data because if the reports are reasonably correct, Machakos and Kitui are heading into a food crisis of greater magnitude than anyone has previously suggested. Urgent measures to reverse the trend are needed. Even using an exponential curve to fit the data (thus flattening out the projected yield losses) the extrapolation is still alarming.

Maize is the predominant crop which is worth about shs. 1.00 per kg to the farmer, so the figures of Table 3.1 are for both kilograms and shillings. Another approach to the evaluation of carrying capacity is reported in the report Human Resources and Social Characteristics, No.6. However it considers only population trends.

3.3 WHY THE RAPID DETERIORATION?

Sixty-four percent of the farmers interviewed in the Baringo/Kerio Valley survey listed soil erosion as the primary cause of loss of soil fertility (Human Resources and Social Characteristics Report Table 26). Another 28% of them thought it was primarily due to continuous planting. We believe them.

3.4 WHAT ARE THE POSSIBLE REMEDIES?

3.4.1 Soil Conservation Works

Soil conservation works acceleration-building grass strips, waterways, cutoffs, terraces, gully erosion structures are important needs on cropped lands (See Chapter 6 for cost estimates).

3.4.2 Improve Farm Management

Improve farm management such that farmers understand and are convinced of the validity of soil conserving tillage practices. It is not clear how easy this is going to be. The farmers in the Machakos, Kitui, Embu rural survey listed their perceptions of problems in terms of the need for more transport, water accessability, roads, hospitals, and schools. A very few listed crop failure and lack of advice as problems. On the other hand there are many self help groups registered in Machakos and Kitui working mostly on land terracing, an obvious indication of their interest in soil conservation.

With the high birth rate producing a population 50 percent of which is under age 15 years it is doubtful that enough people are aware of the yield reduction trend to have become alarmed. So far as cultural attitudes are concerned "The Akamba view of the cosmos is one of balance and order. Anything out of the ordinary that occurs such as drought, famine or death means that the balance has been disturbed and the munda mue (medicine man) must be called upon to restore the cosmological balance. (From Human Resources and Social Characteristics Report No. 6 p.42 quoting from Nida, 1962).

Does this mean that the Akamba tend to ascribe disaster to an outside supernatural power? Dr. Thom suggests this. The prevalence of this concept may determine the farmers' ability to equate good management with higher crop yields even in the drought years.

Another disturbing trait which according to Dr. Thom is emerging is an increasing dependency on government which is undermining their self reliance. An attitude is emerging that the government will always take care of the people's problems.

On the other hand training and education are eagerly sought after by the Akamba.

On balance the prospects seem good for upgrading farm management practices if programs are carefully worked out with the farmers themselves.

We see good agricultural potential still in the semi-arid lands but heroic efforts at getting the local farmers to commit strongly to better management of their resources are needed to stem the slide down what Bernard calls the ecological gradient (Human Resources Report No. 6 Appendix 1)

A wide front massive education program is needed,(see Section 6 for further detail).

3.4.3 Land Adjudication

The soil is being mined. The uncertainty of ownership before adjudication encourages soil mining in both cropping and livestock activities. A secure land title is a prerequisite to farming systems which are to maintain stable, long term agriculture, given the mounting population pressures.

3.4.4 Rangeland Revegetation

The Engineering Report No. 4 and the Livestock and Range Management Report No. 8 stress the relationship between overgrazing and soil erosion. We believe that since most of the land in the study areas is used for grazing, it is the major source of the heavy sediment loads in the streams of the areas. This is another case of slipping down the ecological gradient. Illustrative of this is the example given from Baringo (Report No. 8) of the dramatic decrease in the livestock carrying capacity of the rangelands.

We have suggestions for reversing this trend discussed in Section 6. Without a reversal, chronic famine is inevitable with its frequency and severity increasing each year.

3.5 PRODUCTION SUPPORT SYSTEMS

A farmer may be well trained and committed to stabilizing his land and increasing production, but he has to have support in the marginal lands or he cannot prevent his downward slide toward disaster. He needs a package of improvements.

3.5.1 Yield Improving Physical Inputs

i. Seeds which are frequently in short supply,(tabulated in the Agronomy Report No. 2 and the Seed Report No. 9 are a very serious bottleneck.

ii. Energy; eighteen times as much energy is put into each farmed hectare of land in the USA as in Africa (Agronomy Report page 18). One reason is that unit energy costs are lower. Since a farmer can handle by his own energy only about 0.5 ha he simply cannot farm enough land under traditional technology to spare the energy needed to carry out soil conservation works and feed his family. He is caught in a vicious circle. The more his land is depleted the less the yield, the more he has to work to raise enough to eat, the less energy he has to combat the soil depletion problem.

Grade dairy cows as draught animals are recommended as one intermediate and possibly long-term solution. Figure 1.1 in the Agronomy Report shows the costs of alternative energy sources. The dairy cow used for plowing and weeding is the clear winner, at least for farms of the sizes prevailing in the study areas. This means a food supply for them is needed, (mostly bana grass). Few farmers in Ecozone V have grade cattle. None in this country that we know of use them as draught animals. Elsewhere they are used extensively. In spite of the increasing population, a chronic complaint among farmers is a seasonal labour shortage, at land preparation, weeding and harvest time.

iii. Crop nutrients; very little fertilizer is used. With the loss of the long fallow period technology, farmers must turn to other means of maintaining soil nutrients. A major factor inhibiting use of commercial fertilizers is risk. Even if a farmer has access to credit, if he has to weigh the possible loss of his mortgaged farm in a drought year against a good crop in a wet year he will often opt for the lower return less risky choice with no fertilizer. Moreover this is related to seed supply. Most of the home grown varieties do not respond well to fertilizers. Seeds that do can, in low rainfall years yield less than local "low yielding" varieties because they deplete the soil moisture before producing usable grain. Another vicious circle- farmers avoid the risk so there is no market for high yielding seeds. If a farmer decides to chance it he can't because he can't get seeds.

Grain legume breeding holds promise but its future is still uncertain.

Besides the common N,P,K soil nutrients some farm land may suffer from micronutrient deficiency or toxicity. Farmers need easy access to professional testing facilities. Sometimes the reasons for poor yields are easy to detect, sometimes not. Problem soils often require a high level of professional skill to be made productive. (See also the Soil Science Report No. 10).

iv. Crop pests and diseases; the agronomists list 51 pests and diseases that afflict crops in the study areas. Although many are specific to only one or a few crops it is still a formidable technological battle from the moment of planting through storage up to the time of consumption..

Insecticides are well known to farmers in the study areas. We haven't seen data on insecticide poisoning but the extent of its use to prevent storage losses combined with a shortage of wash water on most farmsteads leads us to express concern over the high likelihood of acute and chronic human and livestock poisoning.

With many young children now attending schools the scaring of birds which are very damaging to most cereal crops and others devolves mostly on the older people of which there are comparatively not nearly as many.

The increasing restriction on fallowing is excaberating the insect and disease problem.

Although we haven't heard of any immediate moves to ban the use of DDT in Kenya, the worldwide trend on banning it will probably reach Kenya soon.

Honey production is a major industry in the study areas. Any increased use of insecticides is bound to be met with resistance from apiarists.

v. Supply of fertilizers, insecticides and other chemicals; insecticides to be effective must be applied in a timely manner. Even one day's delay can seriously lower the quality and/or yield of a crop. Most agricultural chemicals and fertilizers are marketed through local cooperatives. In the Institutions Report No. 7 Professor Mutiso points out some of the difficulties experienced by cooperatives in supplying farmers with supplies and equipment when needed. Shortages up and down the chain of supply ultimately cause yield losses.

Credit (see also below) if not supplied when needed can adversely affect application dates of chemicals.

vi. Tools; those requiring less draught power and designed to loosen the soil and kill weeds without turning it over are urgently needed. The mold board plow should be replaced for most farming activities because of its high energy requirements and its adverse effect on soil moisture storage.

More efficient (less water consuming) backpack insecticide sprayers are needed to keep ahead of pests and diseases. Self help groups need many more shovels. We have a rough estimate of a deficit of about 75 thousand shovels in Machakos and Kitui.

vii. Transport and Roads; as long as roads are few and poorly maintained the movement of people out of traditional technology will be confined to those living within 3 or 4 km of roads serviced by public transport. The interval between the short rains and the long rains is often too short to permit repair to washed out roads in time to move crops to market. Farmers are operating on such a small profit margin they cannot pay the high prices truckers must charge to drive over bad roads.

3.5.2 Agricultural Research

Research has dimensions of:

i. Relevancy - the matching of needs with programs

ii. Breadth- the number of crops, implements, management technologies, chemicals, animals under study

iii. Depth - the intensity of each research program

iv. Quality - the quality of the design, execution and evaluation of results

v. Scale - the relationship between the research investment of people and money to the productive potential of the area served.

Semi-arid land research is short on all five dimensions. Scaling of these five dimensions appropriately is a very subjective exercise, one that itself needs some research. Everyone knows that more research is needed. How much more? Are the current programs, augmented by the recent FAO and USAID proposals targetted at the marginal lands properly scaled; relevant; broad and deep enough?

Perusal of the research section of the Agronomy Report No. 2 leads one to conclude that even the augmented programs are not by any means optimal in any of the dimensions. With several new irrigation projects getting ready to start, with the current struggles going on, on several other functioning projects to make them economically attractive to farmers and with our recommendations to push irrigation in ecozone V in the study area we feel that irrigation research, especially on-farm water management research needs at least a one order of magnitude increase in all the dimensions.

We have noted a tendency to not be as concerned with the scale dimension as the situation warrants. This may be due to "excessive" pragmatism; an attitude of "lets get on with the job with what we already know". We are convinced that high agricultural production is directly related to high investments in agricultural research,

There is a large unfilled demand in MOA for trained researchers. Pay, environment and training requirements mitigate against getting qualified people to permanently locate in the study area. Until salary scales, local amenities and training opportunities for Kenyans are very markedly improved, the bulk of semi-arid land agricultural research may have to be carried by external donor agencies and expatriate researchers.

3.5.3 Socio Economic Inputs

1. Credit: The notion that easy access to timely credit will solve most farmer problems is too simplistic. It is a necessary but not sufficient requisite for moving from traditional to higher technology levels. Credit, as discussed in the Institutions, Economics and Agronomy reports is multidimensional with vectors of:

   i. Timeliness

   ii. Efficiency of administration

   iii. Collateral/security

   iv. Cost

   v. Risk

   vi. Supervised or not supervised - i.e. whether to tie to an approved farm production program

   vii. Repayment terms

   viii. Strategy for handling (and minimizing defaulters

   ix. Multiple and overlapping sources of credit

   Failure to deal adequately with any one of these vectors will doom the credit program to failure.

2. Price structures: The economists assert that price controls increase rather than lower prices, cause shortages for consumers and discourage production for cash sales. Certainly price influences farmer decisions. Livestock marketing problems appear to be closely related to the difference between the government controlled prices and that obtainable outside the official system.

   Low grain prices discourage moving to intermediate and high technologies because these require chashinputs. There appears to be a political choice between subsidizing the farmer from the public

treasury or letting him sell his produce at a rate sufficient to recover his cash inputs, otherwise few will risk moving out of traditional low input, soil mining technology.

We believe that the agricultural price structure is the major leverage the government has to move people into the soil conserving, food and cash producing intermediate and high technologies. Freeing the price would also open a place for commercial food storage depots. Perhaps the high cost of crop and livestock price control administration could be more profitably spent ensuring that in a free economy no single trader is able to gain control (corner the market) of a commodity.

3. Farm labour: There is the paradox in the marginal lands of seasonal labour shortages and high population pressure. The issues here are:

   i. Low prices for farm produce which holds down wages

   ii. Few amenities in the rural areas to hold workers there; housing, schools, health clinics, entertainment

   iii. Many of the prime labour force have found work in Nairobi, Mombasa and rural centers. Some people are willing to work for 7 shillings per day in the city but will not work for 30 shillings in the more isolated rural areas. The too old, too weak, too young are left to run the family farm

   iv. The farm labour requirement peaks seasonally. Everyone in an area is doing the same thing at the same time. Weather controls planting, weeding and harvesting operations, all labour intensive. In some countries seasonal labour shortages are met by migrant farm workers who move usually in a south-north direction in the northern hemisphere as the cropping seasons dictate. In Kenya there is no advancing of the seasons with latitude. Everything happens everywhere at about the same time.

   An approach to this problem is to focus research activities toward developing farm labour calendars that level out peaks.

   v. Not withstanding seasonal labour shortages there is a chronic labour surplus that is increasing for at least two reasons - the increasing population and declining food production. Our recommendations should provide considerable

relief to the tensions of unemployment

4. Farm Management: Farmer effectiveness in managing his land and livestock resources has vectors of all the other physical and socio cultural constraints already mentioned plus:

   i. His past training

   ii. His own goals

   iii. Competing interests and obligations

   iv. His relationship and attitudes toward his neighbors and those who are able to help, especially MOA and cooperatives' officers

   v. His values, beliefs, i.e. his motivation to be a successful farmer

   We have suggestions in Chapter 7 on dealing with training and relationships with government officers.

3.5.4 Government Support

There is already a complex government support system in the semi-arid lands. Its support effectiveness has dimensions of:

i. Available funds

ii. Institutional objectives

iii. Organizational efficiency

iv. Capabilities of the staff

v. Staff-farmer relationships

Professor Mutiso (Institution Report No. 7) has commented on these issues and we have some specific suggestions in Chapter 7. Suffice at this point to observe that the recommendations in these reports seem to mandate a massive additional intervention by government. The indigenous institutions in the area - self help, religious, fraternal are actively engaged in good causes and will undoubtedly continue to make worthwhile contributions to the quality of life. But the dimensions, complexities and urgency of action needed can be financed and coordinated only by the national government, with appropriate collaboration at the local governments levels.

Government is now functioning at a certain level with certain outputs. If our previous statements of trends

are realistic and if the prime mover to reverse the downward trend is to be government, it becomes axiomatic that government involvement will have to be several times more intensive (and/or efficient) than it now is.

The vicious circles mentioned previously which are rapidly degrading the environment have a tremendous amount of momentum. A commensurate amount of energy will be required to reverse the direction. However, once the key element, production, is reversed and people get a taste for more food and a higher standard of living, we are optimistic that the massive intervention needed to reverse the trends will not have to be sustained.

3.6 QUALITY OF LIFE ISSUES

People don't live to produce. They produce to live. Production is a necessary, but not the only goal. Certainly among the more than 3000 farmers surveyed, development was seen more in terms of water supply, roads, education facilities, health facilities. These are the key issues perceived by them. One can argue that by increasing production, people will then be in a position to provide for these quality of life items. This may make good economic but poor political sense. Moreover most production goals are interrelated with quality of life goals. Good health is a prerequisite to taking care of land and livestock. Adequate water nearby releases time for more constructive activities than carrying water and of course water is an essential production input.

1. Water: If the people in the study area were given one choice of additional assistance from outside sources, the overwhelming majority would ask for a nearby, reliable adequate, safe water supply. Most don't have it because:

   i. Streams flow only intermittently

   ii. Ground water is too expensive to develop

   iii. People are too scattered to be able to afford a piped system

   iv Surface reservoirs require high technology inputs and are costly to build and maintain

   See Section 6.3.1 and the Engineering Report 4 for a discussion of these issues. Any integrated development program that ignores water supply augmentation will not receive the local support it will get with water.

The Ministry of Water Development has the objective of getting water to the people. The issues are how to do it, where to get the water, how quickly to do it, where to get the technical staff to design and supervise construction, how to finance capital and recurring costs.

2. Educational facilities: The study team has not directed its attention to the formal school system, this being outside its terms of reference. However it has considered the issues of farmer and farm advisor training. Chapter 6 of the Institutions Report No. 7 discusses adult education the essence of which is that present adult training activities in the study areas are so minimal as to have an insignificant influence on agricultural production. This is not to say that the Farmer Training Centers in Machakos, in Ravine Division of Baringo and in Embu or the Better Living Institute in Kitui or the other training institutes are not providing value for the money invested in them. Rather, the level of investment is hopelessly inadequate. The vectors of farmer training include but probably are not limited to:

   i. Level of literacy

   ii. Population and growth rate

   iii. Ability of people to get away from the farm for training

   iv. Technology delivery system alternatives

   v. Training needs

   vi. Farmers perception of his training needs

   vii. Availability of successful technologies to transfer to the farmers

   viii. Availability of trainees

   ix. Current capabilities of the adult training centers

   x. Role of the formal school system in providing farm management training

   xi. Availability of trainers

We have heard arguments in favor of and against mobile training units which move from village to village offering short specialty courses directly relevant to farmer training needs at the particular season of the year. Comments were made at the mid-point review favouring an increase in the use of radio and cinema for farmer education. Staff have brought back reports of farmer

resistance to accepting advice from extension agents and the extensionists concentrating their efforts on the farmers who can make the best use of their services, i.e. the more progressive ones.

Farmer training and the training of their trainers is a very high priority key issue. The data presented by Dr. Mutiso showed for Machakos 2643 persons receiving 4127 person days of training at the Farmer Training Center giving a total of 1.56 days per person trained. With about 100,000 farm families in the district, if each head of household were to receive 20 hours of training in a year, the operations of the F.T.C. would have to be increased sevenfold.

3. The Increasing Population Issue: As noted in Chapter 6 even with "advanced" technology farming techniques, there will continue to be food shortages in the study areas during dry years. One obvious reason is overcrowding.

We have avoided making specific recommendations to accelerate family planning because none on the team are sufficiently wise to formulate an effective program. From the data in I.D.S. which we have seen it is far from clear that current programs will meet intended objectives. One line of argument goes that as people improve their standard of living the birth rate falls. If this works in the Kenya culture then the population increase problem may automatically be taken care of if production is increased. On the other hand, the issue is such a vital one that we suggest further study.

There are really three alternatives, and combinations:

i. Improve technology considerably beyond that which we call "advanced" to handle the population explosion, or

ii. Drastically lower the birth rate fairly quickly or

iii. Accept the need to move people off the semi-arid lands or frequently move in famine relief supplies.

The team's attitude toward pinning much hope on current family planning programs to relieve overcrowding is one of skepticism. We hope we are wrong.

3.7 CONCLUSIONS

People have been saying for a long time that the semi-arid lands of Kenya are deteorating rapidly, yet they still have viable farming activities therein. We hesitat to sound unnecessarily alarmist but from what we have learned during a year's intensive review of the current and past history of the

study areas we forecast a continuing rapid drop in productive capacity unless massive coordinated, integrated interventions are accelerated. The EEC financed Machakos Integrated Program is an extremely important contribution to the development of that district. However it remains to be seen whether it will pull the district out of its downward spiral before its funding is exhausted.

A vexing problem is the absorptive capacity of an area to receive massive infusions of money and technical assistance. We have not had the time or resources to evaluate this issue but recommend it be looked into in the project design phase. There is undoubtedly a high level of correlation between government organization efficiency and a region's absorptive capacity for development. This is why we have included an institutional development project in our project recommendations.

Finally there is the leaky bucket analogy issue. Most of the issues just reviewed can be thought of as holes in a bucket. A bucket will hold water only if all the holes are plugged. A number of the issues must be dealt with simultaneously. It does no good to arrange farmer credit for seeds if there are none to be bought at planting time. On the other hand some issues can only be resolved consecutively. There is no point in providing dairy cattle before developing a supply of forage.

Timing of farming activities is an issue that everybody recognizes but in our interdependent society is probably the single greatest difficulty the farmer has to contend with. The rains are late (early); supplies are late; illness prevents timely land preparation; credit processing is delayed; land adjudication is held up. Timeliness is everyting in farming. Any improvement program that cannot cope with timeliness will fail.

This list of issues is not intended to be exhaustive. We have said nothing here about rural housing, the status of women, boundary constraints- whether irrigation supervision should be in MOA or MOWD or both; plus a host of other issues raised in the individual professional reports. Not that other issues are not important. This section highlights what we believe to be the key issues- those that cannot be ignored without serious consequences to the development of the study areas.

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CHAPTER 4

THE SURVEY PROGRAMME

4.1 PHYSICAL RE ES INVENTORIES

4.1.1 Soil Survey

The Soil Survey work has been the backbone of the entire study. This is understandable since transformation of extensive land use and nomadic grazing to more intensive use requires adoption of a high degree of technology, amongst other things, and a broad knowledge of soil resources. This kind of information assists the planner to make appropriate, rational decisions on land use alternatives.

The kind of Soil Survey undertaken was at a reconnaissance level at the scale of 1:250,000 involving some 1837,800 ha. in the Eastern Province (Machakos, Kitui and Embu) and some 459,450 ha. in the Rift Valley (Baringo/Kerio Valley), bringing it, altogether to some 2297,250 ha.

The actual boundaries of the study areas were defined as:

i. Machakos and Kitui - areas lying between 1° 00' and 2° 00'S. latitude parallels - and 37° 15'E and 38° 30'E longitudinal meridians.

ii. Mbere - area lying between 37° 30'E and 38°E and 0° 30'S and 1°S.

iii. Baringo/Kerio Valley - areas bounded by the 0° 15'N and 0° 45'N latitude parallels; and 35° 30'E ahd 36° 15'E longitudinal meridians.

The geographical boundaries selected were influenced by three constraints; the project agreement between GOK and USAID, which established the general areas for the study, the manpower, physical resources and time assigned to the study and finally the need to key the study into the ongoing program of the Kenya Soil Survey which is also mapping the country. So avoid unnecessary overlap with KSS work, the study boundaries were established on 15 minute meridians and parallels of latitude. This decision to use straight line boundaries presupposed that the inventory work will continue and spread out such that political (district), geographical (drainage basin), climatological (ecozone) or physical (soil groups) boundaries will eventually be used as more rational bases for limiting the areas studied.

Other than providing the Soil Survey data for the study areas (an area with 46 soil units) and preparing soil maps, description of map units and discussion of their utilization, the soil scientists have cooperated

fully with other disciplines in preparing land use maps.

The land evaluation system used is a modification of a system developed by FAO. The system recognizes the fact that intensive land use requires injection of a lot of inputs so as to reach the desired goals. It therefore necessitates having a system of classifying land under prevailing use and the potential utilization after application of various levels of inputs.

The soil survey that has been carried out in the study is expected to meet the needs of broad, generalized programme planning.

Of the original 3.0 million ha that the survey was supposed to be covered, only 2,297,250 ha has been covered leaving a balance of 712,750 ha. The remaining part should possibly be surveyed in the subsequent phases of the study.

The soil survey work has been the most exacting part of the inventory and it will be necessary in future to drastically increase staff in this field so that soil survey work can proceed at about the same rate as the other fields. A lot of laboratory work should increasingly be done at National Agricultural Laboratories - Kabete and where necessary extra facilities should be provided to cater for this need.

The soils mapped and described occupy various types of physiographic features. Their details are given in the Soil Science Report.

4.1.2 Ground Water Reconnaissance

Availability of adequate water, with satisfactory chemical quality, for both human and livestock consumption and for limited irrigation, is probably the one single most important factor, necessary for the rapid development of the semi-arid areas of Kenya. Realising this, the project hired for 3 months, a hydrogeologist consultant, Mr. George C. Taylor, to collect, review and analyse all the available data on ground water and recommend to us on the availability or otherwise of the aforementioned type of water in the study areas. The consultant worked closely with the staff of the Ministry of Water Development.

In his report the consultant says that both the precambrian basement rocks - mainly in Machakos/Kitui study area - and the tertiary and quarternary volcanic rocks found mainly in Baringo/Kerio study area, do not yield sufficient quantities of water that could be used for large or even moderate scale irrigation projects. The limited quantities of water available could be developed by pumping from boreholes, subsurface dams and rock catchments. It is also recommended that borehole water supplies should generally be given more priority when planning for future rural and urban water supply schemes.

This limited water could also be used by individual small holders in their vegetable gardens or in orchards of sizes less than 0.4 hectares.

The details of this report are found in the Engineering Inventory and we would recommend it to all those who would want to know more in this field of our survey.

4.1.3 Range Resources

Rangelands of Kenya cover 87% of the total area and comprise practically all the study area. A range management specialist, Roy Martin, was hired from U.S. to undertake short-term studies on the range lands falling within the boundaries of the study areas. The details of this study form a part of the Livestock Inventory Report.

Over a 2 month period a systematic range vegetation survey was conducted in Machakos/Kitui/Embu study area and also in the Baringo/Kerio Valley study area, in 5 phases. The phases included:

i. Remote sensing
ii. Preliminary ground observation
iii. Area data collection and aerial reconnaissance
iv. Data compilation
v. Writing of report and range map preparation

It was found that although most of the range lands in these areas are, on average, of moderate to high potential, their condition was, on the whole, poor. A set of recommendations are given in the report which, if adopted, might more than double the current range production.

Intensive use of a helicopter in the range survey, like in the soil survey, though very expensive, made it possible for a lot of data to be collected over a relatively short period. It is recommended that in future fairly extensive use of helicopters be made so as to expedite the more exacting inventories like soil and range surveys.

4.1.4 Agronomy

This inventory covered all current food, horticultural and industrial crops that are grown in the study areas. Other potential crops that could be introduced in these areas are suggested.

Information on crops was obtained through spot checks in the field, D.A.O.'s reports, other sources of literature and from agronomy and agro-social field surveys.

The reports make detailed recommendations on:

i. Tillage practices to be adopted in these areas
ii. Assistance of farmers in the provision of tools for soil conservation and other related jobs
iii. Packages of crops to be grown in various ecological zones
iv. More training of farmers (in the field) and widespread retraining of extension agents on methods of soil and water conservation.

One of the problems encountered in the study areas, is the unavailability of certified seed and the related inputs, at the time and place that the farmer needs them. A separate report on seeds discusses this issue and highlights the need for bulking up selected, certified seeds, in the study area. A proposal is made of establishing a large scale farm for this purpose where seeds would be bulked up, possibly under irrigation, and the same distributed to the farmers in a timely manner.

It is not intended to duplicate information in these individual discipline reports in these summaries and we will continually refer the more interested reader to these detailed reports.

4.1.5 Livestock

This report highlights the serious, well known widespread problem of overgrazing, with its inevitable nsequences, that is prevalent in all the study areas. singles out man as his own victim in the desertifi- tion process. The report also argues against launching isolated, uncoordinated programmes and calls for clamation of overgrazed and overstocked land through tablishment of proper balance between livestock numbers d the production capcity of land. Since it is recog- zed that a lot of people living in the Marginal/Semi- id areas of Kenya are significantly dependent on live- ock as a source of their subsistence, the report commends introduction of more suitable crops, to be own under rainfed conditions or irrigation, as a means reducing heavy dependence on livestock as the main ans of survival. A lot of livestock projects (grassland vegetation, fodder bulking, livestock improvement) are oposed in the report but it is argued that these will t succeed if the cardinal problem of human survival is t appropriately addressed.

4.1.6 Engineering

The report contains three sections, namely:

i. Rural water supplies including water conservation
ii. Irrigation
iii. Soil conservation

There is very little surface and ground water in the study areas. The report therefore argues against the case for large scale rural and urban water supply schemes in the more sparsely populated areas on account of the prohibitive costs involved in reticulating water

to distant areas of variable topography. To satisfy the greatest felt need of water, the report advocates other methods of tapping water from roof catchments, rock catchments, subsurface dams and small dams.

The report gives a warning on viewing irrigation as a solution to water and land problems and calls for more research to avail more meteorological and hydrological data upon which future soil and water plans can be based.

Finally, the report recommends an accelerated programme of training in soil and water conservation involving the top brass of decision makers and the district and location technicians who are next to the farmer, and the farmers themselves.

Again this is a mere attempt to simplify the detailed Soil and Water Management Report and we would refer anyone requiring more information to the latter report.

4.1.7 Forestry

The inventory explores the forestry situation in the study areas and attempts to analyze some of the problems that hamper afforestation programmes in these areas. The species that could do well in these semi-arid areas are spelt out and a case is made for a rigorous afforestation programme on both private and public land, through establishment of tree nurseries in all divisions of the study areas. The report also identifies the need for further research into the problems of establishing forests in marginal/semi-arid areas.

4.2 SOCIAL - ECONOMIC SURVEYS

This was the most intensive of all the surveys that were undertaken in the study areas. Although the main emphasis in the survey was on socio-economic data, all the other disciplines had some input - of questions that related to their particular discipline.

With the guidance of our social scientist, Dr. Thom, a questionnaire in which all the disciplines had an input was prepared - discussed and finally approved. With collaboration of school authorities and the local administration, reliable local high school students/or leavers were drafted and trained as enumerators.

Altogether over 3,000 farmers were interviewed in both Machakos/Kitui/Mbere study area and the Baringo/Kerio Valley study area.

A colossal amount of data has been collected but with the time we have had, it has not been possible to analyse all of it. However, with the assistance of Central Bureau of Statistics, we have been able to analyse quite a sizeable portion of this data and the details of this are found mainly

in both the Social Perspectives Report, the Agricultural Economics Report and indeed in all our reports.

Detailed information of population characteristics and the implications this population has on the economy of the study areas are discussed in the Human Resources and Social Characteristics Report No. 6. The Agricultural Economics Report No. 3 on the other hand, has analysed the various farm data with a view to identifying constraints that hamper development in these areas.

4.3 MID POINT REVIEW

A mid-point review (seminar) was held at Kenyatta Conference Centre from November 29 - December 2, 1977. The purpose of this review was to critically review the information that had hitherto been assembled by the study team and fill any gaps that might have been in the data collected.

Over 100 people from government departments, non-government organizations, the university and donors, assembled at K.C.C. and discussed the various subject matter reports and the proposed projects. For a period of four days the reports were exhaustively discussed by this group.

A summary report on the deliberations of the seminar and the recommendations made on both the subject matter reports (Inventory) and the project proposals will be released about the same time as this report, or shortly thereafter.

Judging by the comments and the mood of the seminar, a lot of people were very pleased by it as it brought together many ideas on an area that is of greatest concern to Kenya; that is the arrest of encroaching desertification process and raising of productive capacity of the marginal/semi-arid lands of Kenya to meet the needs of a rapidly growing population.

Finally, we think that the seminar was very useful to the study team as we were able to orient our thinking, emphasis and direction towards meeting the desires and aspirations of the people for whom the project efforts are aimed.

4.4 APPROACH

This has been a unique study, at least as far as Kenya is concerned. Not everybody will agree with this statement, but I think we have sufficient reasons to make it:

i. This is the first multi-disciplinary and inter-disciplinary study that has ever been launched in Kenya.

ii. The study was directed to make an inventory of developable resources and suggest development proposals, in a small part of the marginal/semi-arid areas, representing what is climatically 18% of Kenya.

iii. The targetted study area is least known in terms of development potential and development constraints. It is a sensitive area whichever way one looks at it and it is of greatest concern

iv. The study was constrained by the time allocated to it and the initial take-off problems associated with launching a new project like this one

v. GoK/USAID agreement laid directives in terms of the nature of the study and the depth we had to go into. This has been a study at reconnaissance level. We had therefore very little room for manouvre.

v. We have had a mix of people in terms of nationality, age, experience and knowledge, all working for variable periods within the 15 months study life.

Organisation of a study like this one is not easy and will never be easy, and like all humans we have had our short comings. We are however satisfied that we have lived up to the big challenge of carrying out the job entrusted to us by our sponsors. Our reports will of course bear testimony to this.

To achieve the integration that is so vital in a study of this kind we:

i. Organized regular subject matter seminars

ii. Consulted with virtually all the relevant national and local officials, N.G.O.s, the university and donor agencies

iii. Carried out intensive field surveys in all the locations of the study areas. Over 3,000 farmers have been interviewed. The same information has been analysed at the Central Bureau of Statistics and used in all our reports

iv. Initially prepared a plan of work which was reviewed and accepted by our sponsors

v. Kept everybody informed of our progress through our quarterly progress report

vi. Called a seminar in the beginning of December 1977 at which all our disciplines presented reports on both inventory and project proposals. Through this exposure at which all interested parties were invited, we were able to know and identify our shortcomings which we hope we have avoided in the final documents.

vii. Established a steering committee representing all signatories and relevant bodies which has met regularly and reviewed our progress.

viii. Finally, analysed our data and presented it in a manner that has been consistent, systematic and integrated and could be applied elsewhere.

In reviewing these documents, it should be noted that when we refer to "the study areas" we are refering to those portions of the districts which are inside the boundaries for which we have completed the soil survey.

The data which the team secured from district reports is of course based on district-wide inventories. The reader is cautioned therefore to check, when he is looking at the data in these reports to ascertain whether it pertains to the study area portions of the district or the whole district. If extrapolation of the study area data throughout each district is desired, the following populations and areas may be useful. Users are cautioned that those parts of Machakos and Embu outside the study area are in general, higher and therefore have a higher proportion of ecozones II and III while the parts of Kitui which are outside the study area are mostly lower, drier and more sparcely populated

	Study Region		District	
	Area Km	Population x 1000	Area Km	Population x 1000
Machakos	7670	773.8	14,160	895.9
Kitui	9150	306.2	31,100	434.4
Embu	1550	77.9	2,870	226.6

Thus the Machakos portion of the study area has 54% of the total district area and 86% of the population. The Kitui portion covers 29% of the district area and includes 70% of the population. Embu covers 54% of the district and has 34% of the population.

The Baringo/Korio Valley study area includes relatively small portions of four districts, Laikipia, Baringo, Elgeyo Marakwet and Uasin Gishu.

Faced with the situations mentioned at the beginning of the section, we would like to think that we have come up with proposals that may not necessarily surprise you, but ones if adopted, might go a long way towards improving the lot of our people living in these disadvantaged areas. But, as critics you have theonus of assessing the worthiness of our methodology and the kinds of things it has led us to put on paper. In assessing our approach, we hope personalities will be put aside and the target people be put in front. The future may propose different approaches. What is important is that whichever methodology is proposed, that it be systematic, analytical, replicable and easy to implement. We would want not only the best methodology but also the most practicable one.

CHAPTER 5

SYNTHESIS OF RESULTS FOR MACHAKOS - KITUI - EMBU

The study team has taken the approach that viable, long-run development programs for the project area should be founded on solid opportunities for improving the level of production, especially that of small holders. Programs geared to improving the productivity of this group will benefit the overall economy from the increased output, will improve the distribution of income by reaching this target group, and will ease the financial burden on the national treasury by reducing the need for famine relief and by providing surplus revenues that can help to finance improvements in social services. This emphasis on productive efficiency is not intended to displace concern over the general level of social services and amenities available to the rural poor. Rather, it is intended to provide the wherewithall to carry out these socially responsible programs. Unless fundamental improvements can be made in the economic production of the area, other programs of assistance will become an ever increasing burden on the economy.

With these concepts in mind, the study team undertook a series of analyses of alternative production possibilities. These centered on intermediate and advanced technologies for cropping and dairying and improvements in range management and livestock production, irrigation and forestry. Each of these production possibilities is described in this chapter. An integrated production program is developed in Chapter 6, which includes consideration of necessary and desirable investments in economic and social infrastructure. But before delving into the analyses of possible programs and projects, a look needs to be taken first at some of the more salient aspects of current conditions in the area. Another perspective that needs to be viewed is what conditions are apt to be like in the area if some form of development programs is not undertaken*

5.1 EVALUATION OF PRESENT CONDITIONS

Physical, economic, social and political conditions in the project area are described extensively in the various team reports. Topics of particular relevance to the analysis of this report are selected for summary review and comment. These topics include population and land pressures, soil suitability under traditional agriculture, land use, range conditions, erosion hazard, irrigation, transportation, water supply and social services.

5.1.1 Population and Land Pressure

The project area is already crowded considering the the carrying capacity of the land under present

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*Since a development program is already underway for the Machakos District, this analysis of future conditions without development program will apply primarily to Kitui and Embu.

activities and the levels of technology employed by local farmers. The total area, made up of portions of Machakos, Kitui and Embu Districts and shown in Figure 5.1.1 comprises 1.8 million hectares. The approximate 1977 population for the area is 1,140,000* The full subsistence model for human carrying capacity applied by Dr. Bernard** shows a current excess population in 25 of the locations in the study area. These locations and the degree of excess population are shown in Figure 5.1.2. They cover nearly half of the total area. The present situation is not so bleak when consideration is given to the fact that part of farmer income is received from off-farm employment. The situation under partial subsistence (assuming 50 percent of income is earned off the farm) is much less severe. (See Figure 5.1.3) But, of course, this means that farm families must rely on other sources of income than their own farms. At the same time, opportunities for urban and industrial employment within the region are not great. Little local industry exists and urban populations are small. For example, the two largest towns, Machakos and Kitui, have respective populations of about 5,000 and 2,500.

According to the study's social and economic survey average farm income in the area is about Shs. 3,500 per year. For the typical family of eight, this amounts to an annual per capita income of about Shs. 440 ($55 at 8 shillings to the US dollar). Considering the low per hectare returns from predominantly traditional technology, this level of income includes significant contributions from off-farm employment.

5.1.2 Soil Suitability

The basic soils map (see The Soils Report) provides data on the mapping units (soils classification). Suitability of soils for traditional technology, which predominates in the area, is shown in Figure 5.1.4. As can be seen from this figure, no soils are rated as highly suitable (Class A). Amounts for the other categories are listed below:

Rating	Soil Class	Amount (hectares)	Percent of Total
Moderately Suitable	B	201,660	11
Marginally Suitable	C	1,047,530	57
Unsuitable	D	587,080	32
		1,836,270	100

* This estimate of population was made by assuming a uniform 3 percent annual increase since the 1969 census for all locations and prorating population according to proportion of land within the study area. The report by Dr. Thom (Human Resources and Social Characteristics Report No. 6) provides the basis for assuming the 3 percent rate of increase for the area.

** Refer to Dr. Bernard's study in the Appendix, Report No. 6

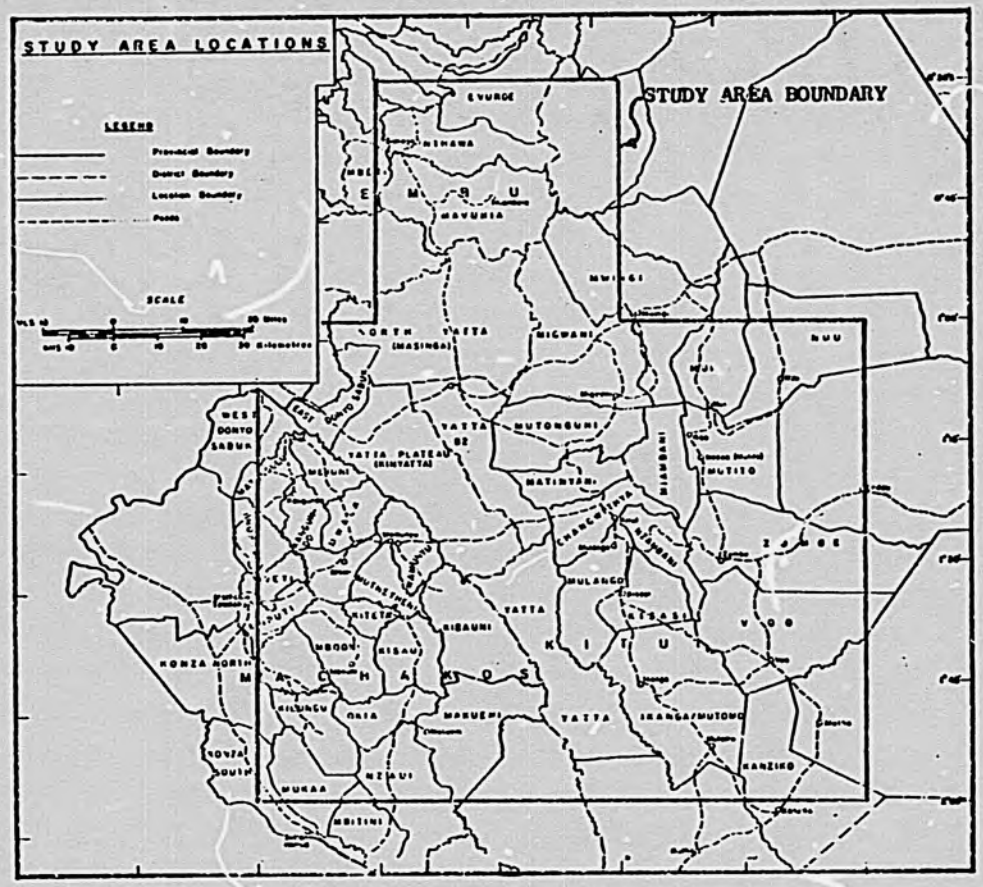

Figure 5.1.1

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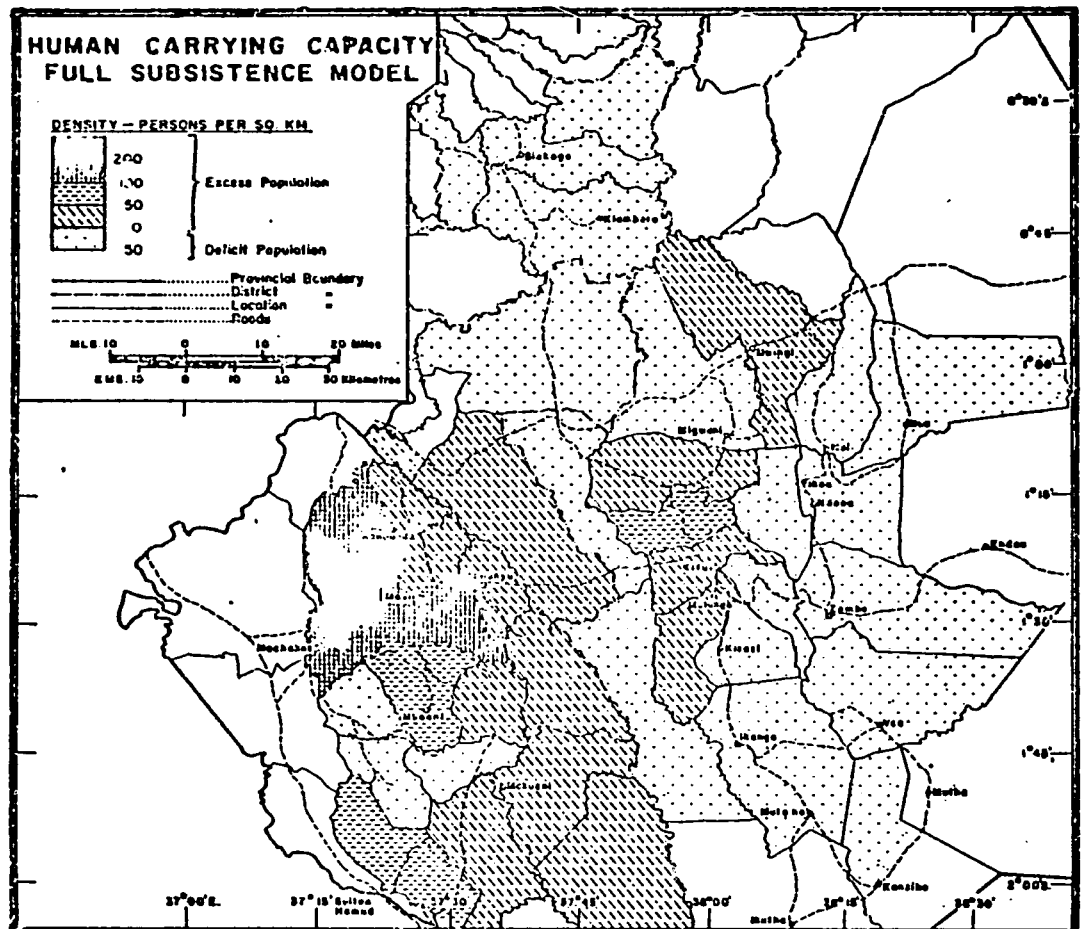

Figure 5.1.2

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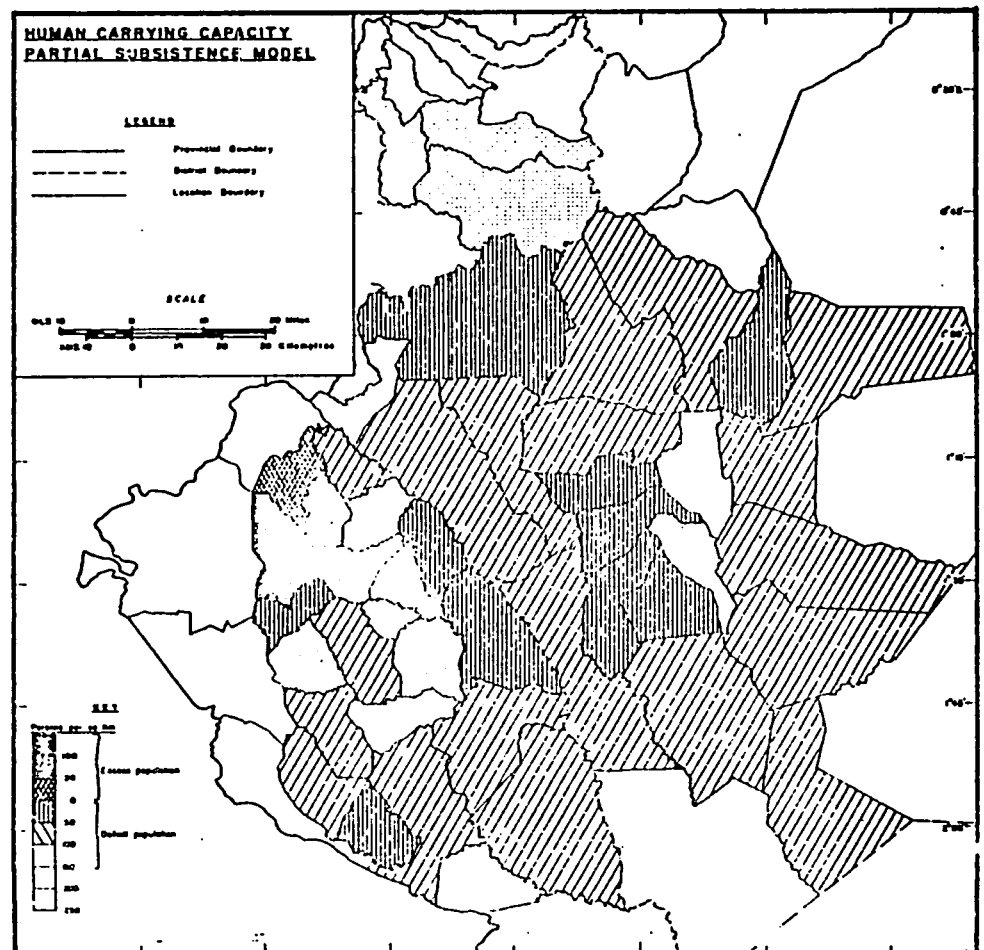
HUMAN CARRYING CAPACITY
PARTIAL SUBSISTENCE MODEL
LEGEND
SCALE

Figure 5.1.3

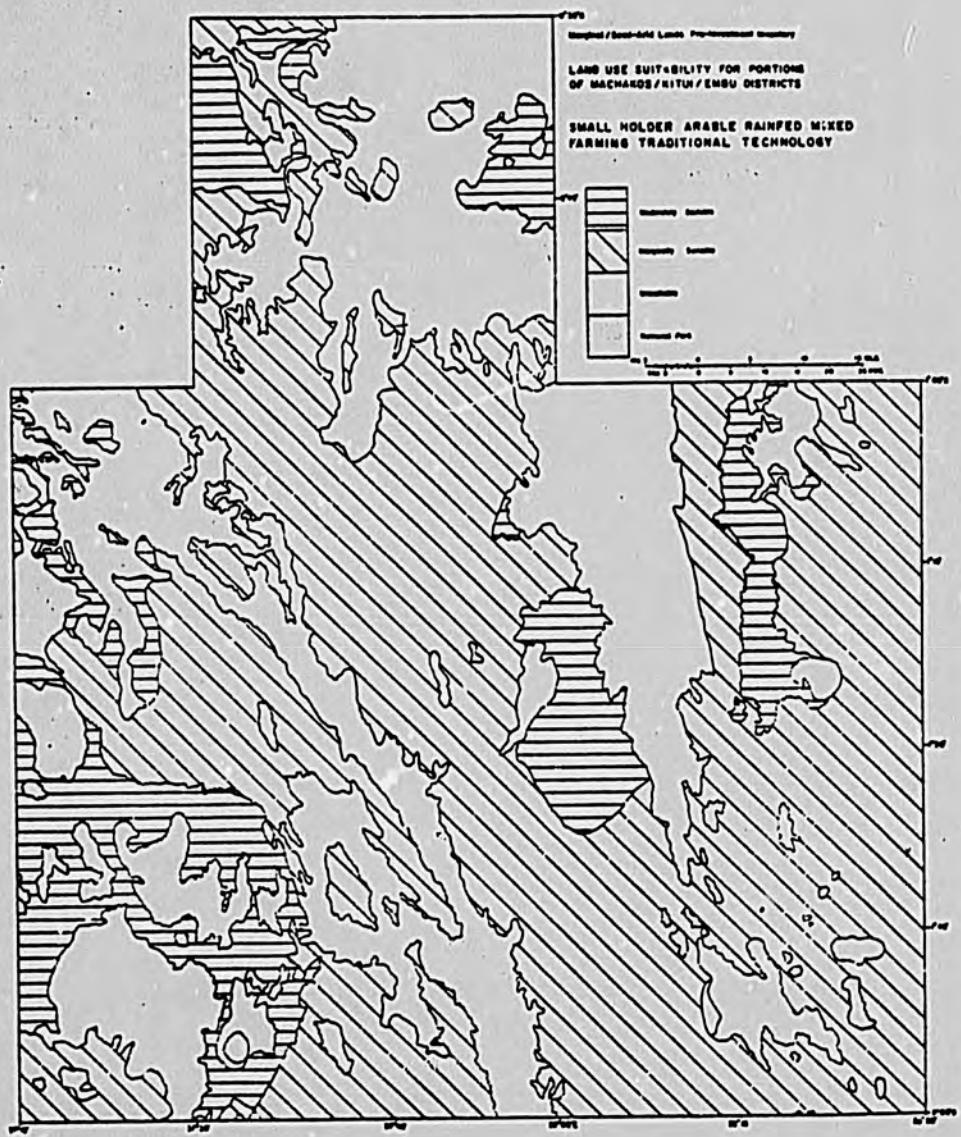
LAND USE SUITABILITY FOR PORTIONS
OF MACHAKOS/KITUI/EMBU DISTRICTS
SMALL HOLDER ARABLE RAINFED MIXED
FARMING TRADITIONAL TECHNOLOGY

Figure 5.1.4

Thus, for traditional agriculture more than half the lands are only marginally suitable and only 11 percent are moderately suitable. This low rating is primarily due to a combination of low rainfall and poor farming techniques, which do not adequately take advantage of the rainfall that does occur. Most of the soils are not inherently of poor quality, since soil suitability ratings increase significantly when higher levels of technology are considered. This generally low rating of soils explains rather forcefully the reasons for low yields and family incomes, as well as the reason for the low carrying capacity of the land under traditional technology.

5.1.3 Land Use

Estimates of land being cropped during 1977 are 18 percent for Machakos District, 6 percent for Kitui District, and 9 percent for lower Embu.* A weighted average (according to area) yields a global value of 9.7 percent for the area cropped. Separate estimates for the project area itself were made based on field observations.** This rather crude estimate produced a value of 11.5 percent. Little of the area is in forests, which leaves the bulk for range activities. Levels of net annual returns to family land, labor, management and whatever capital range from a high of Shs.1320 per hectare on Class B soils in Ecozone II to only Shs.200 per hectare on Class C soils in Ecozone V. While low, these compare favorably with the per hectare returns from purely range livestock land use under traditional technology. Net annual returns from livestock are less than Shs.30 per hectare for Ecozones IV and V. Of course, family income is dependent on the number of hectares that can be cropped and grazed. Given the family labor constraint under traditional technology, which limits cropping to three hectares or less, off-farm employment and livestock are needed on all but the most productive areas to supplement the income from cropping. These estimates of returns from traditional technology, along with returns from higher levels of technology, are discussed in greater detail in Section 5.3 of this chapter.

Consequently, considerable scope remains to upgrade the returns per hectare by moving out of ranching into cropping activities and from traditional cropping to more advanced means of production. But to do this in a way that will provide small holders with an adequate standard of living calls for a number of measures, which are described in subsequent sections.

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* See the Agronomy Report No. 2 Table 2.2 p 64 for estimates of hectarages under crops

** These are described in Appendix V.

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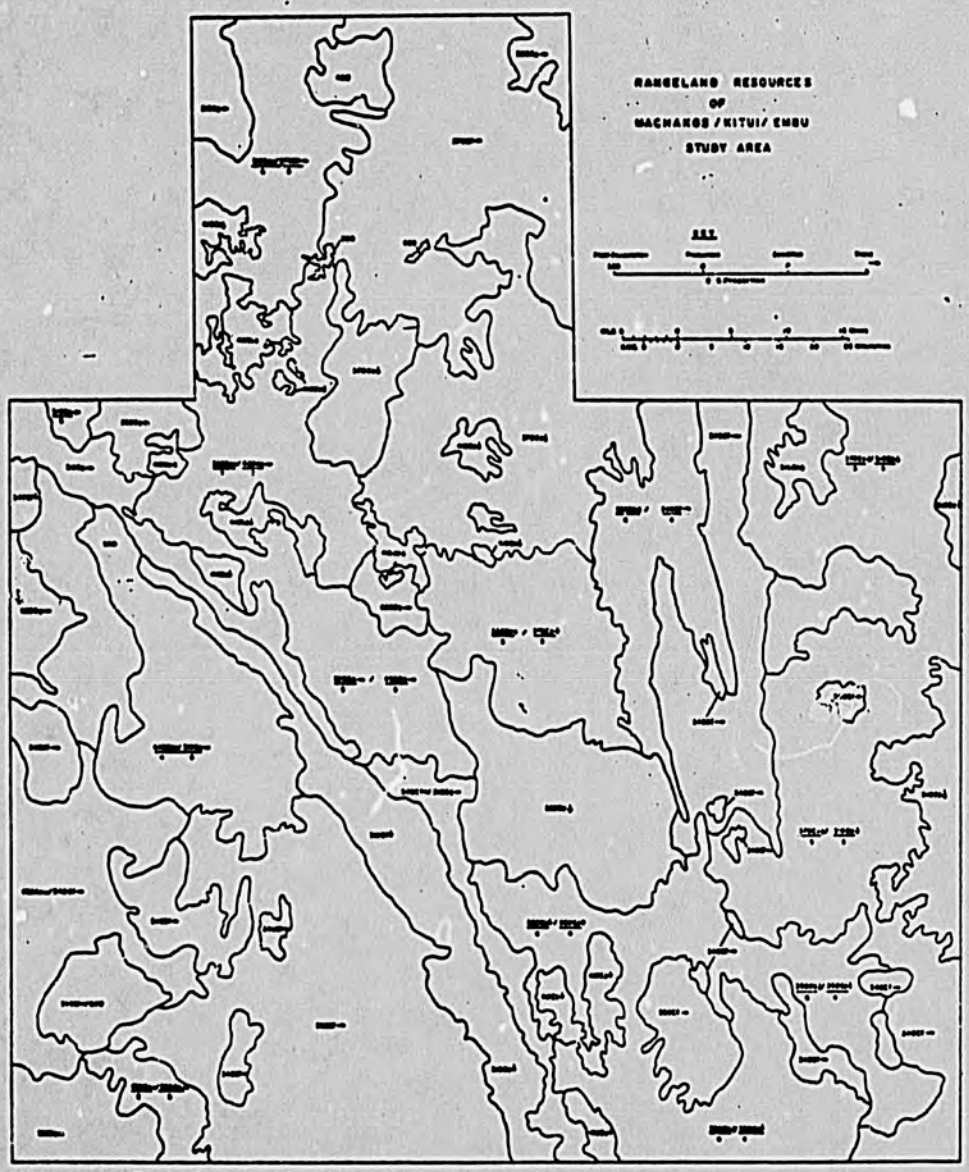

Figure 5.1.5

5.1.4 Range Conditions

Present range conditions are shown in Figure 5.1.5 Most of the area is divided between those of moderate yields (classified by Martin* as C) and low yields (D and E categories). A small portion with high yields (category B) is presently being operated according to intermediate and advanced technologies. Annual forage rates for these three categories, according to Martin are:

Rating	Suitability Class	Yield (kgs. per ha.)
High	B	1000--4000
Moderate	C,D	50- 200
Low	E	0- 50

Another characteristic of present ranching activities is the ability of the rangelands to maintain their present ratings. In this respect, conditions are not particularly good. Overgrazing has caused serious erosion in a number of areas. Unless some means of controlled grazing can be introduced, continued degradation in range conditions can be expected. By observing general conditions, Martin divided the area into those whereby range conditions are reasonably stable and those that are deteriorating. These two conditions are also depicted in Figure 5.1.5.

5.1.5 Erosion Hazard

Overgrazing and cropping on slopes without soil conserving measures are principal causes for concern about erosion. An index of erodability for lands being cropped has been applied by the Kenya Soil Survey (KSS). This index rates soils being farmed according to their degree of resistance to erosion. The ratings are very high resistance, high, moderate, slight and very slight. These ratings are dependent on slope, susceptibility to sealing, climate and slope length. A form of weighting is assigned to each of the factors, except slope length, and the soils classified according to the sum of these weights. A suitable measure for slope length has not yet been incorporated into the KSS method.

Results for the project area are shown in Figure 5.1.6. The index shown in the figure reverses the ratings by distinguishing soils according to their susceptibility to erosion. As can be seen in the figure, conditions of severe to moderately severe

* See Livestock and Range Management Report No. 8

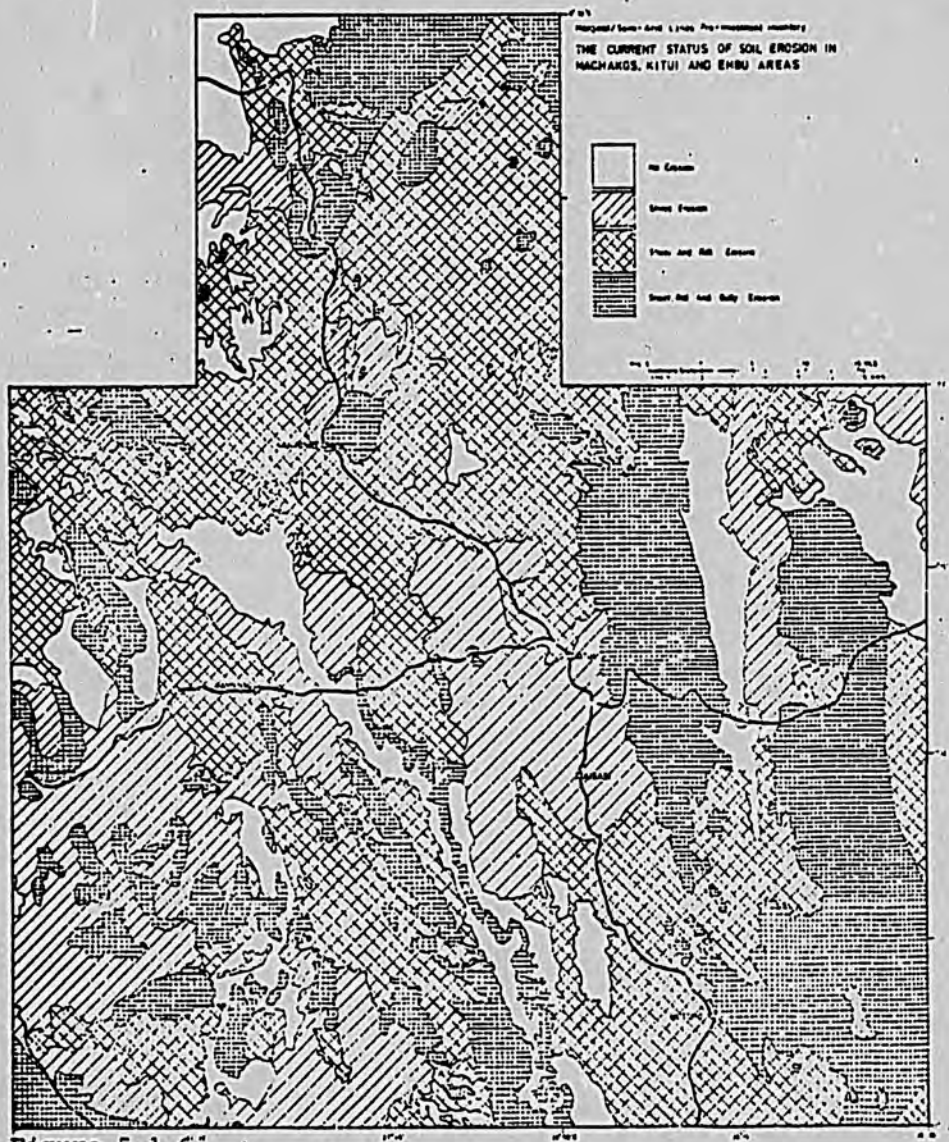
THE CURRENT STATUS OF SOIL EROSION IN
MACHAKOS, KITUI AND EMBU AREAS

Figure 5.1.6

erosion are not abundant. Those that do fall within these two categories are the mountainous and highland soils. Some of these areas of erosion severity are also suitable for forestry, e.g., the large block of MNr/DG soils in Ecozone IV in Kitui District. So, an economic solution to this potential problem appears to exist, at least for some of the areas. In other cases, terracing and other soil conservation measures will have to be implemented if erosion is to be checked. More will be said on this subject in subsequent sections

5.1.6 Irrigation

Irrigation is only practiced to a limited degree in the study area. A few private activities are reported as being reasonably successful north of Machakos. But in general, irrigation is neither widespread no particularly profitable. Part of the problem lies with inexperience in farming under irrigated conditions. Another problem, concerning the project area, is the lack of an abundant, low-cost water supply. More on this subject is contained in the Ground Water section of the Soil and Water Conservation Report No. 4 and in section 5.3.2 below.

5.1.7 Transportation

The area is reasonably well served by main roads that connect the two principal towns--Machakos and Kitui--with the main highway between Nairobi and Mombasa. Even so, the roads leave much to be desired, especially during the rainy season. Farm-to-market and penetration roads are far less adequately supplied. These will need to be provided if the area is to move from ranching and subsistence, traditional cropping to a market economy and a higher level of technology for cropping.

5.1.8 Water Supply

The residents of the area are not well served by a safe and convenient source of potable water. Survey results indicate that 50 percent of the population must travel more than 5 kms to fetch water during the dry season. Naturally, conditions are not so severe during the wet season. The government plans to correct this deficiency and has set a target of providing an "adequate" water supply for every resident by the year 2000. Discussions with water resources experts indicate this target to be realistically within the government's capabilities. Fortunately, a variety of sources are available to meet the demand. Groundwater is generally available throughout the area at depths and quantities suitable for potable, if not irrigation, use. Other possibilities and discussion on this topic are contained in Chapter 6 of this report and in Soil and Water Conservation Report No. 4.

5.1.9 Other Services

While the more populated areas are provided with some social and economic services, beyond those described above, the area is generally quite deficient in this regard. Storage, marketing, credit and other commercial facilities need to be expanded. Also, social services such as schools, clinics and village centers deserve expansion and upgrading. An indication of the quantities of such services available within the various locations can be obtained from Report Nos. 3, 6, and 7. Recommendations for improvements depend in large measure on the government's financial capabilities and the urgency of competing claims on government funds. Some possible programs of expenditures for the area have been suggested in Chapter 7 of this report.

5.2 FUTURE CONDITIONS WITHOUT DEVELOPMENT PROGRAM

Evaluation of possible programs for the area needs to take into account future conditions without any development program. This calls for an evaluation of trends and a projection of key factors in the area's economy. The following sections contain the study team's evaluation of some of the more crucial factors that would affect the study in the absence of a substantive development program. Factors to be discussed are population and land pressure, employment, productivity, range conditions, droughts and famine relief, soil loss and income levels. As noted earlier the following scenario applies most strongly to Kitui-Embu, since a development program is already underway for Machakos District.

5.2.1 Population and Land Pressure

Thom* projects annual population growth at 3 percent. According to his findings, this growth is expected to be fairly uniform across the area. Past growth of 10 percent and above in some locations is believed to be the result of unique post-independence conditions. Even so, a general trend will be to move from the more crowded and more productive areas into the less crowded and less productive areas. Internal migration would consequently be into the eastern and western portions of Ecozone V. Such internal movement will call for an expansion of roads, potable water supply and other services if the present standard of living is to be maintained.

By 1985, the time required to implement a widespread development program, the area's population will have increased to nearly 1.5 million. By 2001 the 1977 population of 1.14 million will have doubled. Note should be taken that this rate of population increase approximates the national average and does not allow for significant immigration. Were this to occur, crowding would become even worse.

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*See Report No. 6

5.2.2 Productivity

Movements to areas of lower rainfall and to poorer soils, as land pressure builds up, will lower unit productivity. Greater pressure on the land will also reduce the amount of shifting cultivation, with the corresponding decrease in yields from overworking the soil, a condition which is already occuring (see Chapter 3). As long as traditional agriculture prevails, farm families will probably be unable to cultivate more than three hectares. At net annual return of shs.200 to Shs.400 per hectare on the poorer soils, families will obviously have to resort more and more to off-farm employment and to livestock. But as population builds up, productivity decreases, and lands available for grazing become more scarce, these solutions to the farmers' plight will become less available. Should such a low income situation become widespread, underemployment will become more severe, emigration from the area would occur, and the rate of population growth would decline.

5.2.3 Range Trends

Decreased land available for grazing and the custom of allowing herd size to build up during years with abundant rainfall and grass cover will accentuate difficulties when the drought years do occur. Such a condition would seem to lead to greater livestock losses and lower prices during poor years, greater need for famine relief, and a speeding up of the rate of soil loss and range deterioration. The effect of land adjudication may save some of the rangelands from this fate. But substantial improvement in range management practices calls for more extension and other assistance than seems to be forthcoming without a major development program.

5.2.4 Erosion Losses from Cropping

Considerable crop farming is presently taking place in the project area on lands with slopes ranging from flat to steep. Two-season cropping, lack of extensive soil conservation measures, and increasing pressure of people on the land combine to make the question of soil erosion of concern to the government. Gully, rill and sheet erosion are serious problems for long-term use of these lands. The general hazard of erosion has already been described in the previous section and problems of gully and rill erosion are discussed in the engineer's report. This section uses the universal soil loss equation to approximate the seriousness of sheet erosion in terms of rate of soil loss, decrease in soil depth, reduction in crop yields and the overall implications on net returns to farmers. The intent of

the calculations is to gain an indication of the economic implications for the area if present largely traditional methods of farming are continued. Included in the results is the level of investment justified to prevent reduction in crop yields due to sheet erosion. As a generalization the farmers are not considered to be practising soil conservation measures to any meaningful extent. While the calculations necessarily require a number of assumptions about specifications, the overall factors used in the analysis are believed to be reasonably representative for the area as a whole. It should be noted that the method estimates yield loss as a function of soil depth only and does not take into account nutrient depletion from the soil remaining.

Methodology: The method for arriving at the economic implication of sheet erosion includes the following factors:

i. soil classification by mapping units
ii. type and extent of land use
iii. elements of the universal soil loss equation, which requires information on rainfall intensity, cropping patterns, soil erodibility percent and length of slope, and erosion control practices
iv. soil depths and bulk densities
v. net returns per hectare as a function of soil depths,
vi. a social rate of time preference (discount rate)

With this information, annual soil losses in tons per hectare are converted to soil losses in centimeters per year. Reductions in soil depths increase soil productivity by diminishing fertility and moisture holding capacity, except where soils are deep and topsoil is abundant. For shallow soils a point will eventually be reached where crops cannot be profitably grown. The effects of reduced yields over time are converted to annual equivalent yields for an infinitely long time. The results for each soil classification (mapping unit) are then compared with current yields to determine the long term productive losses due to sheet erosion.

In keeping with the evaluation guidelines of the Planning Unit in the Ministry of Agriculture, a discount rate of 8 percent was used in converting future production losses to their annual equivalents. The effects of using an interest rate of this size is to give little significance to events beyond fifty years or so. Yet future as well as present generations are the concern of responsible national leaders. Two additional calculations were consequently made to bring the interests of future generations more into account. One of these was to measure the net returns to farmers in the year 2000. Another was to lower the discount rate.

Results: According to the analysis the effects of sheet erosion on equivalent annual net returns to traditional farmers is not significant for the area as a whole. Comparison of values for the present and future levels of production shows a reduction in equivalent annual net returns of only 3 percent. An explanation for this lack of overall impact lies with much of the area (especially Ecozone V) being relatively flat. Many of the steeper slopes are still not being cropped. In making the calculations, land use rates were held constant, traditional technology was assumed throughout and no soil conservation measures were assumed. Modifications to these assumptions to allow for population increases, some intermediate technologies and limited conservation measures are not expected to materially alter the results. Values by ecozones are shown in the table below.

Table 5.1.1 EFFECTS OF EROSION LOSSES ON ANNUAL NET OPERATING RETURNS TO TRADITIONAL FARMERS IN THE MACHAKOS-KITUI-EMBU AREA

Eco-Zone	Cropped Area ha.	Totals for Area at Present Rate of Production Millions of shs/yr	Totals for Area Including Effects of Sheet Erosion Millions of shs/yr	Total Loss in Production Millions of shs/yr	Reduction %
II	4,700	5.01	4.28	0.73	15
III	49,700	63.18	59.81	3.37	5
IV	192,017	191.71	185.68	6.03	3
V	211,710	134.83	132.26	2.57	2
Totals	459,027	394,73*	382.03	12.70	3

* This estimate of the total value of production for the area is used only for the purpose of analyzing the effects of erosion. It does not necessarily represent the actual level of net operating returns for the area.

This table also shows that the long-term losses from erosion for the cropped areas will average shs. 13 million per year. Capitalizing this infinite stream of annual losses at 8 percent produces a present value of shs.160 million as an approximation of a justifiable level of investment in soil conservation measures. This averages out to about shs.350 per hectare of cropped land. This figure needs to be reduced to allow for long-run reoccurring investment costs. On the other hand, increased yields from higher levels of technology would justify higher expenditures. This level of investment is not out of line with estimates of terracing costs as described in Chapter 6.

While the overall percentage reduction in equivalent annual yields is not great, the 15 percent reduction in ecozone II would have important effects on localized areas. In fact, mapping unit MQ2/DF* (slopes ranging from 8 to 50 percent and soil depths between 25 to 50 cm) which comprises 28,500 hectares in ecozones II and III, 10 percent of which is estimated as being cropped, is expected to have a 55 percent reduction in equivalent annual yields. Some other mapping units with significant reductions are: NMr/DG (slopes from 8 to over 50 percent, soil depths 50 to 80 cm and 68,000 has. of which 10 percent is cropped) shows a 77 percent reduction in yield for the portion in ecozone V and 62 percent reduction in ecozone IV. The difference in percentages results from different cropping packages in the two zones. Mapping unit UU3/DE in ecozone V (slopes from 3 to 30 percent, soil depths 25 to 80 cm and 7,700 has. with five percent cropped) has a reduction of 44 percent. UQ1/CD in ecozone V has a 50 percent reduction, but the area affected is small.

The calculations carried out to measure rates of annual net returns in the year 2,000 reductions greater than the above. The overall values are shown below:

Table 5.1.2 EFFECTS OF EROSION LOSSES ON ANNUAL NET RETURNS IN THE YEAR 2000 IN THE MACHAKOS-KITUI-EMBU AREA

Eco-zone	Cropped Area ha.	Totals for Area at Present Rate of PRODUCTION Millions of shs/yr	Totals for Area Including Effects Of Sheet Erosion Millions of shs/yr	Total Loss in Production Millions of shs/yr	Reduction %
II	4,700	5.01	3.63	1.38	28
III	49,700	63.18	56.89	6.29	10
IV	192.917	191.71	180.76	10.95	6
V	211,710	134.83	130.40	4.43	3
Totals	459,027	394.73	371.68	23.05	6

Effects on individual mapping units are also proportionally larger. In the case of mapping units MNr/DG and MQ2/DG, the soils, if continually cropped, would be eroded to the point of being unproductive.

The other evaluation tested was the effect on equivalent annual net returns from lowering the discount rate. As would be expected reductions in the discount rate cause net returns to be reduced even further. A discount rate of 4 percent, for example, more than doubles the annual losses relative to those

*These mapping units can be located on the base soils map

that result when using an interest rate of 8 percent. At 4 percent interest even higher investment in erosion control measures is justified.

In the final analysis, decisions to conserve soils subject to high sheet erosion will probably be taken on the basis of other national considerations as well. These issues include downstream costs of siltation and a general policy of resource conservation. Moreover, the approach that has been described is preliminary in nature and subject to modification as more accurate data becomes available. Nevertheless, the results provide information on the magnitude of the problem in a way that is not provided by the erosion hazard index or by a standard limit to the annual rate of soil losses. The index used by the Kenya Soil Survey provides a basis for comparing the relative, not the absolute, degree of erosion. The standard to limit erosion to 5 tons per acre per year (11.2 metric tons in the United States, is an attempt to provide for a high level of crop productivity for an indefinitely long period.* Whether or not such a standard is appropriate for Kenya is for its policy makers to decide. To the extent that good farm land is in short supply the results of the foregoing analysis confirm the wisdom of the government's concern about erosion in the marginal and semi-arid areas. Programs to conserve the limited water supply that falls on the marginal and semi-arid lands is still another issue, which is taken up in the section on soil and water conservation in the next chapter.

Details of the analysis procedures and results are to be found in Appendix II.

5.2.5 Conclusions

The scenario in which population continues to expand in the face of no significant program of development for the area leads to several conclusions. First, incomes--especially in the more newly settled areas--will become lower. This results from cropping on poorer soils and in lower rainfall areas, as well as from soil loss and degradation due to erosion and overworking of the soil. Second, variances in incomes should increase and the need for famine relief heightened during years of lower than average rainfall. Third, degradation of range and crop land will be accelerated. Fourth, an exodus from the area would eventually take place with families, or more likely family members seeking employment in urban areas.

Consequently, marginal and semi-arid lands such as those in Machakos, Kitui and Embu do not appear to

* Walter H. Wischmeier and Dwight D. Smith. Agricultural Research Service, US Department of Agriculture, "Predicting Rainfall-Erosion Losses East of the Rocky Mountains". Agricultural Handbook No. 282, US Government Printing Office, Washington DC, 1967.

offer a long-range solution to the government unless substantive development programs are provided. In other words, these lands do not offer much in the line of relief from present land pressures without major government intervention. And even with government intervention the results will not be easily attained. An elaboration of this latter point will be made in Chapter 6 when the impacts of intermediate and advanced technologies on the project area are discussed.

5.3 PRODUCTIVE POSITIES

Agricultu livestock production, and to a lesser extent, proces supplemented by timber for fuel and building poles continue to provide the livelihood for most of the pen the two study areas into the foreseeable future. Theresome mineral resources, notably fluorspar in the Baringo Valley study area. They provide work for a very small pion of the populace. Perhaps for this reason mineralrce inventory was not included in the terms of refenf the study team.

There are e number of agricultural and livestock alternatives wre climatologically feasible in the study areas. An in-analysis of all the possibilities, taking into account w, soil, topography, water supply, transport, markets, instis, education, attitudes and beliefs has not been possiven the team's financial and time constraints. With computer simulation and operations research techn now available we suggest that the Ministry of Finance anding through the Development Planning Division in MO the Central Bureau of Statistics with collaboration SS, the Division of Research MOA, and possibly others develop an ongoing semi-arid lands evaluation uni search priorities could be reviewed and field data coln expanded to provide information more directly usefuPD than may otherwise prevail.

Although tudy has now been "completed," the real value will onlealized if the process is continued, refined and ex.

We are usiew representative crop packages to which we have ascribnfall-production relationships which we believe to be tic but are admittedly only educated guesses. Our g and production cost figures are based on a fairly sota base. But data collection in the field requires vement. Too many estimates appear in reports as a fercentage increase over the previous year's figuress type of estimating is inevitable for human populatiures between census years but is often misleading whe to estimate annual crop and livestock production.

Relative Land Ility Classification: The FAO defines land suitabili "the fitness of a given type of land for a defined use. land may be considered in its present condition or aprovements. The process of land suitability classibn is the appraisal and grouping of specific areas d in terms of their suitability for defined uses."*

The determ of the suitability of the lands in the study area for s productive uses is the core of the

*FAO 1976 "A Fk for Land Evaluation." Soils Bulletin 32.

inventorying process. The team has devoted a large proportion of its time to this effort. Land suitability classification can be an extremely complex activity because of the large number of variables. One inevitably makes a series of value judgements of which factors to consider and how to weight them knowing full well that not all factors, nor all interaction effects can be properly considered. This is especially true at the reconnaissance level of this survey. This does not mean that generalizations are too vague to be useful. Rather, the classification process is an attempt to organize the available data with professional opinion such that it can be logically evaluated, objectives for development identified and action programs initiated.

Establishing Criteria: To establish the criteria of land suitability we have focused on five questions:

i. What are the primary objectives of the farmers and the institutions servicing their needs?

ii. What are the alternatives for meeting these objectives?

iii. What resources are, or can be made available? This includes land, water, energy, institutions, markets, know how, farm inputs, including credit, infrastructures, tools, chemicals.

iv. What information can be secured about the resources given the team's time and talent constraints?

v. How to express the suitability?

Farmer and Institution Objectives: We assume that a primary objective of the farmer, insofar as his land is concerned is to maximize its utility. By utility we mean a combination of his expected net return and his risk. A risk adverse farmer may forego a crop that on the average brings a fairly high return but which in low rainfall seasons fails to yield. Thus in ecozone 4 a cowpea crop, yielding during an average precipitation season 300 kg/ha may be preferred over a maize crop yielding under average conditions at 400 kg/ha. When a drought occurs the farmer still expects to harvest some cowpeas.

Institutions, especially government may have additional objectives; earning foreign exchange, creating political stability, etc. We have assumed that maximizing the farmer's utility will materially assist government to reach its objectives too.

The issue of short range vs long range utility is given consideration. Most of us are more interested in a shilling today than the promise of a shilling tomorrow. This time value of returns is indeed a major issue in considering costs and benefits of soil conservation in the semi-arid lands. Because of the discounting rate of the present value of future returns from increased production resulting from soil

conservation works built today, it is often difficult to economically justify the capital investment. And yet future generations cannot be ignored. Just as we are turning to other sources of fuel as the fossil fuels become depleted, perhaps future generations of farmers will rely less and less on soil to grow food. But dare we count on it?

In spite of some difficulty in supporting soil conservation works based on economic theory for all but the shallow soils, few will argue the need to slow the loss of soil in Kenya. One way to deal with this is to lower the discount rate. More on this in section 6.3.1.

One can postulate many other objectives; status, power, prestige, good health, education, peace and harmony. We suggest that at the level of operation possible in semi-arid land agriculture, utility maximization makes a positive contribution to all of these other objectives. It has the added virtue of being quantifiable.

Alternative Activities for Maximizing Utility: Hundreds of combinations of activities are taking place in the study areas. It is neither possible nor necessary to evaluate all these combinations separately. We have therefore (with an eye on Kenya Soil Survey classification system) selected eight alternative land use strategies for development of land suitability criteria. These are:

i. Small-holder rainfed arable mixed farming, traditional technology

ii. Small-holder rainfed arable mixed farming, intermediate technology

iii. Small-holder rainfed arable mixed farming, advanced technology

iv. Large scale farming, advanced technology

v. Small scale irrigated farming, intermediate technology

vi. Large scale irrigated farming, advanced technology

vii. Livestock grazing

viii. Forestry

One might break each of these into small increments, use several combinations of mixed cropping, multiple cropping, pure stands--different ratios of crop to grazing land--factor in for some areas, especially in Baringo, honey production; add poultry, fruit, horticulture components--the possibilities are endless. We have deliberately fixed the farming activities to one specific set of assumptions, for each of the eight categories and computed the economics for the small-holder rainfed alternatives. Since we were unable to identify which of several possible sources of water could

be utilized for large scale irrigation, costs could not be assigned to it.

Suitability Classes: We have rated each soil on its suitability (we prefer the term "relative suitability,") to produce food, fodder and grass. It is important for those reviewing and evaluating the methodology to recognize that although we have classified the soils as Highly Suitable (A), Moderately Suitable (B), Marginally Suitable (C), and Unsuitable (C), our system is not a carbon copy of that currently in use by KSS. The fundamental difference is that our agronomists, forester, livestock and range specialist and economists postulated components of the technologies, involved then said: "Under conditions of average rainfall in each of the three principal ecozones, yields will be about as shown in Table 6 page 168 of the Economics Report. It shows crop yield estimates by soil suitability type by ecozone. By synthesizing all of the data in the Economics Report No.3 we have prepared a series of Model Farm Budgets (Table VI.1 to VI.3, Appendix VI). The reader can get a clear picture of what is meant by intermediate and advanced technology by studying these tables. Table 6 in the Economics report shows the levels of inputs and expected yields by ecozone by soil suitability class. The Model Farm budgets show the crop livestock mixes expected returns and costs upon which the economic analyses have been based. Table VI.4 and VI.5 show how the labour estimates were derived.

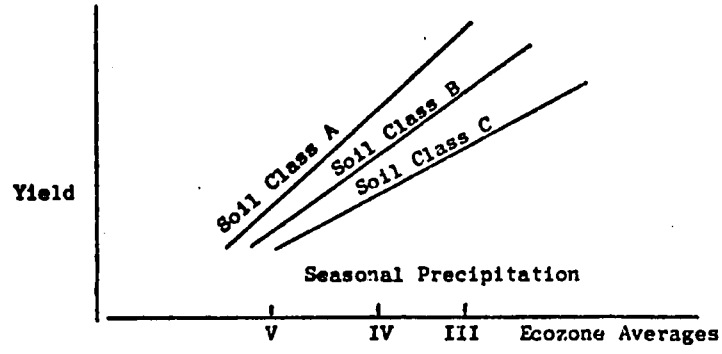
We believe this analytical method is useful but caution that it will require frequent updating to remain relevant.

These production inputs had to be kept in mind as the team worked toward a soil suitability classification. When we say a soil in ecological zone V is highly suitable (class A) we mean that under average conditions (especially average rainfall) with the farmer applying the inputs shown in a timely manner he can expect yields in about the amounts shown. Thus we have attempted to establish what can be thought of as multiple regression relationships where yield is the dependent variable and seasonal rainfall, technology level and soil suitability are the independent variables.

There is a good deal of guess work in establishing these yields. There are not enough emperical data to compute coefficients of determination (R^2 values) so we cannot talk about confidence limits on the figures used.

A factor which may disturb careful reviewers is that class B soils in ecozone III will for some crops overproduce class A soils in ecozone IV. Hence our preference for the term "relative suitability classification." A class A soil in ecozone V will not produce the same crop yield as a class A soil in ecozone IV. Figure 5.3.1 may help the reader visualize how we are using suitability classes relative to ecozone.

Figure 5.3.1 SCHEMATIC OF RELATIONSHIP OF YIELD TO SEASONAL PRECIPITATION FOR ONE TECHNOLOGY LEVEL



We are not arguing for a change in the KSS land classification system. We simply suggest this as one way to organize the data to estimate the farmers' production, net return and finally his utility. In ecozone V yields on class A land traditional and intermediate rainfed small-holder technology are thought to be about the same as that on class B land per the established criteria, with the net result that the A designation was dropped for those technologies in ecozone V.

Criteria for Establishing Suitability Classifications: For the rainfed farming alternatives, the criteria used to classify the mapping units were:

Drainage

Ecological zone

Slope

Soil texture

Soil depth

Stoniness

For the irrigation alternatives, ecological zone was dropped and available water capacity added.

There are, of course, other factors which affect the suitability of land for various uses. Notably absent is the availability of water for irrigation. The classification rates only the soil suitability. There is the presumption that irrigation water can be secured. At the farm planning level, one would want to look at the chemistry of the soil, the transport and marketing situation, slope orientation, labour supply, availability and cost of soil amendments and nutrients and perhaps other factors before making a suitability classification. This being a reconnaissance survey, such detail is neither available nor warranted.

Table 5.3.2 indicates the limits of the criteria in assigning suitabilities for the various uses.

Table 5.3.2 CRITERIA FOR ASSIGNING SOIL SUITABILITY

Farming Type - Small-holder Rainfed Arable Mixed
Technology Level - Traditional

Suit-Ability Class	Drainage	Ecozone 4/	Slope 4/	Texture	Depth	Stoniness or Complex
A	Well	≥ III 1/	≤ B	Sandy Loam to Clay	Deep	Drop one class for gravelly or stoney or complex
B	Moderately	≥ IV 2/	≤ B-C			
C	Poor	≥ V 3/	≤ D	Any	Any	
D	Any	Any				

1/ Only in Ecozones II and III
2/ Only in Ecozones II, III and IV
3/ Only in Ecozones II, III, IV AND V
4/ There is an interaction effect between Ecozone and Slope such that mapping units with C Slopes or steeper in Ecozone IV are not rated higher than C Suitability

Farming Type - Small-holder Rainfed Arable Mixed
Technology Level - Intermediate

A	Well and Moderately Well	≥ IV 1/	≤ C	Sandy Loam to Clay	Deep	Drop one class for gravelly or stony or complex
B	Poor	Any	≤ D			
C	Any	Any	Any	Any	Moderately Deep	
D	Any	Any	Any	Any	Any	

1/ Only in Ecozones II, III and IV

Table 5.3.2 continued

Farming Type - Small-holder Rainfed Arable Mixed
Technology Level - Advanced

Suitability Class	Drainage	Ecozone	Slope	Texture	Depth	Stoniness or Complex
A	Any	Any	≤E	Sandy[1/] Loam to Clay	Deep	Drop one class for gravelly or stony or complex
B	Any	Any	≤F		Moderately Deep	
C	Any	Any	≤G	Any	Shallow	
D	Any	Any	Any	Any	Any	

1/ Soils designated sandy in Ecozone VI, drop one class

Farming Type - Large Scale Rainfed Arable
Technology Level - Advanced

A	Well Moderately Well	Any	≤B	Sandy Loam to Clay	Deep Moderately Deep	Drop two classes for gravelly or stony; one class for complex
B	Any	Any	≤C			
C	Any	Any	≤D	Any	Shallow	
D	Any	Any	Any	Any	Any	

Farming Type - Small-Holder Irrigation [1/]
Technology Level - Intermediate

Suit-Ability Class	Drainage	Slope	Available Water Capacity	Depth	Stoniness or Complex
A	Well and Moderately Well	≤B-C	≥.12	Moderately	Drop one class for gravelly or stony or complex
B	Any except Poor	≤ C	≥.08	Deep	
C	Poor	≤ D	≥.06	Shallow	
D	Any	Any	Any		

1/ Small-holder irrigation contemplates the farmer getting a water supply sufficient for supplemental irrigation from a local source (small surface or subsurface dam, rock catchment, farm pond) rather than from a major irrigation system.

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Table 5.3.2 Continued

Farming Type - Large Scale Supervised Irrigation[1/]
Technology Level - Advanced

Suitability Class	Drainage	Slope[3/]	Available Water Capacity[4/]	Depth	Stoniness or Complex	Contiguity[5/]
A	Poor/well[2/]	C	≥.06	Moderately Deep	Drop one class for gravelly or stony or complex	10,000
B	Excessive	D				5,000
C	Any	E	Any	Shallow		1,500
D	Any	Any	Any	Any		

1/ Large scale supervised irrigation does not necessarily mean large size farms. However, it implies a high level of farm management and timely, controlled (measured) distribution of water from a well managed water distribution system serving a number of farmers in the area.

2/ The only poorly drained soils in the study area occur on A and AB and AC slopes. They are mostly suitable for paddy rice culture.

3/ More severe slopes are permitted for large scale irrigation than for small scale irrigation on the assumption that sprinkle or trickle irrigation technologies can be used on the large scale farms.

4/ Available water capacity requirements for large scale farming are not as severe as for small scale farming, assuming that the higher management capability of the farmer make it possible to replenish the root zone more frequently. Also, the large scale irrigation project will not have to rely so much on storing rainfall in the soil.

5/ Large scale irrigation is in general feasible only where fairly large irrigable tracts are available. To supply water to a number of small scattered farms puts the distribution costs too high per unit of land to make it economically justifiable. The term "contiguity" refers to the minimum hectarage that would be permitted in one block of land. Thus, a mapping unit may in itself have too small a hectarage to qualify for large scale irrigation, but if it is adjacent to (contiguous with) other suitable mapping units, it will qualify.

The hectarages chosen for suitability ought to relate to the cost of bringing and distributing the water. Since these costs are not available, these hectarage constraints should be re-evaluated when water source feasibility studies are carried out.

Suitability of the Soil Units for Production Under Various Technologies: Table VII.1, Appendix VII classifies all of the soil units in the Machakos/Kitui/Embu study area for their suitability for the activities shown, based on the criteria described in the previous section. The classification of the Baringo/Kerio Valley soils will have to await completion of the laboratory analyses since soil salinity may have to be included for some of these soils.

Summary of Steps Used in Land Suitability Classification and Subsequent Analysis

i. Establish levels of suitability for each ecozone, i.e.

Highly Suitable	A
Moderately Suitable	B
Marginally Suitable	C
Unsuitable	D

ii. Decide on climatic and soils criteria for establishing suitability while concurrently carrying out the next step

iii. Decide what technologies to classify the land for

iv. Decide on inputs needed to reach the yield levels considered to be realistic (average conditions) by the agronomists

v. Collect labour, cost and price data and estimate soil conservation costs

vi. Select typical, desirable farming strategies; -crop/livestock mixes appropriate to the ecozone and soil type

vii. Using average yields, farming costs and farm gate prices, build farm budgets for each technology, ecozone and soil type

viii. Break the area down by ecozone and soil type and determine expected net returns for the technologies of interest

ix. If desired the returns can be used to compare with the costs needed to bring about the new technology level

x. For the technologies studied estimate their population carrying capacities

xi. Estimate the risk by constructing a net return - rainfall probability chart to provide returns at several drought probability levels.

The following sections describe in more detail the productive alternatives.

5.3.1 Rainfed Crops Including Dairy Cattle

Description: Substantial opportunities exist in the area for increasing small-holder income and the quality of local diets through the extension of intermediate technology to those localities where it has not penetrated. Certain segments can also move rather quickly into advanced technology. As the terms are used here, intermediate technology involves the use of presently available tools, implements and other inputs. Use of improved varieties of seeds, use of modest levels (below rates recommended on the basis of research results) of chemical fertilizers, moderate use of modern plant protection chemicals, currently available soil and water conservation measures, and mechanical cultivation based on oxen traction constitute the principal features of intermediate technology as applied to cropping activities. In dairying this technology involves the growing of cultivated forages (Bana grass) to support grade dairy cattle obtained by artifical insemination of indigenous cows and rearing the heifers to provide the dairy herd.

Advanced technology is envisioned to include pest resistant, drought escaping and/or drought tolerant crops - including a single season cotton - supported by use of modern inputs at recommended levels. Tillage equipment better suited to dryland farming than the mold board plough is assumed for both land preparation and weeding. Dairying under advanced technology in zones III and IV is based on grade cattle bred-up by several generations of use of artificial insemination. These cattle are also nourished by Bana grass forage but supplemented by purchased and homegrown concentrates. In zone V, Boran or Sahiwal cattle are used, supported on forage sorghums to supplement improved range. The improved nutrition levels and increased size and vigor of the cattle are assumed to be sufficient to allow the cows to become the source of power for land preparation and weeding. Improved harnesses and/or yokes of the sort used with cows in Western Europe (and adapted very successfully to African conditions at the Angar-Guitin project in Ethiopia) are assumed.

Level of Profitability: Projections of per hectare return to farm families utilizing these technologies are presented in table 5.3.3. These projections are based on estimates of yields of crops and forage made by the team's agronomists and range scientists and brought together by way of model farm budgets which can be found in Appendix VI. The estimates are an attempt by these specialists to estimate the interacting influences on soil, precipitation, management practices and inputs for the several soil types and ecological zones. Further judgements on the rates of stocking and offtake were made. Physical quantities were converted to value terms using market prices

where possible (1977 official buying prices were used for cotton, sunflower, cattle and goats). The values of purchased inputs at 1977 prices were deducted. Investment costs were annualized at 8% and deducted leaving a residual to family labour and other farm resources. Estimates of costs, returns, etc. for ecozones II and III (High potential areas) are not as reliable here as those for zones IV and V but were projected on the basis of similar types of subsistence and annual cash crops to facilitate more reasonable comparisons.

Table 5.3.3 ESTIMATED RETURNS PER HECTARE

Ecozone	Soil Suitability	Traditional[i/] Technology	Intermediate[i/] Technology	Advanced[ii/] Technology
II[ii/]	A	NA	1580	2400
	B	1320	NA	2304
	C	670	920	1940
III	A	NA	1320	2050
	B	1100	1270	1920
	C	560	770	1450
IV	A	NA	645	980
	B	560	575	890
	C	380	390	700
V	A	NA	NA	465
	B	250	300	425
	C	200	200	305

i/ Farm sizes assumed were: Zone II - 4 ha; Zone III - 5 ha; Zone IV - 7 ha; and Zone V - 9 ha.

ii/ Estimated at 120% of zone III returns

Table 5.3.3 is displayed graphically as Figure 6.2 in Section 6.2.

The high potential areas were felt to be outside the scope of this study even though small "islands" of such lands occur within the study area. These high potential areas amount, in total to less than 5 percent of the area under study and as the government has programmes for and ample experience in the development of such areas it was felt that the major effort should be concentrated in zones IV and V - the semi-arid areas. In making judgements about the magnitude of benefits to be expected by moving from one technological level to the next, one should be aware that there is substantial upgrading that goes along with the movement. Substantial areas of soils rated unsuitable at the traditional level become marginally suitable (class C) at

the intermediate level, others rated class B at one level become class A at the next and so forth. In no case is a soil rated lower with a higher level of technology.

Analysis of labour requirements for the several on-farm activities was undertaken and an estimate was made of requirements for hired labour to supplement that available within the family. As hired labour is required at nearly the same times on most farms it was valued at an estimated 1977 market rate of Kshs.6/- per day. Detailed labour analysis may be found in Appendix VI.

No estimates were made for large scale mechanized farming. Yields under such a system were felt to be only slightly better than those obtainable under small-scale advanced technology. Land preparation, some on-farm transport and some weeding are the activities for which tractors are usually used in Kenya. Costs for tractor ploughing do not become competitive with the sort of ploughing assumed for small-holder advanced technology except on very large units. Further, most of the area is presently occupied by small-holders and reorganizing to accommodate units of economically viable size for tractor operations would face considerable socio-political difficulties. Large scale units may however, be better able to bear the risks associated with dryland farming than are small-holders. All land units suitable for large scale were rated by the team agronomists to be equally or better suited to small-holder advanced technology.

Areas Covered: Suitability of soils in the area for intermediate technology is shown in Figure 5.3.2 while a similar representation for advanced technology is to be found in figure 5.3.3. These maps should be compared with Figure 5.1.4 showing suitability of the areas under traditional technology. Some striking things about such a comparison are:

i. No area is rated highly suitable (suitability class A) under traditional technology

ii. No area in zone V is rated highly suitable under intermediate technology

iii. Substantial portions of the area rated marginally suitable (class C) under traditional technology are rated moderately suitable (class B) under intermediate technology

iv. A substantial portion of the area is rated highly suitable under advanced technology. This is due in large part to the moisture saving tillage implements, the better suited planting materials and more effective weed control availabe under the higher technology

v. No area is rated higher under intermediate technology than under advanced technology.

ANALYSIS AND PROJECT IDENTIFICATION Report No. 1

KENYA
MARGINAL/SEMI-ARID LANDS
PRE-INVESTMENT INVENTORY

Prepared for

The Government of Kenya

by

The Consortium for International Development

(a USAID Contractor)

The United States Soil Conservation Service (USDA)

Staff of the Ministries of Agriculture, Water Development

and Natural Resources

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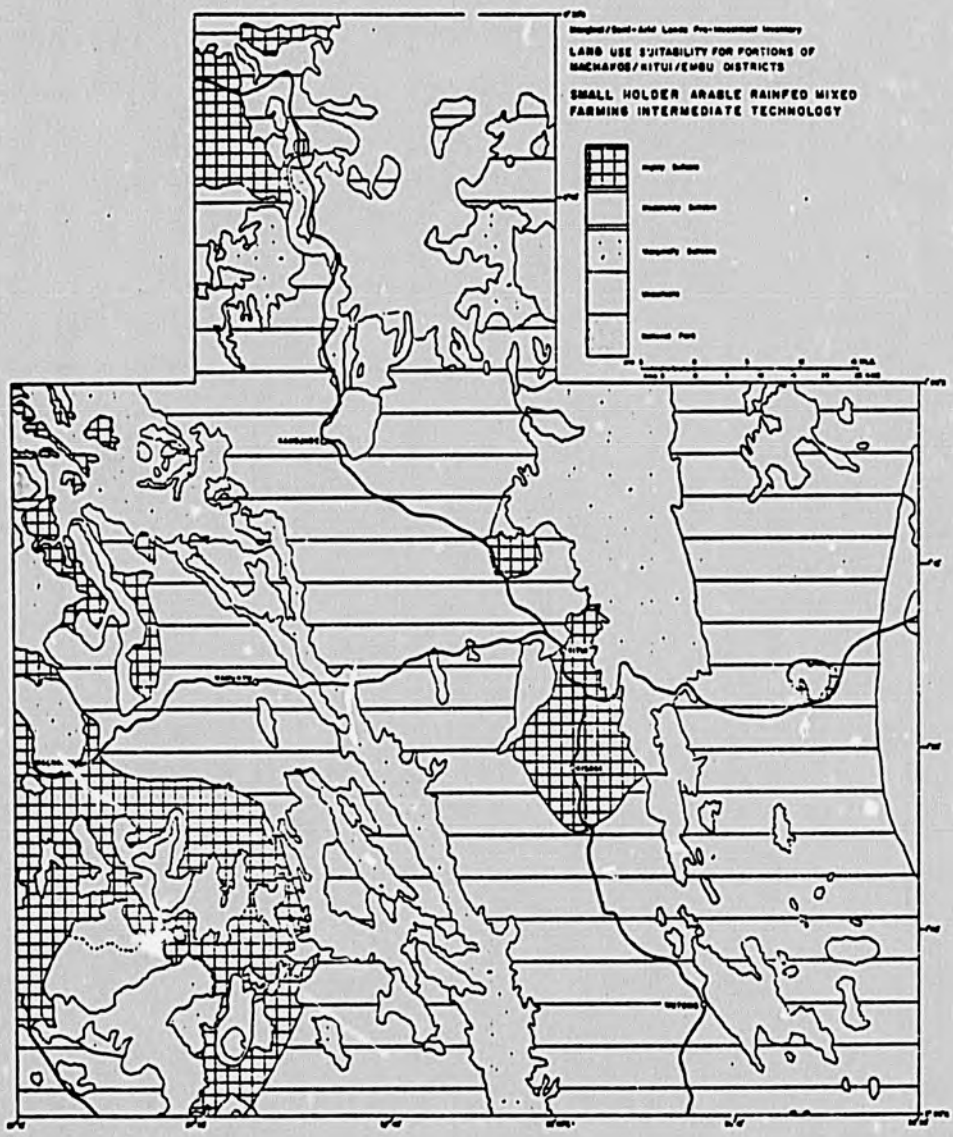

Figure 5.3.2

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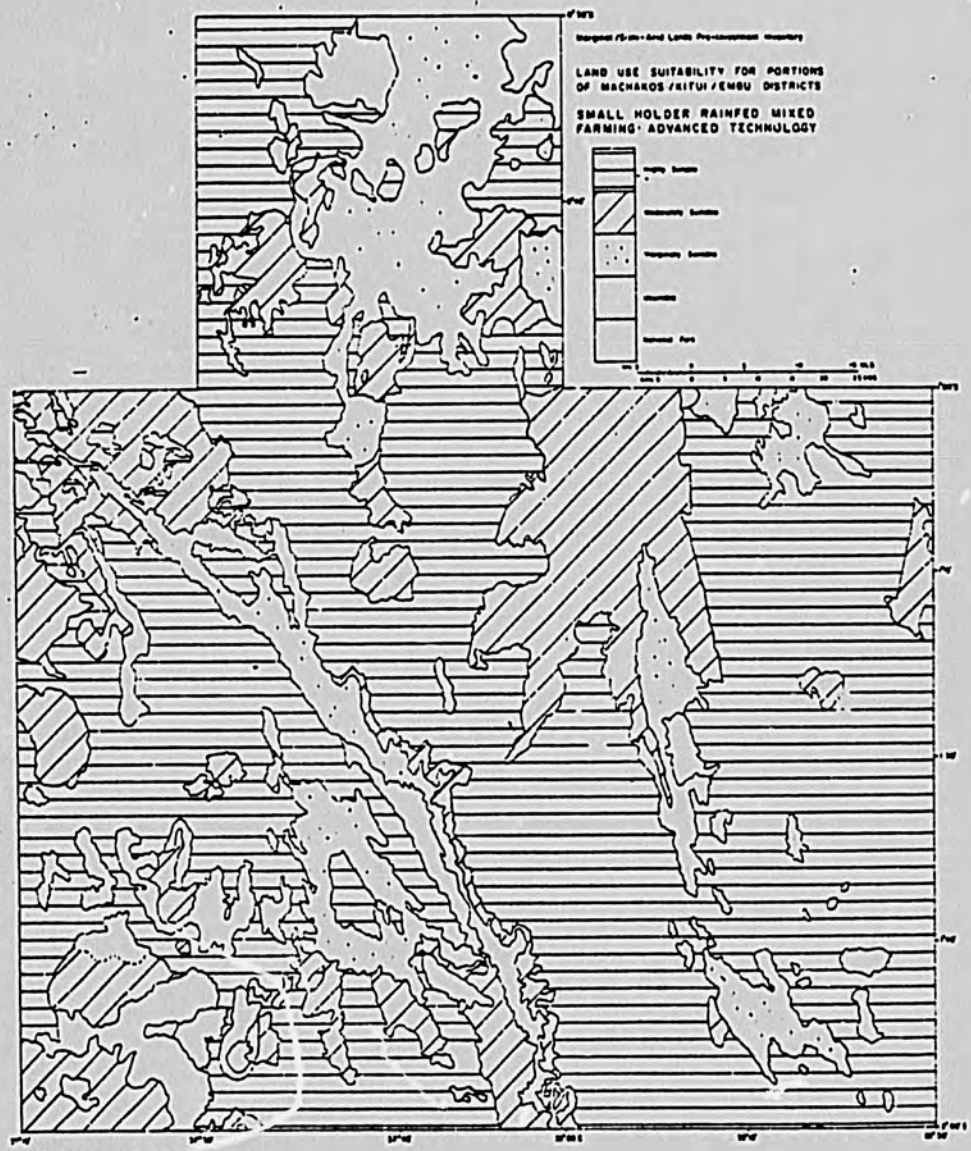

Figure 5.3.3

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Project Possibilities: The cropping-dairy packages discussed above are dependent upon the expansion of some services currently available in the higher potential areas into the semi-arid areas plus the creation of some new services or institutions. As has been indicated, advanced technology will require more of the new services than will intermediate technology. Intermediate technology is perceived as a stage of rural development logically taking place in an area where farmers gain sufficient experience with and confidence in modern inputs and management practices to allow them to move into advanced technology. While the quantum leap from traditional to advanced methods is possible, successful examples are not abundant and where attempted have required an extremely high input of technically trained personnel. Required numbers of such personnel are likely not available. The projections discussed earlier assume development in the semi-arid areas going through the intermediate technology stage enroute to advanced technology.

The cropping and dairy packages for intermediate and advanced technology require at least four direct support activities: extension, input supply, credit and marketing. The present levels of services of this sort in the area have been discussed in the several subject matter reports and indications are that substantial expansion of such services is needed to support the movement to higher technological levels.

A higher density of extension personnel with training in dryland farming methods is needed. Extension assistance should also be made available in soil conservation, forestry, animal husbandry and range management practices suited to the localities in which the operate. Farm development should be tailored to the needs of the farm as a unit as an integral part of the local and regional land use system. Necessary inputs (such as seed, fertilizer, pesticides and artificial insemination services) must be reliably available on a timely basis and at prices low-enough to encourage farmers to accept the risks associated with their use. Every effort should be made to reduce these risks.

Cooperative Societies seem to be the approved vehicle for input delivery but have not been an unqualified success. Areas of difficulty have been lack of sufficient qualified personnel to ensure timely availability of inputs and enforce collection of small-holder crop loans. (See Agricultural Economics Report No. 3). Since many traditional farmers are unlikely to have the necessary cash to purchase modern inputs, a credit programme along the lines of those in use in neighbouring areas is necessary. Intermediate and long term financing for on-farm investments can likely be furnished through existing agencies once land is adjudicated and land-title security can be furnished. If adjudication cannot be accelerated, an interim lending security mechanism should be created.

Facilities for the propagation, processing and distribution of seeds for the semi-arid areas are sorely needed. A proposal for such facilities is contained in the report of the seed scientist. (No.9)

Farmers are unlikely to adapt output increasing innovations in the absence of reliable outlets at attractive prices for production in excess of family needs. Reliability of the outlet involves a high probability (approaching 1!) of the farmers being able to obtain the anticipated price for his produce when it is convenient for him to deliver it to the outlet. If post-harvest prices are consistently depressed, opportunities will exist for profitable storage on the farm. Storage in the study area is currently far from satisfactory and losses to insects and rodents are high. Special problems exist in some years in getting the short rains harvest dry enough to store before the onset of the long rains. Projects aimed at overcoming these difficulties should be undertaken as part of the regional development programme.

The above direct activities in themselves require certain support services and activities as well. Extension can hardly be effective on a continuing basis without a foundation of research and an effective in-service training programme for extension officers. This is doubly true when moving to advanced technology where continual problem oriented research is necessary to avoid the vulnerability to pests and diseases that is inherent in the use of many high yielding varieties and hybrids as pointed out in the reports of the agronomists and the seed scientists. Timely delivery of inputs, access to local market outlets; and links with the national marketing system depend on all weather roads. Some indications of the location and extent of needed roads are set forth in Section 6.3.3 of this report.

Large Scale Rainfed Farming: Implies cropping rather than mixed cropping-ranching and on a scale such that modern mechanized farm implements can be used. The economists have commented (Economics Report No.3) that for the foreseeable future large scale rainfed farming will likely not bring in a higher average return than small-holder rainfed farming at an advanced technology level. The one foreseen advantage would be decreased risk. We have therefore omitted this alternative from our analysis except to estimate relative soil suitability, Table 6.1.1 and VII.1, and Figure 5.3.4.

Selection of Farm Sizes: Table 20, Farm Size, in our Report No. 6 "Human Resources and Social Characteristics" lists the average farm size as 5.2 ha. Interpolation of Table 20 data puts the median farm size at about 3.2 ha. The reason for the difference between the average and the median is that the farm size data is not normally distributed. No farm is less than 0 size but there is no upper limit. Hence the skewness in the distribution of the data.

In order to keep the computational work load manageable we have limited the size of farm analyzed to a few average hectarages. Table 5.3.4 shows the sizes upon which all computations are based. For ease of comparison, sizes have remained the same for each technology package.

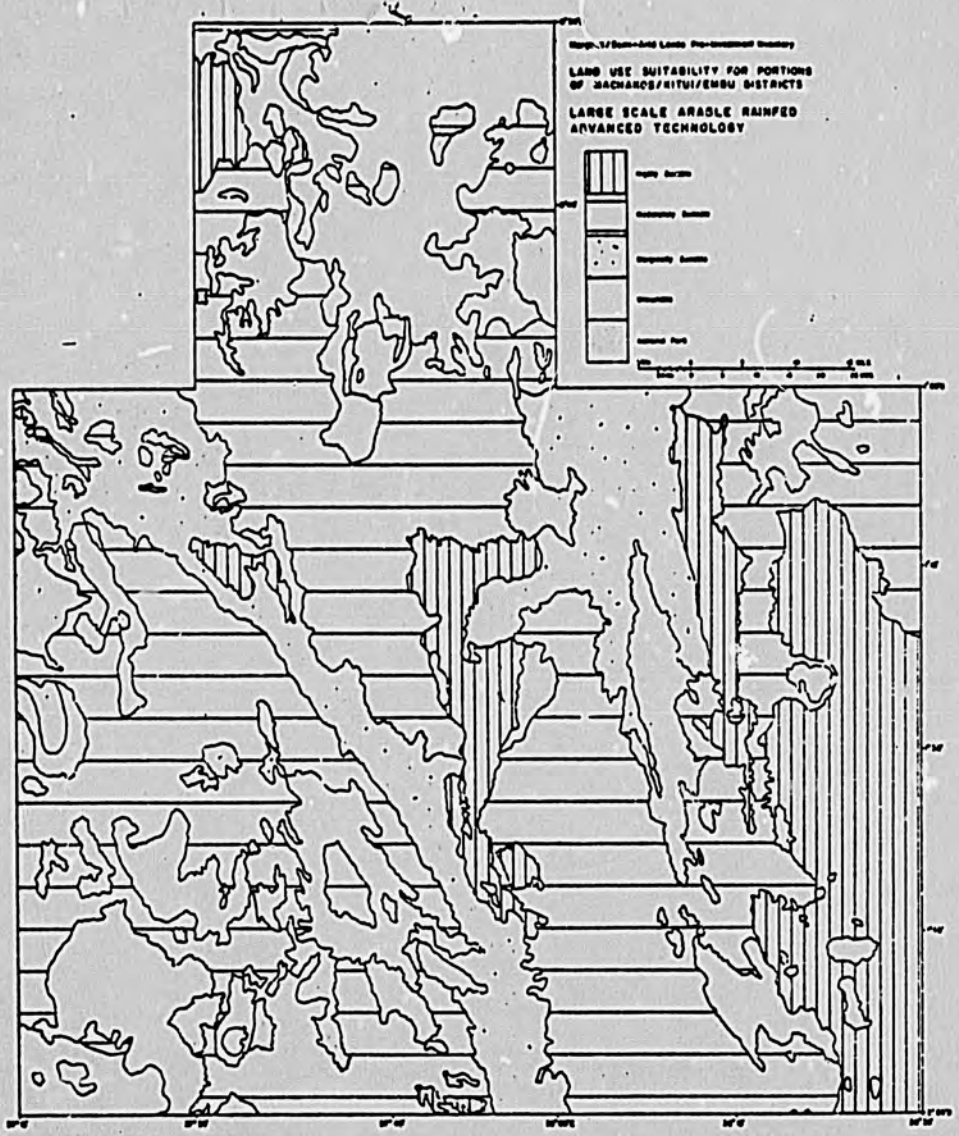

Figure 5.3.4

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Table 6.3.4 FARM SIZE ASSUMPTIONS

Ecozone	Crop ha	AREA IN HECTARES PER FARM Bana Grass	Improved Range	Total Size/ha
III	3	1	1	5
IV	3	2	2	7
V	3	0	6	9

Obviously not many farms will exactly fit these assumptions. However with an eye to using economically viable farm packages we believe these sizes to be reasonable averages upon which to base analyses.

We have tried to make the computations sufficiently clear so that anyone wishing to change any of the assumptions can work logically through to a new set of conclusions.

Constraints on Farming Components: Few farmers opt for monoculture. The reasons are several. Agronomically monoculture without crop rotation results in soil nutrient depletion and an increase in disease and pest problems. Although there is a high correlation between crop yields and rainfall, not all crops can use equally efficiently the same amount of stored soil moisture at the same time, especially if planting dates are not uniform. A mix of crops is therefore a risk minimizing strategy. (Statistically, the correlation coefficient between crop yields is significantly less than +1). Although, as noted in the economic analyses, one crop will yield the highest return, the selection of one crop is constrained by the above considerations plus others: markets, taste and nutritional preferences. We took a look at the use of linear programming to select efficient crop mixes but decided that the short time available for doing the analysis and computer programming precluded this refinement.

Tables VI.1, VI.2 and VI.3 in Appendix VI describe the crop-livestock mixes upon which the calculations are based. Note that these do not include soil conservation works. For Machakos/Kitui Embu a map has been prepared (Figure 6.3.1) which shows the areas recommended for soil conservation works. See Section 6.3.2 for details of cost estimates.

There is a question whether or not to include the cost of soil conservation works in the calculations used to estimate net returns for the various land use alternatives. If this were to be fully subsidized, from the point of view of the farmers, these costs could be ignored. However since we suppose that these documents will be used for area-wide decision purposes, it seems more reasonable to include their costs.

In general, the farming enterprises studied are made up of combinations of maize, beans, sorghum, cowpeas, sunflower and cotton with dairy and livestock in accordance with the arguments advanced in the Agronomy and Economics reports and displayed in

Tables VI.1 through VI.4 in Appendix VI.

5.3.2 Irrigation Suita

In spite of the difficulties of developing irrigation as outlined in Section 1.5 of the Soil and Water Conservation Report, the question of e panding irrigated agriculturein the study area will und tedly receive careful attention in the future.

Irrigated agriculture can mean anything from diverting a small stream to water a few fruit trees to carrying water from a well to keep some potted plants alive to large complicated systems serving thousands of farmers. We have provided some soil suitability guide lines for two levels; small holder irrigation, and large scale irrigation.

Small holder irrigation means a small group of farmers getting water from a subsurface or surface dam or rock catchment, or a small river diversion. They would not likely have enough capital to reshape their land mechanically althought they might do some hand terracing. Delivery would be by gravity and water would be spread by furrows, ponding or flooding. They would not have the time or know-how to carefully control the amount and timing of water applied.

In a large scale system it is assumed that modern equipment, ample credit, trained system operators and knowledgeable farmers are available, that attractive gate prices are offered to the farmers and that water is available in sufficient quality and quantity to meet the demand.

Irrigated land suitability classifications are based on the above assumptions.

It will be noted that for land classification purposes large scale irrigation is less demanding of the soil to produce a good crop than is the small scale operation. The small scale farmer is more constrained on the slopes he can irrigate. He needs a deeper soil or at least one with a better moisture retention capacity than does the large scale operation where irrigation amounts applied and intervals can be more carefully controlled. Thus except for the best, flatvest soils the small scale farmer will find his soil classed in a lower grade than if it were to be used in a large scale scheme.

This is not to say that a small farm cannot be operated at a high level of technology. There is the presumption that if there is to be large scale irrigation in the project area, those responsible for its development, will, because of the high capital costs, include an effective on-farm management training program. On the other hand, small scale irrigation is likely to develop in a less spectacular manner, with fewer capital and management resources available to the farmer at least in the early stages. The small scale farmers who become good efficient managers could reclassify their land to correspond with its classification as shown under

large scale irrigated farming.

Classification Factors to Consider: Successful irrigated farming requires appropriate consideration of a number of factors. One way to classify them is in accordance with their relationship to the soil. Some factors are highly related to the soil-depth, water holding capacity, permeability, sodium content. Some are somewhat related - rainfall intensity, slope, water quality, some are not related - management know-how, pricing structure, government policies, i.e. land adjudication, water law.

None of the soils in the M/K/E study area are known to have adverse concentration of sodic ions. Infiltration rates are highly variable and at the scale we are using cannot be factored into the suitability classification. Table 5.3.2 shows the factors and weighting used to determine both small and large scale irrigation suitability.

Water Sources and Strategies for Irrigation:

Small Scale: In small scale irrigation a single farmer, or preferably a small neighbouring group of farmers get their water from limited, local sources; - small earth or masonry dams, bore holes, springs, rivers. Water harvested from rock outcrops or even from roof catchments or plastic sheeting as described in the section on rural water supplies can be used to irrigate small garden plots.

Small scale irrigation strategies used will depend on the location and amount of water available. Suppose for example that a bore hole for domestic water is drilled but instead of yielding at the average rate for the area of 42 l/min it tests at say 500 l/min. If it is in a fairly low population density area it may have a surplus capacity of 450 l/min. This is enough water to supply an extra 30 cm of water to up to 90 ha. of land over a four week period if pumped at 12 hours per day. This high a well yield is not likely but is mentioned to illustrate the potential interrelationship between the development of water supplies for domestic and agricultural uses. It also points out the need to maintain flexibility in establishing strategies for developing water supplies for irrigation. As discussed under the rural water supply section, the average well in the area may be expected to produce 42 l/min. That means half the wells will produce more. Twenty-five percent are yielding over 106/l/min. However bore holes for irrigation are not expected to provide the major source. Taylor's estimate of about 8 percent of the bore holes being used for irrigation may be representative of what to expect in the future (Soil and Water Conservation Report No. 4 Appendix 4)

Streams and Rivers for Irrigation:

Reliance on undammed streams for irrigation water is risky and technologically fairly complex. With all

the streams in the study area flowing only intermittantly it would often happen that just when the farmer is in most need of the water is when the stream dries up.

Another difficulty will be maintaining head works on streams that have wide seasonal flow fluctuations. These structures require careful, expensive design to avoid destruction and are subject to silting up. River turnouts then, should be confined to a few on the Athi and perhaps on the Ikoo and Thua Rivers, if storage sites can be located such that water could be turned out further down stream. However, this type of operation can better be considered under large scale irrigation development.

Small Surface Reservoirs:

This is undoubtedly the most promising alternative for small scale irrigation. We have referred elsewhere to the difficulties of developing surface reservoirs sites; - design, siting, construction, disease, wash out, silting up, capital and maintenance costs. For a community reservoir there is the additional problem of organization such that the users receive an equitable share of the water and participate appropriately in the operation and maintenance costs.

Nevertheless, as Figure 6.1 so dramatically illustrates, rainfed agriculture especially in ecozone V is a risky operation, even under advanced technology. The prospect of tripling, and quadrupling yields under irrigation (See Table 6 in the Economics Report No.3 Appendix II) is a strong reason for investing heavily in irrigation infrastructure.

Reservoir sites need to be identified. They will bring the greatest return in the drier parts of the study area. Since runoff is less in ecozone V than in IV or III, silting should not be as severe. As a first step to their siting, a good new set of aerial photographs needs to be secured for the entire area. More on this in the Implementation Chapter 7.

Criteria for site selection should be developed with input from MOA, MOWD, DDC's and whoever is selected to identify suitable sites. This criteria will no doubt include but not necessarily be limited to:

i. Ecozone
ii. Soil Suitability
iii. Topography
iv. Availability of suitable soil for dam construction
v. Local farmer interest
vi. Access to markets
vii. Access to other inputs
    (a) Extentsion service advice
    (b) Credit
    (c) Agricultural chemical (recalling that projected high yields are contingent on using recommended fertilizer, pest and weed control practices).

viii. Hydrological information on the drainage area.

Water Harvesting:

Whereas the construction of small earth and masonry dams requires a considerable degree of "customizing" to fit the conditions of each catchment area and dam site, individual farm installed water harvesting systems should be fairly standard with a limited number of collection and storage alternatives. (See Section 6.3.1 for details on individual farm water harvesting). Although there will be few opportunities to collect sufficient rain water on a farm to irrigate several hectares, the maintenance of a small garden plot and a few fruit and nut trees from water harvesting is certainly feasible and desirable. As mentioned in the section on rural water supply, the major obstacle appears to be to find a cheap storage tank. We suggest that a research contract be given to an appropriate entity to develop one. Emphasis should be on local materials in-so-far as possible. Blocks made of soil cement formed into a sunken tank lined with plastic or butyl, roofed over with a plastic covered pole truss structure would, we believe offer a starting point for research.

Springs:

There are several springs located in the escarpment on the west side of the Kerio Valley as well as on the east of the Baringo Valley. There is probably no easier, cheaper, safer water than these springs. It is likely that they are all being used for domestic and livestock purposes. It is equally likely that they can be used more efficiently by installing collection boxes, furrows, and where appropriate storage tanks and reservoirs. (See the Appendix 4 on ground water in the Soil and Water Conservation Report No.4 for more details).

Wells:

Wells to most farm families mean shallow pits dug in the bed of dry streams or in the sand upstream from subsurface dams. We are not aware of these being used as sources for irrigation water. However, a careful investigation along the edges of dry river beds would undoubtedly turn up people carrying water from these sources to irrigate small gardens.

In contrast to springs coming from the sides of escarpments where water can be lead by gravity to irrigate plots at lower elevations, wells dug in stream beds are not usually above the field to be irrigated. Where a stream bed is not too far below the surrounding ground elevation it may be possible to irrigate small gardens by laying plastic pipe from a shallow well or a piped outlet through a subsurface dam and leading the pipe line away from the river bed by laying it on a shallower gradient than the river bed. This alternative would not be satisfactory in areas where there is a likelihood of theft of the pipe.

Amount of Land Suitable for Irrigation:

From the tabulations of Table 6.1.1 land suitability for irrigation in the Machakos/Kitui/Embu study area is as follows (displayed also in Figures 5.3.5 and 5.3.6)

Land Suitability Class	Small Holder %	Large Scale %	
A	45	52	Highly suitable
B	17	20	Moderately suitable
C	10	5	Marginally suitable
D	28	23	Unsuitable

Thus over a million hectares have soils suitable for irrigation in the M/K/E study area. (A and B suitablity classes).

To provide some idea of the returns potential of irrigated agriculture, average bean yields in ecozone V under advanced technology, rainfed are exptected to be about 550 kg/ha. Under irrigation they would be 2500 kg/ha. At the current price of Shs.2.03 per kg. a farmer could afford to spend up to Sh.3950 per ha per season for irrigation and get the same return while avoiding most of the risk. Many farmers with irrigated water supplies would opt for growing even higher valued crops. But using the example of beans; assume seasonal water requirement of 700 mm. Nine years out of ten, in ecozone V the farmer can count on at least 110 mm of precipitation so he needs about 600 mm of water from storage. To irrigate 5 ha he would require a reservoir of about 50,000 m^3 to allow 40% losses due to evaporation and seepage. Reservoir costs from Figure 5.3.1 would be about Sh.30,000 if built with hand labour. Add another Sh.20,000 for fencing and plastic pipe. If the reservoir covers, say 2 ha. he would lose about Shs.2000 in production from the area. Amortize the construction costs at 10% per year. His annual capital costs and loss of revenue because of the reservoir equal Sh.7000 for a cost per hectare of his irrigation system of Sh.1400 putting him something like Sh.12,000 ahead every year on his 5 ha.

Irrigated agriculture is hard work. In North America we say that it takes a generation to turn a dryland farmer into an irrigation farmer.

How much might be irrigated by small storage dams:

Using the TAMS estimate of 40 mm per year runoff rate in Ecozone V or 20 mm per growing season, only about 2% of the land could be irrigated. This is about 36 thousand hectares for a two season program. This is probably on the conservative side since water draining lands outside the project area passes through it.

The spectacular projected yield increases, not to mention the drop in risk highlights the need to vigorously

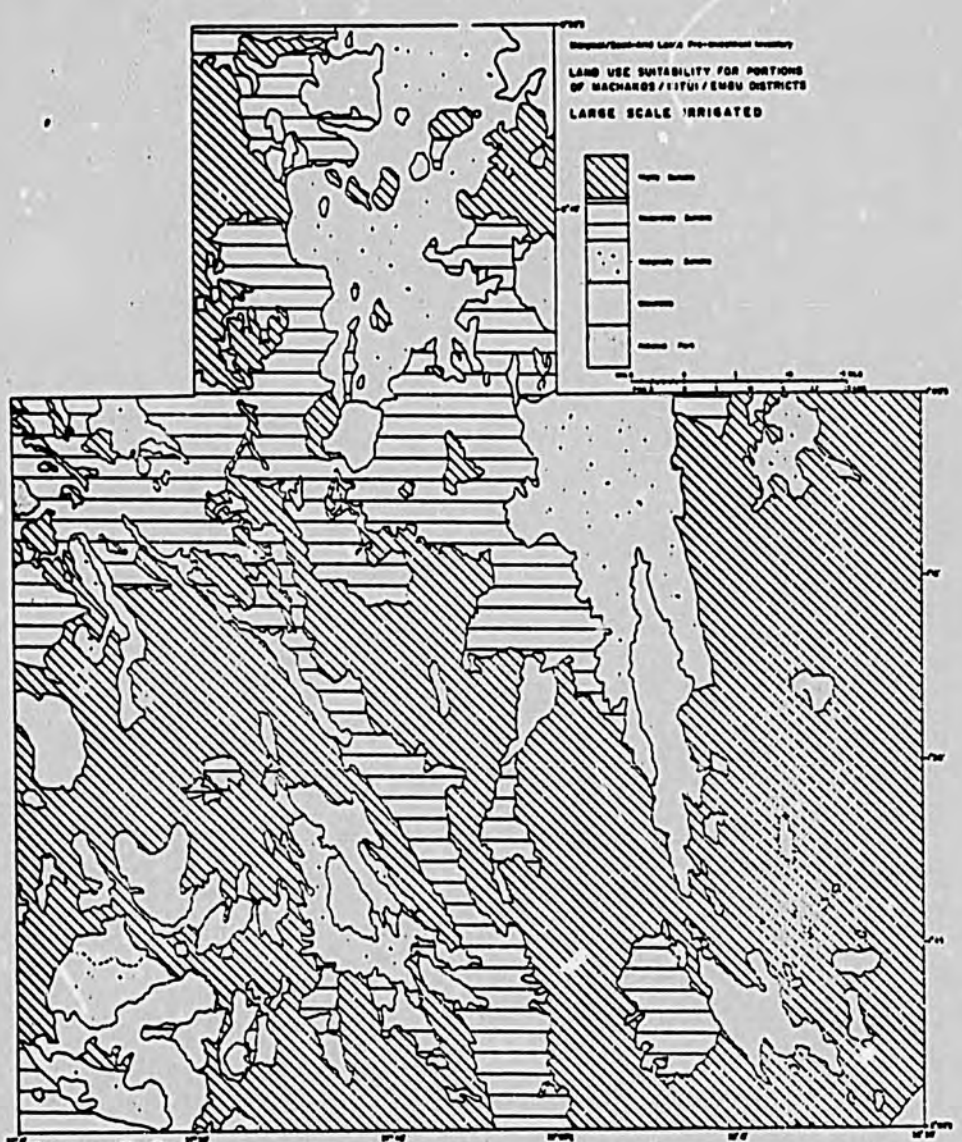
LAND USE SUITABILITY FOR PORTIONS
OF MACHAKOS / KITUI / EMBU DISTRICTS
LARGE SCALE IRRIGATED

Figure 5.3.5

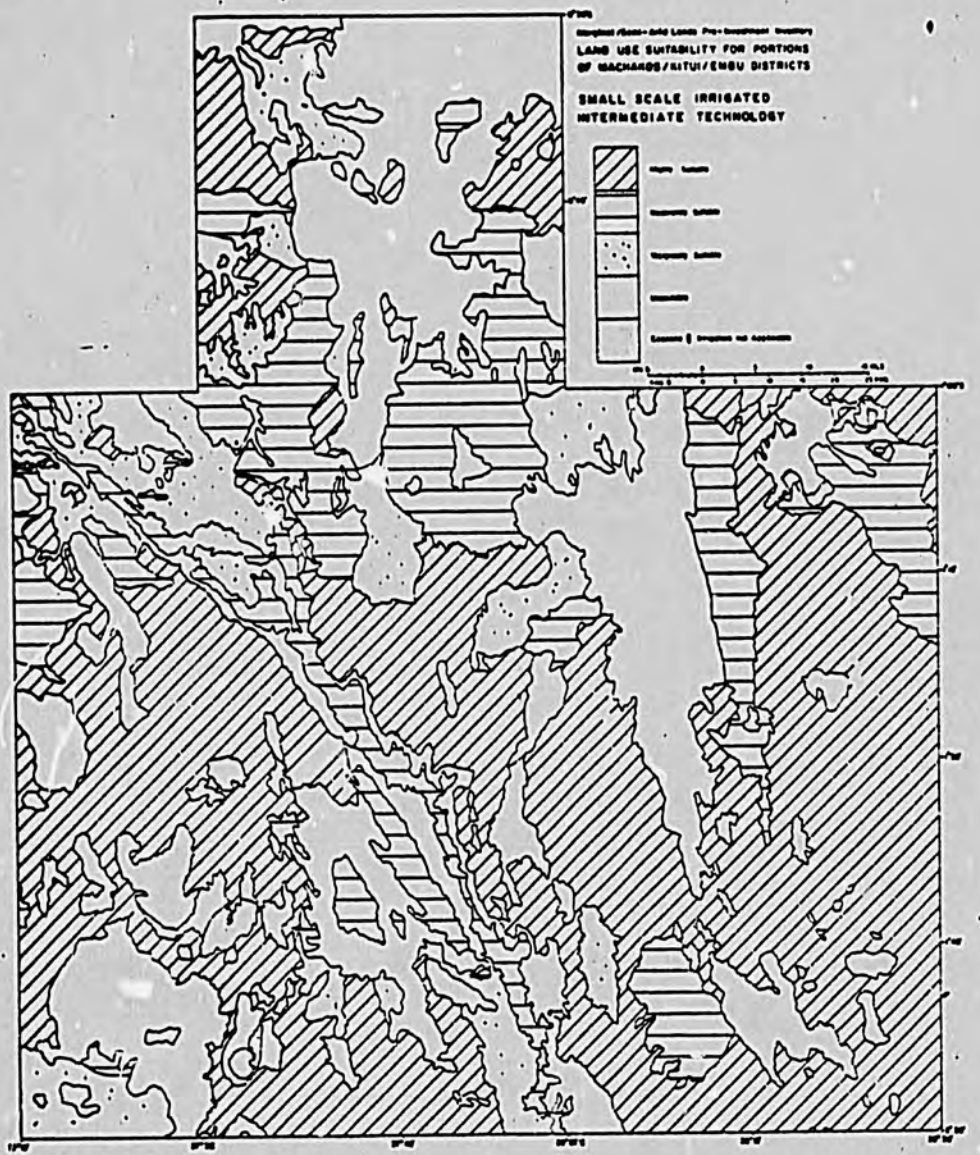
LAND USE SUITABILITY FOR PORTIONS
OF MACHAKOS/KITUI/EMBU DISTRICTS
SMALL SCALE IRRIGATED
INTERMEDIATE TECHNOLOGY

Figure 5.3.6

promote irrigated agriculture especially in ecozone V.

Large Scale Irrigation:

This term refers to an irrigation system supplying a number of farmers from a canal or pipeline distribution network. Water is usually supplied from a single or small number of supply sources, often by damming a river at a suitable point to create a storage reservoir. The operation of the system is centralized and under the supervision of a project manager who reports to a governing body - either a department of government or a water users association board of directors. Rules for water delivery are established such that everyone gets an agreed on portion of the available water. Water is delivered on a demand basis - whenever the user asks for it (usually on one day's prior notice) or on rotation (by turns).

This is a high technology operation and subject to many opportunities for failure some of which include

Reservoir silting
Headworks of river diversions silting
Insufficient storage during dry years
Inadequate maintenance of the storage and distribution works
Disputes over amounts of water delivered
Poor water quality
Poor soil
Lack of training of system operators and farmers
Insufficient capital

As reported in the irrigation section of the Soil and Water Conservation Report, most of the irrigation systems in Kenya are having operating difficulties. This is not to suggest that large scale systems do not have a place in Kenya. The need to settle the lands in ecozone V dictates an irrigation strategy. We think the Athi, Ikoo and Thua rivers have irrigation potential and should be thoroughly investigated hydrologically and reservoir sites sought as recommended in the Machakos EEC program for the Athi. With one and a quarter million acres of irrigable land in the M/K/E study area, every drop of water can be profitably used. Without the hydrology of these streams it is difficult to estimate hectarage potentials. From Table 2 Appendix 1 of the Soil and Water Conservation Report we can infer an annual average flow in the Athi River of 4.3×10^9 cubic meters. If one-half of that could be stored and used for irrigation, using one cubic meter of water per square meter of land about 200,000 ha could be irrigated; hence the interest in the Athi River.

The combination of year round good weather, relatively good quality soils, flat topography, fairly good siting to supply export markets through Mombasa and by air from Nairobi makes the potential for production of exotic crops -fruits, vegetables, flowers etc. under high technology, large scale irrigation interesting. We

have not gone into the economics of this because we do not have a sound basis for estimating the water supply. But we strongly encourage more stream gauging and special attention by the National Irrigation Board and MOA to Eastern Kitui and indeed all the irrigable lands of the study area.

5.3.3 Ranching

(i) Description:

Range Scientists who have visited the study area are consistently enthusiastic (Livestock and Range Management Report No.8) about the potential of the area to support increased livestock production. At present, however, the area has generally been badly overgrazed for many years and large areas are facing, if not actually experiencing, serious erosion which threatens the long term productivity of the land resources.

To halt the erosion and bring the land to its range production potential a well supported programme of grassland revegetation is needed. Properly executed, such a programme could raise the productivity of the range areas by a factor of from five to ten while giving additional benefits in soil and water conservation, reduced siltation, etc.

The range renovation package involves a combination of extension effort and incentives to encourage farmers/ranchers to undertake the programme. Key elements of the non-farm part are grazing deferral with some reseeding of badly damaged areas following burning. In order to generate enough fuel to carry the fire, areas to be reseeded must be left ungrazed through one rainy season. Necessary fire breaks can be constructed during the following dry season with burning taking place just before the onset of the rains. Suitable grass seed (Cenchrus ciliarus, for example) would be broadcast in the ash. The seeded areas would be allowed to go ungrazed for two more rainy seasons with slight use the third season after planting. As farmers/ranchers would likely be unable to keep all their herd out of grazing it is envisioned that renovation would take place on only 1/5 or ¼ of the total area in this first stage.

When the first block of renovated range is ready for grazing sufficient seed to renovate the next block can be collected and the same process repeated until the entire area has been renovated. In the meantime, the first renovation block (only 1/5 to ¼ of the grazeable area) will likely be producing sufficient forage to support as much livestock as could have been supported on the whole area before any renovation.

The difficult part of the renovation programme is likely to be that of convincing the farmer/rancher to withold the renovation area entirely from grazing for the two years necessary to bring about the natural recovery and/or stand establishment whichever is appropriate. A combination of positive and negative motivators is needed. Making the extension of veterinary services, supervised dips, artificial insemination etc. into an area contigent upon range renovation might provide part of the necessary incentive. Some of the present suplus of maize in the country could be used in a food

for work programme to encourage farmers to undertake the fence-fire break construction. The food could also compensate for the sacrifice of the income from the areas held out of production. A vigorous programme of purchasing surplus livestock - even at highly subsidized prices might be included. A deferred exchange programme might be instituted allowing the farmer to surrender cattle to-day in return for the right to receive a lesser number purchase of better quality (say grade dairy or Boran or Sahiwal) animals later, once a suitable portion of his range has been renovated. A programme for extension of cooperative savings societies to the ranching areas to provide an attractive readily available earning asset in lieu of livestock liquidated to allow renovation should also be included.

ii. Location:

Areas to be renovated include the extensive ranching areas of southern Machakos and eastern Kitui plus small inclusions of lands unsuited to crop agriculture within the mixed farming areas many of which are not discernable at the scale of mapping used in the soil survey. Figure 5.1.5 shows the current productivity rating and projected potentials for the range in the study area.

iii. Levels of profitability:

On lands that are suitable for crop agriculture range livestock is not likely to be competitive in the long run. There are areas however, which due to soil and climatic characteristic and topography are not suited to crop agriculture but which are and continue to be utilized as grazing areas for livestock. Many of these areas are in such a run down condition that their productivity is only a fraction of the productive potential under good range management.

Estimates of the gross returns, costs, and net return to farm families for livestock activities under three technological levels is presented in table 5.3.5. (It is felt that the situation at present in the area is well represented by traditional technology with the exception of a few of the intensively managed ranching operation on the western edge of the area and in Yatta B2).

As all the areas not under intensive cropping are felt to have high forage production potential (see report of range scientists) and after renovation could move into a higher livestock technology some areas of zones III and IV might be available for range livestock use (indigenous zebu cattle and goats on the renovated ranges) during the intermediate technology phase but are projected to be integrated into dairy operations at the advanced stage. In zone V the advanced stage presumes a multipurpose cattle operation based on improved breeds of livestock (Boran or Sahiwal cattle, Gala Goats, Dorper or Persian Blackhead sheep, etc.) on the ranges renovated in the intermediate stage. The returns presented are based on only cattle and goats as sheep tend to compete directly with cattle for forage while goats are

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TABLE: 5.3.5 SUMMARY OF COSTS i/ AND RETURNS. RANGE LIVESTOCK (KSHS. per Ha/Year)

	Zone III			Zone IV			Zone V		
	High	Mode-rate	Low	High	Mode-rate	Low	High	Mode-rate	Low
Traditional Technology									
Gross Revenue	NA	101	49	NA	49	37	NA	10	7
Operating Costs		16	7		7	5		1	1
Net operating		85	42		42	32		9	6
Investment costs									
Livestock(at 8% perpetual)		31	15		15	11		3	2
Net return		54	27		27	21		6	4
Intermediate Technology									
Gross Returns	431	NA	NA	233	NA	NA	78	NA	NA
Operating costs	109			60			20		
Net Operating	322			173			58		
Investment costs at 8%									
Livestock	100			54			18		
Range Renovation	8			8			8		
Total annualized Investment	108			62			26		
Net return	214			111			32		
Advanced Technology (Multipurpose breeds)									
Gross Revenue	See Dairy		See Dairy				516	NA	
Operating costs (includes 2 Ha forage sorghum per LS i)							240		
Net operating							276		
Investment costs at 8%									
Livestock							53		
Range renovation							8		
Total Annualized Investment costs							61		
Net returns							215		

i/ See Economics Report for details supporting these estimates.

complimentary to a certain extent on bush land as they utilize the browse and thus allow the grass to better compete with the bush. Cattle were felt preferable as values of meat off-take are about the same but cattle supply for ploughing and some milk produced in the zone V livestock activities will be consumed on the farm or sold locally and no special equipment is required.

iv. Project possibilities:

The principal component of the ranching programme is extension. A team of two or three experienced range specialists should be posted in a ranching region to work with range technicians to be posted on each of several selected ranches in the area. The technician with the support of the experts and local officials would undertake the rehabilitation effort on a very small part of the ranch that was highly accessable, visible and likely to be renovated quickly. Grass seed to accomplish reseeding planned for the next season could be planted almost immediately.

In the mixed farming areas special training in range restoration could be given to the extension officers or the team of range specialists could work on a rotational basis with extension workers and farmers over a wide area(say an entire district).

Equipment to execute the project would be quite limited involving transport for the personnel, some audio-visual equipment to facilitate demonstration of methods and benefits of renovation and perhaps of locally grown grass seeds. Original seed stocks should be obtainable through Kenya Seed Company at Kitale or through the proposed dry land seed multiplication facility.

5.3.4 Forestry

Quite a number of possibilities are available for forestry development in the project area. These are described by Uvoo in the Forestry Report No. 5. They include growth of eucalyptus for soil conservation, shelter, wind-breaks, shade, posts, poles, and firewood; cacia for shelter, windbreaks and shade; acacia for fodder, firewood, and tannin; pines and cyprus for sawlogs, and so on. Due to the range of climate in the area, from ecozones two to six, promotion of individual schemes must take into account the suitability of various species to local conditions.

The approach to be taken towards these possibilities depends on their economic viability, small-holders preferences for the amenities offered by certain types of trees, and the government's attitudes towards conservation and forestry as a natural resource. The general climatic requirements of pine and cyprus favour their development in higher rainfall areas than those prevalent in the project area. Certain highly specialized species such as acacia for tannin and trees for nut and fruit production may be of special interest for industrial and commercial purposes- but their development is not crucial to the area nor does it appear to offer a major opportunity as of the moment.

Eucalyptus as a source of firewood and poles for local construction remains as the prime forestry activity deserving consideration for its productive potential. According to a World Bank Study* over 90 percent of the 1970 consumption of forest products in Kenya was for fuel and poles. With a growing population and increasing costs of petroleum products, provision of an adequate supply of fuel wood will become increasingly important over time. In fact research in a number of industrialized countries centers on energy sources alternative to those of fossil and nuclear fuels. One of these alternatives is biomass, of which wood production is one of the possibilities.

The sections that follow concentrate on the possibilities of profitably growing eucalyptus for firewood and poles. Not covered are forests for soil and water conservation or as part of the farmstead. Programmes of afforestation and reforestation need to be evaluated in conjunction with range development while planting of trees and shrubs as windbreaks, shade, and general improvement in ambient conditions can be undertaken by individual small-holders, with some local and national support. This latter activity can be supported as part of the Government of Kenya's overall programme of social services to the rural sector and need not be amplified in this report.

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*See Volume 10 of the Agricultural Sector Survey - Kenya, December 20, 1973.

Eucalyptus Production: Various species of eucalyptus have been introduced to Kenya and have become an important element in the economy. Those of prime significance for firewood and poles, because of their rapid growth and ease of management are the saligna and gradis varieties. While recommended rainfall for these species is 900 mm or more,* other varieties do reasonably well in lower rainfall areas. An Australian variety (sideroxylon) can even get by with as little as 300 mm of rainfall annually.**

A number of reports recommended eucalyptus as being well suited for firewood and pole production in semi-arid areas.***

With this in mind, and the idea of providing a convenient local fuel source for the rural populace in the project area, the profitability of eucalyptus production for firewood and poles was investigated. The results show wide scope as far as soil suitability is concerned. Decisions to use the land in this manner will be largely influenced by the profitability of eucalyptus relative to the profits from crops and livestock. The benefit-cost calculations for eucalyptus to be described shortly, will provide a basis for such comparisons. However, these calculations are based on rather meager data and future conditions can alter the picture. Fuel shortages and substantial increases in royalty rates (stumpage price) would increase profit rates. Smallholder raising of eucalyptus on marginal lands would be an added source of income at relatively low investment of labour and funds. On the other hand, oversupply could seriously drop the price. Also, the investor must wait about eight years to receive his first cash returns. Both of these factors constrain the rate of eucalyptus production.

Location Suitability: The characteristics of the project area were reviewed by a forestry specialist from the government's forestry department to appraise the suitability for growing various species. The criteria included soil depth and permeability, rainfall, and stoniness. Figure 5.3.7 shows those areas considered suitable for a least one of a variety of

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*W. G. Dyson, "Experiments on Growing Eucalyptus Wood Fuel in the Semi-deciduous Forest Zone in Kenya", East African Agricultural and Forestry Journal, April 1974, pp.349-355.

**G. R. Davis, "Potential for the Production of Eucalyptus Oil and Gum Arabic in Kenya", UNIDO for FAO, Nairobi, 1978.

***For examples, see "Industrial Charcoal Project" by B. J. N. Obiri, Industrial Survey and Promotion Centre, Ministry of Commerce & Industry, Nairobi, August, 1976 and Dennis M. Kabagame, "Aspects of Resource Conservation and Utilization: The Role of Charcoal Industry in the Kenya Economy", Institute for Development Studies, University of Nairobi, Nairobi, June 1976.

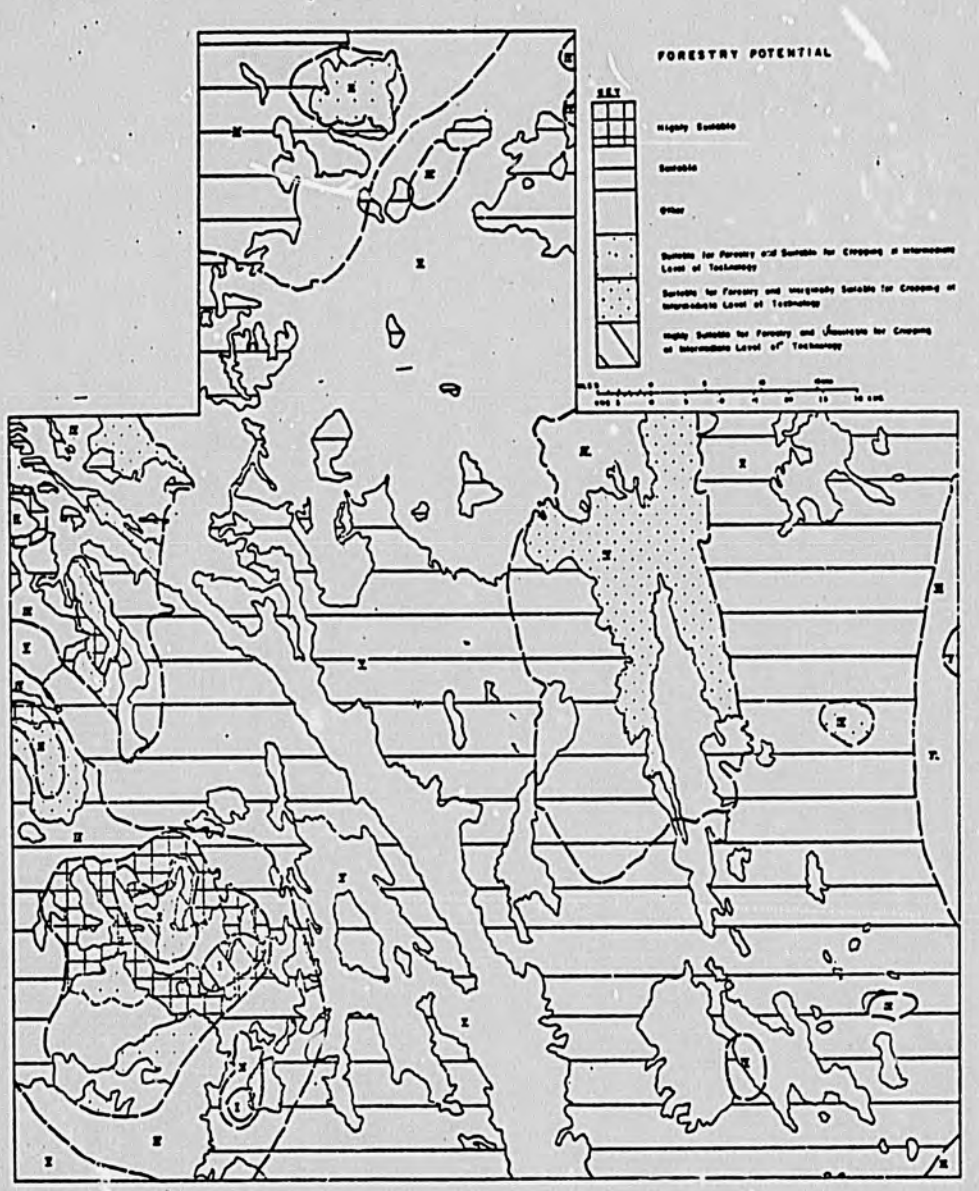

Figure 5.3.7

species, including eucalyptus. The extensiveness of suitable areas results from the general adaptability of various species to a wide range of climatic conditions. This adaptiveness does not necessarily mean that eucalyptus can be commercially grown in all these areas. In fact as subsequent analysis indicates, profitable eucalyptus production will most likely be confined to ecozones II, III, and IV. Before recommending areas for firewood production, a look needs to be first taken at anticipated profitability.

Benefit-Cost Analysis: Production of eucalyptus is another activity that can be undertaken on a small-scale basis by farmers in the area. The demand for firewood exists and will expand. The technology is not difficult and labour requirements are not excessive. With adequate supply of seedlings and credit and with instructions in planting and plant care, farmers in the area should be able to enter into this means of production.

Of course they will need access to lands that are both suitable for forestry and not pre-empted by higher-valued activities. The analysis summarized below provides a basis for evaluating the profitability of eucalyptus production relative to cropping and livestock production. Details of the analysis are provided in Appendix II.

Returns to small-holders are the net of the delivered value of timber and purchased inputs. The results measure the farmer's returns for his inputs of land, labour, management and capital, and includes a small cost for government services. Data on which to make this evaluation are skimpy, which require extracting information from several sources and adapting them to the situation under study. The principal references were those written by Solberg and Dyson.* The other references noted earlier also provided useful information in judging the economic viability of growing eucalyptus.

The evaluation consists of estimating investment, cutting and delivery costs, yields, times to harvesting, selling price and technical assistance. As with the other analyses farm labour is omitted as a cost (since returns include those for the farmer's labour). The time value of money is 8 percent; results are presented as equivalent annual amounts, and only the direct costs of government assistance are included.

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*B. Solberg, "Profitability of Eucalyptus Saligna Plantations in Ngong Forest District from a Social/Benefit Point of View, and Estimates of Fuel Wood Royalties," Forest Department, Ministry of Natural Resources, GOK, Nairobi, June, 1975. See earlier footnote for the Dyson reference.

Yields will vary according to soil and rainfall. Figure 5.3.6 distinguishes between soils in ecozones that are suitable for forestry. But yield-response data were not encountered that permits one to quantify yields according to soil types. As a result, a single level of output is estimated for all suitable soils within individual ecozones. In contrast, data from Solberg's study for high, average and low yields at Ngong, together with data from other sources, can be used to approximate a production rate based on rainfall levels. This analysis is described more fully in Appendix II.

Table 5.3.6 indicates that net returns from eucalyptus are roughly competitive with cropping activities on class C soils in ecozones III, IV, and V. Eucalyptus production under rainfall conditions is not considered feasible in ecozone VI. In fact, further investigation is needed to confirm such feasibility in ecozone V, where rainfall averages 540 mm per year.*

Table 5.3.6 EQUIVALENT ANNUAL RETURNS FROM SMALL-SCALE EUCALYPTUS PRODUCTION IN MACHAKOS-KITUI-EMBU (Shs/ha/year)

Ecozone	III	IV	V
Gross Revenues	1,130	780	530
Costs:			
Investment	75	75	75
Annual Operations	20	20	20
Cutting and Delivering	285	205	135
Total	380	300	230
Net Returns	750	480	300

As will be recalled from the section on rainfed crops and dairy cattle, these net returns are reasonably close to those for class C soils not requiring terracing for ecozones III, IV and V and superior to those class C soils requiring terracing. That is, eucalyptus returns for ecozone III are shs.750 per hectare per year if terracing is not required and shs.530 on average if terracing is required; shs.480 per hectare per year if terracing is not required and shs.190 per hectare per year on average if it is required; and shs.300 per hectare per year for ecozone V compared with shs.390 per hectare per year without terracing and shs.350 per hectare per year on average with terracing. Moreover, some of the areas suitable for forestry are unsuitable for crops. In these areas, the only other major use would be for livestock.

The areas where forestry can thus be justified are the dotted and diagonally hatched areas in Figure 5.3.7. They represent concurrence of suitability for forestry with soils

*This is compared with 690 mm per year in ecozone IV and 960 mm in ecozone III.

marginally suitable (class C) and unsuitable (class D) for intermediate technology for cropping. The areas so marked fall within ecozones II, III, and IV and amount to 109,600 hectares.

A Development Programme: The foregoing suggests that eucalyptus production for fuel and poles is a viable possibility for the project. If five cubic meters average per capita consumption is accepted as the present rate and as a reasonable target for future consumption, the number of hectares to be devoted to eucalyptus production can be estimated.* All of this supply need not be from eucalyptus groves, since part of the population will use other forms of fuel. Also, firewood and charcoal can be supplied from existing acacia and scrub trees. Nevertheless, long range planning could lead to eucalyptus production as a renewable and continuing basis for supplying a convenient, local source of firewood and poles. If the total supply to meet the 1985 needs of the area were to come from such eucalyptus production 903,000M^3 would need to be produced that year.**

If 50 percent of the soils highly suitable and suitable for forestry and marginally suitable for cropping under intermediate technology and 75 percent of the soils highly suitable and suitable for forestry and unsuitable for cropping under intermediate technology were planted in eucalyptus, an average annual production of about 1,713,290 M^3 would be produced. This result comes from the following calculations:

Table 5.3.7 FORESTRY YIELD POTENTIALS

Ecozone	Potential	Total area Hectares	Use Rate %	Average Yield per Hectare (M^3)	Total Yield (M^3)
II	Forestry only	10,720	75	29*	233,160
	Forestry or crops	4,840	50	29*	70,180
III	Forestry only	29,660	75	23	511,640
	Forestry or crops	22,350	50	23	257,030
IV	Forestry or crops	82,410	50	16	659,280
Total		149,980			1,731,290

*Taken as the average of high yields for Ngong but according to the curves for the project area. Annual yields per hectare are 21 M^3 for the first rotation, 35 M^3 for the second rotation and 31 M^3 for the third rotation. These values are from Figure II.1 in Appendix II.

*See Page 3, Annex Ten of the World Bank's Agricultural Sector Survey - Kenya.

**Based on 5 M^3 per family, 8 members per family and a projected population in the area of 1,444,000. The latter figure projects current (1977) population of 1,140,00 forward at a 3 percent annual rate of growth.

On this basis the rate of output is 192 percent of that required to serve the areas' complete needs for firewood and poles. Stated differently, 78,230 hectares prorated according to the above mix would have to be planted to exactly meet the area's needs. Note that these areas are fairly well spaced throughout the area so that delivery distances and costs would not be great.

At an initial investment cost of shs.540 per hectare, total costs at the outset (exclusive of the farmers' own labour) would be shs.42 million. The shs.540 per hectare includes nursery, box materials, tool, extension and miscellaneous costs as detailed in Table II.1 of Appendix II.

Project Possibilities: The aforementioned programme can be supported in a number of ways. These include:

i. Assistance to the Department of Forestry in its program of developing nurseries and supplying low-cost seedlings to local farmers.

ii. Training extension agents to work with local farming groups and supplying them with needed inputs and demonstration materials for the expanded program in the area.

iii. Provision of funds to carry out research on suitable eucalyptus and possibly other species for the lower rainfall areas. This research should concentrate on adaptive trials, measurement of yields, and calculation of reliable profits to small-holders from eucalyptus production.

iv. Consideration of credit requirements for small-holders and assistance in marketing their production.

5.3.5 Risk

One of the difficulties facing farmers in the semi-arid areas is the uncertainty of the rainfall both as to timing and amount. Table 5.3.9 tells a good part of the story. This tabulation was developed by analyzing stations in the ecozones and defined since 1972 by the Kenya Soil Survey* They zoned the country according to the scheme shown

ECOLOGICAL ZONES

Zones	r/E
II	67%
III	52-67
IV	37-52
V	22-37
VI	-22

Where r = Rainfall
E_o = Evaporation (Penman method)

This zonification has become an important component of the analysis. Although rainfall in the study area is rather closely related to elevation, the short period of the study required some simplifying assumptions. Therefore instead of using rainfall as a continuous variable across the study zone, it was assumed to be uniform within ecozone boundaries. Evaporation was also assumed to be uniform within ecozone.

We have considered only the probability of the annual rainfall amounts during the two growing seasons in determining risk. If credit risk insurance is to be established, risk calculations should be improved by including rainfall distribution patterns. For example in Machakos during the February-May rains of 1978 the amount was adequate but the distribution created planting difficulties which adversely affected yields. This will require a computer analysis of the weekly rainfall, combined with the seasonal rainfall probability distribution to get a joint amount - distribtion probability function.

Four stations in each ecozone were used to establish the probabilities of seasonal rainfall. There are more rainfall stations in the study area but most of them have very short periods when data was collected. It is undesirable to use these stations in the data analysis since they tend to weight the probability distributions too much toward the precipitation received in those years.

*Kenya Soil Survey Internal Communication No.9, 15/11/77

As mentioned in the Soil and Water Conservation Report, April and November are the months with the highest rainfall. Most publications count March through May as the "Long Rains" and October through December as the "Short Rains". There is on the average, significant precipitation in January and February. For this analysis the January precipitation has been added to the short rains and that received in February to the long rains. June through September precipitation has been ignored on the supposition that it makes no useful contribution toward crop production.

Precipitation Probability Distribution: With so few years of data available in the study area, in order to develop a continuous probability distribution function, the data was fitted to a gamma curve* and checked for goodness of fit by the Chi square test. It fits with a level of probability of error of less than 0.05. i.e. a good fit.

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*The gamma equation used is:

$$f(x) = \frac{1}{\beta^{\alpha}(\alpha - 1)!} x^{\alpha-1} e^{\frac{-x}{\beta}}$$

Where x = precipitation and f (x) = precipitation frequency. The coefficients α and β can be computed from the data by making use of the following relationships:

$$\mu = \beta\alpha$$
$$\sigma^2 = \beta^2\alpha$$

where μ= the mean

α^2 = the variance

α must be rounded to the nearest integer in order to compute the factorial (α-1)!.

The coefficients used to generate the gamma distribution function were computed as follows:

Table 5.3.8 GAMMA COEFFICIENTS FOR ESTIMATING RAINFALL PROBABILITIES

	ECOZONE					
	III		IV		V	
	February-May	October January	February-May	October-January	February-May	October January
α	9	3	5	3	3	3
β	63.475	151.720	75.673	187.045	95.603	106.557

By equating the gamma probability integral to 1 then integrating under the curve, one can iteratively calculate the precipitation for any level of probability.

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Table 5.3.9 PRECIPITATION PROBABILITIES IN THE MACHAKOS-KITUI-EMBU STUDY AREA: Precipitation in mm

Probability of exceeding precipitation %	ECOZONE III PERIOD Feb-May	Oct-Jan	Annual	IV Feb-May	Oct-Jan	Annual	V Feb-May	Oct-Jan	Annual
90	347	169	516	185	140	325	106	117	223
80	409	233	642	234	195	429	147	164	311
70	458	290	748	274	243	517	183	204	387
60	505	347	852	313	290	603	218	243	461
50	550	405	955	353	340	693	255	285	540

The 50 percent probability is the median, not the mean. Five years out of ten, precipitation will exceed the amounts shown on the 50% line. Nine years out of ten precipitation will exceed that shown on the 90% line.

Although the uncertainty of rainfall is not the only risk faced by the farmer, most of his other risks are related to his management capability and can presumably be minimized by training and other forms of assistance. The risk of low rainfall can be decreased substantially by using water conserving tillage practices. Still, rainfall is by far the major source of risk for the average farmer and it is treated here as the sole source of risk.

Table 5.3.10 is a listing of expected returns at several rainfall probability levels for intermediate and advanced technology activities. They have been plotted as net return functions against rainfall in Figure 6.2. These data do not include costs of soil conservation works.

Of some interest are comparisons between long and short rains. In ecozone III the long rains are heavier and less variable than the short rains. The same is true in ecozone IV but the trend is less pronounced. In ecozone V the short rains are heavier but the variability (90% probability/50 probability) about the same. The data in ecozone V was statistically tested (Mann-Whitney non parametric test) to see if the difference is significant. It is!

The Effect of Rainfall Variability on Subsistence

One of the risk issues is to quantify what is likely to happen to food supplies during dry years. Neither intermediate nor advanced technology guarantee a full grain storage bin every year. Table 5.3.10 has been generated to study the probability of food shortages. The expected net returns have been read off Figure 6.2. The farm sizes are those used by the economists in their farm budget analyses. The column "Equivalent Maize Deficit Surplus was calculated by assuming an average adult equivalent farm family size of 6 people, converting their expected

Table 5.3.10

RISK EVALUATION

Expected Net Returns to Small Holder Rainfed Arable Agriculture

Ecozone	Soil Suitability Class	Probability of not Exceeding surplus Deficit(-) %	Farm size ha.	INTERMEDIATE Expected net return sh/ha.	INTERMEDIATE Equivalent Subsistance Maize Deficit(-)/ Surplus kg/capita/yr.	ADVANCED Expected net return sh/ha.	ADVANCED Equivalent subsistance Maize Deficit(-)/ Surplus kg/capita/yr.
III	A	10	5	260	-149	390	-86
		20		540	-14	810	116
		30		750	87	1190	298
		40		1010	212	1610	500
		50		1330	366	2050	712
		10					
	B	10	5	250	-154	350	-105
		20		450	-57	710	68
		30		690	58	1070	241
		40		950	183	1490	443
		50		1270	337	1900	640
	C	10	5	180	-187	260	-149
		20		330	-115	570	0
		30		450	-57	840	130
		40		570	0	1150	279
		50		700	63	1450	423
IV	A	10	7	-200	-408	-200	-408
		20		90	-213	110	-200
		30		260	-99	360	-18
		40		440	22	670	177
		50		650	164	980	386
		10	7	-200	-408	-200	-408
		20		70	-227	100	-206
		30		230	-119	330	-52
		40		390	-11	580	117
		50		570	110	870	312

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Table 5.3.10 continued

RISK EVALUATION

Expected Net Returns to Small Holder Rainfed Arable Agriculture

Ecozone	Soil Suitability Class	Probability of not Exceeding surplus Deficit(-) %	Farm size ha.	Expected net return sh/ha.	Equivalent Subsistance Maize Deficit(-)/ Surplus kg/capita/yr.	Expected net return sh/ha.	Equivalent subsistance Maize Deficit(-)/ Surplus kg/capita/yr.
IV	C	10	7	-200	-408	-200	-408
		20		70	-227	80	-220
		30		180	-153	270	-92
		40		280	-85	470	43
		50		390	-11	690	191
V	A		9			-200	-447
						-200	-447
						-40	-308
						200	-101
						460	124
	B	10	9	-200	-447	-200	-447
		20		-200	-447	-200	-447
		30		-20	-291	-40	-308
		40		110	-179	160	-135
		50		300	-14	420	90
	C	10	9	-200	-447	-200	-447
		20		-200	-447	-200	-447
		30		-20	-291	-40	-308
		40		110	-179	130	-161
		50		200	-101	330	12

net return to kg. of maize at shs.1.04 per kg., assuming 60% of it is available to eat (the rest being lost to spoilage and/or other uses and allowing 2400 calories/capita/day and 3200 cal/kg of maize.

Thus for example in ecozone IV on soil suitability class A, three years out of 10 (30% probability level) the expected net return will be 380 sh/ha (advanced technology) and the expected equivalent maize deficit can be calculated as follows:

Equivalent maize produced per farm =

$$\frac{380 \text{ sh/ha} \times 7 \text{ ha} \times .6}{1.04 \text{ sh/kg}} = 1535 \text{ kg}$$

Maize required for the average farm family for the year:

$$\frac{2400 \text{ cal/c/day} \times 365 \text{ days/year} \times 6 \text{ people}}{3200 \text{ cal/kg}}$$

= 1642 kg/family/year

Family deficit = 1642-1535 = 107 kg/yr

Per capita deficit = 107/6 = 18 kg/yr

By using Table 5.3.10 and Table 6.2.4 for hectarages under intermediate technology for the various locations, maize equivalent shortages/surpluses were estimated for a number of locations (Table 5.3.11.) It must be kept in mind that there are a number of assumptions which can be individually questioned--but the exercise should give an order of magnitude indication of the risk situation and may provide a useful framework to GOK planners in deciding on the type of data they may wish to collect henceforth.

Land suitability D has been omitted from the analysis. The boundaries of the M/K/E study area have bisected some of the locations. Only that part of the location inside the study boundary has been considered.

One can conclude from the data of Table 5.3.11 that on the average under intermediate technology there will be a modest surplus but that at least 40% of the time there will be a food deficit and that one year out of 10 it could run toward 500 million pounds of maize- a rather strong argument for water conservation and irrigation. It assumes everyone is farming at an intermediate technology level. This may not be a bad assumption since hopefully some will move fairly quickly to an advanced technology level and counterbalance those who are slow in moving out of traditional technology.

Food Storage Implications: The above tabulation suggests a rough set of figures on which to base government food storage warehouse locations and capacities.. If storage in the study area is to be provided for serious droughts; those which can be

Table: 5.3.11 EXPECTED FOOD SURPLUSES/DEFICITS(-) KG x 10^6/YR UNDER SMALL HOLDER RAINFED INTERMEDIATE TECHNOLOGY USING 1985 POPULATION ESTIMATES

Location	Population in study area 10^3	Maize Equivalent kg x 10^6/year Years out of 10 that the surplus/deficit will be worse than that shown 1	2	3	4	5
Mitaboni	50.1	-14.5	-7.3	-3.2	1.0	6.0
Iveti	49.6	-15.9	-8.8	-5.0	-1.2	3.0
Muputi	26.7	-10.9	-6.1	-4.0	-1.9	0.1
Masii	29.5	-12.5	-12.5	-8.1	-5.0	-2.8
Wamunyu	21.1	-8.9	-8.9	-5.8	-3.6	-0.3
Konza North	3.6	-1.5	-0.8	-0.4	0.1	0.6
Mbiuni	26.3	-10.2	-6.7	-4.0	-1.6	1.3
Matungulu	62.0	-21.2	-16.2	-9.6	-3.3	3.2
Kangundo	64.4	-24.4	-19.6	-11.6	-4.9	1.0
Mwala	28.2	-10.5	-9.4	-5.9	-3.2	0.7
Kalama	34.1	-5.5	-2.0	-0.4	3.1	6.4
Kilungu	67.9	-10.5	-5.1	-1.2	3.0	8.0
Okia	36.4	-5.6	-2.3	0	2.5	5.5
Mukaa	47.1	-10.4	-5.8	-3.0	-0.1	3.2
Konza South	5.2	-2.2	-1.9	-1.2	-0.7	0.2
Muthetheni	28.6	-12.8	-12.8	-8.3	-5.2	-0.4
Mbooni	69.1	-6.8	-3.8	-1.8	-0.2	2.6
Kiteta	17.3	-4.4	-1.8	-0.1	1.8	4.1
Kibauni	26.9	-5.4	-5.4	-3.5	-2.2	-0.2
Kisau	25.4	-6.3	-3.1	-1.1	1.0	3.5
North Yatta	35.1	-13.4	-13.4	-8.7	-5.3	-0.8
Yatta Plateau	47.2	-17.9	-17.9	-11.7	-7.2	-2.2
East Donyo Sabuk	5.6	-2.3	-2.3	-1.6	-1.0	-0.1
West Donyo Sabuk	9.3	-3.6	-2.1	-1.2	-0.3	0.5
Makueni	82.3	-22.7	-19.8	-12.4	-6.6	0.9
Mbitini	14.4	-2.9	-1.8	-1.0	-0.2	0.7
Matinyani	29.5	-12.7	-10.5	-6.4	-3.3	1.1
Miambani	22.1	-9.1	-4.9	-3.2	-1.7	0.1
Changwithya	29.0	-12.7	-11.0	-7.0	-3.9	0.2
Nzambani	19.0	-6.6	-3.6	-2.1	-0.9	1.0
Kisasi	24.8	-10.6	-7.7	-4.4	-1.4	2.2
Malango	32.3	-13.8	-11.1	-6.9	-3.4	1.2
Yatta	19.7	-8.8	-8.8	-5.7	-3.5	-1.0
Yatta B2	3.4	-1.5	-1.5	-1.0	-0.6	0
Mwingi	21.2	-6.9	-5.3	-3.4	-2.1	-0.6
Migwani	33.8	-11.6	-9.5	-6.2	-3.3	-0.3
Mutonguni	41.2	-14.4	-12.8	-8.1	-4.3	0.9
Nuu	9.1	-2.6	-2.6	-1.7	-1.1	-0.1
Mui	8.1	-3.4	-3.1	-2.0	-1.2	-0.1
Mutito	10.3	-4.5	-4.3	-2.7	-1.7	-0.1
Zombe	9.9	-3.7	-3.3	-2.1	-1.2	0
Voo	12.8	-4.0	-4.0	-2.6	-1.6	-0.1
Ikanga	31.9	-13.2	-13.0	-8.4	-5.1	-0.3
Kanziko	9.4	-2.4	-2.4	-1.6	-1.0	-0.1
Mbeti	17.1	-6.5	-3.6	-1.7	0.3	2.5
Gaturi	13.8	-5.6	-3.1	-1.6	0	1.6
Mwea	9.4	-3.7	-3.0	-1.8	-0.9	0.3
Ithanga	5.3	-2.0	-1.1	-0.6	-0.3	0.3
Lower Makueni	29.7	-12.6	-12.6	-8.1	-5.0	-0.1
Ikutha	6.4	-2.9	-2.9	-1.9	-1.2	-0.2
Totals		-439.0	-343.0	-206.0	-90.0	52.0

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expected only once in ten years, about 500 million kg. of cereals will have to be stored. To meet the once in five year drought will require 350 million kg. of storage.

CHAPTER 6

DEVELOPMENT PROGRAM

6.1 APPROACH

The development of the two study areas is visualized as taking place in an evolutionary manner. For the M/K/E study area we have prepared figure 6.1 as one possible development time table. Its premise is that most farmers will move from traditional technology through intermediate rainfed and ultimately to advanced rainfed, intermediate irrigated or large scale irrigated over the next 12 years or so.

Many farmers have several blocks of land, some of which they should reserve either for forest or controlled grazing.

This time table is very ambitious and will not be met without a strong will to do so by the people, and their leaders. Nevertheless, if the data of Table 3.3 which shows an alarming loss of crop production in the study area is to be believed, it will never be easier to do what needs to be done than it is now. The longer the delay in starting and the more leisurely the rate of progress, the greater the environmental degredation and the harder it will be to reverse the trend.

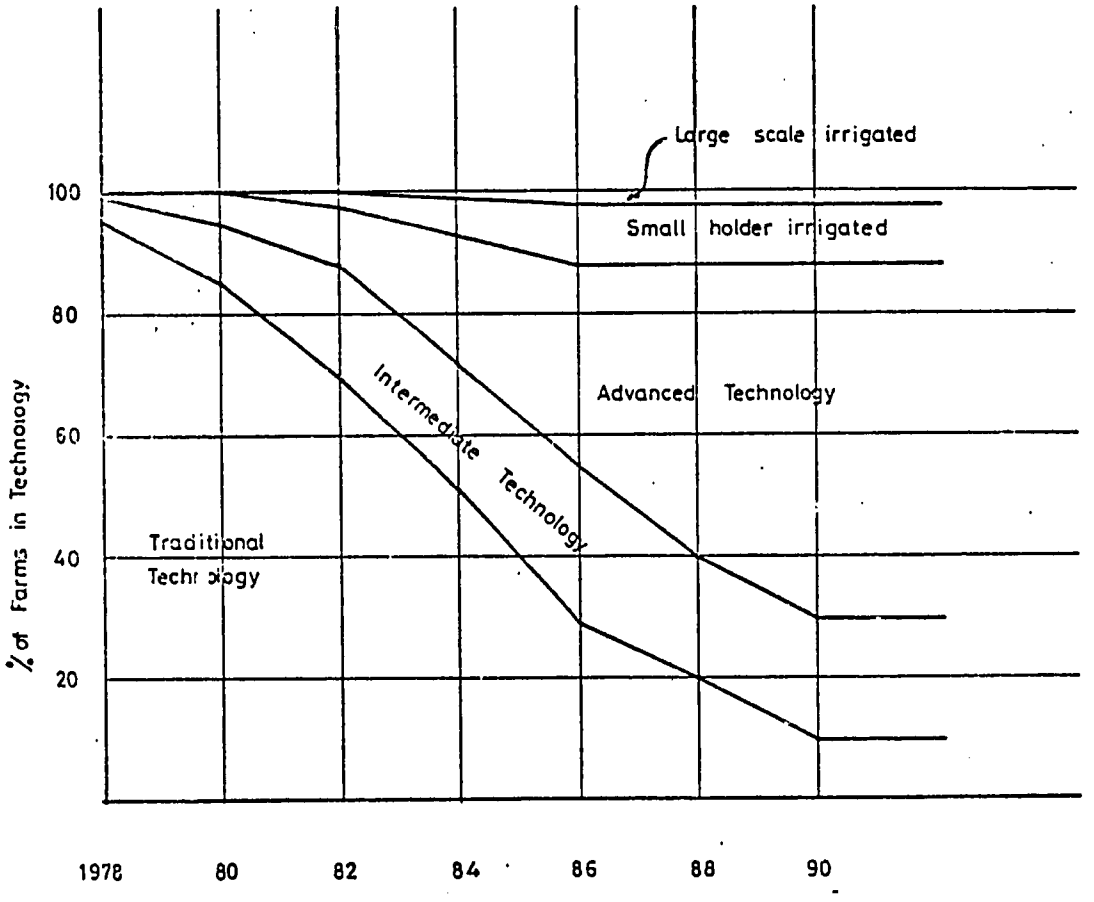
Part of our analysis has been to estimate the probable returns and costs to the alternative uses of the land. Our attention has been focused primarily on the Machakos/Kitui/Embu area since this is the region specified for project identification procedure. The inventorying process for the Baringo/Kerio Valley area has been at the same level of intensity. However, the collection of the soils data, its writeup and the laboratory analyses from the area came along too late to extend this analysis into that area.

The project agreement specifies that project identification for Baringo/Kerio Valley will be carried out by the Kenyan members of the team after the departure of the Americans. Most of the analytical procedures used in the M/K/E area are applicable to the B/KV area. An exception will be the need to consider soil and water salinity/alkalinity more carefully in the latter area.

There are many ways of accelerating the development of these areas. A major responsibility has been given to the District Development Committees. No development can succeed without the active support of the farmers and local involved people - government officials, church and voluntary agencies, private entrepeneurs. On the other hand, the financial resources of these people are meager. The scale of inputs needed as outlined in Chapter 7 makes it difficult to visualize that all the policy making, planning, organizing, scheduling, executing, monitoring, evaluating, adjusting that will be needed can be entirely delt with at the district or even the provincial level. It is essential that the roles of the interested parties be continuously reviewed and adjusted to the realities of the situation as development programs are launched. This is a major function of the Ministry of Finance and Planning who, with other ministries are not without experience in dealing with the multifacited problems of Integrated Agricultural Development.

Figure 6.1 TIME TABLE FOR MOVING FARMERS INTO HIGHER TECHNOLOGY LEVELS

	PERCENT OF FAMILIES IN TECHNOLOGY LEVEL						
	1976	1980	1982	1984	1986	1988	1990
Traditional	95	85	70	51	30	20	10
Intermediate	4	10	18	23	25	20	20
Advanced	1	5	10	20	33	48	58
Small Scale Irrigated	0	0	2	5	10	10	10
Large Scale Irrigated	0	0	0	1	2	2	2



As a part of the design phase a comprehensive, detailed, step-by-step strategy that encompasses all facits of finance, organization, input supply, transport, marketing, water, soil conservation, health, education and employment should be prepared. These documents have been prepared to provide project designers with an adequate data base to do their job.

In Chapter 7 we have suggested ten programs composed of 28 projects which the team has identified as necessary to meet the basic needs of the people in the study area. As to how to develop organizationally to carry out these programs we suggest serious consideration be given to the recommendations contained in the Institutions Report No.7. Although some of the proposals contained therein may seem far reaching, none are really radical. Rather they are suggestions for adjustment to existing organizations. For the same reason we have suggested Program 7.9 "Systems and Procedures" which should help managers in government to get more efficiency out of their organizations. No new organizations are proposed since there are enough already in place.

The district development committees role in pivotal. It is extremely important to have it redefined in a program of the magnitude we are suggesting.

One of the challenges to designers, especially to those coordinating the design work will be to dovetail the projects into existing activities. There are already many activities going on in the study areas, not the least of which is the Machakos District Integrated Development Program which will invest upwards of K£ 22 million in Development and Recurrent Expenditures over the next five years. Not surprisingly the objectives of the MDIDP are more or less congruent with the development proposal made here.

Those responsible for the administration of the MDIDP program should find some value in the data of this inventory. We especially urge consideration of Table 3.3 based on tables 2.1 and 2.7 of our Agronomy Report No.2. Table 2.1 is similar to Table 7.1 in the Machakos District Integrated Development Programe Report of August, 1977. However, the conclusion on page 7-5 of that report that productivity levels are rising at 1% annually is not supported by our Agronomy Report Table 2.7.

The 22 million Kenyan pound investment in Machakos may be all that the district can absorb over the next 5 years. It may be worthwhile for the administrators of that program to review those portions of the costs found in this document which relate to their area to determine if more funds could be made use of. We note for example that the MIDP funding will, over the five year period assist 24,000 rainfed farm families and 4000 irrigated farmers in the district. Yet with an estimated 1981 number of farm families at 126,000, that program will reach only about 22% of them. Table 7.13 of the MIDP report proposes EEC funding for the assistance of farm families on 23,600 ha. It seems that on the average each of the 24,000 farm families helped will get the help on about one hectare of

of their land.

We therefore raise the issue; is the EEC funded program going to provide resources at the maximum rate that can be absorbed? Is it going to be enough to bring the people out of the vicious downward spirals they are now in?

6.2 PRODUCTIVE PROGRAMS

In order to evaluate the benefits of moving from traditional technology to more advanced technology levels, the current situation needs to be kept in mind.

According to the Agronomists' Survey (Agronomy Report No.2 page 83) the following farm sizes and hectarages prevail in the two major districts.

	Machakos	Kitui
Number of farms	60,000	25,000
Average size of farm ha	4	6.6
Gross area Km^2	14,156	31,099
Percent of land farmed	17	5

The weighted average percent of land farmed is about 9%.

So it can be assumed that the project area, which contains about 18300 Km^2 has about 170,000 ha. in farming. If we use an income of Sh.3470 (Economics Report Table 67 p 82) per farm of average 5 ha, the total annual farm income is about Sh.118 million. The remaining area is primarily being grazed. The average annual return per hectare for range livestock has been estimated for ecozone V (where most of the non farmed land is) as about Sh.9.00.* Thus the additional net return to grazing is about Shs.15 million giving an annual return of Shs.133 million.

Figure 5.1.4 shows the suitability of land for traditional technology. Table 6.1.1 gives a breakdown in hectares by ecozone. land use suitability and technology. This forms one of the main bases of the calculations in this analysis. This tabulation is based on Table VII.1 in Appendix VII.

Projecting Returns Under Intermediate Technology:

Figure 5.3.2 showed the suitability of the M/K/E project area for small holder rainfed intermediate technology. This is a reduction from the original map made at a scale of 1:250,000 which is in the possession at the time of this

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* See Economics Report No.3, table 54, p.65

Table 6.1.1 RELATIVE SUITABILITY OF LAND FOR ALTERNATIVE USES*

Ecozone	Soil Suitability class	Small-Holder Trad. ha	Small-Holder Inter. ha	Rainfed Advanced ha	Large Scale Arable	Irrigation Small Holder	Irrigation Large Scale	Forestry
II	A	0	990	990	0	NR	NR	11,510
	B	990	0	4,840	990	"	"	6,040
	C	0	4,840	1,200	0	"	"	0
	D	16,560	11,720	10,520	16,560	"	"	0
Totals		17,550	17,550	17,550	17,550			17,550
III	A	0	35,560	39,590	0	35,560	35,560	37,670
	B	35,560	6,140	25,400	43,660	4,070	8,100	45,250
	C	8,100	23,290	15,950	1,590	4,030	21,330	17,650
	D	56,910	35,580	19,630	55,320	56,910	35,580	0
Totals		100,570	100,570	100,570	100,570	100,570	100,570	100,570
IV	A	0	156,090	187,560	24,000	162,440	168,520	0
	B	165,110	53,730	94,770	164,320	32,440	87,240	296,360
	C	88,300	159,490	97,350	78,600	60,880	45,200	170,650
	D	213,600	97,700	87,330	200,090	211,250	166,050	0
Totals		467,010	467,010	467,010	467,010	467,010	467,010	467,010
V	A	0	0	726,320	257,620	583,020	705,390	0
	B	0	[illegible]	189,530	609,890	275,900	261,990	736,670
	C	916,050	123,050	145,170	106,510	108,460	29,840	479,390
	D	300,010	220,430	155,040	242,040	248,680	218,840	0
Totals		1,216,060	1,216,060	1,216,060	1,216,060	1,216,060	1,216,060	1,216,060
VI	A	0	0	27,580	27,580	35,080	35,080	0
	B	0	35,080	7,500	9,300	0	0	0
	C	35,080	0	0	0	0	0	0
	D	0	0	0	0	0	0	35,080
Totals		35,080	35,080	35,080	35,080	35,080	35,080	35,080

*Based on Table VII.1 Appendix VII

Table 6.2.1 POTENTIAL NET RETURNS[a] FROM CROPPING & LIVESTOCK PACKAGES UNDER INTERMEDIATE TECHNOLOGY

Ecozones	Soil Suitability Class	Conservation Measures	Revenues	Operating Costs	Net Operations	INVESTMENT Shs/ha/yr @ 8%			Net Overall Return	Gross Area ha.	% Use Potential (c)	Net Area ha	% of Total Area	Total Net Overall Return Millions of shs/yr	% of Total Returns
						Tools, Build. Stock, etc.	Soil Conservation (b)	Totals							
II	A	Grass strips	2990[d]	1150	1840	250	20	270	1570	993	90	890	0	1.4	0.3
	C	Terracing	2800[d]	1520	1360	440	300	740	620	4,844	80	3880	0	2.4	0.6
		Total								5,837		4,770	0	3.8	0.9
III	A	Grass strips	2490	960	1530	210	20	230	1300	35,561	90	32,000	3	41.6	9.9
	B	Grass strips	2420	950	1470	210	20	230	1240	2,111	90	1,900	0	2.4	0.6
		Terracing	2420	950	1470	210	110	320	1150	4,030	90	3,630	0	4.1	1.0
	C	Grass strips	2400	[illegible]	1140	370	30	400	740	3,543	80	2,830	0	2.1	0.5
		Terracing	2400	1260	1140	370	250	620	520	19,736	80	15,790	1	8.2	1.9
		Total								64,981		56,150	5	58.4	13.9
IV	A	No conservation	1590	780	810	170	0	170	640	23,751	85	20,190	2	12.9	3.1
		Grass strips	1590	780	810	170	20	190	620	132,341	85	112,490	9	69.7	16.6
	B	No conservation	1500	740	760	170	0	170	590	20,339	85	17,290	1	10.2	2.4
		Grass strips	1500	740	760	170	20	190	570	24,409	85	20,750	2	11.8	2.8
		Terracing	1500	740	760	170	100	270	490	27,369	85	23,260	2	13.7	3.3
	C	No Conservation	1250	690	560	170	0	170	390	15,113	75	11,330	1	4.4	1.1
		Grass strips	1250	690	560	170	30	200	360	24,607	75	18,460	1	6.7	1.6
		Terracing	1250	690	560	170	220	390	170	127,957	75	95,970	8	16.3	3.9
		Total								395,886		319,740	26	145.7	34.8

Table 6.2.1 continued POTENTIAL NET RETURNS[a] FROM CROPPING & LIVESTOCK PACKAGES UNDER INTERMEDIATE TECHNOLOGY

Ecozones	Soil Suitability Class	Conservation Measures	Revenues	Operating Costs	Net Operations	INVESTMENT Shs/ha/yr @ 8%			Net Overall Return	Gross Area ha.	% Use Potential	Net Area ha.	% of Total Area	Total Net Overall Return Millions of shs/yr	% of Total Returns
						Tools, Build. Stock, etc.	Soil Conservation	Totals							
V	B	No conservation	570	270	300	30	0	30	270	351,356	85	298,650	24	80.6	19.2
		Grass strips	570	290	300	30	20	50	250	495,212	85	420,930	34	105.0	25.1
		Terracing	570	270	300	30	30	60	240	48,246	85	41,010	3	9.8	2.3
	C	No conservation	430	200	230	30	0	30	200	52,142	75	39,110	3	7.3	1.9
		Grass strips	430	200	230	30	50	80	150	52,762	75	39,570	3	5.9	1.4
		Terracing	430	200	230	30	50	80	150	19,934	75	14,950	1	2.2	0.5
		Total								1,019,652		854,220	69	211.3	50.4
		Grand Total								1,486,356		1,234,880	100	419.2	100.0

Note: Totals may not add up due to rounding

(a) Net returns to land, farmers' own labor and management and capital

(b) Terracing costs are taken as 90% unit terracing costs for ecozone II, 80% for ecozone III, 71% for ecozone IV, and 33% for ecozone V. These percentages reflect the proportion of terraced cropped land to total land farmed. Includes grass strips, cut-off drains, etc., on C slopes (5-8%)

(c) Percentages are general estimates of potential level of development. Class C soils are considered to have a lower use rate than Class A and B soils because of the possibilities of less suitable terrain, rock outcrops, etc. Ecozones IV and V are considered to be less fully utilized because of their general remoteness over the near term.

(d) Not calculated but assumed to be 20% above that for Ecozone III.

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Table 6.2.2 LAND USE STRATEGY WITH EXPECTED RETURNS
USING A MIX OF SMALL-HOLDER RAINFED INTERMEDIATE TECHNOLOGY
GRAZING AND FORESTRY

Ecozone	Soil suit-ability	Gross Cropping Area(1)	Net Cropping Area(2)	FORESTRY(3) ha	sh/ha	Net.Ret. shx10^6	GRAZING ha	sh/ha(4)	Ret.
II	A	990	890				100		
	B	0	0					321	1.5
	C	4,840	3,880				960		
	D	11,720	0	8,000	750	6.0	3,720		
III	A	35,560	32,000				3,560		
	B	6,140	5,530				610		
	C	23,290	18,620				4,670	321	5.6
	D	35,580	0	27,000	480	13.0	8,580		
IV	A	156,090	132,680				23,410		
	B	53,730	53,730					173	18.0
	C	159,490	133,330				26,160		
	D	97,700	0	43,000	300	19.9	54,700		
V	A	0	0						
	B	872,580	760,590				111,990		
	C	123,050	93,630				29,420	58	21.0
	D	220,430	0				220,430		
VI	A	0	0						
	B	35,080	0				35,080		
	C	0	0						
	D	0	0						
Totals			1,234,380	78,000		38.9	523,390		46.1
Subtract 3% for roads, homes etc.							55,000		4.8
				Net to grazing			468,390		41.3

Notes: (1) See Table 6.1.1 These are gross hectarages calculated for Int. Technology
Notes (2) See Table 6.2.1
(3) See Forestry Sec. 5.3.4
(4) See Economics Report No. 3 Table 58, p.71

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writing of the Kenyan staff of the study team. It is suggested that for readers who wish to make use of this, and the corresponding maps of the other technologies, they request from the study team coordinator ozalid (opaque) or sepia (translucent) full size copies. These can be individually coloured and/or used as overlays. The area map showing the land units on which the suitabilities are based is in the Soils Report Number 10. If analysts wish to revise any of the land use classifications as listed in Table VII.1 of Appendix VII, that map can be used by suitably coloring the land units.

Table 6.2.1 summarizes the expected returns from cropping and livestock under, intermediate technology. This could yield up to 419.2 million shilling per year. Note that this is net after deducting annualized costs for soil conservation works of Shs.45 million. In addition there are some 600,000 hectares available for forestry and grazing. Combining Tables 6.1.1 and 6.2.1 one can estimate the land remaining for grazing as in Table 6.2.2.

Table 6.2.3 summarizes the strategy of Table 6.2.2

Table 6.2.3 SUMMARY OF LAND USE STRATEGY

	Area ha	Returns Shs x 10^6
Cropping & Livestock Intermediate Technology	1,234,880	419.2
Forestry	78,000	38.9
Grazing	468,390	41.3
Roads, home sites etc	55,000	-
Totals	1,836,300	499.4

This is 3.8 times the average return under current conditions. Moreover, as already mentioned, the current trend unless a major effort is made to stop the loss of soil and soil nutrients is downward so the benefits will be even more pronounced as time passes. Figure 6.3 shows the distribution of returns.

Can the Area Support the Population Under Intermediate Technology? The mix of farming, grazing, forestry as proposed in Table 6.2.3 works out as follows

Mixed farming	67%
Grazing	26
Forestry	4
Unproductive	3

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The production returns figures for mixed farming were worked out on the basis of 5, 7 and 9 ha per farm for ecozones III, IV, and V respectively. Is there enough land to provide farms of this size to everyone? Table 6.2.4 is a summary of our estimate of surplus (+) or deficit (-) populations which will exist in the various locations of the project area by 1985 using 3% annual population growth rates. See Appendix III for computation procedures used in Table 6.2.4. Figure 6.2 is a graphical representation of the relationship between annual precipitation and expected net returns based on the farm budgets of Appendix VI.

We have also calculated the surpluses and deficits using a target annual family farm income of Sh.4500. For some farmers this will have the effect of decreasing farm size. However, for the locations with a high proportion of land in ecozone V they can't make the target income under intermediate technology with 9 ha. So for that area, the population surplus increases using the target income concept.

The data of Table 6.2.4 has been summarized in Table 6.2.5.

What about the people on D Class Land? Under intermediate technology, insofar as mixed farming is concerned about 18% of the people in the Machakos study area will live on land that is unsuitable for mixed farming. In Kitui it will be 13% and Embu 26%. Recall that this is on the basis of an even population distribution throughout each location. This is 255,000 people for about 600,000 hectares of land or about 19 ha per family. These people will earn their living in grazing livestock, cutting timber for fuel and poles, and working as wage earners, technicians, professionals etc.

Conclusions from Table 6.2.5

1. There will be a surplus population area/wide of 411,000 people under intermediate technology if the target income of Shs.4500/family/year is the criteria used.

2. If the model farm sizes are used there will be a surplus of 232,000 people in the Machakos area (as compared with a projected population increase of from 1978 - 1983 of 184,000). This surplus can be handled in Kitui, assuming suitable relocation arrangements can be made. The average family income using the model farms concept will be about Sh.2760 per year.

3. Under advanced technology there will still be a surplus population of between 100,000 and 150,000 people under target income or model farm strategies in Machakos which could be handled in Kitui and Embu. (See Table 6.2.6 for basis). Income from the model farm sizes is roughly equivalent to the target farm income of Shs.4500. The overall deficit number of people, 116,000 represents slightly less than an additional 3 years of population growth.

Figure 6.2

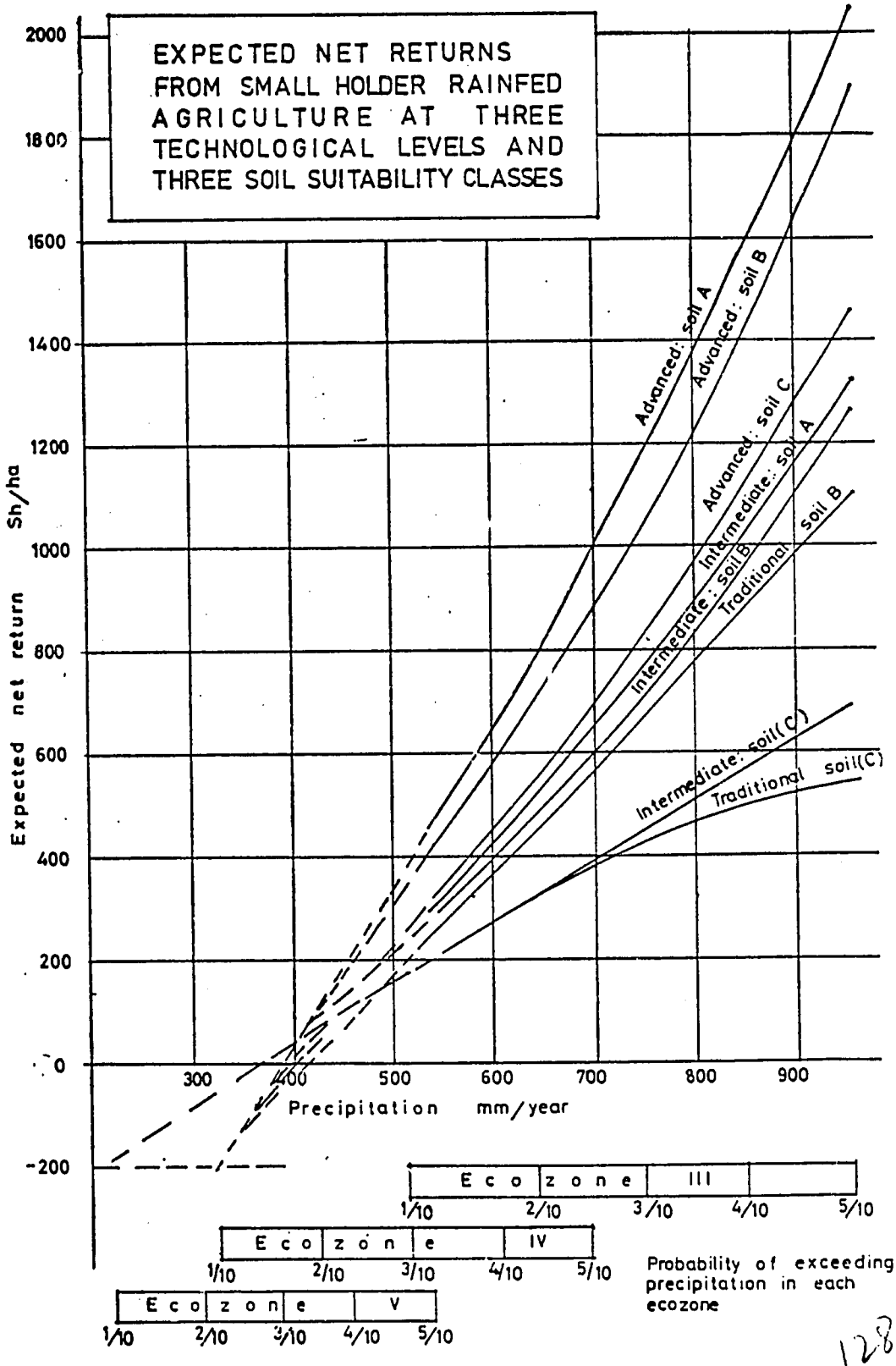

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Table 6.2.4 EXPECTED SURPLUS(+)/DEFICIT(-) POPULATIONS IN THE M/K/E STUDY AREA IN 1985 UNDER INTERMEDIATE OR ADVANCED TECHNOLOGIES

District and Location	Population 1985[1] x1000	INTERMEDIATE TECHNOLOGY Model farm size ha.[2]	INTERMEDIATE TECHNOLOGY Target income farm size ha.[3]	ADVANCED TECHNOLOGY Model farm size ha.	ADVANCED TECHNOLOGY Target income farm size ha.
		Families, to convert to population multiply by 8			
MACHAKOS					
Mitaboni	50.1	+ 4,386	+ 4,780	+ 3,547	+ 2,348
Iveti	49.6	+ 4,971	+ 5,487	+ 4,960	+ 4,579
Muputi	26.7	+ 2,165	+ 2,903	+ 1,859	+ 1,429
Masii	29.5	+ 2,036	+ 2,770	+ 2,122	+ 2,385
Wamunyu	21.1	+ 806	+ 1,656	+ 767	+ 997
Konza North	0.7	- 1,041	- 1,000	- 1,121	- 1,639
Mbiuni	26.3	+ 1,241	+ 1,550	+ 1,463	+ 1,197
Matungulu	62.0	+ 5,184	+ 6,385	+ 2,074	+ 1,436
Kangundo	64.4	+ 6,415	+ 6,983	+ 2,661	+ 3,541
Mwala	28.2	+ 1,478	+ 2,039	+ 2,363	+ 1,790
Kalama	34.1	+ 982	+ 440	+ 1,513	- 477
Kilungu	67.9	+ 3,446	+ 3,169	+ 3,179	+ 897
Okia	36.4	+ 1,095	+ 861	+ 912	- 764
Mukaa	47.1	+ 1,628	+ 2,022	+ 2.345	+ 1,369
Konza South	5.2	- 786	- 294	- 818	- 888
Muthetheni	28.6	+ 2,131	+ 2,853	+ 2,132	+ 2,378
Mbooni	69.1	+ 1,887	+ 1,237	+ 1,752	- 1,295
Kiteta	17.3	+ 980	+ 736	+ 874	+ 65
Kibauni	26.9	- 154	+ 680	- 183	+ 788
Kisau	25.4	+ 136	- 47	+ 249	- 924
North Yatta	35.1	- 4,162	- 48	- 3,480	- 1,856
Yatta Plateau	47.2	- 1,029	+ 2,238	- 4,584	- 1,207
East Donyo Sabuk	5.6	- 589	+ 56	- 642	- 273
West Donyo Sabuk	9.3	- 1,127	- 604	- 1,043	- 1,605
Nzaui	34.8	- 1,017	- 24	- 182	- 2,705
Mukueni	82.3	- 1,750	+ 1,252	- 2,026	+ 1,710
Lower Makueni	29.7	- 839	+ 1,540	- 906	+ 13
Mbitini	14.4	+ 438	+ 503	+ 907	+ 941
Ithanga	5.3	- 597	- 163	- 1,009	- 807
KITUI					
M[illegible]inyani	29.5	+ 969	+ 1,571	+ 1,353	+ 1,152
Ki[illegible]bani	22.1	- 58	+ 2,120	- 305	+ 185
Cha[illegible]withya	29.0	+ 1,179	+ 2,120	+ 1,108	- 636
Nzamboani	19.0	+ 96	+ 867	- 198	- 421
Kisasi	24.8	- 847	- 58	+ 1,871	+ 1,786
Mulango	32.3	+ 1,548	+ 2,439	+ 503	+ 33
Yatta	19.7	- 4,050	- 426	- 4,085	- 1,340
Yatta B2	3.4	- 3,805	- 1,703	- 4,045	- 2,811
Mwingi	21.2	- 517	+ 1,050	- 615	- 197

Table 6.2.4 concluded

District and Location	Population 1985[1] x 1000	INTERMEDIATE TECHNOLOGY Model farm size ha.[2]	INTERMEDIATE TECHNOLOGY Target income farm size ha.[3]	ADVANCED TECHNOLOGY Model farm size ha.	ADVANCED TECHNOLOGY Target income farm size ha.
KITUI (continued)		Families, to convert to population multiply by 8			
Migwani	33.8	- 1,877	+ 829	- 2 003	- 1.083
Mutonguni	41.2	+ 429	+ 2,429	+ 406	+ 390
Nuu	9.1	- 2,8'6	+ 1,096	- 2,960	- 1,099
Mui	8.1	- 370	- 259	- 1,350	- 481
Mutito	10.3	- 2,728	- 644	- 1,273	- 639
Zombe	9.9	- 4 768	- 2,199	- 4,090	- 3,932
Voo	12.8	- 3 502	- 1,272	- 2,053	- 1,627
Ikanga/Mutomo	31.9	- 3,615	- 218	- 3.217	- 2,322
Kanziko	9.4	- 1,730	- 578	- 1,955	- 1,427
Katse	11.0	- 772	- 111	- 787	- 694
Endau	2.5	- 4,148	- 2,139	- 5,858	- 4,149
Ikutha	6.4	- 3,000	- 1,027	- 2,497	- 1,827
Mutha	6.5	- 1,530	- 799	- 117	0
EMBU:					
Nthawa	18.0	- 1,585	- 1,748	- 1,542	- 3 195
Evurore	11.9	- 56	- 64	- 71	- 196
Mbeti	17.1	+ 201	+ 297	+ 254	+ 461
Mavuria	28.5	- 1,591	- 736	- 329	- 376
Gaturi	13.8	+ 839	+ 963	+ 839	+ 422
Mwea	9.4	- 1 177	- 428	- 1,172	- 1.440

(1) That portion of the location within the study area boundary
(2) Farm size in Ecozone III = 5 ha; IV = 7 ha; V = 9 ha.
(3) Target income is shs.4 500 per family

Table 6.2.5 SUMMARY OF PROJECTED POPULATION SURPLUSES(+)/DEFICITS(-) UNDER INTERMEDIATE AND ADVANCED SMALL-HOLDER, RAINFED TECHNOLOGY BY 1985 - MACHAKOS-KITUI-EMBU STUDY AREA

		INTERMEDIATE TECHNOLOGY						ADVANCED TECHNOLOGY					
		Number of Locations with				Net Pop.x10^3		Number of Locations with				Net Pop.x10^3	
		Surpluses(+)		Deficits (-)		(+)	(-)	Surpluses(+)		Deficits (-)		(+)	(-)
District	Population 1985 x 1000	Model Farm	Target Farm	Model Farm	Target Farm	Model Farm	Target Farm	Model Farm	Target Farm	Model Farm	Target Farm	Model Farm	Target Farm
Machakos	983	18	22	11	7	+232	+400	18	16	11	13	+157	+107
Kitui	388	5	9	17	13	-287	+ 25	5	5	17	17	-257	-169
Embu (Mbere)	99	2	2	4	4	- 27	- 14	2	2	4	4	- 6	- 35
Totals	1470	25	33	32	24	- 82	+411	25	23	32	34	-116	- 97

Table 6.2.6 POTENTIAL NET RETURNS[a] FROM CROPPING & LIVESTOCK UNDER ADVANCED TECHNOLOGY

Ecozones	Soil Suitability Class	Conservation Measures	Revenues	Operating Costs	Net Operations	INVESTMENT Shs/ha/yr @ 8% Tools, Build. Stock, etc.	Soil Conservation (b)	Totals	Net Overall Return	Gross Area ha.	% Use Potential (c)	Net Area ha.	% of Total Area	Total Net Overall Return Millions of shs/yr	% of Total Returns
II	A	Grass strips	4600(d)	1540	3070	250	40	290	2780	2,300	90	2,070	0	5.8	.8
	B	Terracing	4430	1510	2920	250	350	600	2320	4,990	90	4,490	0	10.4	1.4
		Total										6,560	1	16.2	2.2
III	A	Grass strips	3840	1540	2300	250	40	290	2010	46,000	90	41,400	3	83.2	10.9
		Terracing	3840	1540	2300	250	350	600	1700	470	90	420	0	0.7	.1
	B	Grass strips	3690	1510	2180	250	40	290	1890	4,350	90	3,920	0	7.4	1.0
		Terracing	3690	1510	2180	250	350	600	1580	23,670	90	21,300	2	33.7	4.4
	C	Terracing	3840	1940	1900	450	440	890	1010	24,180	80	19,340	1	19.5	2.5
		Total										86,380	7	144.5	18.9
IV	A	No conservation	2240	1070	1170	190	0	190	980	21,880	85	18,600	1	18.2	2.4
		Grass strips	2240	1070	1170	190	40	230	940	131,880	85	112,100	9	105.4	13.8
		Terracing	2240	1070	1170	190	350	540	630	280	85	240	0	0.1	0
	B	No conservation	2090	1010	1080	190	0	190	890	15,320	85	13,020	1	11.6	1.5
		Grass strips	2090	1010	1080	190	40	230	850	84,660	85	71,960	5	61.2	8.
		Terracing	2090	1010	1080	190	350	540	540	18,690	85	15,890	1	8.6	1.1
		Grass strips	1790	900	890	190	40	230	660	32,610	75	24,460	2	16.1	2.1
		Terracing(2)	1790	900	890	190	350	540	350	58,150	75	43,610	3	15.3	2.
		Terracing(1)	1790	900	890	190	440	630	260	29,550	75	22,160	2	5.7	.7
		Total										322,040	24	242.2	31.6

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T[illegible].2.6 Cont. POTENTIAL NET RETURNS [a] FROM CROPPING & LIVESTOCK UNDER ADVANCED TECHNOLOGY

Ecozones	Soil Suitability Class	Conservation Measures	Revenues	Operating Costs	Net Operations	INVESTMENT Shs/ha/yr @ 8% Tools, Build. Stock, etc.	Soil Conservation (b)	Totals	Net Overall Return	Gross Area ha.	% Use Potential (c)	Net Area ha.	% of Total Area	Total Net Overall Return Millions of shs/yr	% of Total Returns
V	A	No conservation	1150	610	540	70	0	70	470	268,120	85	227,900	17	107.1	14.
		Grass strips	1150	610	540	70	40	110	430	390,590	85	332,000	25	142.8	18.6
	B	No conservation	1080	590	490	70	0	70	420	78,960	85	67,120	5	28.2	3.7
		Grass strips	1080	590	490	70	40	110	380	176,820	85	150,300	11	57.1	7.4
		Terracing	1080	590	490	70	350	420	70	3,150	85	2,680	0	0.2	0
	C	No conservation	880	500	380	70	0	70	310	38,670	75	29,000	2	9.0	1.2
		Grass strips	880	500	380	70	40	110	270	93,850	75	70,390	5	19.0	2.5
		Terracing	880	500	380	70	350	420	0	43,850	75	32,890	3	0	0
		Total										912,280	68	363.4	47.4
		Grand Total										1,327,260	100	766.30	100.

a,b,c,d, for explanation see footnotes on Table 6.2.1

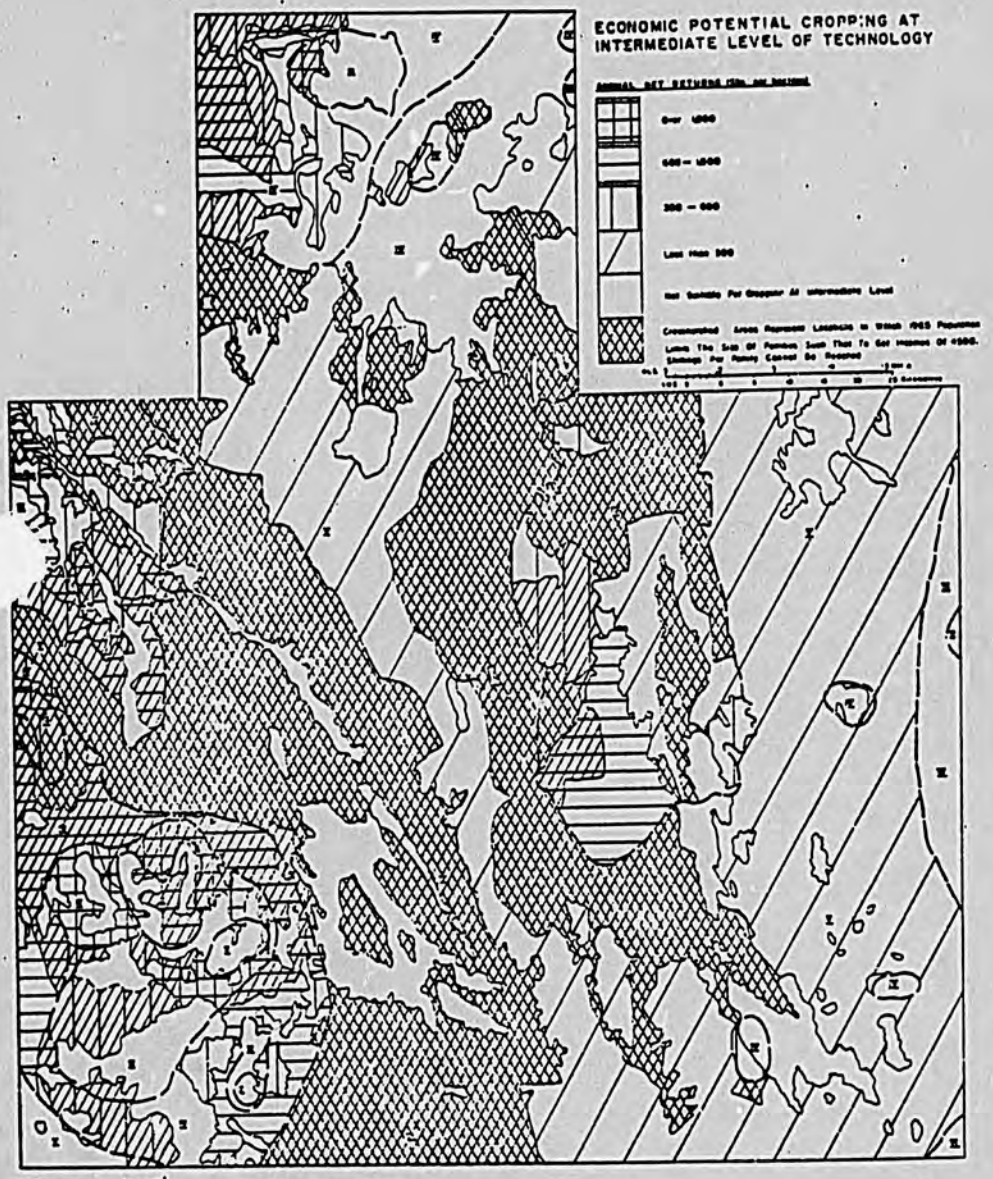
ECONOMIC POTENTIAL CROPPING AT
INTERMEDIATE LEVEL OF TECHNOLOGY

Figure 6.3

4. Even with dryland advanced technology being practiced throughout the study area, by 1988 there will begin to be a surplus population pressure again. The message is that either growth rates must come down or even higher production rates must be sought through improved technology; i.e. higher yielding crops, more supplemental irrigation, better husbandry.

Estimates of Labour Requirements under Intermediate and Advanced Technology

Of interest is the projected labour requirement under intermediate and advanced technologies. How many people can be gainfully employed? Will there be seasonal bottlenecks?

Summarizing the labour requirements (Appendix VI Tables VI.4 and VI.5) the hectarages from Table 6.1.1 and the seasonality of the labour inputs from Table 10 of the Economics Report No.3, Table 6.2.7 displays the expected labour demand.

It is interesting to compare the weighted average farm family labour requirements under intermediate and advanced technologies of 365 and 418 person days per farm respectively with the data of Table 10 in the Economics Report No.3 quoting Heyer's study in Masii location which gave an average labour input of 134 person days per year per farm. We can use this figure to indicate the increase in labour requirements. With as estimated 36,000 farms currently in the project area the number of person years to operate these farms is about 16,080 (using 300 working days per year). If the hectarages shown in Table 6.2.7 come under intermediate/advanced technology there will be a 15/22 fold increase in the labour requirement.

The projected 1985 population in the study area portions of the M/K/E districts is:

Machakos	980,000	
Kitui	388,000	
Embu(Mbere)	99,000	
Total	1,467,000	
Subtract those in non farming activities	255,000	
Farming population	1,212,000	
Number of farm families @ 8 per family		151,500

Using the seasonal labour distribution from Table 10 of the Economics report, the monthly labour requirement is as follows (Table 6.2.8) (converted to person days/month/family.)

Table 6.2.7

LABOUR REQUIREMENTS FOR INTERMEDIATE AND ADVANCED TECHNOLOGIES
SMALL HOLDER RAINFED MIXED FARMING

INTERMEDIATE TECHNOLOGY

Ecozone	Gross Hectares Farmed	Utilization Factor %	Net Hectares Farmed	Farm Size ha	Number of Farms	Annual Labour Requirement Per Farm, Person Days: Family	Hired	Total	Total Annual Labour Requirement Person Years(1) x 1,000: Family	Hired	Total
II	5,830	90	5 250	5	1,050	327	137	464	1.1	0.5	1.6
III	64 990	90	58,500	5	11,700	327	137	464	12.8	5.3	18.1
IV	369,310	85	313,900	7	44 800	346	212	559	51.7	31.7	83.4
V	995,630	80	764.500	9	84 900	380	125	505	107.5	35.4	142.9
VI	35,080	75	26,300	9	2,900	380	125	505	3.7	1.2	4.9
	Totals				145,350	365 (weighted)			176.8	74.1	250.9

ADVANCED TECHNOLOGY

Ecozone	Gross Hectares Farmed	Utilization Factor %	Net Hectares Farmed	Farm Size ha	Number of Farms	Annual Labour Requirement Per Farm, Person Days: Family	Hired	Total	Total Annual Labour Requirement Person Years(1) x 1,000: Family	Hired	Total
II	7,030	90	6,300	5	1,300	349	219	568	1.5	0.9	2.4
III	80,940	90	72.800	5	14,600	349	219	568	17.0	10.7	27.7
IV	379,680	85	222,700	7	48,100	356	245	601	54.7	37.6	92.3
V	1,061,020	80	848,800	9	94,300	458	243	701	144.0	76.4	220.4
VI	35,080	75	26,300	9	2,900	458	243	701	4.4	2.3	6.7
	Totals				159,200	418 (weighted)			221.6	127.9	349.5

(1) Person years estimated at 300 working days/year

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Table 6.2.8 PERSON DAYS PER MONTH PER FAMILY REQUIRED FOR ON-FARM LABOUR

Technology	J	F	M	A	M	J	J	A	S	O	N	D	Total
Intermediate	49	50	78	54	15	11	11	18	36	67	56	56	495
Advanced	68	70	111	75	21	15	15	25	50	93	70	79	692

Advanced technology will require 40% more labour than intermediate technology.

Since according to the information in Section 2.5 of the Economics Report there is an average labour equivalent on each farm of about 7.15 persons, one can conclude that the seasonal labour shortages being experienced by many farmers are not for a lack of people in the area. It must therefore be the inability of the farmer to attract labour at a price people are willing to work for. If, for example there are 20 working days per month, even in the peak work month of March under advanced technology farm related activities will demand only 78% of the time of the available help. In ecozones III and IV it will be somewhat less because of needing less hectarage to make a living. In Ecozone III the peak month of March will require only 52 percent of the available farm family labour.

Irrigation: As mentioned in Section 5.3.2 there is difficulty in estimating the hectarages of land potentially irrigable since we do not have good water supply data. Nevertheless we have made an estimate in Section 5.3.2 on irrigation of an increased revenue of Shs.2,400 per ha. over what might be expected under rainfed advanced technology. If 50,000 ha. could be irrigated the increased annual revenue generated would be around Shs.120 million. That can buy enough maize to feed an additional 400,000 people. These revenue estimates are made on beans. There are more exotic high valued crops that, given the technology could raise returns. We reiterate that everything possible must be done to conserve and use water. Without an accelerated water and soil conservation program there is no hope for the area to sustain its current production let alone to meet population increases.

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6.3 INFRASTRUCTURE

6.3.1 Rural Water Supply

The most urgent need in the study areas as perceived by the inhabitants is an increased, dependable accessible water supply. This section considers the interrelationships between:

- water requirements
- water source
- water quality
- accessibility
- cost
- financing

Water Requirements

How much water do people need? They can probably survive on five litres per day. City dwellers often consume 400 litres per day and feel deprived if forced to limit consumption to 200 lpd. Above the survival minimum, domestic consumption is a function of cost, accessibility, quality and custom.

Livestock requirements are related to animal size, activity and health needs.

Agricultural requirements are a function of usage, efficiency of use, and in irrigation the evapotranspiration requirements of the crop and the water supplied by rainfall frequency, intensity.

Other local activities can create a demand for water: fish culture, recreation, industry, pollution abatement.

In preparing recommendations, one strategy is to establish target objectives, then develop a program to meet them. The GOK has set an objective of providing potable piped water to everyone by the year 2000. Ministry of Water Development (1977) objectives for water supply to rural households outside growth centers do not include piped water to all homes. Their objective is to provide water within a reasonable walking distance as follows:

i. within 1 km in high potential areas
ii. within 2-3 km in medium potential areas
iii. within 5 km in areas of lower potential and sparse population.

The following standards of service have been adopted: (MOWD, 1977):

	Water per head	
	Individuals	Grade Cattle
Individual connections	50 litres/day	75/litres/day
Communal water points	25 litres/day	50 litres/day

Percentage individual connections with 20 year design period:

Potential: High: 50%; Medium: 30%; Low: 10%

Institutions and trade centers: 80%

Discussion of Objectives

The supply of potable (World Health Organization standard) water to every Kenyan is certainly a worthwhile objective. Of immediate interest is the question of how to reach the objective. The rural survey results show that most rural residents of the study area must go more than five kilometers from home to find water during the dry season. The usual means of transporting it is on the backs of the women. There will inevitable be a series of progressive steps in moving from the current situation to the national objective. In examing a phased program the possibilities of linkages should be considered. Some of the more obvious are:

i. Securing multi-purpose water close to use points: water that can be used for supplementary irrigation of small garden plots or fruit and nut trees as well as for livestock and human consumption. This may require some sacrifice of quality. Possible sources include roof catchments, surface collection and storage in ponds, behind dams, and in cisterns.

ii. Tieing in technical and/or financial assistance for water supplies to individual and group water and soil conservation programs. The promise of a water supply can serve as a powerful incentive to action. For example, a subsidy for small surface dam construction can be tied to soil conservation works (terracing, grass strips or rangeland rehabilitation for example).

Water Source

Water sources in the area include boreholes, roof catchments, ground surface catchments, dug wells, rock catchments, sub-surface impoundments, springs, rivers and streams. Each of these sources is useful under a given set of circumstances. By far the most used sources of supply are the streams and rivers including shallow wells dug in their beds during the dry season. The popularity of this method is undoubtedly due to its low capital and operating cost and the relative scarcity of alternative low capital

sources such as springs. There may be some social benefits to the water carriers.

Each of these sources has dimensions of location, quality, cost (installation and operating), reliability of supply, quantity and possibly social implications. The selection of a water source for a specific group of people then becomes an exercise of measuring alternatives against these dimensions and against the user's own resources and where subsidies are feasible, the resources of the state.

High population densities favor central supply points with piped distribution systems because of economics of scale and for public health reasons.

Boreholes and springs are less likely to be bacteriologically contaminated than surface supplies. Sub-surface supplies are more likely to have higher dissolved mineral concentrations than surface supplies.

Effect of Cost on Water Source Selection: In most developing countries there is a long tradition of the rural populace not paying cash for water. The survey team has heard of instances in Machakos and Kitui where people living close to communal treated water supply hydrants will opt to walk several kilometers to a river for their water rather than pay a nominal price at the hydrant.

High government subsidies on water supply systems carry their own set of problems. The system competes with the rest of society for scarce shillings with the usual result that it is chronically underfunded. There is usually a direct correlation between water system efficiency and the financial responsibility assumed by the system users.

An equally hazardous fiscal policy is to use water system revenue from customers to finance other unrelated works such as schools, roads and garbage collection. When this is permitted it usually inhibits the buildup of adequate reserves to finance major repairs and other emergencies. This problem is unlikely to be an issue in the study area for a long time.

Another subsidy related issue in Kenya is whether to increase outside donor funding for water supplies. In contrast to funding of income generating enterprises where donor loans can be expected to generate sufficient revenue to retire the debt or at least meet recurrent expenses, domestic water systems contribute only indirectly to income generating activities. Each shilling of capital invested will require a corresponding outlay in recurrent costs. Unless water can be sold to the users, recurrent costs will come back on the national treasury. These recurrent costs may not attract donor funds except during the early operating stages.

A strategy is needed to increase water supplies in the study area that is fiscally realistic. Easy solutions

would have been implemented long ago.

Let us next examine the economics of some alternatives. Although the Machakos District Integrated Development Report (1977 p.5-5) expressed pessimism about the reliability of ground water resources in the area, we do not feel that they should be written off. Although there is no evidence supporting ground water use for large scale irrigation there does appear to be sufficient ground water for it to be considered a significant source for domestic use (Engineering Report No.4). The major constraints are probably more the lack of power and difficulty of maintaining and servicing pumping installations than an inadequate supply of water, at least for supplying 25 l/c/day in the study area.

The following sections assume sufficient water and capability of the MOWD to service borehold equipment and diesel generators. Both assumptions require careful analysis if boreholes are to be seriously considered. Also in the higher population density areas a rural electrification network would likely be much more satisfactory than installing diesel electric generators at each borehole.

i. Boreholes: According to the Engineering Report No.4, there is a fairly good likelihood of finding potable water at about 30 meters with an average flow of 42 litres/minute. Thirty meters depth is beyond the usual limit for lifting water manually. The average cost for developing a borehold (not counting dry holes) is about as follows:

Drilling (private contractor cost)	100,000 K/shs.
Plastic well casing	8,000
Electric submersible pump	45,000
Diesel electric generator	55,000
Storage tank	20,000
Total capital cost	228,000

Assuming that power from the diesel electric generator can be produced for an average cost (fuel, maintenance, repair) of Ksh 3/-kwh, the operation of an average borehole pumping 42 l/min over a vertical distance of 30 m for 8 hours per day at an efficiency of 50% requires about 4 kwh per day for a cost of shs.12/day. Pumps powered by solar energy cells are beginning to become financially interesting. They may eventually partially replace conventional diesel electric generating sets.

Based on a daily average per capita requirement of 25 liters, the average 42 l/min well could serve at 8 hours daily running time.

$$\frac{42 \times 60 \times 8}{25} = 806 \text{ people}$$

However, this should be cut back to say 600 to allow for less than 100% distribution efficiency. The daily per

capita cost, amortizing the equipment over twenty years at 8% interest is:

$$\frac{(228{,}000 \times .1019)}{365} + 12 / 600 = \text{shs.}0.13$$

The family cost at 8 per household is shs.1.00/day.

Ground Water Adequacy: Since there are no data giving the ground water reserves in the study area there is no way to confidently estimate how much water can consistently be withdrawn. Taylor reports (Soil and Water Management Report No. 4, Appendix 4) that the existing boreholes are subject to considerable annual fluctuation owing to variations in recharge and ground water levels. During prolonged droughts the less productive boreholes may fail completely. Since they depend on surface recharge, it is desirable to locate them near streams and reservoirs. Soil and water conservation practices can also signficantly increase ground water recharge. Taylor puts the number of boreholes he is confident could be developed at two hundred.

Number of boreholes needed: The number needed is a function of the demand and the distance people are willing to go for water. A few people are using boreholes to supply water for irrigation, according to Taylor, 8.6 percent of those drilled in the study area. The remaining boreholes are supplying water for human and livestock needs. If all the water for domestic consumption were to be supplied by boreholes, assuming the ground water reservoir could meet the demand, the number and annual cost would be about as indicated below.

District	Population	Population Currently Served	Borehole Deficit	Required Capital Investment £ x 10^6	Annualized Costs £ x 10^6
Machakos	798,500	88,800	1,180	13.4	1.6
Kitui	320,400	42,909	460	5.2	0.6
Embu	76,800	10,300	110	1.2	0.2
Total			1,750	19.8	2.4

If livestock are to be watered from wells, assuming 6 animals per family consuming 50 lpd each, the boreholes needed would increase by 130 percent.

Boreholes are a good source of high quality water. Assuming 600 people can be supplied from an average borehole, Table 6.3.1 has been generated to indicate the average and extreme walking distances people would have to go for water as a function of population density. Table 2 of the Report "Human Resources and Social Characteristics" gives population densities by location. One may therefore determine the average walking distance for any location by comparing the figures in these two tables if the locations were to be

totally supplied from boreholes.

Table 6.3.1 AVERAGE AND MAXIMUM WALKING DISTANCES TO BOREHOLES SERVING 600 PEOPLE EACH

Population Density Persons/km^2	Percent of Population in each Density: Machakos %	Machakos Cumulative	Kitui %	Kitui Cumulative	Embu %	Embu Cumulative	Average Distance, Farmstead to Borehole km	Maximum Distance, Farmstead to Borehole km
	5							
400		5					.49	.69
	6							
350		11					.52	.74
	0							
300		11					.56	.80
	12							
250		23					.62	.87
	7							
200		30					.69	.98
	13							
150		43		0			.80	1.13
	23		15					
100		66		15		0	.98	1.38
	19		33		52			
50		85		48		52	1.38	1.95
	12		36		48			
20		97		84		100	2.19	3.09
	3		13					
10		100		97			3.09	4.37
			3	100				

Table 6.3.1 is based on the assumptions that:

i. average distance = $(600/\text{population density}/2\pi)^{\frac{1}{2}}$
ii. maximum distance = $(600/\text{population density}/2\pi)^{\frac{1}{2}}$

Thus 85 percent of the people in Machakos would have to go less than 2 km for water. With a district population density of 91/km^2 the average walking distance would be slightly over one kilometer.

In Kitui about half the population would have to go less than 2 km for water.

These are of course all based on average borehole yields. A strategy of supplying domestic water from boreholes would require a capital investment to cover the study area of about K£19 (US$48) per capita.

If tenders for the drilling and supply of equipment for

1,750 wells were solicited, there should be some significant economics of scale.

The idea of installing 1,750 diesel electric generator sets in an area where there are not enough mechanics to properly service the bicycle population seems ludicrous. However, as mentioned earlier, there are no easy solutions. Moreover it is doubtful that the ground water supply could support such a large number of boreholes. Cutting down on the number of boreholes will necessitate developing other sources of water. At an average yield of 42 l/min, a population of 1.2 million people consuming 25 liters each per day would require 2,000 boreholes.

Since it is unlikely that boreholes will become the sole source of potable water let us examine other options.

Reticulated Water Supplies with Water Treatment: This refers to water delivered by pipeline. The higher the population density the more attractive a reticulated system becomes.

The Distribution System: For boreholes, as noted, walking distances were mostly less than the 2-3 km maximum allowed because of the average yield limit of a well. A centrally supplied reticulated system can be placed at any spacing. Lines spaced 4 km apart would meet the maximum walking distance constraint if hydrants are spaced at least every 4½ km.

The cost of borehole water per capita is more or less a constant. This is not the case with a piped supply. If the 2-3 km maximum walking distance constraint is applied, then per capita costs are inversely proportioned to the population density.

As mentioned earlier, the higher population densities favour piped water systems. From figures supplied by the planning division of MOWD, we estimate water treatment capital costs (exclusive of reservoir construction costs as would be the case if a plant were sited at the upper Tana reservoir) at about shs.76 per capita (breakdown in Table 6.3.2).

Pipeline costs are difficult to estimate because they will vary with the distance from the treatment plant to the users. Using a figure from MOWD of shs.111.45/M for PVC class 'B' pipe 150 mm diameter installed (1976 prices) and assuming a spacing such that the piping required to serve one km^2 of area is 1/3 km (maximum walking distance 2 km) gives a 1977 cost per km^2 for piping of 1000 x 111.45 x 1.15/3 = shs.42,700.

Table 6.3.3 shows the variation in treatment and pipeline costs with population density. Based on the cost assumptions presented, locations with population densities greater than 150/km^2 would be better off with reticulated

water supplies than borehole supplies.

Table 6.3.2 COST OF WATER TREATMENT WORKS TO SERVE 100,000 PEOPLE (10,000M^3 DAY)

Item	Cost kshs	Convert to M^3/day x 10^4 multiply by	Cost M^3/day x 10^4
Site works	39/m^2	3000	117,000
Sedimentation	3630/m^3	833	3,025,000
Rapid gravity filter	5318/m^2	417	2,200,000
Clear water tank	700/m^3	416	290,000
Pump house	2517/m^2	40	100,000
Administrative buildings	2046/m^2	80	164,000
Parking bay	146/m^2	120	18,000
Staff houses	1784/m^2	400	714,000
Total cost (per 10^4m^3/day)			6,628,000

Population served @ 100 lcd by a plant of 10,000 M^3/day =

$$\frac{10,000 \times 10^6}{100 \times 10^3} = 100,000 \text{ people}$$

capital cost of treatment = shs.66/capita, add 15% to bring it today's prices = shs.76/capita.

Table 6.3.3 COST OF WATER TREATMENT AND DISTRIBUTION PER CAPITA FOR SEVERAL POPULATION DENSITIES

Population Density	Treatment Works	Distribution costs/capita	Total
Pricing favours reticulated supplies			
400	76	107	183
350	76	122	198
300	76	142	218
250	76	171	247
200	76	213	290
150	76	285	360
Pricing favours borehole(1) supplies			
100	76	427	503
50	76	854	930
20	76	2135	2210
10	76	4270	4350

(1) On the basis of boreholes to serve 600 people each costing shs.228,000 for a per capita capital cost of shs.380.

Locations in Machakos having 150 people per km^2 or greater currently account for more than 50% of the population. In Kitui, no locations have this density. However Matinyani and Mulanga locations will approach 150 people per km^2 in about 12 years. If a 25 year planning horizon is used, with a population annual growth rate of 3 percent, those locations with a current population density of greater than $72/km^2$ will reach $150/km^2$ in 25 years. This will be about 35 percent of Kitui's population and 70 percent of Machakos.

Based on this data, we suggest that Machakos and Kitui use as targets to provide potable water the data presented in Table 6.3.4.

Table 6.3.4 SUGGESTED TARGETS FOR RETICULATED AND BOREHOLE WATER SUPPLY SYSTEMS

	Reticulated Systems		Boreholes	
	Population to be served	Capital cost	Population to be served	Capital cost
	$x\ 10^6$	sh $x\ 10^6$	$x\ 10^6$	sh $x\ 10^6$ 2/3
Machakos	1.2	240 (1)	0.5	190 (2)
Kitui	0.2	40	0.4	150

(1) Use shs.200/capita average
(2) Use shs.380/capita average

This gives a grand total of 620 million shillings, or if spread out evenly over 25 years, about 25 million shillings per year in 1977 shillings.

Surface Water Sources: Given the expected low yield of wells, a reticulated supply almost certainly means surface supply and treatment except for small population centers where water may be delivered from wells by pipe to the customer's residence or place of business.

Water treatment is an expensive operation. In the marginal lands the sediment load to be handled by a plant is likely to fluctuate seasonally. This complicates the operation and requires careful supervision of the process if costly system maintenance is to be avoided. In other words there are good arguments for large treatment plants.

The best alternative for piped water in the study area may be a single treatment plant at the upper Tana Reservoir to serve all of Machakos, Kitui and Embu. There are a number of factors to be taken into consideration in locating and sizing a treatment plant. Possibility of:

i. Serving areas outside the present study area
ii. Allowing for areas in the study area already served from other suitable sources

iii. Allowing for water systems about to be built such as the treatment plant on the Yatta furrow and pipeline from it to Kitui town. With 5 cusecs legally available from the furrow this source could provide for a population of one quarter million at 50 lpcd.

iv. Securing a firm water allocation from the Tana River Development authority.

v. The Machakos EEC financed program provides for a reconnaissance survey of the Athi as a source of water. Athi river water currently carries a heavy silt load. This will, it is hoped decrease with improved soil conservation methods. However, if Upper Tana water can be used to supply domestic needs, the best use of the Athi may be for irrigation.

The Upper Tana reservoir is high enough on the watershed to avoid most of the siltation problems that are going to continue to plague the smaller streams in the area. At an estimated population in the three districts in the year 2000 of something in excess of 3 million people, the plant should be sized to ultimately treat a minimum of 200 l/cd to meet domestic and livestock requirements or about 0.6 million cubic meters per day (162 mgd). This could be phased. The present need is for a plant about half this size. One strategy would be for MOWD to build the plant and several trunk mains. The District Development Committees could be used to plan and control the operation of distribution networks fed by MOWD trunk mains. The degree of involvement of DDC's in water distribution would require careful study. These are good arguments in favor of local control, especially if they are given revenue collecting authority.

If the proposals made elsewhere are implemented, there should be enough revenue generated from increased agricultural production to carry a significant portion (eventually all) of the operating and debt retirement costs of the system.

Boreholes and reticulated systems are suggested as the long term answers to domestic and livestock water needs. However, the Upper Tana Reservoir is not scheduled for completion before 1981. With the detailed planning that will be required and a more careful survey of the ground water resources it may take eight to ten years for these alternatives to start supplying a major portion of the study area. Moreover they do not address the water needs for irrigation. The short term domestic and irrigation needs also require attention. These will be discussed next.

Surface Water Catchment: The Machakos EEC financed program proposes the rehabilitation of approximately 93 earth dams. Earth dams in the district have not been outstandingly successful. Of the more than 800 that have been built over the years, many have fallen into disrepair or are badly silted (Machakos EEC report 1977 p.5-15). In addition to the

serious siltation problem, heavy flash floods are fairly common. It is difficult to design a small dam (especially earth dams) to withstand short, intense flood flows. They require careful siting, a good knowledge of the hydrology of the drainage basin, good design to ensure routing of the flood flows around the dam, careful attention to construction to ensure a proper combination of earth selected, moisture content and compaction and finally, adequate continuing supervision to ensure that the dam is not damaged by animals or vandals and that needed maintenance is performed in a timely manner.

In other words, earth dams are high technology structures. Unless the technology is there, the effort required to build them will likely be wasted. This does not mean that high technology can not be developed and installed in the study area. But it does raise the issue of whether such a major effort should go into surface dam construction when it might alternatively go into borehole exploration, construction and operation. Boreholes have a number of advantages (and a few disadvantages) over surface dams. They are more flexible in their siting, they produce bacteriologically safer water. They do not breed mosquitos or bilharzia carrying snails; they do not silt up or wash out and are probably less affected by single season droughts. The major disadvantages of boreholes are the need to have a qualified mechanic available to service the equipment and the risk of drilling dry holes.

Cost of Dam Construction: Figure 6.3.1 shows two costs for earth dam construction. Curve 1 is based on figures for mechanical construction supplied by the Ministry of Water Development Dam Construction Unit. Curve 2 is based on limited data collected by the Small Irrigation Projects Section of the Ministry of Agriculture for hand labour. As would be expected, hand labour is cheaper for small reservoirs below 135,000 m^3 storage capacity.

Optimum Reservoir Size: Reservoir size will be a function of runoff drainage area, demand, technology constraints, site topography, evaporation and seepage losses and economics.

Runoff data is not well documented in the study area. A MOWD commissioned study by TAMS extrapolated runoff from the study area. An annual average runoff figure of 40 mm was estimated as typical of ecozone V which covers 66% of the study area.

Assume the following:

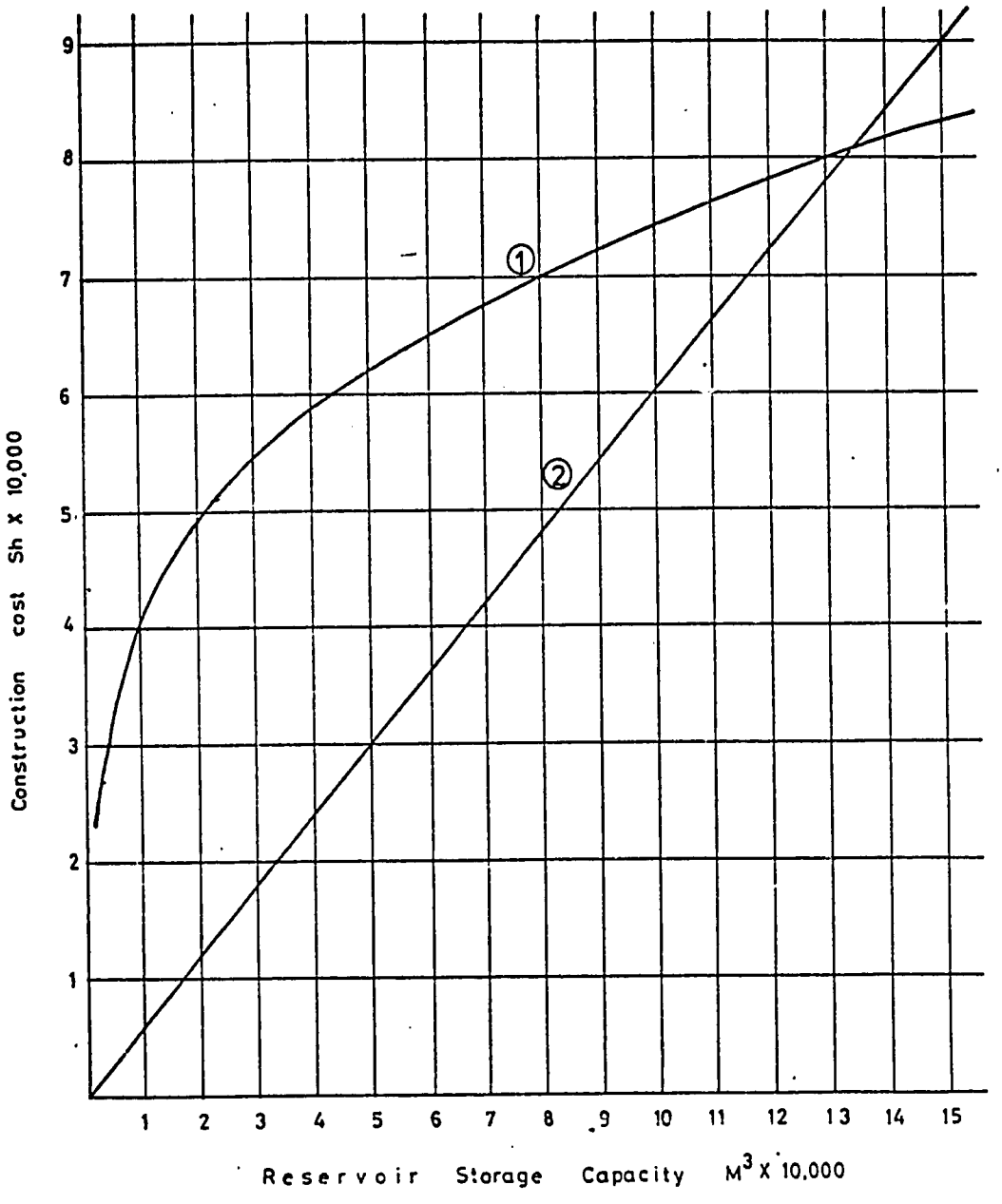
i. One year's storage required
ii. Domestic and livestock demand is 100 lpcd
iii. Fifty percent of water impounded is evaporated or lost through percolation
iv. Fifty percent of reservoir is taken up by dead storage and siltation.

Figure 6·3·1

Cost of Reservoir Construction with Earth Dams
in Machakos/Kitui

Curve ① Using MOWD Dam Construction Unit

Curve ② Using hand labour
(Data from Small Irr. Projects section MoA)



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The reservoir size needed per 1,000 people is therefore:

$$\frac{100 \text{ lpcd} \times 1{,}000 \text{ people} \times 365 \text{ days}}{1{,}000 \text{ l/m}^3 \times .5 \text{ (losses)} \times .5 \text{(silting)}} = 146{,}000 \text{ m}^3$$

At an annual runoff rate of 40 mm this could be collected from a catchment area of

$$\frac{146{,}000 \text{ m}^3}{.04 \text{ m} \times 10{,}000 \text{ m}^2\text{/ha}} = 365 \text{ ha.}$$

However, the 40 mm is based on average precipitation. If one uses the idea of dependable precipitation and defines it as the minimum rainfall that can be expected eight years out of ten, then only 58% of the average will be received on a dependable basis. This would require a drainage area of 630 ha/1,000 people.

The population of the study area is estimated at 1,092,000. At an annual increase of 3% they will increase to over 2 million by the year 2000. If they were to get all their water from surface reservoirs one and one-quarter million hectares of land would be needed to collect the precipitation or 70% of the total land area.

Estimating per capita costs of small surface storage dams: using the hand labour curve of Figure 6.3.1 gives a cost per capita of

$$\frac{8.3 \times 10{,}000}{1{,}000} = \text{shs.}83.$$

There would be land acquisition, fencing and for domestic use, treatment costs on top of this but even tripling this figure to shs.250/ per capita, it is only about two-thirds the cost of boreholes.

With the uncertainty of the numbers, and the generalizations made here, from a cost point of view, one cannot say that surface reservoirs are always less costly than boreholes. There will be local features, topography and geology that will determine the advantage of one over the other.

A much more important decision is where to opt for surface dams and boreholes rather than a reticulated central system. The cost and technology levels are so high that boreholes and surface dams cannot be used as stopgap, short-term solutions. It can be a mix of surface dams (with some form of treatment) and boreholes or alternatively reticulated water supplies but not a series of dams and boreholes to be replaced after 10 years with piped water from a central facility, unless, as discussed under "Irrigation" surface reservoirs are built for supplemental irrigation.

Let us now consider some short-term alternatives.

Subsurface Dams: These are described in the engineering report. They have been quite successful in the study area. However the conditions needed to install them limit their use to a fairly small portion of the population. There are some 200 in Machakos. At an average population density of 90 people per square kiometer, if walking distances are to be kept to 3 km they could, if appropriate sites could be found provide untreated water to half a million people. They are less vulnerable to washing out than surface reservoirs and if properly constructed do not silt up.

They are built of masonry and/or concrete and must be carefully sited. For a subsurface dam to service an area with a three kilometer walking radius at 90 people per km^2 requiring 75 lpcd for domestic and livestock requirements, a year's storage would require about 70,000 m^3 storage capacity. We are not aware of any in the study area that hold over 20,000 m^3.

Considering their low installation and maintenance costs we believe that more reliance ought to be placed on subsurface dams than on surface dams and that a reconnaissance team be assigned to identify all feasible subsurface dam sites.

Water Harvesting: This refers to collecting water from a small area such as the roof of a dwelling, a rocky hillside or even a small catchment area. It is usually small serving the needs of one or a few families. There are two main requirements, an area to collect rainwater and a place to store it. Roof catchments offer an attractive possibility. Another is to cover an area with black plastic sheeting and funnel the water collected into a storage tank.

Assuming a dry season lasting five months, a family of eight with eight head of cattle would need to store

$$\frac{8 \times 75 \text{ lcpd} \times 5 \times 30}{1{,}000} = 90 \text{ m}^3 \text{ of water}$$

This could be stored in a tank 2m deep by 9m by 5m. Assuming a seasonal rainfall of 300 mm and a collection efficiency of 80%, the area required to harvest this much water is

$$\frac{90 \text{ m}^3}{.3 \times .8} = 373 \text{ m}^3, \text{ about a square 20 m to a side.}$$

Materials required are black heavy plastic or butyl 375 m^2, 80 m of fencing, a concrete tank and a hole to set the tank in. An estimate for the cost is

Plastic @ shs.2/m^2 = shs.750
Concrete tank with walls 15 cm thick
.15 2 (9x5) + (2x9) + (2x5) = 22 m^3 of concrete.

at shs. 400/m^3 for concrete the cost of the tank is shs.8,800.

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The overall cost (ignoring the fencing) is shs.9,000 or shs. 1,125 per capita. This is three times the borehole cost but only 30% more than the borehole cost if we add an equivalent livestock demand to the boreholes. An advantage of water harvesting is that it is a low technology activity. The key to its success is to get the cost of a storage container down to a more reasonable figure. At the moment, the only group studying this problem that we are aware of is the UNICEF Village Technology Unit at Lanet. There is an urgent need to develop large cheap water storage tanks for individual farms.

Springs: In the Machakos/Kitui/Embu area these are few and far between. The Baringo/Kerio Valley has more possibilities, especially along the escarpments. They should be fully exploited since they will usually provide the cheapest, cleanest source of any supply.

Short-Term Water Supply Programmes: It is argued elsewhere that there will be years of crop failure under rainfed farming, especially in ecozone V which covers about two-thirds of the study area, even using advanced technology. If the area is to become self sufficient in food, either improved storage facilities must be installed to carry over wet-year surpluses or/and supplemental irrigation is needed. Table 6 p.170 in the Economics Report No.3 gives the agronomists' estimates of yields which can be expected under irrigation. It seems therefore that there are good economic reasons for vigorously promoting irrigation works, of which the principal water sources will likely be small earth dams.

In spite of the high technology features of these structures they probably offer the best alternative for irrigation along with the water in the Athi, the Ikoo and Thua Rivers which have potential for supplying large scale irrigation systems if suitable reservoir sites can be found. With appropriate incentives and technical assistance, many can be built. These can temporarily supply domestic water, admittedly of inferior quality until piped or well water is made available, after which their use should be restricted to irrigation and livestock watering. Concurrently, bilharziasis and malaria control programmes should be intensified.

Summary of a Rural Domestic Water Supply Programme:

Short Range:

i. Develop all existing springs
ii. Develop cheaper on-farm water storage tanks and set aside 400 m^2 or so on each farm to harvest water
iii. Locate more sites for subsurface dams and begin construction
iv. Locate sites for surface dams and build them but orient their major use to supplemental irrigation.

In connection with these four activities, it may be that a breakthrough in lowering the cost of on-farm water harvesting and storage will obviate the need for boreholes in many areas. This should be researched more intensively.

v. Investigate suitable sites for water treatment works with particular attention being paid to the feasibility of siting one at the Upper Tana Reservoir.

vi. Depending on the success of (ii.) above, make a decision on intensification of ground water exploration. In the early stages of the water storage tank research ground water investigation could begin to accelerate but it should be held back somewhat pending the outcome of the storage tank development project which may result in a cheaper alternative to boreholes.

6.3.2 Soil and Water Conservation

Over the long term viable farming in the area is dependent on improvements in soil and water management. Moreover, for the present, rainfed agriculture offers the prime opportunity for development, given the limited opportunities for irrigation. *Many of the crops grown in the area have reduced yields because of inadequate soil moisture. Yet, study team members generally agree that the level of rainfall in the area is usually sufficient for the types of crops grown provided better use is made of the rainfall that does occur. This can be accomplished through improved soil and water conservation measures, such as proper tillage, grass stripping, contouring, mulching and terracing. The yields assumed for the cropping packages for intermediate and advanced technologies are predicated on appropriate means for conserving available moisture, controlling soil erosion and upgrading soil fertility.

As noted from the earlier analysis, soil losses may represent an immediate threat to cropping yields, except in a few localized areas. Soil conservation measures are urgently needed to maintain present soil depths and fertility. Over-grazing can lead to near-term losses of ground cover and eventual loss of natural range grasses. Rangeland is then lost to production, or requires expensive corrective measures. Soil losses also cause downstream problems related to flooding, siltation of reservoirs, water treatment, and the like.

Consequently, a comprehensive program of soil and water conservation should form an integral part of the area's development. Benefits will accrue to cropping, ranching, and downstream uses. Approaches to conservation such as controlled grazing and improved tillage have been described in the separate technical reports. This section of the final report describes some of the physical facilities that should accompany improved cropping technologies. These facilities include terracing, grass strips, cut-off drains, grassed waterways, and related facilities. Forestry, as will be remembered, has been evaluated for its productive use as fuel and poles. Without doubt, forestry has a role to play in watershed management. But the relative merits

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* Recall that the hydrogeology study was pessimistic about the opportunities for irrigation from ground water. Also, suface storage encounters problems with watershed maintenance and siltation, large-scale programmes require considerable funds and lead time, and although many of the soils are suitable for irrigation appropriately located reservoir sites are still to be identified.

of this means of protection as compared with improved grasses and rangeland management remains to be tested. The direction the GOK takes concerning soil and water conservation will depend in no small measure on its administrative capabilities and the difficulties of alternative means of controlling land use.

Conservation Works*: Grass strips and terracing are proposed for cropping under intermediate and improved technologies. The bana and natural grasses proposed for eco zones, two through five can be planted between the other crops and thereby accomplish the purpose intended for grass strips. This approach to erosion control which does not involve additional investment, can be used for the flatter slopes. Opinion differs concerning the upper limit of slopes for grass strips. For the purpose of estimating the magnitude and location of grass stripping, slopes up to eight percent have been assumed appropriate for this means of erosion control.

Terracing by the fanya juu method is proposed for slopes above eight percent. This method involves excavating ditches (about 0.5 square meters cross section) along the contour and placing the excavated soil on the uphill side of the ditch. Grass is planted on the ridge and in the ditch to preserve the cross-section. With time the land between the ditches tends to become level as a result of the downhill movement of the soil and from cultivation.

Other works should also accompany terracing and grass strips. These include cut-off drains and grassed waterways, as well as other control measures. Cut-off drains of nearly twice the cross-sectional area of the fanya juu ditch are needed to intercept run-off and thereby help to preserve the terraced and grass-stripped areas. According to Wenner drains should be placed midway on slopes of 200 meters or less. Additional drains are needed for longer slopes. Grassed waterways, if they do not exist in natural form, should be developed to receive run-off from the drains, terraces, and grass strips. In estimating area-wide requirements, cut-off drains have been considered necessary for slopes above five percent, i.e. for mapping units with C slopes and above. Requirements for waterways and related improvements are specific to the site and cannot be easily generalized.

Areas recommended for terracing and grass strips, based on potential land use, are shown in Figure 6.3.2.

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* Much of the following discussion on conservation methods and costing comes from "Soil Conservation in Kenya" by C. D. Wenner, Land and Farm Management Division, Ministry of Agriculture, Nairobi, 1977.

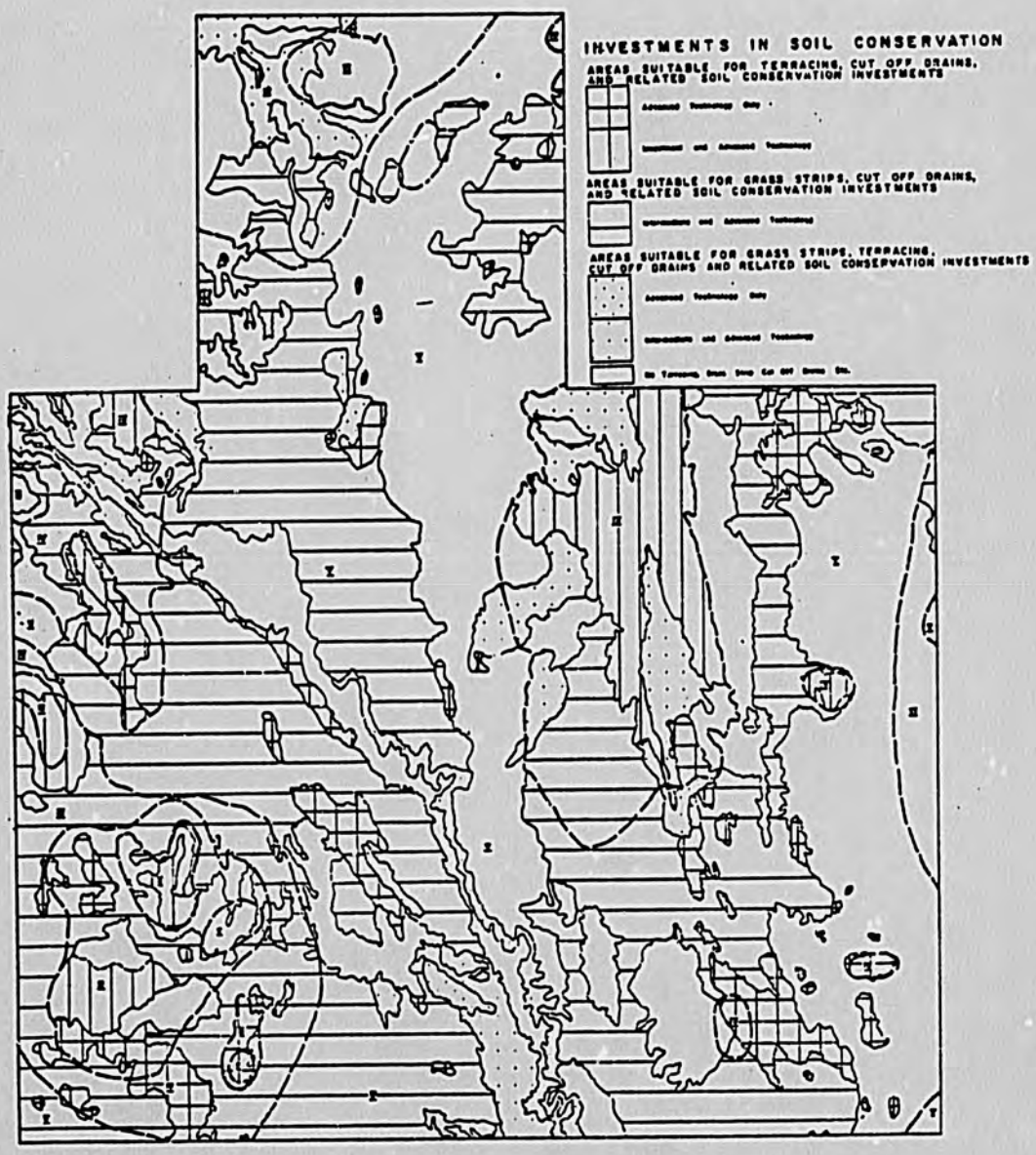
INVESTMENTS IN SOIL CONSERVATION
AREAS SUITABLE FOR TERRACING, CUT OFF DRAINS, AND RELATED SOIL CONSERVATION INVESTMENTS
AREAS SUITABLE FOR GRASS STRIPS, CUT OFF DRAINS, AND RELATED SOIL CONSERVATION INVESTMENTS
AREAS SUITABLE FOR GRASS STRIPS, TERRACING, CUT OFF DRAINS AND RELATED SOIL CONSERVATION INVESTMENTS

Figure 6.3.2

This figure gives the locations for terracing and grass strips according to two levels of cropping technology: (1) advanced technology only and (2) either advanced or intermediate technology. Mapping units with soils suitable for advanced and not intermediate technology are of generally poorer quality than the others. Soils of this type are rated as unsuitable (D category) for intermediate technology and marginally suitable (C catagory) for advanced technology.

The unmarked portions in the figure represent areas in which crop-related investments in conservation are probably not required, either because the slopes are nearly flat or the areas are unsuitable for cropping.

Cost Estimates: The principal element of cost in constructing the terraces and cut-off drains will be for hand labour to excavate the trenches. Such labour will also be required to plant grass along the terraced edges and to maintain these facilities. As noted in the appendix: A Note on Benefit-Cost Analysis, unskilled labour costs for terracing are shadow priced at 50 percent of the going wage. Local wages in the area during the 1977 period averaged six shillings per day, according to Wenner's reports. Should local farmers donate their time to this work during periods of inactivity, even those reduced costs for unskilled labour may overstate the real costs to society.

Mechanized means of construction have not been recommended partly because of the difficulty of operating equipment on steep slopes and in remote areas and because of the Government's desire to provide employment opportunities in rural areas. However, should terraces need to be constructed quickly or if rural labour is in short supply the Government may wish to reconsider this approach to construction.

In addition to the cost for excavation and grassing, costs are also incurred for tools, job supervision, and planning the work. Cost data were not readily available for these items so that approximations were made based on experience with similar types of activities. Similarly, data on maintenance costs for terraces and cut-off drains were not encountered. A value of 15 percent of excavation costs was assumed for annual maintenance of these two items. Details of these estimates are provided in Appendix IV.

As noted earlier, other soils and water conservation investment should accompany terracing, grass strips and cut-off drains. But as with some of the other items costs for grassed waterways, diversion structures and the like are both site specific and not

readily available. For want of better information, the costs of these ancillary works were taken as being equal to those of constructing the cut-off drains. Such rough calculations are believed adequate for planning at the reconnaissance level. Certainly, more detailed estimates are required when proceeding to the design phase.

The study area contains approximately 1,100,000 hectares of land suitable for cropping that could benefit from investments in terracing, cut-off drains and related soil conservation works. This amount represents total possibilities for terracing based on soil suitability, eco zone, and slope of the land. Data were not available on land currently under terracing and grass strips. Consequently, this estimate represents the level of possible development rather than an amount remaining to be accomplished. Specific opportunities for such soil conservation works calls for more detailed investigation. Nevertheless, the total gives an order of magnitude of the possibilities and Figure 6.3.2 provides information on locations. The estimate of the total potential assumes that 90 percent of the lands suitable for intermediate and advanced technologies can be cropped under terracing and grass strip conditions and that 75 percent of the lands suitable for only advanced technology can be so developed. The reduction for the latter condition is based on the generally poorer quality of these soils. Moreover, the total excludes: (1) soils suitable for cropping on slopes less than 5 percent, where strips of bana and natural grasses are considered sufficient for conservation purposes, (2) soils unsuitable for cropping (soil class D) and (3) eco zone six, which is not recommended for rainfed crops.

The total is divided into 1,000,000 hectares (793,000 hectares for cut-off drains and grass strips and 209,000 hectares for terracing) for areas suitable for intermediate and advanced technologies and 10,500 hectares (7,500 hectares for cut-off drains and grass strips and 94,000 hectares for terracing) for areas suitable for advanced technologies only. The latter constitute soils of lower quality, which require advanced technologies if suitable crop yields are to be obtained. Also, the added cost of terracing in some cases will make forestry and range livestock economically more attractive.

Summing all of the investment possibilities gives a total of 694 million shillings. Of this amount 574 million shillings are for terraced areas and 120 million shillings for grassed areas. Annualizing the above at eight percent interest for a life of 75 years produces

an equivalent annual value of investment of 56 million shillings*. This coupled with an annual maintenance cost of 51 million shillings, gives a total equivalent cost of 107 million shillings per year. Unit costs per hectare average 244 shillings per year for terraced areas suitable for intermediate and advanced technologies. Given the level of net operating returns for ecozones three and four (ranging from 600 to 1,580 shillings per hectare) such an investment appears within reason except for the areas with lower yields. Terracing on class C soils in ecozone V is only marginally attractive. The arguement in favor of soil and water conservation is even stronger for grassed areas, where terracing is not needed. Terracing in these lesser attractive areas appears to be unattractive except under advanced technology.

The foregoing values on conservation are shown in Table 6.3.5. Details of these results according to ecozones and mapping units are found in Appendix IV Tables IV.1 and IV.2

Benefit Estimates: The general nature of benefits from these conservation measures was described at the outset of this section. The specific benefits show up in the increased yields over time. But part of the measured yields results from other improvements to cropping practices. Considering the Government's long term desire to make use of marginal lands, the proposed set of conservation measures are considered as an essential feature of improved cropping packages. Consequently, conservation measures need not be tested individually, but only as part of an overall package of practices. Should the net result of the improved package (including costs of conservation) be positive, the scheme is economically viable. Alternatively removing the costs of conservation, to improve the economic returns, is not considered as an acceptable alternative to be tested.

But even were the results of the foregoing analysis to turn out negatively, a case can be made for conservation because of the downstream benefits to others. These so called "externalities" do exist, but their

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* Initial investment costs are converted to equivalent values by multiplying them by $\frac{i(1+i)^n}{(1+i)^n-1}$, where i is the interest rate of 8 percent and n is the 75 year assumed life of the investment. For large values of n, the factor approximates the interest rate itself.

Table 6.3.5

Cost Summary for Terracing, Cutoff Drains and Other Water and Soil Conservation Measures for Machakos--Kitui--Embu

Activity	Potential Area (000 ha)	Investment Average Unit Cost (shs/ha)	Investment Total (Million shs/yr)	Annualize Investment at 8% Interest Average Unit Cost (shs/ha)	Annualize Investment at 8% Interest Total (Million shs/yr)	Annual Maintenance Average Unit Cost (shs/ha)	Annual Maintenance Total (Million shs/yr)	Annual Totals Average Unit Cost (shs/ha)	Annual Totals Total (Million shs/yr)
Terracing and Related soil conservation works for soils suitable for:									
Intermediate and Advanced Technologies	208.6	1,510	315.0	121	25,2	123	25,8	244	51,0
Advanced Technologies only	94.3	2,740	250,7	219	20.7	177	16,7	396	37.4
Cutoff drains and Related soil conservation works associated with grass strips, for soils suitable for:									
Intermediate and Advanced Technologies	791.4	151	119.6	12	9,6	11	8.7	23	18.3
Advanced Technologies only	7.5	63	0.5	4		7	*	11	0.1
TOTALS	1,101.8		693,8		55.5		51.2		106.8

* Less than 0.1

extent and magnitude are not particularly easy to measure. This task, if deemed necessary, should be part of follow-on studies.

Project Possibilities

Government programmes to raise the level of technology for crop farming should incorporate the above-mentioned measures of soil and water conservation. This effort can be facilitated in a number of ways. Following are three possibilities.

Current Activities: The conservation group in the Land and Farm Management Division of the Ministry of Agriculture has an expanding program that concentrates on this very topic. Training and field investigations are currently receiving technical and financial assistance from SIDA*. The afore-mentioned reference by Wenner is one of the outputs of these activities. With an expanded program in the Machakos - Kitui - Embu area, additional training investigations and supervision of construction will be needed. Funds to build or subsidize cut-off drains, improvements to waterways, and other communal facilities will be another requirement. This conservation group appears to be the logical one deserving support for this work.

Soil and Water Conservation Research: Considerable information will be needed if the Government is to launch an expanded program in soil and water conservation. For instance little data are available on mechanical techniques for soil and water conservation. Rainfall intensities and runoff characteristics should be measured within the area, alternative conservation techniques need to be tested in the field and results monitored over time, comprehensive costs need to be compiled for maintenance as well as for construction, the economics of erosion losses and investments using the universal soil loss equation and other approaches ought to be further examined, and soon.

Given the need to conserve water and the Government's commitment to development of the marginal and semi-arid lands, provision of a solid foundation of research data and methodology is fundamental. A program to develop such a body of knowledge could be incorporated in an expanded organization devoted to soil and water conservation.

Soil and Water Conservation Division: Elements of a new soil and water conservation division were presented by the study team during the Mid-point Review.

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* Swedish International Development Authority.

Some form of organizational expansion is in order, if the above programs and activities are to be implemented widely in the project area and elsewhere in the country. The nature of such an organization, its position within the Government, staffing requirements, sources of finance and technical guidance are all issues that can be taken up as part of the project design.

6.3.3 Roads

The arguments for more all-weather roads are already well known. Only those farmers who are sure they can get their produce out to market in a timely manner will decide to go into intermediate and advanced technologies. We don't know just how close to a person's farm a road has to be in order for him to decide he can enter the market system. It is a function of the type (weight, bulk) and value of the produce, the type of inputs; fertilizers etc. needed, the roughness of terrain between his farm and the road, the means he must use to transport his goods to the road, and, no doubt, other considerations.

GOK can influence very strongly where to promote changeovers to more advanced technologies by the way they expand the road system.

Professor Mutiso has made recommendations for upgrading existing roads and installing new ones based on the expressed needs of the district development committees. (Institutions Report No.7) If the area develops in the manner depicted in Figure 6.1 the roads required will have to be significantly increased.

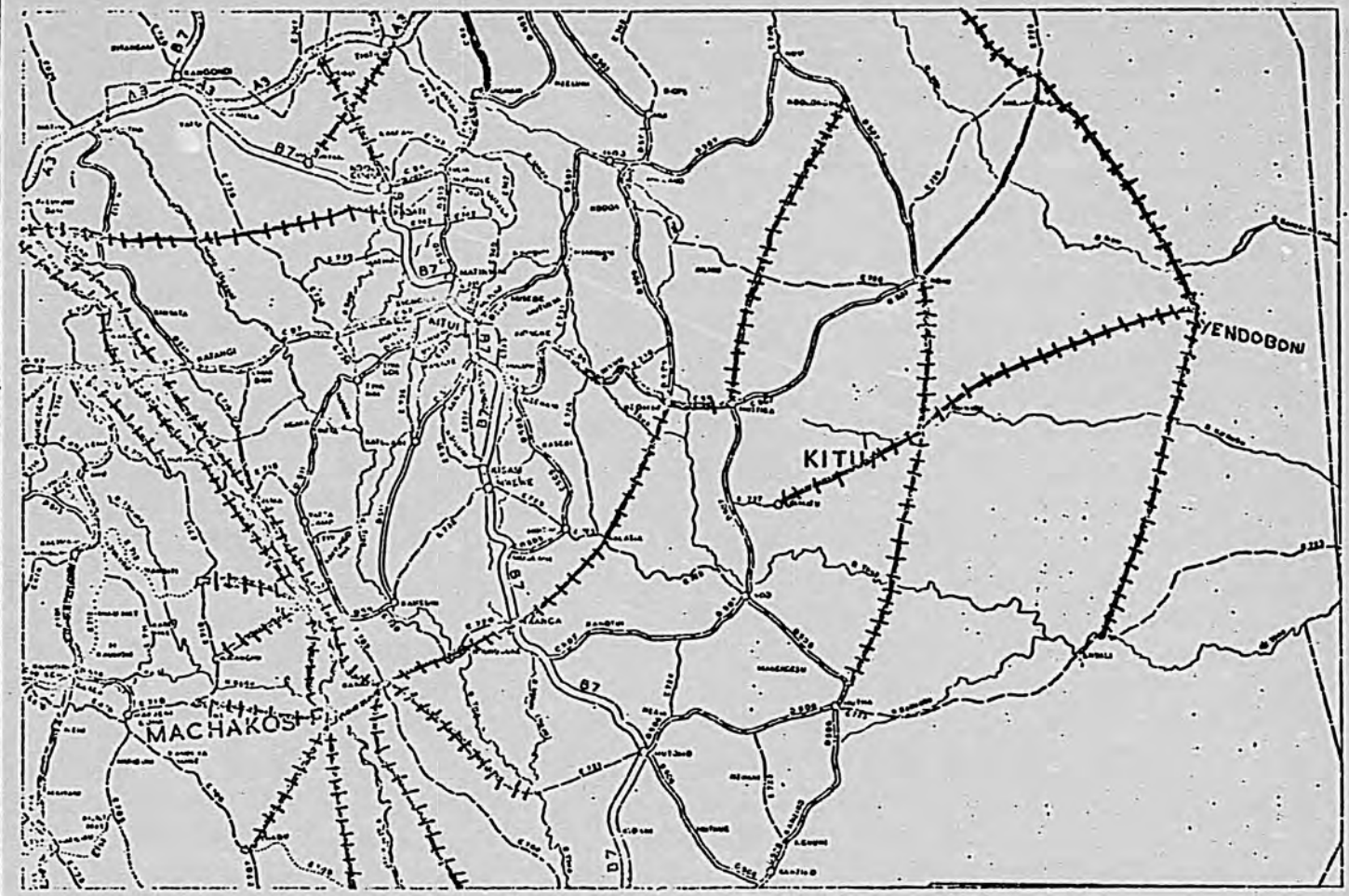
If it is assumed that as an initial target, roads should be within three kilometers of every farmstead then a total of at least 3,000 km of roads are needed in the project area.

In the attached figure 6.3.3 copied from a MOW Roads Department map there are about 300 km of A, B, and C class roads and about 450 km of class D roads serving an area of about 16,000 km^2. This is a density of .05 km of road per km^2 of area. Of course it is not evenly distributed. Additional roads proposed for this area in our Institutions Report total about 600 km, bringing the total to about 1,350 for a density of 0.08 km/km^2. If the roads were evenly distributed this would bring the total up to about half the kilometers need to provide roads within 3 km of everyone. There are of course many kilometers of non-classified roads which can best be described as dry weather trails.

All-Weather Roads: As any resident in the study area will verify, there are often weeks and months when many farms are cut off from markets because of the condition of the roads. The most serious problems are at the stream crossings which, although dry for most of the year can become impassible torrents during the rainy season.

Bridges are infrequent and even the concrete drifts (fords) are limited to the major roads. We have a figure of 25 bridges which the DDC's have recommended for the three Eastern Province Districts.

In the Baringo/Kerio Valley area 208 km of new roads,



Proposed new roads

ROAD MAP OF KENYA

KITUI

Figure 6.3.3

SHEET No. 35

ROADS DEPT.

SRG No. MR/499

Best Available Document

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280 km of roads to be tarmaced, 40 km of roads to be upgraded and 7 new bridges are proposed. See Chapter 4 of the Institutions Report for a discussion of the roads and needs.

Mechanized vs Hand Construction: We have listened to arguments both pro and con on the issue of whether one can construct roads satisfactorily with hand labour. It appears to be a tradeoff problem between time loss in using hand methods and more satisfactory money distribution to local labourers rather than foreign heavy equipment suppliers. Our suggestion is to develop a master plan with a timetable, then program the construction of roads to fit the timetable using all the available hand labour that will still permit keeping to the timetable. Production losses occasioned by unnecessary delays in road construction caused by labour bottlenecks would be false economy.

6.3.4 Rural Health

We have looked at some of the rural health problems in Chapter 18 of the Institutions Report. Although health is of vital concern to each of us personally, it is a less direct concern to mounting a successful production increase programme. It is true that healthy workers are more efficient, productive people so public health does contribute to production. But from a purely pragmatic point of view it, unlike access roads, markets, seeds, etc. is not an essential element.

Nevertheless we have proposed a programme for rural health improvement. This will provide for a mobile health delivery system, health supplies procurement, increased numbers of rural health centers, a disease prevention project, research on the referral system and an environmental health (pollution control) project. Details are in Section 7.7.A suggested level of funding is at shs.38.2 million.

6.3.5 Institutions

If a program of the scope proposed in these documents is to be attempted it will have a major impact on the national, provincial and district institutions. We assume that no one in government supervisory roles is not busy with his current assignments. Professor Mutiso has reported on the major institutions affecting the study areas. The reader is referred to his Report No. 7 of this series. We can only comment here that expansion up and down the line in MOA, MOWD, MONR, MOW, MOH, MOL&S and other institutions such as the Kenya Seed Company will necessarily follow a decision to go into this development programme. Where to find the people who must perform in a coordinated manner all the components of the programme is indeed a challenge.

The Machakos Integrated Development Programme will hardly be far enough along to begin to be evaluated insofar as its organizational components are concerned. We suggest than an organizational planning team be set up in the Ministry of Finance and Planning with representation from senior levels of the above named ministries to evaluate these documents, decide on how to finance those components found acceptable to determine how best to organize in each ministry, what sort of overall control is needed, how to get the additional supervisory staff, and how to carry foreward the inventorying and analytical work into the other semi-arid areas of Kenya.

We have proposed a rather specialized project of assisting the field supervisors in MOA to handle their expected increased work load (see 7.8.1), but the overall grand strategy we have left to the senior officers of the responsible ministries.

CHAPTER 7

IMPLEMENTATION

One of the terms of reference of the study team was to identify development projects in the Machakos/Kitui/Embu study area. No specific definition of what constitutes a project nor how much detail to include was provided in the project agreement.

We have therefore tried to meet the needs of the signatories based on a number of discussions with their staff.

The reasons for selecting these particular projects when others could have been included are related to the team's professional orientation, items specifically mentioned for inventorying in the project agreement, the discussions of the mid-point review and the time constraints of the project.

We have wrestled with the issue of family planning as mentioned in the chapter on key issues. However we have not included it as a specific project: not that we do not believe it is an important issue. Rather the professional composition of the team did not include anyone who felt he could make a contribution that would be particularly helpful to those responsible for family planning in Kenya. We have not suggested projects for reviewing the laws that affect the lives of people in the semi-arid lands in the belief based on experience elsewhere that foreign donors are unlikely to be able to make significant contributions to this very socially sensitive area.

What we have tried to do is identify projects that will materially assist in raising agricultural production and the standard of living of the people. The production oriented projects should receive the highest priority. If people have an income the infrastructure projects-rural water supply, clinics, roads will follow much more easily. However this may not be the order of priority of the people living in the area.

We have indicated project interrelationships but have not drawn up a comprehensive project timetable. Before that can be done GOK will need to make a number of decisions; where to site projects; should they be tied to district boundaries; should more projects go into Machakos having in mind the EEC funded project now getting under way?

We have written the projects with the entire Machakos/Kitui/Embu study areas in mind in the belief that much more can and ought to be done in Machakos than can be handled with the present EEC funding level. This assumes that the district institutions can gear up to accept more projects.

We feel a little presumptuous in our cost estimating

since that is really the job of the design teams. However if reviewers will accept our caveat that the figures are really orders of magnitude (i.e. when we say a project will cost four million shillings we mean it will cost more than 400 thousand and less than 40 million shillings) it may help in ordering design priorities.

Some of the projects have been grouped together and called programmes. This is merely an effort to simplify by classification.

Table 7.9 at the end of the Chapter is a summary showing estimated professional requirements for design and project cost estimates.

The following programmes are suggested for the Machakos/Kitui/Embu area:

7.1 Crop and livestock development
7.2 Soil and water conservation
7.3 Afforestation
7.4 Rural roads improvement
7.5 Rural water supplies
7.6 Large scale irrigation
7.7 Small scale irrigation
7.8 Improved rural health services
7.9 Systems and procedures development programme

We have broken each programme down into sets of projects as follows:

7.1 CROP AND LIVESTOCK DEVELOPMENT

7.1.1 Seed breeding, multiplication, drying storage and distribution
7.1.2 Provision of dairy cattle for milk and ploughing and improved oxen
7.1.3 Improved tillage implements
7.1.4 Improved insect control
  i. crops
  ii. livestock
7.1.5 On-farm crop storage
7.1.6 Crops and livestock marketing including marketing of dairy products
7.1.7 Improved veterinary services including artificial insemination
7.1.8 Fertilizer supply
7.1.9 Technology training packages
  i. for farmers and ranchers
  ii. for extentionists
7.1.10 Credit and drought insurance
7.1.11 Dryland and irrigated farm research into exotic crops

7.2 SOIL AND WATER CONSERVATION PROGRAMME

7.2.1 Hydrology
7.2.2 Soil and water conservation structures
7.2.3 Technology training packages
  i. extensionists
  ii. farmers
7.2.4 Rangeland renovation

7.3 AFFORESTATION PROGRAMME

7.3.1 Nursery and seedling distribution project

7.4 RURAL ROADS IMPROVEMENT

7.5 RURAL DOMESTIC/LIVESTOCK WATER SUPPLY

7.5.1 Design and construction of large scale system(s)
7.5.2 Small scale water supply

7.6 IRRIGATION PROGRAMME

7.6.1 Large irrigation projects
7.6.2 Small irrigation projects

7.7 RURAL HEALTH AND NUTRITION

7.7.1 Mobile health delivery system
7.7.2 Administration and procurement of supplies for existing rural health facilities
7.7.3 Construction and staffing of rural health centers
7.7.4 Environmental health project
7.7.5 Disease prevention
7.7.6 Research on referral system

7.8 SYSTEMS AND PROCEDURES DEVELOPMENT PROGRAM

7.8.1 Ministry of Agriculture

7.9 PROJECT INTERRELATIONSHIPS

Within programmes, projects are interrelated; some cannot proceed until others have been completed. Some must take place concurrently while others can proceed independently. Some projects have a high degree of interdependence, some have a low degree. These relationships are explained in more detail in the project descriptions.

7.10 PROGRAM AND PROJECT DETAILS

(7.1) Crop and Livestock Development Program

Background: As already discussed in Chapter 5, the key to survival in the study area lies in improving crop and livestock production while maintaining a stable ecological environment; one which can support the population demand indefinitely. This program, together with the other seven are proposed to accomplish this.

Improvement will undoubtedly take place incrementally. It seems doubtful that a farmer can progress from traditional to advanced technology without passing through some of the intermediate technology activities en route. It would have been nice to have found a "domino effect" strategy where intervention by, say, government in only one aspect of production automatically generated momentum in all the other components. People have hoped for such effects from "miracle" seeds and supervised credit. We are skeptical of such easy solutions for the farmers of the semi-arid lands of Kenya. It seems that massive, multifacited intervention is needed. This inevitably means a high level of management and commitment by farmers and change agents alike. Limited or half-hearted intervention will not stem the slide into disaster for the inhabitants of these lands. One might successfully argue against the steepness of the trend of the production loss displayed in Table 3.3 but we believe data on its direction. Halting desertification in most of Machakos, Kitui and lower Embu is not a subject for deferral to the twenty-first century. As of today over 25 percent of the land in the Machakos/Kitui/Embu study area is less than 80 cm deep. (Soil Science Report No. 10, see also the Soil and Water Conservation Programme Sec.6.3.2)

Toward a Crop and Livestock Development Strategy: We have discussed elsewhere five major farm production strategies available:

i. Small holder rainfed arable traditional technology
ii. Small holder rainfed arable intermediate technology
iii. Small holder rainfed arable advanced technology
iv. Small scale irrigation
v. Large scale irrigation.

It seems unlikely, given the historical and economic realities that large scale rainfed technology will be a significant strategy for the study area.

Almost all the land is in traditional technology. We suggest the government establish targets for moving people out of this and into more renumerative, soil conserving technologies. Some people will never move into a higher technology, some will move rather easily, given some bottleneck breaking interventions. Figure 6.1 shows one suggested timetable for moving farmers into improved technologies over the next twelve years. This is arbitrary and intuitive. However it is proposed as a starting point.

The intermediate technology level is a transition period. Farmers can move through it to high technology. Some may never go beyond it. The large scale irrigated at 2% of the study area will, if the water can be found, cover up to 30,000 ha. This is an order of magnitude which as explained elsewhere is contingent on finding enough water. The goal of 10% of the area going into small scale irrigated is ambitious but the returns potential is great enough to be worth the effort. This time table is for farm families, not hectarages.

(7.1.1) Seed Breeding, Multiplication, Drying, Storage, Distribution:

Background: The seed research and production business in Kenya is highly developed but geared (with a few important exceptions) to production in the high potential areas. The agronomists have reported seed shortages as a major production bottleneck in the M/K/E study area for maize, sorghum, bullrush millet, finger millet, grams, pigeon peas, beans, castor, sunflower, tobacco, sweet potato, cassava, citrus. (Agronomy Report No. 2)

Purpose of Project: To provide the farmers of the study area with an adequate, timely supply of seeds of consistently high quality at attractive prices.

Specific Project Objectives:

i. To intensify the breeding programs for the cereal crops to improve their drought and pest resistant and/or evading qualities
ii. To establish a seed production farm adjacent to the project area
iii. To produce about 10% of the farmers seed requirements
iv. To install seed drying and storage equipment
v. To establish an effective seed distribution system in the area with components of transport, storage, price and credit

Relationship with Other Projects: These projects in the crop and livestock development programme require close coordination. If the seed programme gets into full production before the farmers have credit for seed purchases seed may spoil in storage. On the other hand, the fertilizer supply project will be viable only as improved seeds start to multiply in farmers' fields.

The higher cost of seed increases farmer risk. The insect control and drought insurance projects need to be in place when farmers start buying the improved seed.

Design Components:

i. Plant breeding: Plant breeding at the Katumani research station is to be strengthened by proposed new FAO and USAID projects. The design team should review the status of these proposals to ensure they

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are still on track and that their scale of activities is apropos of the needs under the small-holder intermediate technology packages (and within 5 years, the advanced technology package) in the study area. Need vectors to be reviewed are: varieties to be developed, staffing, equipment and land requirements, keeping in mind that the Katumani station is in ecozone IV while 2/3 of the study area is in ecozone V.

ii. Seed Production: The seed Report No. 9 by Dr. Bunch proposes a seed farm for all but maize which is being produced at Kitale; to be operated by the Kenya Seed Company of about 1000 to 1200 ha near the area but high enough to minimize drought induced crop failures. This may be difficult to locate since it will no doubt have to be sited on good land in ecozone IV where all the good land is presently intensively farmed. His siting criteria, to ensure avoidance of contamination, further constrain site options. Only strong support and guidance by very senior government officials will make it possible to assemble a block of land for this purpose. The design team, if unsuccessful in locating land should investigate the alternative of leasing or contracting with private producers.

iii. Seed Harvesting, drying, processing and storage. The Seed Report No. 9 goes into considerable detail on these components (pp.33-36 Seed Appendix 4)

iv. Education: A farmer education program including demonstration plots will be needed if early acceptance of the seed is to be assured

v. Training: A staff training program for employees of the seed multiplication farm will be needed.

Design Manpower Requirements: Mississippi State University's Seed Technology Laboratory can, under provisions of an AID funded contract (AID/ta-C-1219) provide, without additional cost, assistance in preparing the final design for the project. We suggest that they be called on to carry this out.

Duration of Assignment: 1 man for six months.

Principal Kenyan Institutions:

i. Kenya Seed Company
ii. Research, MOA
iii. NAL, MOA
iv. KFA
v. Kenya Inspection Services for Seeds

Project Costs (order of magnitude):

Farm @ 1000/ha	shs.1,000,000	
Seed Processing Capital	10,800,000	
Annual Operating	4,900,000	
Total		shs.16,700,000

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(7.1.2) Provision of Dairy Cattle for Milk and Ploughing; and Improved Oxen: In order to move into intermediate and subsequently, advanced small-holder technology, farmers need more draught power. Figure 1.1 of the Agronomy Report No. 2 illustrates the advantages of using, where possible, dairy cows for draught animals. The key to their feasibility is the food supply. Where quality forage (i.e. bana grass) can be grown a dairy cow can be kept and as contrasted with an ox, can produce milk as well as pull tillage implements. In the drier areas (lower parts of ecozone V) it may not be feasible to keep dairy animals, in which case oxen that are less demanding on the food supply and goats for milk will have to do.

Purpose: To increase the energy supply to the farmer while improving his family's nutrition.

Specific Project Objectives:

i. To establish a bana grass production technology for as wide an ecological and soil type spread as possible

ii. To determine the best breed of multipurpose cows for the area

iii. To establish a technology for improved grazing to supplement or where necessary substitute for bana grass

iv. To determine the best breeds of oxen to be used where cows cannot be supported because of low rainfall

v. To identify and introduce a suitable yoke for the cows and oxen

vi. To design a training programme for farmers to care for their animals

vii. To establish a livestock breeding and distribution programme.

Relationship with Other Projects: This program should be designed as soon as possible. The purchase and breeding of appropriate animals should be delayed until the crops technology training packages have been implemented. Until the farmer has learned how to grow bana grass and has an opportunity to bring in a cash income through improved crop production he probably will not be able to afford the animal.

If he is to buy it on credit, the credit and drought insurance programmes will need to be in place first.

Design Components:

i. Identify appropriate breeds

ii. Establish the soil and climate limits of dairy animal feed supply production

iii. Establish for various ecozones and soils the hectarage requirements for forage per animal

iv. Review the veterinary support system in the area - AI, dips, inoculations, etc. and identify deficiencies

v. Determine the optimum number of animals for maximum benefit

vi. Prepare a program for animal breeding

vii. Select a yoke design and propose how to get it fabricated

viii. Design a demonstration program for bana grass production and animal breeding

Design Manpower Requirements:

1 Livestock production specialist
1 Veterinarian
1 Forage-range management specialist
1 Animal draft power specialist (Agricultural Engineer)

The first three will be needed for one year, the Ag engineer for three months.

Principal Kenyan Institutions:

Veterinary Department, MOA
L & FM Division "
Range Management Div. "

Project Costs (order of magnitude): There will be about 60,000 farms on A and B suitability lands in ecozones III and IV which should have dairy draught animals. At shs. 2000 per animal this represents a capital investment of 120 million shillings at one animal per farm.

On ecozone V land under advanced technology, the A and B suitability land totals just over 900,000 ha. At 9 hectares per farm there could be 100,000 farms. These may not be able to support dairy cattle. At shs.500 per animal the capital investment is shs.50 million.

Most of these costs should be born by the farmers. These figures represent their required cash outlay.

(7.1.3) Improved Tillage Implements:

Background: Eighty percent of the farmers in Machakos, sixty percent in Kitui and forty percent in Embu plow their land with oxen. About half own their own plows. These are all or nearly all the "Victory" mold board plow. They are used to prepare seed beds, loosen soil for terracing and sometimes weeding. They have two major problems. Since they turn over the soil and break it up they contribute considerably to the loss of soil moisture. Secondly this turning over of the soil is a high energy consumer. Cultivators which kill weeds, loosen the soil but do not turn it over are available (Agronomy Report No. 2, sec. 1.3.4.). There is a hand tool shortage in the project area that needs to be overcome.

Purpose: To introduce improved tillage equipment especially equipment that can be effectively used with the draft dairy cows and improved oxen.

Specific Project Objectives:

i. Identify a suitable implement for seedbed preparation and weeding to be drawn by dairy cattle and oxen
ii. Evaluate hand tools and determine possibilities of improvement
iii. Educate farmers to their use
iv. Determine the market and whether local implement manufacturers can sell them at a profit
v. Get tools into the hands of farmers on an established schedule

Relationship with Other Projects: Could be started immediately. A good sales campaign could start their distribution independently of any other project. It would be helpful to the previous project (8.1.2). The better the implement the more the incentive to mechanize. Reaching the hectarages and yields proposed for intermediate and advanced technologies is predicated on being able to till the land and markedly improve soil moisture storage. The soil conservation project 7.2.2 depends on an improved supply of hand tools.

Should be implemented no later than introduction of new seeds project. May depend on rural water supply project implementation before it can get into full swing. Probably will depend on credit project.

Design Components: (not necessarily in this order)

i. Evaluate the existing tools for animal draught especially those at the FAO farm equipment testing project at Nakuru.
ii. Design demonstrations of cultivators in the project area
iii. After evaluation and selection design a program to educate farmers in their use

iv. Determine potential demand
v. Identify cultivator production constraints
vi. Assess current MOA shovel distribution programme Is it meeting the demand? If not, determine locations where more shovels are needed
vii. Evaluate other hand tool supply, demand efficiencies and determine if alternatives would be more effective and acceptable.

Design Manpower Requirements: Two agricultural engineers, one to design demonstration, testing programme, one to evaluate production aspects. Design to take four months. Implementation about 3 years.

Principal Kenyan Institutions:

i. L&FM Division, MOA
ii. Research, MOA
iii. FAO - Nakuru
iv. KFA

Project Costs (order of Magnitude):

Plows	@ shs.300 x 100,000	30,000,000
Shovels	shs. 24 x 75,000	1,800,000
Other tools		500,000
Farmer training		
Groups of 100 x 1000 groups		
1000 man days @ shs.400		400,000
Training materials		200,000
	Total	32,900,000

(7.1.4) Improved Insect Control

Background: Pests are major constraints to production increases of crops and livestock. There is a vicious circle to break - no cash, no purchase of insecticides, poor yield, no cash. See Agronomy and Livestock Reports for details.

Purpose: To provide farmers with the equipment and know-how to control crop and animal insect depredations.

Specific Project Objectives:

i. Getting sprayers that require little water into the hands of farmers so they can improve production by timely spraying with appropriate chemicals
ii. Getting farmers to minimize stored grain damage by insects by appropriate, timely, safe use of chemicals

iii. Ensuring control of livestock damaging insects

Relationship with other Projects: Tied in directly with 7.1.5 (on-farm crop storage) and 7.1.2 (provision of draught animals).. Should precede the latter so as to be in place when animals begin to arrive. Needs to be used as an incentive to induce farmers to implement 7.2.4 (Rangeland Improvement Program). Must be preceded by credit program.

Design Components:

i. Specify sprayers
ii. Evaluate sprayer supply, cost, distribution system, identify bottlenecks and suggest bottleneck breaking strategies
iii. Design crop spraying programs for study areas needed
iv. Develop training package for farmers for crop spraying
v. Identify current and potential bottlenecks to livestock insect control program having in mind project 7.1.2
vi. Review livestock insect control program and develop bottleneck breaking activities
vii. Develop livestock insect control training package.

Design Manpower Requirements:

1 Crop entomologist
1 Livestock entomologist
Duration: 6 months each

Principal Kenyan Institutions:

i. Research, L&FM, MOA
ii. Veterinary Department MOA
iii. Kenya Seed Company
iv. Kenya Inspection Service for Seeds
v. Kenya Farmers Association
vi. Crop Science Department, University of Nairobi
vii. Veterinary Department, " " "

Project Costs: (Order of Magnitude)

Back pack insect sprayers 100 x 50,000	shs.5,000,000
Training	700,000
Dips and dip management	5,000,000
Total	shs10,700,000

(7.1.5) On-Farm Crop Storage

Background: The loss rate due to insects, fungus, bacteria, rodents etc. of on-farm stored crops is estimated as high as 35% average. Besides the loss of food it decreases a farmer's flexibility to hold his crop off the market while waiting for more favorable

prices. Some forms of fungus in stored grains are toxic to humans and animals.

Purpose: To decrease loss of food stored on farms.

Specific Project Objectives:

i. To identify alternative storage containers for small holder grain storage use
ii. To get storage containers into production
iii. To get farmers to use them

Relationship With Other Projects: Should proceed concurrently with 7.1.4 (Improved insect control)

Design Components:

i. Develop storage container specifications for various
   - crops
   - sizes
ii. Evaluate economic feasibility for small-holders
iii. Evaluate production bottlenecks
iv. Design a farmer promotion program

Design Manpower Requirements:

1 Entomologist (could be handled by the entomologist recommended for 7.1.4
1 Agricultural Engineer
1 Seed specialist (storage)

6 months each

Project Costs: (order of magnitude):

Storage containers	shs.200 x 50,000	10,000,000
Training and promotion		600,000
	Total	10,600,000

(7.1.6) Crops and Livestock Marketing Including Marketing of Dairy Products:

Background: Most of the farmers in the study area have some market experience but by going into intermediate and advanced technology packages they will have significant surpluses to dispose of in most years. This will alter their farming operations and the existing marketing structure. A project is needed to ensure that a marketing infrastructure is available to handle the increased yields.

This particular project may turn out to be the easiest one for the government to act on (or the most controversial).

Purpose: To ensure the existence of a marketing system adequate to handle the increased production expected from the study area.

Specific Project Objectives:

i. To evaluate the market flexibility (ability to expand its throughput)
ii. To develop bottleneck breaking strategies
iii. To develop an optimal cropping-marketing strategy
iv. To ensure an adequate, functioning crop and livestock marketing system.

Relationship with Other Projects: Needs to parallel crop storage program implementation. Could be designed immediately but will not need to be implemented until yields increase, either by good weather years or improved yields per hectare.

Design Components:

i. Determine current market patterns
ii. Postulate production levels from available data and develop optimum marketing strategy. This may require a computer simulation of the Kenyan market and an optimizing algorithm such as dynamic programming
iii. Design a farmer training package for marketing
iv. Evaluate state and private marketing structures vis-a-vis the marginal lands and propose improvements to the marketing system.

Design Manpower Requirements:

1 Market economist thoroughly familiar with the history of Kenyan farm products marketing
1 Market economist trained in operations research techniques
1 Computer programmer familiar with a high level simulation language compatable with the Central Bureau of Statistics IBM hardware
Duration of design: two years

Project Costs (order of magnitude): Indeterminate until design has been carried out. Lump sum shs.10,000,000

(7.1.7) Improved Veterinary Services Including AI:

Background: With the proposals to increase grade cattle (and decrease indigenous livestock) there will be an increased demand for veterinary services. This can be tied in as an incentive to revegitate the overgrazed range lands. Also the use of dairy cattle for ploughing and weeding will undoubtedly necessitate veterinary assistance to ensure high lactation levels, calving to minimize disruption of ploughing and weeding schedules etc.

Purpose: To make veterinary and AI services available to the farmers.

Specific Project Objectives:

i. Provide adequate veterinary services in the project areas
ii. Provide adequate AI services
iii. Train farmers in use and management of grade cattle.

Relationship with Other Projects: Needs to be in place simultaneously with (7.1.2) (Dairy and Improved Oxen). Should be tied to (7.2.4) (Rangeland renovation) to act as inducement to upgrade quality while reducing temporarily number of animals.

Design Components:

i. Coordinate with (7.1.2) to prepare a schedule for increasing veterinary coverage
ii. Develop a strategy for balancing the demand for veterinarians with trained staff. Transport, housing facilities are major issues
iii. Develop a farmer training package on how to care for his animals and use veterinarians
iv. Identify strategies for training of additional veterinarians and support staff to meet the anticipated increased needs.

Design Manpower Requirements:

2 Veterinarians, at least one of whom should be thoroughly familiar with the operations of MOA Veterinary Department
One should have knowledge of veterinarian training opportunities and farmer training programmes.

Project Costs (order of magnitude):

Training and housing for 10 veterinarians	shs.6,000,000

(7.1.8) Fertilizer Supply

Background: Seventy-four percent of the farmers in the M/K/E Study area use no commercial fertilizer. If they are to move into intermediate and advanced technology they will have to start using it. The high rate of loss of soil nutrients as mentioned elsewhere coupled with the fact that the soils are low in nutrients makes it essential to have this project. This is going to require substantial cash outlay. A number of bottlenecks will have to be broken to get fertilizer to the farmers in the amounts and at the times needed. The potential for supplying a significant amount of the nutrient demand from manure is essentially nil.

Purpose: To establish a system for supplying farmers with fertilizer so that they get the right amounts of the right kinds at the right time at an attractive price.

Specific Project Objectives:

i. Establish a demand schedule with components of:
   - location
   - types of fertilizers needed
   - annual requirements

ii. Set up production/storage/distribution systems or ensure that they will appear spontaneously with farmer demand

iii. Train farmers in fertilizer use.

Relationship with Other Projects: The fertilizer supply system needs to keep pace with the seeds project or be slightly ahead of it. The credit project needs to run in parallel also. Since the fertilizer, seeds, tillage and draught animal projects are designed to increase production, the marketing and farm storage projects should to the extent possible precede this one slightly.

Design Components:

i. Evaluate Kenya fertilizer productive capacity

ii. Determine the potential fertilizer demand and mixes needed for the major crops, soil types and precipitation levels

iii. If production capability is not easily adjusted to the expected rising demand, develop alternatives for increasing it

iv. Design farmer training packages for fertilizer financing selection and application.

Design Manpower Requirements:

1 Agronomist
1 Rural Economist
One year each: 9 months data gathering; 3 months developing training package

Principal Kenyan Institutions:

Ken. . Soil Surveys MOA
Division of Research "
Kenya Farmers Association
Fertilizer Production and Import Companies

Project Costs (order of magnitude): Fertilizer requirements are displayed in Table 7.1. If the time table of Figure 6.1 is followed, then the estimated annual fertilizer costs to 1990 will be as shown in Table 7.2.

Table 7.1 FERTILIZER COSTS BY TECHNOLOGY

Ecozone	Soil suitability class	INTERMEDIATE TECHNOLOGY has. x10³	use factor	net has x10³	cost/ha	Total cost shs x10⁶	ADVANCED TECHNOLOGY Has x10³	use factor	net has x10³	cost/ha	Total cost shs x10⁶
III	A	35.6	90	32.0	177	5.7	39.6	90	35.6	250	8.9
	B	6.1	90	5.5	177	1.0	25.4	90	22.9	270	6.2
	C	23.3	80	18.6	101	1.9	15.9	80	12.7	170	2.2
IV	A	156.1	85	132.6	150	19.9	187.7	85	160.0	287	45.9
	B	53.7	85	45.6	107	4.9	94.8	85	80.3	220	17.7
	C	159.5	75	120.0	95	11.4	97.4	75	73.0	170	12.4
V	A	0	85	0	NA	0	726.3	85	617.4	287	177.2
	B	872.6	85	741.7	101	74.9	189.5	85	161.1	220	35.4
	C	123.1	75	92.3	95	8.8	145.1	75	108.8	170	18.5
	Totals			1188		128.5			1272		324.4
	Average cost/ha				108					255	

Table 7.2 FERTILIZER COSTS PROGRAMMED OVER 12 YEARS

Year	Intermediate Technology @ 108 shs/ha			Advanced Technology @ 255 shs/ha			Small Holder Irrigated @ 108 shs/ha			Large Scale Irrigated @ 255 shs/ha			Total Cost shsx10^6
	%	ha x10^3	cost shsx10^6	%	ha x10^3	cost shsx10^6	%	ha x10^3	cost shsx10^6	%	ha x10^3	cost shsx10^6	
1978	4	47	5	1	13	3	0	0	0	0	0	0	8
1979	7	83	9	3	36	10	0	0	0	0	0	0	19
1978	10	119	13	5	64	16	0	0	0	0	0	0	29
1981	14	166	18	7	89	23	1	13	1	0	0	0	42
1982	18	214	23	10	127	32	2	25	3	0	0	0	58
1983	21	249	27	15	191	49	3	38	4	1	13	3	83
1984	23	273	29	20	254	65	5	64	7	2	25	6	107
1985	24	285	31	26	331	84	7	89	10	2	25	6	131
1986	25	297	32	33	420	107	10	127	14	2	25	6	159
1987	23	273	29	41	522	133	10	127	14	2	25	6	18:
1988	20	238	26	48	611	156	10	127	14	2	25	6	202
1989	20	238	26	53	674	172	10	127	14	2	25	6	218
1990	20	238	26	58	738	188	10	127	14	2	25	6	234

(7.1.9) Technology Training Packages:

Background: Although the other projects have training packages incorporated as part of the design, there needs to be an overall coordination of these packages including the design of a set of delivery systems, review of the role of extensionists and others and drawing up a master plan for farmer and trainer training including evaluation and adjustment.

There are already a number of institutions, both governmental and private in the study area carrying out training (see Institutions Report No.7, Chapter 6). Their scale of operations is extremely small but one possible strategy is to increase support to them. It seems that to reach a majority of farmers in the area a multifacited strategy is needed incorporating all that is currently in place, plus strengthening them and adding new dimensions.

Purpose: To establish an integrated coordinated farmer training program which will introduce the intermediate and advanced technologies on a logical schedule to the farmers and farm trainers.

Specific Project Objectives:

i. Coordinate training programs proposed under other projects
ii. Design delivery systems
iii. Establish an evaluation system for monitoring and modifying the extensionist and farmer training programs.
iv. Develop training materials
v. Train farmers in all necessary components of farming, soil and water conservation and livestock production.

Relationships with Other Projects: This should run concurrently in its design phase with the training packages proposed for the special technologies - handling of draught animals, insect control, use of fertilizers, soil conservation etc.

Design Components:

i. Select target farmers and trainers
ii. Coordinate the various packages into a cohesive set
iii. Test the set on the target trainers
iv. Observe the transfer process from trainers to farmers
v. Modify packages
vi. Design a phased delivery system.

Design Manpower Requirements:

2 Agricultural Extension educators

1 Communications specialist
1 Audio visual specialist
Duration: 3 years

Principal Kenyan Institutions:

College of Agriculture, University of Nairobi
District Officers, MOA
District Training Centers
All national agricultural training institutes.

Project Costs (order of magnitude): Assume a target of 20,000 farmers per year and an investment of shs.200/per farmer, shs.4,000,000/yr. This will reach about 10% of the farm families per year. If radio and cinema are used extensively, dissemination can take place more quickly.

(7.1.10) Credit Requirements and Drought Insurance:

Background: Professor Mutiso has listed six sources of farmer credit in the Institutions Report No. 7, Chapter 3. This should be referred to for background. The issues are mainly how to provide credit to land holders before they can provide a title for security and how to ensure an acceptably low level of defaulters. Timeliness, cost and the appropriateness of the roles of the various institutions are also of importance. Drought insurance may be a necessary component to avoid high default rates in dry years.

Purpose: To ensure that the credit mechanisms for providing funds for capital improvements, especially terraces, water supply facilities, and seasonal farm operating costs are functioning effectively such that farmers have access to credit and creditors are ensured of acceptably low default rates.

Specific Project Objectives:

i. To determine credit levels needed to carry out the projects
ii. To evaluate the capability of the existing credit mechanisms to meet projected needs
iii. To establish strategies for ensuring acceptably low default rates
iv. To install new or modified credit programs which deal appropriately with the problems of farmers in the semi-arid lands, especially the land adjudication and drought induced crop failure problems.

Relationships with Other Projects: The credit programme must be installed before any of the projects within Programmes 1,2,3,5,6 and 7 have reached the capital outlay stages.

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Design Components:

i. Establish a multiyear credit requirement time table.
ii. Examine current credit sources and evaluate their financial and organizational capacity to meet the projected demands.
iii. Evaluate the need and probable effectiveness of a drought insurance program to minimize default on loans.
iv. Evaluate other reasons for default and devise strategies for minimizing them (supervised credit?).
v. Establish a repayment/default strategy which will be acceptable to international credit institutions, those administering credit and those using it. Avoid strategies which teach farmers that defaulting is an acceptable practise.
vi. Design an integrated credit program tailored to the study area.

Design Manpower Requirements:

1 Agricultural Economist
1 Economist, specialist in design of large scale credit programmes.
Duration of assignment - 2 years. One year to design, one year to monitor and evaluate. The second year may not necessarily follow immediately the first.

Project Costs (order of magnitude):

Production programme: The farm budgets list the following:

Capital and Operating Requirements per ha per year in Ecozone V.

Technology	Capital	Operating	Total
Intermediate	33	270	303
Advanced	70	600	670

Based on the technology mix suggested for 1990, the credit requirements for that year would be as follows:

Technology	Has. $\times 10^3$	Unit shs/ha	Total sh $\times 10^6$
Intermediate	365	303	111
Advanced	763	670	511

Total annual credit requirement shs.622 million.
This will build up more or less linearly from now to 1990.

(7.1.11) Dryland and Irrigated Farm Research into Exotic Crops:

Background: Appendix 4.1 p.139 of the Agronomy Report No. 2 lists twenty-three food, forage and industrial crops that have promising possibilities for production in the

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two study areas. Ten of these crops are for Industrial use which considering the projected increasing labour surplus would provide a double blessing. However all of these crops need to be tried on an experimental, then demonstration basis before they can be actively promoted.

Purpose: To increase the level of agricultural research in the study area such that appropriate new crops can be successfully introduced.

Specific Project Objectives:

i. To establish field experiments on exotic crops of promise not now appropriately researched
ii. To set up demonstration plots for these crops throughout the study area.

Relationships with Other Projects: None of the other projects are directly dependent on the results of this one. However as irrigation begins to take hold, farmers will begin looking for higher valued crops. Many farmers will have a mix of rainfed and irrigated crops and dry-land/irrigated is an obvious virtue.

Design Components:

i. Compare current and about-to-commence agricultural research with the agronomists' list of exotic crops
ii. Evaluate each crop in heirarchies of market potential and difficulty of production
iii. Using step 2 establish research priorities
iv. Design research packages to dovetail with ongoing MOA research. Include manpower and equipment needs
v. Locate optimal research and demonstration farm sites with water supplies for irrigated research and demonstration.

Design Manpower Requirements:

2 Tropical Agronomists with experience in experiment station design and operation. One with irrigated crops, one with rainfed crops experience.
Duration: One year each

Principal Kenyan Institutions:

Division of Research MOA
National Irrigation Board
Kenya Soil Surveys (to help locate demonstration farms)

Project Costs (order of magnitude): Difficult to assess before design, however an estimate is:

	Shs x 10^6
20 professionals for 5 years	54
Buildings and equipment	40
Ancilliary help	8
Transport	1
Land	1
	shs.104 million

(7.2) SOIL AND WATER CONSERVATION PROGRAMME

(7.2.1) Hydrology:

Background: Not nearly enough is ›wn of the runoff in the study area. Without ›me degree of confidence in what can be expected, soil and water conservation structures and those proposed for domestic, livestock and irrigation cannot be properly designed. MOWD already has a hydrology monitoring programme in the study area under the direction of Dr. Edwards. This work should be expanded to avoid the need to extrapolate too far beyond the watersheds on which he is collecting data.

Purpose: To develop hydrologic runoff and sediment load models for all the drainage basins in the study area at sufficient precision to use in the design of soil and water conservation works including those needed for small surface water supplies.

Specific Project Objectives:

i. Accelerate the collection of hydrologic data from the study area and tabulate it in a form convenient for use in the soil and water conservation and supply programmes needing it.
ii. Ensure that an ongoing program is in place to meet the needs of future water users.

Relationships with Other Projects: This ought to be a prerequisite to the next project, "Soil Conservation Structures." However, hydrologic models require several years of data collection to build up probability distribution data. It needs to be in place as soon as possible and begin supplying data to the other projects requiring it as needed. They will have to "over design" until this project's precision improves. Project 7.6.2 Small Irrigation Projects should begin at the same time since the latter has a component for securing aerial photography which will be needed in this project.

Design Components:

i. Familiarization with current and past hydrologic data gathering programs.
ii. Evaluate current data collection and processing technology
iii. Identify key monitoring points
iv. Redesign if necessary the collection and data processing programs already in place to conform with agreed on degrees of precision
v. Specify additional equipment and manpower needed to implement item iv. above.

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Design Manpower Requirements:

1 Surface waters hydrologist for 6 months
1 Computer programmer for 6 months

Principal Kenyan Institutions:

Ministry of Water Development
Meteorology Department
National Irrigation Board
Tana River Development Authority

Project Costs (order of magnitude): If the chart of Figure 26-I-1* is used as a guide, a network density of from 0.5 to 1 stations per 1000 km^2 is indicated. There are about 18,000 km^2 in the study area, so approximately 9 to 18 stations are needed. Since intensive use of the watershed is anticipated we suggest going to the 18 station limit, which with the three stations of Dr. Edwards leaves 15 stations to be installed and/or upgraded.

at shs.200,000 per station
15 x 200,000 shs.3,000,000

There will of course be recurrent costs for operation and maintenance.

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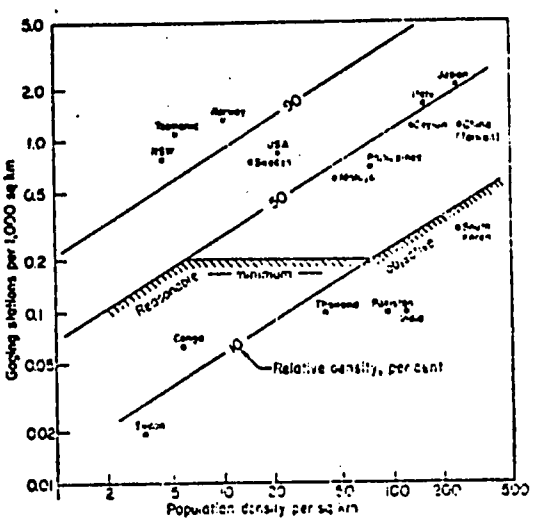

FIG. 26-I-1. Comparative areal densities of streamflow gaging stations. (After Langbein, United Nations ECAFE [28].)

*from Chow V. T. 1964 Handbook of Applied Hydraulics.

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(7.2.2) Soil and Water Conservation Structures

Background: We estimate that the annual production loss due to sheet erosion in the study area is about 12.7M shillings from, 1.3 million hectares. Using present technology this will double by the year 2000 (Table V.1). As mentioned in Chapter 3, if production trend figures are used, the loss may be much higher. There are a number of things people can do to reverse this very serious problem which have been discussed in the Agronomy and Soil and Water Conservation Reports. The issues are:

- what measures to take
- how to take them
- how to pay for them

Purpose: To reduce soil erosion to an acceptable level and conserve water through holding back runoff.

Specific Project Objectives:

i. To develop specifications for soil/water conservation structures which optimize the effectiveness/cost ratio for various combinations of ecozone, slope, soil type, land use and available energy
ii. To establish a cost sharing formula between the government and farmers that is effective in getting the work done
iii. To accelerate the construction of soil and water conservation structures, especially terraces and grass strips.

Relationships with Other Projects: This should be phased to take advantage of the Credit Project (7.1.10). There is considerable work in progress in the project area by Mwethya groups so this can be phased in as soon as useful components are developed. It must precede the Small Scale Irrigation Construction Program (7.6.2) or, more precisely be carefully phased so that after soil conservation works on a watershed are completed, small surface reservoirs under (7.6.2) can be built without the likelihood of their silting up within a year or two. It must also precede the Fertilizer Project on the lands requiring conservation structures since the effectiveness of the Fertilizer Project will only be realized where there is adequate soil moisture storage. The Hydrology Project should be in place first but there is too much urgency to wait for several years to get better data before starting. The design phase should slightly precede the Technology Training Package Project (7.2.3) since this project will determine what goes into the training packages.

Design Components:

i. Evaluate needs, taking into account:

- hydrology
- current practice

- slopes
- soil physics
- land use, current and projected

ii. Design a research component to develop improved methods

iii. Develop a phased program with specifications of site related structures

iv. Prepare alternative financing proposals and work out an acceptable role for government

v. Prepare a methodology for monitoring progress and evaluating effectiveness

vi. Evaluate the present methodology for laying out structures and suggest improvements if needed.

Design Manpower Requirements:

2 Soil and Water Conservation engineers
1 Specialist, in government organization*
Duration: one year.

Principal Kenyan Institutions:

Division of Land and Farm Management MOA
Kenya Soil Survey
District Agricultural Officers

Project Costs** (order of magnitude)

	Capital shs x 10^6	Annual Maintenance shs x 10^6
Terracing	694	51
Grass strips	54	4

(7.2.3) Technology Training Packages:

i. Extensionists
ii. Farmers

Background: There are 3,000 Mwethya groups with 150,000 people working in Machakos (Section 2.3.3 Soil and Water Conservation Report No. 4). They have a tremendous amount of momentum. However 60% of them are engaged in repair work on existing terraces. This high percentage is largely due to poor original layout and construction. More people trained in layout of terraces, cutoffs, grass strips, grassed water ways are needed. The design team members have all seen many examples of terraces badly located, cut-offs with gullies growing rapidly at both ends, grass strips running straight across undulating land etc. The

*The major activity of this individual will be to assist GOK to organize to meet their obligations in an accelerated construction program.

**See Section 6.3.2 for details.

Land and Farm Management Division of MOA has been working effectively with extensionists and many are trained to lay out the structures but neither the number trained nor the depth of training each gets is sufficient to meet current needs.

There is the very interesting question of construction efficiency by the Mwethya groups. Without doubt an increase in the number of shovels available to each group would be a great help. A time and motion study engineer would be amazed at the chant-dance shovel rhythm of the groups. Whether he or anyone else could significantly increase their production rate is an open question, but it is worthy of study.

Purpose: To improve the capability of technicians and farmers to select appropriate soil and water conservation structures to meet the needs of the land and to lay out, construct and maintain them.

Specific Project Objectives:

i. To augment the training of technicians so that they fully understand the criteria by which one selects a particular structure to fit a given situation
ii. To provide farmer training in construction methods and farming practices which minimize maintenance requirements

Relationships with Other Projects: To be phased in with the ongoing Land and Farm Management Division Training Program under the Direction of Dr. Wenner.

Will use as a basis for the training package the specifications developed in Project(7.2.2)

Design Components:

i. Using the phasing developed in(7.2.2) review the current available technical manpower and its ability to cope
ii. Develop training packages for layout of the several structures
iii. Design a technology delivery system
iv. Design a farmer training packaged based on the designs of (7.2.2).

Design Manpower Requirements:

1 Agricultural engineer
1 Agriculturalextension educator
Duration: One year each

Principal Kenyan Institutions:

Land and Farm Management Division, MOA
District Agricultural Officers, MOA
Location Chiefs

Project Costs (order of magnitude): Assume training of 5 technicians per location (average; some locations have less need for conservation structures than others)

Number to be trained 150	
Training at 1000 sh/trainee	150,000
(Preparation of training packages financed as part of the design)	
Training of farmers: On the basis of preparing illustrated training brochures for distribution at barazas: 100,000 brochures @ shs.5	500,000
Total	shs.650,000

(7.2.4) Rangeland Renovation:

Background: Overgrazing has been a serious problem in the study area for many years. It is the principal cause of soil erosion together with rainfall variation. During the wet years, people build up their herds. In dry cycles they try to maintain them until the rains come again. The technology to renovate the range lands is known. For the majority of the range, removing the livestock for three or four rainy seasons will allow it to come back. Where brush is thick enough to burn the land can be cleared by burning and improved seed scattered in the ash.

It is not practical nor necessary to remove all the animals from all the land. Properly managed range land can feed six or seven times the livestock that most range lands in their present condition can handle. We therefore suggest setting aside initially one hectare out of five for exclusion of all livestock for two years. Then move all the livestock back on that hectare for the next two years while the other four hectares are rested and allowed to recover. This will take a massive education campaign, incentives, perhaps additional legislation, staff with authority to enforce the legislation, fencing material in places where indigenous materials are in short supply.

The "theory of the commons" leads us to doubt that this program will succeed where land has not been adjudicated. In Eastern Kitui, where lands are still to some extent used for community type grazing a different approach will be necessary from the settled agriculture areas. Cooperative action by groups of ranchers will have to be encouraged.

Purpose: To restore and stabilize the productive capacity of the range lands so as to maximize returns from livestock while eliminating land depletion from erosion and nutrient loss.

Specific Project Objectives:

i. To develop specific strategies for renovating different soils, especially identifying those

which should be reseeded and those which will be renovated simply by removing the livestock.

ii. To determine the optimum stocking rate for each soil type in each ecozone

iii. To ensure the existence of adequate controlling legislation

iv. To educate and motivate the livestock owners

v. To install, monitor evaluate and if necessary adjust the program

vi. To accelerate land adjudication

Relationships with Other Projects: This project should be installed on the watersheds where it is needed for about three years before surface dams, are installed. The Crops and Livestock Marketing (7.1.6) and Improved Veterinary Services (7.1.7) projects should be phased concurrently to provide support.

Since this project will have a training package, its design and implemention should parallel the Technology Training Package Project, (7.1.9).

The aerial photographs proposed in(7.6.2) will be needed to accelerate land adjudication.

Design Components:

i. Establish criteria and write specifications for selecting the areas to be destocked

ii. Review the district land adjudication programs and suggest strategies for their acceleration

iii. Establish criteria for selecting the areas to be reseeded

iv. Review the control legislation to ensure that location chiefs have the authority to enforce the program. (However it is expected that by proper design and education, resorting to enforcing destocking will be necessary in only a relatively few cases).

v. Design training packages and delivery systems for farmers and district supervisory personnel

vi. Design a monitoring programme so that the rate of progress of the project can be observed and specifications adjusted if necessary.

vii. Determine staff requirements for education and monitoring phases.

Design Manpower Requirements: This program requires very careful matching of the physical resources with the social implications. We suggest a team of short-term and long-term range management livestock specialists, the long-term people to participate in the design and implementation stage.

1 Range Management specialist
1 Livestock specialist
1 Social Anthropologist

for 4 years each; one year design, 3 years implementation

1 Range Management specialist in shrub utilization for browse
6 months
1 Specialist in tropical grasses and reseeding technology
6 months

Principal Kenya Institutions:

Range Management Division, MOA
Kenya Seed Company
Kenya Farmer's Association
Ministry of Lands and Settlement

Project Costs (order of magnitude): The major cost components will be demonstration plots, preparing educational materials supplying grass seed and if it proves necessary, law enforcement expenses.

Operation of Demonstration Plots 50 x shs.20,000	1,000,000
Preparation of education materials	200,000
Staff for monitoring and law enforcement 50 x shs.30,000 x 5 years	7,500,000
Total	shs.8,700,000

(7.3) AFFORESTATION PROGRAM

(7.3.1) Nursery, Seedling Distribution Project

Background: There are about 150,000 ha of land in the project area (8 percent) where forestry is a good economic alternative to cropping and livestock. With a steady decline in forestry resources in the area the price of fuel is increasing, lands are eroding and rivers which once flowed all year have had their regimes changed to flash flooding and dry cycles. The location of nurseries at suitable locations plus an education program to show land owners the economic value of woodlots is in our opinion a highly viable project economically and environmentally. See also the discussion in Section 5.3.4, and the Forestry Report No.5.

Purpose: To increase significantly the hectarage in tree production.

Specific Project Objectives:

i. To establish more tree nurseries
ii. To develop an effective seedling distribution system
iii. To provide land owners with a technology package for planting, caring for, harvesting and marketing their timber.
iv. To establish a nursery research program

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Relationships with Other Projects: This should be started as soon as possible so land owners can be given the information they need before making decisions on which land use technology to adopt.

It may require some credit. Since most land owners own several pieces of land, those with land to be afforested may be able to survive the 8 year period to the first cutting without credit. However the credit project should consider the question of forest land credit requirements.

Design Components:

i. Locate land suitable for tree nurseries
ii. Develop a nursery programme
iii. Develop a tree farmer training programme
iv. Develop a forestry monitoring programme to keep track of progress

Design Manpower Requirements:

1 Silviculturist for one year

Principal Kenyan Institutions:

Department of Forestry, MONR

Project Costs (order of magnitude):

78,000 ha at shs.540	shs.42,000,000
(see Section 5.3.4)	

(7.4) RURAL ROADS IMPROVEMENT

Background: There are a number of road construction activities under way and planned in the project area, many of which are being financed by international agencies. For example, the EEC financed Machakos Development Program (MDIDP) plans to spend KE 1,104,460 over the next five years on 160 km of rural access roads, 9.5 km of tarmac road and two bridges. If the area is to move into intermediate and advanced technologies the requirements are much greater than that currently planned and in progress. However any additional road construction efforts will have to deal with the issue of expanding the technical/administrative staff in the Roads Department. This is especially difficult for any short-term crash programs. These aspects, as well as the financial and hand vs. machine energy alternative must all be considered to mount a successful roads program.

Purpose: To provide sufficient roads in the project area to permit the development of its agricultural potential.

Specific Project Objectives: To provide the roads not now being built or upgraded under other programmes to ensure that farm inputs and products can move economically into and out

of the area. The proposal as detailed in the Institutions Report No. 7, Chapter 4 is as follows:

	Machakos	Kitui	Embu
New Tarmac	330 km	700 km	95 km
New Murram	189	401	55
Upgrading roads	100	345	23

Twenty-five new bridges in the project area are needed.

Relationships with Other Projects: The road construction/improvement program should be phased with the production increase activities of the crop and livestock development programme. The afforestation, large and small scale irriation, and health services programmes are also dependent on this programme.

Design Components:

Phase I: Feasibility

i. Develop with the designers of the above mentioned projects a construction timetable
ii. Determine the status of on-going and about to begin roads programmes in the study area
iii. Review the MOW specifications and make a layout from aerial photographs
iv. Establish the routes of the roads to be constructed and make preliminary cost estimates

Phase II. Evaluate Roads Department of MOW capacity and field and office staff requirements to handle design layout and construction supervision and maintenance.

Phase III, Design; Design the roads, bridges and appurtenant structures.

Design Manpower Requirements:

Phase I: 2 Highway Construction engineers for six months
Phase II: Depends on Phase I study. Should include at least 2 design engineers. A bottleneck may become apparent in Phase I study of a shortage of field survey party supervisors
Estimate 5 survey party chiefs
Phase III: Will depend on Phase I and II results.

Principal Kenyan Institutions:

Roads Department, MOW
District Development Committees

Project Costs (order of magnitude): Based on the estimates presented in the MIDIDP report:

Item	Quantity	Unit Cost KE	Total Cost KE x 10^6
Tarmac	1125 km	11,000/km	12.4
New Murram	645 km	2,400/km	1.6
Upgrading	468	2,000/km	1.0
Bridges	25	57,000each	1.4
			KE 6,400,000
			shs.328,000,000

(7.5) RURAL DOMESTIC/LIVESTOCK WATER SUPPLY

(7.5.1) Construction of Reticulated Systems:

Background: This project is proposed in order to accelerate the Ministry of Water Development's programme of supplying water to everyone by the year 2000. As discussed in Section 6.3.1 the locations with population densities above about 72 per km^2 are potential targets for reticulated water supplies. It should have two phases, first the location of suitable water sources: the Upper Tana Reservoir now getting underway seems a logical source for some of the water needed in the project area. Since this is to be a multipurpose reservoir, the Tana River Development Authority will have to allocate supplies. Other sources, especially the Athi need to be investigated.

Purpose of Project: To provide piped water to the locations with higher populations (initially a network such that no one will have to go more than 3 km for water).

Specific Project Objectives:

i. To locate reservoir sites
ii. To design treatment works and distribution systems
iii. To construct the necessary works.

Relationships with Other Projects: Reservoir site location should proceed in unison with the reservoir site location portion of the large scale irrigation works project. The roads project would be useful if it precedes this project. It may be necessary to add some sections to the roads project to get into reservoir and treatment plant sites. Depending on the decision by GOK on the proportion of the costs to be born by the wananchi, it may necessary to phase the programme so as to follow the crop and livestock development programme so they will have cash to pay their assessments. Must be dovetailed with ongoing MOWD projects.

Design Components:

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Phase I: Feasibility

i. Make a reconnaissance survey of possible storage reservoir sites
ii. Review the current programme of MOWD for the study area and if necessary prepare an accelerated schedule
iii. Determine additional requirements of technical/administrative staff in MOWD to design/supervise an accelerated programme
iv. Develop a construction timetable (a phased programme)
v. Prepare a preliminary cost estimate of sufficient accuracy to permit donor agencies to commit financing.

Phase II: Design, Construction Operation

i. Based on the Phase I Feasibility Studies, design the reservoir(s) treatment plants and distribution system.
ii. Supervise construction
iii. Set up a system for recovering costs in accordance with GOK policy
iv. Review operation and maintenance procedures of MOWD and suggest strategies for ensuring effective system O and M.

Design Manpower Requirements:

Phase I: Two water system engineers for one year

Phase II: Two water system engineers for 5 years, plus 4 water system inspectors to supervise the pipeline construction programme.

Principal Kenyan Institutions to be Involved:

Ministry of Water Development
District Development Committees

Project Costs (order of magnitude):

Machakos	shs.240,000,000
Kitui	40,000,000

See section 6.3.1 for more details.

(7.5.2) Small Scale Water Supply

Background: As discussed in Section 6.3.1 on Rural Water Supply, about 30 % of the people of Machakos and 65% of those in Kitui will probably best be served by small water supplies such as boreholes and water harvesting from roofs or small portions of the farmstead. Subsurface dams are fairly good, if not a very sanitary source of water supply which needs to be further developed. Temporary supplies which are eventually relegated to livestock use and

irrigation also have a place.

Purpose of Project: To provide potable water within 2-3 km from small supply sources for families beyond the reach of large scale reticulated systems.

Specific Project Objectives:

i. To compare alternative sources of water supply
ii. To establish criteria for selecting a particular source for specific areas
iii. To upgrade institutional mechanisms to carry out an accelerated small scale water supply programme
iv. To carry out a programme of construction

Relationships with Other Projects: Needs to parallel the large scale water supply project to ensure adequate coverage of the area. Construction will have to be phased with the timetable of the crop and livestock development programme. Needs to be coordinated with existing small systems some of which can be upgraded.

Design Components:

Phase I: Feasibility

i. Establish criteria for selecting between alternative sources
ii. Propose a water harvesting research programme for Kenya. Develop the plan of work and identify an appropriate research group
iii. Evaluate a representative number of existing small water supply systems and establish or modify costs of alternatives and construction specifications
iv. Develop a construction timetable
v. Reestimate costs
vi. Review MOWD manpower vis-avis a construction program and make appropriate recommendations

Phase II: Design and Construction

i. Prepare sets of alternative designs based on the feasibility study and research results
ii. Dovetail program with ongoing construction
iii. Install systems
iv. Set up system servicing program
v. Establish a system evaluation unit in MOWD

Design Manpower Requirements:

Phase I: 1 Hydrologist
1 Research water engineer
1 Mechanical engineer experienced in borehole pumping equipment

Duration: 6 months

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Phase II: 1 Hydrologist
1 Well drilling expert
1 Mechanical engineer

Duration: up to 5 years

Principal Kenyan Institutions to be Involved:

Ministry of Water Development
District Development Committees

Project Costs (Order of magnitude): Based on borehole supplies per the analysis of Section 6.3.1 an ultimate amount of shs.340,000,000 may be needed. However many of the supplies will be from water harvesting subsurface dams and springs. The estimate for boreholes given in the Soil and Water Management Report is about shs.32,000,000.

(7.6) IRRIGATION PROGRAM

(7.6.1) Large Irrigation Projects

Background: As discussed in Chapters 5 and 6, rainfed agriculture in Ecozone V is risky even under advanced technology. Even with on-farm water conservation management techniques crop yields will be frequently constrained by water shortages at critical times. With the good soils and climate of the area, it is economical to bring water to the land at fairly high delivery costs. The sooner the area's limited water supply is fully developed the better. However it is far from clear at this point just how much land can be irrigated. Large scale irrigation programmes must be developed carefully since they are usually high cost high technology activities and the possibilities of long delays in reaching objectives are high. Nevertheless, efficient irrigation systems in the suitable lands of the M/K/E area can be highly profitable enterprises.

Purpose of Project: To construct and ensure the profitable operation of large scale irrigation projects.

Specific Project Objectives:

i. Determine the sources and volumes of dependable water supplies
ii. Determine which lands are most appropriate to irrigate
iii. Organize GOK and farmers to construct and operate the systems and manage irrigated farms.

Relationships with Other Projects: Reservoir siting should be completely coordinated with Project(7.5.1), Rural/ Domestic Large Scale Water Supply Systems. Since the project may be competing with other areas for limited water, it needs to be carefully coordinated with such activities to avoid double commitments of water. The new Bura Irrigation Scheme in the Lower Tana should be watched carefully since there will be lessons to be learned from its initial problems in the development of large scale irrigation in the study area. The Hydrology Project (7.2.1) should provide essential data for this project.

Design Components:

Phase I : Feasibility

i. Using inputs from the Hydrology Projects determine suitability of reservoir sites
ii. Estimate water yield potentials
iii. Determine water quality for irrigation
iv. Establish suitability criteria and locate the lands most suitable for irrigation
v. Prepare a development time table
vi. Make preliminary cost estimates
vii. Evaluate National Irrigation Board's administrative and technical needs to carry out project supervision and evaluation.

Phase II: Design and Construction

i. Design the systems
ii. Supervise construction
iii. Establish an operating programme. This will include administrative supervision, water delivery schedules, maintenance organization and procedures.

PHASE III: Training

i. Prepare an on-farm water management training programme for farmers
ii. Design the delivery system
iii. Design a training programme for extensionists

Design Manpower Requirements:

PHASE I: Feasibility

1 Irrigation engineer
1 Economist
1 Hydrologist
1 Soil scientist familiar with irrigated soils in the tropics.
Duration of assignment: one year.

PHASE II: Design and Construction: Difficult to estimate needs until after Phase I is completed. Assume for now two people to supervise design and construction, both phases of which to be executed by private contractors. If NIB is to do the design assume an 8 man professional team.

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Phase III: Farmer Training:
2 on-farm water management specialists (irrigation engineers) experienced in preparing training materials and designing training delivery systems.
Duration: Two years.

Principal Kenyan Institutions:

National Irrigation Board
Ministry of Water Development
Small Irrigation Projects Section,MOA
L & FM Division, MOA
Kenya Soil Survey
Tana River Development Authority
Ministry of Lands and Settlement
Edgerton College
University of Nairobi

Project Costs (order of magnitude):

Assume shs.10,000/ha development costs and 30,000 ha to be irrigated shs. 300 million

(7.6.2) Small Irrigation Projects

Background: Although there are good possibilities for large scale irrigation projects in the study area, it is likely that small scale supplemental irrigation can be developed sooner and have as great effect (possibly greater) on production increase as large irrigation systems.

As described in Section 5.3.2 the possible water sources are smallsurface dams, boreholes, rock catchments, springs, subsurface dams and water harvesting on small areas on the farm. Even careful shaping of the land around two or three fruit trees to impound rain is a form of small scale irrigation. The two principal components are training of extensionists to advise farmers and providing credit for construction of small reservoirs. Most farmers who install small supplemental works will operate with a mix of rainfed-irrigated strategies.

Purpose: To increase agricultural production through small scale supplementary irrigation.

Specific Project Objectives:

i. To construct reservoirs, water harvesting and storage structures, spring and rock catchment collection boxes, boreholes and other relevant structures
ii. To train farm advisors and through them, farmers in supplementary irrigation techniques.

Relationships with Other Projects: The small scale water user will in most cases be basically a rainfed farm operator using his limited stored water sparingly. He will need to have the training provided under Project 7.1.9 to

supplement that received in this project.

It is essential that where surface dams are to be constructed, the Soil Conservation Structures and Rangeland Renovation Projects be in place or the reservoirs will silt up. It is suggested that where a group of farmers control a small watershed, dam construction subsidies be increased contingent on soil stablization of the watershed.

This project should run concurrently with the Small Scale (domestic/livestock) Water Supply Project No. 7.5.2)

Design Components:

i. Develop criteria for selecting between alternative sources of water supply
ii. Identify, with the use of aerial photographs and field observations, a number of sites suitable for small surface reservoirs to serve as Phase I (demonstration) projects
iii. Develop designs of small scale systems based on identified rock catchments
iv. Propose an equipment installation for getting water from subsurface dam reservoirs to nearby farms
v. Prepare specifications of water harvesting for use on small farm gardens and fruit trees
vi. Prepare an extension training package for farmers
vii. Prepare a training package for technicians in the location design, and construction supervision of small dams.

Design Manpower Requirements:

1 Agronomist
1 Horticulturalist
1 Irrigation Engineer
Duration: Two years

Principal Kenyan Institutions:

Small Irrigation Section MOA
L & FM Division MOA
MOWD

Project Costs: (order of magnitude):

Aerial Photographs	3,000,000
Small dams, 250 @ shs.60,000	15,000,000
Boreholes, 30 @ shs.228,000	6,800,000
Other (water harvesting)	10,000,000
Total	shs. 34,800,000

(7.7) RURAL HEALTH AND NUTRITION PROGRAM

(7.7.1) Mobile Health Delivery System:

Background: The fundamental question is whether to bring the people to the health care centers, or take the health care centers to the people. Mutiso documents the argument for providing mobile clinics in Chapter 18 of the Institions Report No. 7. A combination of mobile and fixed rural health units is suggested.

There is no optimum number of units. One criteria is to supply people in the semi-arid areas with the same facilities as those living in the high potential areas.

Purpose: To provide better access to health care by supplying mobile health clinics in the study area.

Specific Project Objectives:

i. To ensure service to all the residents on a regular routine basis
ii. To provide emergency health care such that people can be treated in a timely manner, either at home or in a hospital when seriously ill.

Relationships with Other Projects: Lack of suitable roads is a major constraint to providing mobile health facilities This programme should follow slightly behind Project (7.4) Rural Roads Improvement, and should parallel the other projects in this program.

Design Components:

i. Establish an acceptable level of service. This must be financially feasible
ii. Develop a mix of mobile and fixed rural health units in accordance with component i. above
iii. Determine the most appropriate means of delivery
iv. Establish the components of the service units, equipment, staffing, supplies.
v. Evaluate the labour supply and compare with the needs as outlined in component iv.
vi. If the trained labour supply does not meet the requirement, develop means of training staff
vii. Establish program evaluation procedures.

Design Manpower Requirements:

2 Public Health Officers
Duration one year

Principal Kenyan Institutions:

Ministry of Health
District Development Committees

Project Costs (order of magnitude): (capital costs only considered.) Assume 80% of the population spend ½ hour per year at a clinic; the number of hours available per

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unit per year is 200 x 75 = 1400. If each unit could handle one family at a time, the number of units needed per million people is:

$$.8 \times 10^6 / (1400 \times 16) = 36 \text{ units}$$

Assume a capital cost to put one unit in the field of shs.300,000 Total shs.10,800,000

(7.7.2) Administration and Procurement of Supplies for Existing Rural Health Facilities

Background: Obstacles to effective health care in the study area as identified by Mutiso are the difficulties of meeting the demand of supplies by the rural health centers. He suggests that part of the problem is administrative bottlenecks.

Purpose: To ensure that medical supplies at the rural health centers are adequate.

Specific Project Objectives:

i. To eliminate administrative difficulties in procurement of medical supplies
ii. To ensure a distribution of supplies such that demand and supply are in balance
iii. To establish inventory/reordering procedures that are effective.

Relationships with Other Projects: This should be operated concurrently with the Mobile Health Delivery System, Project 7.3.1 and the following project 7.8.3.

Design Components:

i. Describe the present budgeting, procurement, allocation, storage, dispensing, reimbursement system in operation in the study area and identify bottlenecks
ii. Determine methods acceptable to MOH administrators of breaking the bottlenecks
iii. Estimate the demand of medical supplies
iv. Determine the administrative requirements for ensuring a smooth flow of supplies from supplier to ultimate user and design a programme.

Design Manpower Requirements:

1 Medical health officer
1 Medical supplies procurement officer
Duration: 6 months

It is assumed that they will leave a programme in place acceptable to and implementable by MOH

1 Medical supplies procurement officer (to advise during the first two years of programme implementation)

Principal Kenyan Institutions:

MOH
Local medical supplies companies

Project Costs (order of magnitude): Excluding specialist manpower assistance the major cost will be for medical supplies. Assume a current deficit of:

shs.20/capita/year this amounts to
20 x 1 million people shs.20,000,000

(7.7.3) Construction and Staffing of Rural Health Centers:

Background: Perusal of the Tables at the back of Report No. 6 Human Resources and Social Characteristics, and the Institutions Report, Chapter 16 reveals the following situation with respect to medical services. (See Table 7.8). The MOH draft of the 1978-1983 rural health center improvement schedule calls for construction of four more centers. This modest construction schedule is apparently constrained by funding limitations.

Purpose: To increase the number and accessibility of rural health centers.

Specific Project Objectives: It is not possible at this point to specify the "appropriate" number and type of rural health centers. Therefore this project will need to be funded in two parts: first, establish an appropriate number, and type and make a cost estimate; second, finance, build, supply and train staff.

Relationships with Other Projects: This should be developed concurrently with projects (7.7.1) and (7.7.2).

Design Components:

Phase I:

i. Review MOH construction programme and funding arrangements for the study area
ii. Establish a basis for setting ratios of population to facility and maximum allowable distances from householders to facilities
iii. Propose types and specific locations for facilities
iv. Estimate ensuing construction costs and recurrent expenditures
v. Review the staffing requirements and suggest a programme for meeting it

Phase II: Design supervision of the specific components identified in Phase I.

Design Manpower Requirements:

Phase I:
1 Public Health Administrator
Duration: 6 months

Table 7.8 RURAL HEALTH FACILITIES IN THE STUDY AREA

Facilities	MACHAKOS			KITUI			EMBU (MBERE)		
	Number in study area	% of Locations with none	Population ratio x 1000	Number in study area	% of Locations with none	Population ratio x 1000	Number in study area	% of Locations with none	Population ratio x 1000
Hospitals	4	74	1:193	3	88	1:102	1	75	1:78
Hospital Beds	651	74	1:1.9	390		1.0.8	116		1:0.7
Clinic	16	56	1:48	9	65	1:34	2	50	1:39
Dispensary or Health Center	38*	11	1:20	24	23	1:13	5	25	1:16

*The Machakos MDIDP report lists only 19

Phase II:

2 Public Health Administrators; one experienced in public health construction, one in staffing requirements.
Duration: Three years

Kenyan Institutions:

Ministry of Health
DDC's

Project Costs (order of magnitude): The Machakos MDIDP programme calls for an expenditure of over 5 years of shs.10 million (this is about 2% of the projected national expenditure over the same period. (Institutions Report No. 7, p.228). With 8 percent of the population, a starting point figure is
(shs.459M x 0.8) - 10m shs. shs.26,700,000

(7.7.4) Environmental Health Project

Background: In the context of the study area, environmental health means principally, sanitation. The Institutions Report (p.229) lists eight waste disposal units and 300 latrines planned for construction in the study area over the next five years. As compared to the need, this is just a drop in the bucket. Mutiso quotes a planner in the Ministry of Health as saying that "with all the money allocated to the provision of latrines in the past 20 years. 10 million should have been constructed." The MDIDP programme plans to construct 90 at rural market centers.

It seems there is a social problem in getting people to build and use latrines. We speculate that, on the basis of recent newspaper accounts of success in getting people in the far east to use latrines, some types are more acceptable than others. Therefore, rather than needing just a construction program, it appears that to be successful it must be preceded by a user acceptance study with field trials of various designs.

The question of sewage disposal from villages and towns in the area has been touched on by Mutiso. It is not always clear under the circumstances of the study area whether it is best to put sanitation money into sewage disposal systems or into better protection of the water supplies. Most developing countries bring their water supplies along to a further point of development before making major investments in pollution control works.

Wherever there are sewage collection systems there should be pollution control works. Oxidation ponds would seem to be the logical treatment method in most of the study area except where there is insufficient flat land.

Purpose: To install needed community and individual family sewage disposal systems.

Specific Project Objectives:

i. To develop a phased programme of sewerage works installations
ii. To generate a programme of installing acceptable latrines at village markets and on farmsteads.

Relationships with Other Projects: This ought to be developed concurrently with Project (7.5.1) the Design and Construction of Large Scale Domestic Water Supply Systems.

It is likely that portions of the reticulated systems will serve towns and villages by providing individual services. This will pose the problem of waste water disposal. There are often substantial economies in installing water and sewerage works at the same time.

If oxidation ponds are built, their effluent can be used as a source of water for small scale irrigation projects. (project 7.6.2).

Design Components:

i. Inventory of:
   - community sewerage works
   - pit latrines
ii. Survey of user attitudes toward use of latrines
iii. Select alternative designs and have a number built and installed to study user acceptance.
iv. Locate potential sites for oxidation ponds near community centers.

Design Manpower Requirements:

Phase I: Investigation

1 Sanitary engineer
Period of study: one year

Phase II: Sewerage Works Construction

1 Sanitary engineer
Duration will depend on the scope of the work identified in Phase I, say 2 years.

Principal Kenyan Institutions:

MOH
MOWD

Project Costs (order of magnitude): The MDIDP program has allocated shs.500,000 for the construction of 90 pit latrines in rural market centers. At shs.5,500 each they will be rather more elaborate than what is needed on the farmstead. If a target of 50,000 latrines, one for every 20 people is set, at a cost of shs.100 each, this program will cost

	shs.5,000,000
Oxidation ponds,10 @shs.100,000 each	1,000,000
Total	6,000,000

(7.7.5) Disease Prevention

Background: In 1976 only 1.5% of Kitui residents were immunized against various communicable diseases. The major disease hazards are malaria, acute respiratory infections, diseases of the skin and diarrhoeal diseases. The problem seems to have dimensions of communication—getting people to health centers, and education. The small scale water and irrigation programs will bring with them an increase in bilharzia.

Purpose: To increase the level of disease prevention through increased immunization and health education programmes.

Specific Project Objectives:

i. To reach MOH approved immunization rate objectives
ii. Make available to every family information on how to prevent diseases of importance in the area.
iii. Design and implement a program of bilharziasis disease control.

Relationships with Other Projects: Should be installed concurrently with the construction of small dams (Projects 7.5.2 and 7.6.2). Will be dependent on the installation of mobile health clinics(7.7.1)and rural health centers (7.7.3) May also be dependent on the medical supplies procurement project (7.7.2).

Design Components:

i. Establish immunization objectives
ii. Determine labour,equipment and supplies needed
iii. Prepare a family educational programme on immunization and other forms of disease prevention
iv. Design an education delivery system
v. Evaluate the potential hazard of bilbarziasis (schistosomiasis) by surveying existing small reservoirs in the area
vi. If it is a significant potential hazard, prepare a program for implementation concurrently with Projects (7.5.2) and (7.6.2) for control of the disease.

Design Manpower Requirements:

2 Public Health officers
Duration: 6 months

Manpower for project implementation to be identified during the design phase.

Principal Kenyan Institutions:

MOH
MOWD

Project Costs (order of magnitude): With roughly one million people in the study area, half of whom are under 15 years of age, assume a target group of 500,000 with education, supply and delivery costs of shs.10/capita

shs.5,000,000.

(7.7.6) Research on Referral System:

Background: There is a hierarchy of medical assistance. People go to local health clinics and dispensaries and their problems are taken care of or they are not. If not, they are referred to the district hospital and then, if necessary, to the Kenyatta National Hospital, or other specialized hospitals. According to Mutiso, (Institutions Report No. 7), the number of referrals is never more than 1 percent. He raises the question whether the referral system is functioning well enough to justify the expenditures contemplated at the higher levels. Stated another way, how can the people of the study area be given better access to the higher level, more specialized hospitals? There needs to be some research to determine what obstacles impede the process.

Purpose: To improve access by the people in the study area to specialized medical services.

Specific Project Objectives:

i. To establish target referral percentages
ii. To institute practices which will lead to reaching the target.

Relationships with Other Projects: Part of this project will be a rural survey. This should be combined with the data collection requirements of the other Rural Health Projects.

Design Components:

i. Data collection
   - from existing MOH data
   - from new field surveys
ii. Data analysis
   - social obstacles
   - financial obstacles
iii. Establish referral percentage targets

Design Manpower Requirements:

2 Public Health officers experienced in collecting and analyzing field data.
Duration: One year.

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Principal Kenyan Institutions:

MOH

Project Costs (order of magnitude): Since this is a research project, the only costs other than for the professional staff are for field data collectors, transport, computer programmer, computer time, secretarial and publication costs. Lump sum shs.500,000

(7.8) SYSTEMS AND PROCEDURES DEVELOPMENT PROGRAM

(7.8.1) Ministry of Agriculture Systems and Procedures Project

Background: One of the major policy decisions in inaugurating a set of new programmes is whether to install new supervisory/administrative institutions to direct the new programmes or accommodate them with the existing institutional structures. Although, in our Institutions Report, we have suggested changes it does not seem desirable to set up some new hierarchical level - say a new Ministry or a "Semi-Arid Lands Development Authority" providing the existing agencies can adjust to handle the increased scope of activities thrust upon them.

With so many government agencies already operating in the study area who have competent people, familiar with local conditions, the momentum of their efforts is considerable. Another bureaucratic layer imposed in the study area would probably be less likely to succeed than would strengthened existing organizations.

The ongoing programmes in the districts are taxing the resources of the staff operating these programmes. A District Agricultural Officer faced with the prospect of having to implement the crop and livestock programme proposed herein will immediately recognize that with his existing resources he will simply be unable to cope.

The GOK, recognizing the institutional organizational challenges of development has ongoing programmes of institutional improvement. One of these involves the "Harvard Group", whose major efforts are directed toward MOA organization, especially the planning functions. These programmes need to be encouraged and intensified to meet the semi-arid lands.

This project is targetted at the field supervisors

in MOA at the Provincial and District levels. It is not proposed to tell them what their jobs are. They already know that better than anyone else. It is to be a specialized resource to help them find easier, quicker, cheaper, smoother ways to get their work done. We have watched with considerable admiration the efforts of field officers to deal with the mountains of paper work associated with their duties. It seems that the fuel of government bureaucracy is paper.

If a DAO could be freed from half his paper work he would probably have cut his total work load by at least one-third. Paper flow is essential in any organization but it is an unusual office that does not have redundant, obsolete, obscure, inaccurate, paper flowing through it. The senior author has participated in office systems and procedures analysis in a large government bureaucracy and has been a beneficiary of the work of specialists in helping him to streamline his operations.

Paper flow is not the only focal point for systems improvement. All facits of a supervisor's planning, programming and control have opportunities for improvement.

This project will not establish new organizations, but it will focus on making the work of key supervisors easier and more effective.

Purpose: To assist MOA field officers to adjust their planning, programming and resource control functions so they can cope with the increased responsibilities of managing new projects.

Specific Project Objectives: To provide a team of experts so that, acting on the request of field supervisors, they can assist them to plan program and control their operations in an effective, efficient manner.

Relationships with Other Projects: Programmes (7.1,7.2, 7.6, and 7.7) will all make demands on the time of MOA supervisors. This programme should parallel those. It can be commenced even before the others are implemented to help officers "clear the desks" before the new programmes start to make fresh demands on their time.

Design Components:

i. Identify the supervisors'primary and secondary objectives
ii. Identify the obstacles he has to overcome to achieve his objectives
iii. Suggest bottleneck breaking innovations including redeployment of resources and/or securing additional resources to help in accomplishing objectives such as;

- chart communications patterns to and from a supervisor
- identify communications objectives
- compare results of communications with objectives

iv. Using flow charting and other systematic procedures suggest communications systems improvements.

Design Manpower Requirements:

6 Systems and Procedures specialists
1 Computer Programmer
Duration of assignment: Two years.

Principal Kenyan Institutions: This project has been proposed for the Ministry of Agriculture. If it proves helpful to that Ministry, after a year's trial, it should be duplicated with the field staff of the Ministries of Water Development, Works, Natural Resources and Health.

Project Costs (order of magnitude): Transport, office space and adequate housing in the field, secretarial assistance and computer time. Lump sum shs.3,000,000.

7.11 PROJECT SUMMARY

Table 7.9 has been prepared as a summary of projects, suggested manpower requirements for the design (or feasibility) studies and costs. Again the reader is cautioned not to make firm budget commitments using these figures. That should await the work of the designers.

Although the projects have been based on the needs perceived for the portions of Machakos, Kitui and Embu lying within the study areas, every one of these projects could profitably be applied to the Baringo/Kerio Valley area. It is suggested that they be reviewed with that area in mind as well.

Table 7.9 PROJECT SUMMARY-DESIGN MANPOWER AND COSTS

Program	Project	Manpower Requirements Design man years(1)	Implementation Costs(2) shsx10^6 Direct cost to farmers	Not directly chargeable to farmers
Crop and Livestock development	Seed breeding, multiplication etc.	.5	16.7	
	Provision of dairy cattle	3.25	170.0	
	Improved tillage implements	2.3	32.9	
	Improved insect control	1.0	10.6	
	On-farm crop storage	1.0	10.7	
	Crops, livestock dairy marketing	6.0	10.0	
	Improved veterinary services	2.0	6.0	
	Fertilizer supply	2.0	234.0	
	Technology training packages	12.0		4.0
	Credit requirements and drought insurance	2.0	622.0	
	Dryland farm research	2.0		104.0
Soil and Water Conservation	Hydrology	1.0		3.0
	Soil conservation structures	3.0	400.	403. (4)
	Technology training packages	2.0		0.7
	Rangeland renovation	4.0		8.7
Afforestation	Nursery, seedling distribution	1.0	42.0	
Rural Roads Improvement		1.0		328.0
Rural Domestic Water Supply	Reticulated systems	2.0		280.0
	Small scale water supply	1.5		340.0
Irrigation	Large scale projects	4.0	300.	
	Small irrigation projects	6.0	34.8	
Rural Health & Nutrition	Mobile health delivery system	2.0		10.8
	Supplies procurement	1.0		20.0
	Rural health centers	0.5		26.7
	Environmental health	1.0		6.0
	Disease prevention	1.0		5.0
	Referral system research	2.0		0.5
Systems and Procedures		14.		3.0
	Totals	81.0	(3)	1543.4

(1) Some project manpower requirements have been broken into two parts: Feasibility and Design. These totals include only the feasibility component since the manpower requirements for design will be better known after the Feasibility Study.

(2) Does not include design costs

(3) These figures have not been added up in order to avoid double counting.

(4) Assumes a 50% government subsidy for soil conservation works

APPENDIX I

A NOTE ON BENEFIT - COST ANALYSIS

The viability of various project activities is demonstrated in this report by means of benefit - cost calculations. As noted in the introduction. these estimates of benefits and costs are preliminary in nature and are intended to give only a general indication of potential profitability and financial requirements. Even though preliminary and subject to further refinement, a certain care needs to be taken in the way benefits and costs are presented. The purpose of this note is to set out the basis for these calculations. The topics to be covered include types of analyses, profitability criteria, pricing, inflation, costs of credit, and economic and social infrastructure.

I. 1 Types of Analysis

Several types of analyses and feasibility are commonly described in the literature on project investment, these can be combined into those related to technical, economic and financial analysis. Technical feasibility is considered as meaning that a proposal project can be carried out in the manner described. This applies to physical, engineering, social and political factors. Reasonable accuracy in these areas is needed if meaning is to be given to subsequent economic and financial analyses. For example, cropping yields should respond as indicated to alterations in moisture, tillage and nutrients, peasant farmers should be willing to accept proposed changes and the Government must be able to supply requisite services. Obviously, it makes little sense to estimate benefits and costs for proposals that cannot function as indicated.

Economic analyses are undertaken to reveal whether or not a suitable return will be obtained from the costs incurred. In simplest terms, benefits must exceed costs if a project is to be considered economically desirable. Because benefits to some are costs to others, the point of view of the decision-maker needs to be identified. For example, taxes paid by private industry are costs to them, where they are revenues to the Treasury and ultimately the public at large. Consequently, economic feasibility of projects involving Government support or private activities will normally be carried out from both private and public points of view. A project economically viable from the national point of view but not from the private point of view means that society received more than it pays, while private groups participating directly in the project receive less than they pay. Such a project may be highly desirable to the Government, but it will have to be redesigned since the private sector would not be interested. Conversely, a project that is of interest to private groups but is not in the national interest should be discouraged by the Government even though private groups may be willing to undertake it. Judicial use of taxes, subsidies, and tariffs is a common way for governments to encourage or discourage private participation in such projects.

Financial analyses as described in this note refer to the availability of cash funds to meet investment and operating requirements.* Projects may be desirable economically; but if funds are not available--from whatever source--as needed, then the project cannot be undertaken or continue to operate. Those with limited assets may know of many good investments but will be unable to take advantage of them because they do not have the resources at their disposal. In contrast, few national governments should have to forego projects with high economic returns simply because governments have much greater access to sources of funds. Note, this point was put forth during the Mid-point Review.

The analyses conducted as part of this study are limited to a general presentation of technical feasibility, economic analysis from the private point of view, more general references to the national interest, and certain financial implications. Such a presentation is considered sufficient for the purposes of project identification. More detailed and complete analyses constitute the essence of project design, which is to be undertaken by others.

I.2 Profitability Criteria

The economic viability of a project is normally estimated by one of four alternative measures; rate of return, net present worth, equivalent annual values, and benefits cost ratio.** Subject to a few minor reservations all four methods give comparable results when evaluating one or more projects, provided of course that procedures are properly followed.

The equivalent annual value method*** converts all cash flows to a uniform set of values over the life of the investment. The time value of money is taken into account by first converting cash flows to the beginning or end of the analysis period and subsequently converting this result to the uniform annual value. For further insight into these techniques see texts on project analysis such as those of Grant and Ireson and Gittinger. This method of analysis was chosen for this study because the results can be seen in the form of annual incomes, which can be more readily compared with current income levels of the region's farmers.

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* This interpretation follows that of Eugene Grant and W. Grant Ireson in Principles of Engineering Economy. World Bank Specialists, on the other hand, tend to refer to economic feasibility from the private point of view as financial feasibility. For this latter view see J. Price Gittinger in Economic Analysis of Agricultural Projects.

** This generalization applies to Western Societies and certain International Institutions such as the World Bank. Other measures are sometimes used, but they are generally less effective.

*** Alternatively called the equivalent uniform annual cash flow method or the equivalent uniform annual cost and benefit method.

The authors of this study realize that the measures of economic profitability according to the above mentioned procedures has its limitations and reveals only part of a project's real worth to the individual and to society. Social and political objectives, variability of possible outcomes, inter-industry linkages, the dynamics of savings and reinvestments, and in some cases the income multiplier are all topics of analysis that may be taken up once a project moves from the identification to the evaluative stage.

The emphasis in the present study on annual returns to the farmers is taken as a primary test of the viability of alternative productive schemes. The authors felt that the measure of development potential should be made on such productivity grounds. Meeting the productivity test helps to assure increased production for the area and in turn the social and related benefits that increased incomes and revenues can provide. Of course how one goes about measuring future values of output and revenues is tricky business, which is the subject of the next section. Also the prices that farmers see in the market place do not necessarily reflect national values. Some regulated prices are either above or below an equilibrium value- and some factors of production such as domestic capital, unskilled farm labor, and foreign exchange are priced at other than their true economic value to society. These factors, which will be discussed again, are worked into the evaluation of alternatives as related issues rather than as an integral part of the analysis. Such an approach is dictated by time constraints and by the focus on project identification. Where projects do not lend themselves to normal profitability tests as with rural water supply, a cost effectiveness approach was taken. This concept involves considering alternative ways of providing various levels of service.

I.3 Pricing of Inputs and Outputs

The choice of proper prices of inputs and outputs requires careful consideration if benefit - cost calculations are to reveal the real value of projects to participants and to the economy. The concepts described below were followed in selecting the values to be used in the economic analysis.

I.3.1 Farm - Gate Prices

Costs and benefits occuring to the farmer and rancher were taken as those occuring at the so-called farm gate. These values represent what he pays for his supplies and what he gets from the sale of his production. The farmer's own consumption is valued at its equivalent market prices. Sales by this assumption are those that take place either at his farm or at a nearby market. As the farmers' or ranchers' products move through the market system, their value will increase. But whereas values increase, so do costs. Any increment of benefits over costs from additional processing or handling represents further benefits to society. However, computations of such additional values requires

careful analysis and is usually unwarranted so long as the basic activity is well justified. As a general rule all primary activities such as farming, contain their own set of complementary activities that tend to increase the overall impact on the economy. Under conditions of capital constraint, as in Kenya and most developing economies, the prime purpose of project evaluation is to distinguish between good and bad projects in an economic sense. Good projects are generally considered to be those whereby primary benefits exceed costs. On occasion a project may not produce primary benefits in excess of primary costs and still be economically good for the country. Such an example might be the production of raw materials to be used by a processing industry with surplus capacity. Overall benefits might then exceed overall costs whereas primary benefits might not exceed primary costs. But such cases are not sufficiently abundant to abandon the general principle of requiring benefits of primary activities to exceed their respective costs.

I.3.2 Market Values

Official prices, as for maize and certain other commodities, do not always represent values received by farmers and ranchers. If they are forced to sell at below official prices for whatever reason, or if they are able to sell above official prices, these values more accurately reveal the real value of production to the farmers. Consequently, official prices were not used when evidence indicated that farmers were actually receiving some other price. Similarly, in valuing forestry production for firewood, royalty payments were not considered as representing the full value of this resource because of the Government's practice of subsidizing this activity.*

I.3.3 Family Labor

Farm-family labor does not lend itself to easy evaluation of its economic worth. The going rural market wage tend to overstate its value except in times of labor scarcity. When jobs are scarce and labor abundant, hired labor rates should drastically drop. Yet they seldom do to the point of clearing the market. Alternatively, family labor whether knowingly or not often works for an effective wage below that prevailing in the market. As a consequence of the difficulty of

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* Such views are described in greater detail in the World Bank's "Appraisal of the Second Forestry Plantation Project, Kenya" and in the Forestry Department's Study of the "Profitability of Eucalyptus Saligna Plantation in Ngong Forest District from a Social Cost/Benefit Point of View and Estimates of Fuelwood Royalties".

estimating a realistic market wage for farm-family labor, returns from farming investments and activities are calculated net of family labor costs. The results are consequently expressed as returns to family labor, management, land and capital, rather than just the latter three items. The interpretation of the results then requires determining whether the net is sufficient reward to interest the farmer. Departures from this approach were taken in costing out the construction of terraces, roads, and similar works. The reasons for this lies with the assumption that the bulk of these activities will be carried out by hired labor, or that family labor would demand such payment for this type of work. Such an approach facilitates the evaluation of the costs of these facilities. However, should these assumptions not be correct and family labor donate their services for road building, terracing, and related works or be willing to work for less than the going rate, then the costs of these facilities are obviously overstated.

I.3.4 Discount Rate

The selection of a discount rate for evaluating investments can be subject to considerable debate, depending on the purpose for the analysis, the point of view of the decision-maker, and the economic leanings of the analyst. To lend precision to the analysis, at least two interest rates should commonly be used. One represents the incentives required to interest private parties, including small holders. The other represents the value of capital to society. Because of the preliminary nature of the analyses carried out in this study, a single value of ten percent has been chosen. This value has been used in other Government analyses and is midway between eight and twelve percent, which have been suggested by Government officials as reasonable possibilities for evaluating investments from the national point of view. Such an interest rate supposedly represents the real value of capital to society free of risk and inflation. Such a rate is probably low for private investors, but may not be very much so, as long as cash flows are neutralized for inflation and represent "best estimates" of possible returns and to the extent that small holders are investing their labor and not cash savings or borrowed funds.

I.3.5 Foreign Exchange

Medium-term forecasts, such as those made by the World Bank in Kenya Into the Second Decade point to foreign exchange as one of the prime constraints to Kenya's rate of economic growth. Various policy proposals contained in this and other reports, stress the importance of earning foreign exchange through increased export and through import substitution. Such state-

ments indicate that Kenya, as with many other countries at similar stages of development, values foreign exchange more highly than the official exchange rate. Under these circumstances a premium can be placed on foreign exchange earnings (and savings) and expenditures to represent their real value to society. Again because of the preliminary nature of this report's investment analysis, such a "shadow pricing" of foreign exchange has not been attempted. Instead, general levels of foreign exchange impacts are pointed out as appropriate.

I.4 Inflation

The manner for properly allowing for inflation is frequently a problem for those carrying out analyses of economic profitability. Projecting the general level of inflation over the economic life of a project is difficult enough. To estimate inflation rates for each project benefit and cost is particularly difficult. Moreover, at inflation rates on the order of ten or more percent per year, future values soon dwarf present values.*

A suitable means for treating inflation is to assume inflation permeates society in such a way that all factors of the benefit-cost analysis are uniformly affected, including the cost of money. Under this assumption, inflation can be left out of the analysis, without affecting the accuracy of the calculations. Even where inflation rates diverge, the differences are usually not great. In addition, difficulties in estimating future costs of basic components of a project normally make estimates of differences in inflation rates an unnecessary refinement.

For these reasons, the effects of future inflation have been omitted from the economic estimates of profitability. All values used in the calculations have been taken as those prevailing during 1977. When estimating future monetary requirements, which is part of financial considerations such as total investment costs and loan requirements, estimates of inflationary trends are needed. But this reference to fund requirements, is part of the analysis to determine how the project is to be financed, not whether it is economically desirable.

I.5 Cost of Credit

In line with the distinction between financial and economic analyses, interest payments for borrowed money are not included in annual benefits and costs. The costs of medium and long-term loans and bonds are subsumed in the discount rate.

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*For example, a 15 percent inflation rate for 25 years produces a terminal value that is .33 times the initial value. That is, $(1.15)^{25} = 32.9$.

I.6 Economic and Social Infrastructure

Economic calculations have been divided into three types: those that are directly productive, such as crop farming, dairying, and ranching; those that support economic activities, such as roads, marketing, and credit; and those that respond to the social desires of the populace.

The directly productive activities are evaluated on their individual merits. Those with positive net benefits are economically acceptable; the rest are not. For all but traditional, subsistence agriculture some minimum level of economic services has been assumed. The surplus of benefits over costs of the directly productive activities represents the margin to cover such economic infrastructure requirements as roads, marketing, and extension. If the margin is sufficient to cover these supportive costs, the overall program passes the economic test. Should the costs of the necessary economic infrastructure exceed the margin for the directly productive activities, the overall program fails the economic test and program revisions are in order.

Most of the social services, such as general education, health, community centers, and family planning, are not so closely linked as are directly productive activities and the economic infrastructure. As a result, more freedom is allowed in the type, location and size of social programs. Decisions concerning social services are therefore more a function of broad Government policy than the dictates of particular economic activities. This is not to say that linkages do not exist. They do, as with the provision of convenient water supply which frees up labor for more productive uses or with a healthy labor force that is capable of working longer and harder. But for the most part the relationships are more tenuous. As a result, the recommendations on social services contained in this report are not, except in the case of rural water supply, tied specifically to the economic activities.

Finally, housing costs have been omitted from the benefit-cost calculations. As population expands in the area and homesteads are created on new lands, a considerable investment in individual housing will be required. This investment has been omitted on the assumption that the benefits of rural housing approximate the value of service and that farm families will be able to finance this cost as they have in the past. Should the Government wish to subsidize or otherwise upgrade the standard of housing, it can do so on the same grounds as any other social services program.

APPENDIX II

DETAILS OF BENEFIT - COST ANALYSIS OF GROWING EUCALYPTUS FOR FIREWEOOD AND POLES IN MACHAKOS - KITUI - EMBU

The summary of equivalent annual returns from small-scale eucalyptus production in the Machakos - Kitui - Embu area is based on the analysis described below. Factors taken into account are investment, cutting and deliverying costs, yields, times to harvesting, selling price and technical assistance. Since cost data and yields are only specific to ecozone III, values for the other zones are less precise. Nevertheless, the outcome is believed to be sufficiently accurate for planning purposes. Results were summarised in Table 5.3.6 of the text and are detailed in Table II.1 below.

II.1 YIELDS

Yields for eucalyptus production come from several sources. The most complete information encountered is that by Dyson. He reports equivalent annual yields for the Department of Forestry plantation at Muguga that range from 18 M^3 per hectare for the first cutting (8th year) to 33 M^3 per hectare for the second cutting (16th year). A third (24th year) and final cutting is 24 M^3 per hectare. Estimates by Solberg for Ngong, which has similar climatic conditions to those at Muguga, including annual yields averaged over the three cuttings of 31 M^3 per year under average conditions, 24 M^3 per year under low yields and 38 M^3 per year under high yields. The spread between low and high yields indicated by Solberg can be explained at least in part by variations in rainfall. Dyson tested variations in yields against rainfall and found the correlation to be statistically significant. By using approximations to possible high and low rainfall conditions, together with yield data suggested by Kabagambe and authors of the Bura report* and by taking into account the possibility of having some useful production at annual rainfall levels of 300 mm, a production curve was traced out.** The average annual yields according to rainfall, shown in Figure II.1 were reduced by roughly 25 percent from those reported by Solberg. This adjustment brings them more in line with Dyson's figures and is in

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*Dennis M. Kabagambe "Aspects of Resource Conservation and Utilization: The Role of Charcoal Industry in the Kenya Economy", Institute for Development Studies, University of Nairobi, June 1976," Sir M. MacDonald & Partners, Bura Irrigation Settlement Project, for Ministry of Agriculture and National Irrigation Board, Republic of Kenya, August 1977.

**See G. R. Davis, Potential for the Production of Eucalyptus Oil and Gum Arabic in Kenya, "UNIDO acting for UNDP, Nairobi 1978.

Table II.1 EQUIVALENT ANNUAL RETURNS FROM SMALL-HOLDER GROWING OF EUCALYPTUS FOR FIREWOOD AND POLES IN MACHAKOS - KITUI - EMBU

Activity	ECOZONES III	IV	V
Yields in year 8, M^3/ha	136	96	64
16	224	152	112
24	200	136	96
Values in year 8 at shs 70/M^3	9,520	6,720	4,480
16	15,680	10,640	7,280
24	14,000	9,520	6,720
Equivalent Annual Value of Output for 24 years at 8 percent interest	1,130/yr	780/yr	530/yr
Investment at outset			
Nursery (seedlings)	280	280	280
Box materials	60	60	60
Tools	20	20	20
Miscellaneous	30	30	30
Total	390	390	390
Replacement after one year at 15% of original cost	60	60	60
Special care and treatment during first four years	50/yr	50/yr	50/yr
Extension costs at outset	160	160	160
Continuing direct costs of Forestry Department for years 1 to 24	20/yr	20/yr	20/yr
Cutting and delivering costs in year 8 at Shs.18/M^3	2,440	1,720	1,160
16	4,040	2,740	1,880
24	3,600	2,440	1,720
Equivalent Annual Value of Costs for 24 years at 8% Interest			
Initial Investment	40	40	40
Replacement	5	5	5
Special care	15	15	15
Extension at outset	15	15	15
Continuing direct costs	20	20	20
Cutting and delivery	285	205	135
	380/yr	300/yr	230/yr
Net returns	750/yr	480/yr	300/yr

*All values are on a solid volume basis

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response to Dyson's suggestion that actual yields (applicable to small-holders) are expected to be less than those shown in his report.

Yields corresponding to average annual rainfalls for ecozones III through V, which are taken from Figure II.1, are as follows:

Ecozone	III	IV	V
Average annual rainfall, mm	955	695	540
Average annual yields, M^3			
1st rotation (year 8)	17	12	8
2nd rotation (year 16)	28	19	13
3rd rotation (year 24)	25	17	12

Note should be taken that the yields for other than ecozone III are extrapolations and subject to the limitation associated with such extensions of data. Also, values were not estimated by the above procedures for ecozone II because of the doubt concerning the linear extrapolation that would produce such high yields at the average rainfall (1240) in this ecozone.

II.2 VALUE OF PRODUCTION

The value of producing eucalyptus can best be estimated by obtaining the selling price of the trees before cutting. Royalty rates paid to the government represent the costs to contractors for the right to harvest the timber. But rates charged by the government are below the real value of this resource to society.*

Consequently, these values do not give a meaningful value for eucalyptus production. This situation requires going to the next marketing level to obtain a more realistic measure of economic worth. Data were available from Solberg's report on the unit price paid by East African Industries for large purchases of eucalyptus for firewood. In 1975 this organization paid the equivalent of shs.51 per M^3 (solid volume), which in 1977 prices would be about shs.75 per M^3. Reducing this slightly to account for lower prices prevailing in areas outside Nairobi, gives the value of shs.70 per M^3 used in this appendix.

II.3 EQUIVALENT ANNUAL VALUE OF OUTPUT

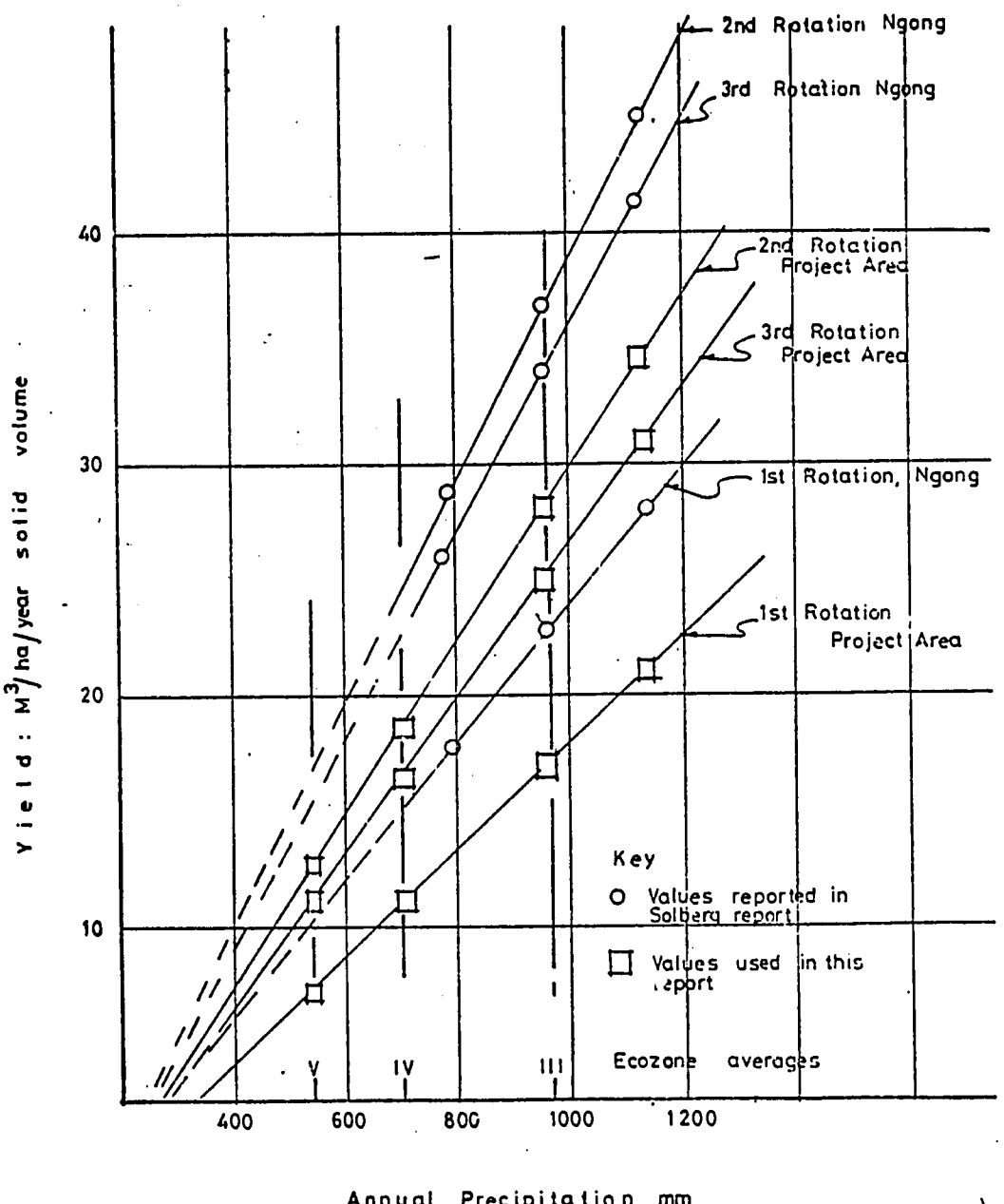
Average annual output was multiplied by eight to give total volumes obtained in year 8, 16, and 24. These amounts

*For example, see Solberg, Annex 10 of the World Bank's Agricultural Sector Survey (Kenya) December 20, 1973, and Annex 7 in the World Bank Appraisal of the Second Forestry Plantation Project: Kenya, June 4, 1975

Figure II. 1

Eucalyptus Yields for Ngong and Project Areas

(Note: Project Area taken as 75% of Ngong Station)



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were discounted by 8 percent to obtain their present worths. This result was then converted to an equivalent annual amount by applying the capital recovery factor.*

II.4 INVESTMENT COSTS

Investment costs comprise land clearing, purchased inputs, technical assistance, tools and labour. Land clearing is site specific and difficult to estimate. Costs of land clearing were not specified in the aforementioned references on forestry production. Should the owner clear the land himself, he will have little cash expenditures and will very likely obtain value from the sale or use of the cleared bush and shrubs as firewood and charcoal. Should he hire labour for this purpose, the value of the cleared material will offset to some degree his hired labour costs. For want of adequate information on this item, the value received from clearing is assumed to equal the costs.

Solberg estimates initial nursery and seed costs to be 280 shillings per hectare and box materials to be 60 shillings per hectare - both adjusted to 1977 values. To this have been added an estimate of the cost of tools (20 shillings per hectare) and miscellaneous costs of 30 shillings per hectare for occasional use of chemicals and other items. Labour for planting is assumed to be provided by the farmer himself and has thus been omitted as a cost.

Fifteen percent replacements are assumed necessary after one year. The cost is taken as a percentage of initial investment. Some form of special care, including watering and possibly sprays are assumed for the first four years. After that the stand is assumed to be well established.

Services of an extension agent will undoubtedly be necessary to help the farmer plan his production and lay out the field. The estimate of shs. 160 per hectare assumes each farmer plants two hectares and receives two days of assistance from an extension agent, which includes his salary and per diem costs.

A small amount (shs.20/ha) is assumed as general support costs by the Forestry Department as part of its overall expenditures in boundary clearing, fire patrolling, and similar services. These services are listed by Solberg as part of the overhead costs for the Department's forest stations. The above estimates, however, assumes less involvement by the Department and is accordingly less than Solberg's estimate.

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* $\frac{i(1+i)^n}{(1+i)^n - 1}$, where i is the eight percent discount rate and n is the investment life of 24 years. The resultant factor is 0.0950.

A much more significant cost is that for cutting and delivering the wood to market. Solberg obtained estimates of contractors' costs for this operation. As before, costs have been adjusted to bring them to 1977 values and costs of labour for cutting and stocking have been omitted on the assumption that this activity will be provided by the farmer. A breakdown of these cost items on a solid volume basis is:

	Shs./M^3
Driver and his helpers	3.00
Truck use	13.50
Miscellaneous	1.50
	18.00

No amount is allowed for contractors gross profit on the assumption that part of the farmer's return is from arranging for the necessary services to deliver the wood and to make the sale.

II.5 RESULTS

The results of the profitability calculations therefore approximate returns to the small-holder for land, labour, management and capital. Actual returns may be somewhat higher, since it is doubtful if the farmers will pay for extension and Forestry Department services. Or his returns may be lower if he contracts to have the timber cut and marketed, for in this case he will have to share the returns with the contractor doing the cutting and marketing. In any case, the net returns are considered as a reasonably accurate indication of profitability, which can be compared with farmer returns from cropping and livestock.

APPENDIX III

CALCULATION METHODOLOGY FOR ESTIMATING POPULATION CARRYING CAPACITIES BY LOCATION UNDER INTERMEDIATE AND ADVANCED TECHNOLOGY

Population surpluses (+) and deficits (-) were estimated as follows for each location:

Three maps of the area at 1:250,000 were prepared, one showing proposed soil conservation works (coloured, opaque); one showing land suitability classes for intermediate technology (coloured translucent); and one showing location boundaries (line, translucent). Areas and 1985 population estimates were tabulated for each location. By overlaying the two translucent maps over the opaque soil conservation map the percentages of Class A, B, C, and D suitability land in each location were estimated. We did it by eye. It would theoretically be more accurate to use a planimeter but the uncertainty of the boundary lines between soil units at this scale makes this level of refinement unnecessary .

Multiplying the area of the location by the percent in a soil class gives the hectarage in each soil suitability class by location. It is assumed that the population is more or less evenly distributed throughout the location, so the number of people on a given soil suitability is estimated by multiplying the total population in the location by the percent of area occupied by the particular soil suitability. Thus for Kangundo location, with a population estimate in 1985 of 64,400, ten percent of it is in ecozone III, soil suitability class A. So about 6,440 people will have to earn a living on this area. This method of "assigning" people to areas will tend to assign too many people to the poorer soils and too few to the better soils but since we are looking for a total (summed) population excess (+)/deficit (-) estimate for each location, these errors finally cancel out.

Kangundo has a total area of 148 km^2 of which 14.8 is in land suitability A ecozone III. We have estimated a land use potential by land suitability class and ecozone (see Table 6.2.1). Thus for III A, 90% of the 14.8 km^2 is available for farming. Assuming 8 people to a farm, we have then a need for 6440/8 = 805 farms. Using the model farm size as described in Appendix VI of 5 ha in ecozone III, 805 x 5 = 4,025 ha of land are needed to handle the population. However only 1,330 ha are available which can handle 1330/5 = 266 families so there will be a surplus of 805 - 266 = +539 families. Now at 5 ha per farm, in ecozone III land suitability level A, a family should be able to earn on the average about Shs 6,500. (Table 6.2.1). If we set a target income of say Shs 4,500, a family could get along with 5 x 4500/6500 = 3.46 ha, in which case the number of farms could be increased to 1330/3.46 = 384 which decreases the surplus to 805 - 384 = +420.

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Similarly we have gone through calculations for each location by ecozone and soil type. It is important to note that soil conservation costs have been annualized and charged against the farm. If these were to be subsidized, slightly smaller farms would yield the target income.

APPENDIX IV. Details of Investment and Maintenance Cost for Terracing, Cut-off Drains and Related Facilities

Unit costs presented in Table IV.1 are based on the breakdown of activities described below. Estimates of current market costs of labour hired to excavate the cut-off drains and fanya juu ditches are reasonably firm. These values are based on detailed cost data by location collected by Wenner. Other costs are less precise and deserve further investigation as time permits.

Details in Support of Table

Excavation

Excavation costs for terraces developed by Wenner (Soil Conservation in Kenya, pp 99 and 100) show a functional relationship of $y=17+27x$, where x equals average slope in percent and y equals the costs of excavation per hectare. This function has been adjusted to 1977 conditions for the project area and incorporates the shadow wage of shs. 3.00 per day (i.e., 50 percent of the shs. 6.00 market wage). The shs. 6.00 per day comes from terracing costs of shs. 2.00 per cubic meter of excavation and a production rate of 3.0 cubic meters per day.

Costs for BD, CD and BE slopes have been reduced in proportion to the percentages below 8 percent that do not require terracing. Costs have been increased by 50 percent where stony conditions are likely to be encountered. These occur for some of the mapping units with slopes of CD, DE and EF. Two values are given for these slopes, since some of the soils are not stony. The 50 percent increase is based on actual cost data for stony verses normal soils.

Grassing

Costs of obtaining grass shoots, planting, tending and replacing bare spots were not available from the conservation group in the Land and Farm Management Division. Such costs are estimated as being slightly less than half the cost of excavation based on the amount of effort involved. This estimate assumes that grasses are planted at the outset of the rainly season so that problems of watering during the early stages of growth are minimized.

Supervision

Supervision of work is estimated at roughly 20 percent of the market cost of excavation. This is divided between the costs of job foremen to supervise excavation and Government technicians who are needed to help lay out

Table IV.I

Breakdown of Costs of Soil Conservation Facilities for Terraced Areas in Machakos--Kitui--Embu

(Shillings per hectare)

Slopes	Investment: Terracing: Excavation	Grassing	Supervision	Tools	Total	Cutoff Drains & Other Facilities	Total	Annualized Investment Cost at 8% Interest	Annual Maintenance Costs	Total Annual
BD (2-16%)	150	70	80	20	320	280	600	50	50	100
CD	210	100	120	20	450	280	730	60	60	120
(5-16%)**	320	100	180	30	630	380	1,010	80	60	140**
BE (2-30)	350	170	190	30	740	280	1,020	80	90	170
DE	530	250	290	40	1,110	280	1,390	110	120	230
(8-30%)	800	250	430	60	1,540	380	1,920	150	120	270**
DF (8-50%)	800	380	450	60	1,690	280	1,970	160	170	330
EF	910	440	510	80	1,940	280	2,220	180	190	370
(16-50%)**	1,370	440	760	120	2,690	380	3,070	250	190	440**

** These lines represent increased costs due to the soils being stony.

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the scheme. Central office expenses have not been included in these costs.

Tools

Approximately five percent of excavation costs are assumed to be for tools needed for earth work. They include shovels, mattocks, hoes, and "pangas" (bolo knives). These items are assumed to have a useful life of two years, with some losses in less than two years.

Land Lost to Production

Even though the area taken up by ditches and ridges may amount to 15 percent or so on some of the steeper slopes, no cost is attributed to this case. According to the conservation group, the area is not lost to production. Grass coverings can be used as cattle feed, fruit trees can be planted on the ridges, and bananas in the ditches. Without belaboring the point, the value of land used for these purposes was assumed to equal that of the terraced areas.

Cutoff Drains

Wenner shows that the linear meter costs of excavating cutoff drains is about twice that for terracing. By assuming that cutoff drains are spaced 150 meters apart on average, each meter of drain would serve 150 square meters of terraced area, or 1.5 percent of a hectare. At a shadow cost of excavation of one shilling per linear meter, a hectare of area protected by the drain would cost shs. 67. Allowing for about the same relationship between excavation and total costs as for terracing, the overall costs of cutoff drains come to approximately 140 shillings per hectare of terraced area. As with costs for excavating terraces in stony soil, the costs of cutoff drains also increase where stony soils are encountered.

Other Facilities

Costs of other facilities such as grassed waterways, check dams, and other works might well be more than for some of the drains. But their frequency of accurrence is less. For want of more specific information, the costs of these other works are considered to equal the costs of cutoff drains, i.e., 240 shillings per hectare of protected land.

Annualized Costs

Initial investment costs are converted to their equivalent annual amounts by applying an eight percent

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discount factor for an assumed life of 75 years. For these values, the annualizing factor approaches the interest rate itself, namely eight percent.

Maintenance Costs

Reliable data on maintenance costs were not uncovered. As a result, an estimate of 15 percent of excavation costs for terraces, drains and other workss was assumed. This value is not considered excessive in the light of high maintenance costs expected in the early years while the terraces, drains and other facilities are becoming established.

Grass Strips

The costs of cutoff drains and related works for grass strips were reduced by about one-third to allow for the lesser need for soil conservation measures on these shallower slopes. Costs were further reduced for mapping units with AC (0-8 percent), BC (2-16 percent) and BE(2-30 percent) slopes the account for the savings from not having to provide cutoff drains on slopes of less than five percent. But as noted earlier, this conclusion about the point where cutoff drains are not needed is a generalization that requires further inputs from those most knowledgeable on soil conservation in Kenya.

Table IV.2 COSTS OF TERRACING AND OTHER SOIL CONSERVATION MEASURES FOR MACHAKOS-KITUI-EMBU

				Potential Land Use						Investment		Annualized Investment 8%		Maintenance Costs		Total Costs	
		Area ha.								Totals Millions of shillings			Totals Millions of shs/yr		Totals Millions of shs/yr		Totals Millions of shs/yr
Ecozone	Mapping Unit	A	IA	Rate	A	IA	% of Potential** to be cropped	Area of Potential to be cropped A	Area of Potential to be cropped IA	Unit Cost shs/ha	A	IA	Unit Cost shs/ha	A	IA	Unit Cost shs/ha	A	IA	Unit Cost shs/ha	A	IA
II	MQ1/EF		4,840	90%		4,360	90%		3,920	1,970		7.7	160		0.62	170		0.67	330		1.29
III	MN1/CE		3,500	93		3,150	50		2,520	1,390		3.5	110		0.28	120		0.30	230		0.58
	MN3/EF	15,940		75	11,960		80	9,570		3,070*	29.4		250	2.35		190	1.82		440	4.17	
	MQ1/EF		16,240	90		14,620	80		11,700	1,970		23.0	160		1.84	170		1.99	330		3.83
	UN1/CD		4,030	90		3,630	80		2,900	730		2.1	60		0.17	60		0.17	120		0.34
IV	MN1/CE		350	90		320	71		220	1,390		0.3	110		0.02	120		0.03	230		0.05
	MN2/LE		10,330	90		9,330	71		6,620	1,920*		12.7	150		1.02	120		0.79	270		1.81
	MN1/EG		55,960	90		50,360	71		35,760	2,870		102.6	230		8.21	240		8.58	470		16.79
	MN3/EF	32,690		75	24,520		71	17,410		3,070*	53.5		250	4.28		190	3.31		440	7.59	
	MQ1/EF		9,810	90		8,830	71		6,270	1,970		12.4	160		0.99	170		1.07	330		2.06
	UN2/CD		5,870	90		5,280	71		3,750	730		2.7	60		0.22	60		0.23	120		0.45
	UN1/CD		12,050	90		10,840	71		7,730	730		5.6	60		0.45	60		0.46	120		0.91
	UN2/ED		25,220	90		22,700	71		16,120	600		9.7	50		0.78	50		0.81	100		1.59
	UQ1/CD		5,540	90		4,990	71		3,540	730		2.6	60		0.21	60		0.21	120		0.42
	UU2/CD		9,410	90		8,470	71		6,010	730		4.4	60		0.35	60		0.36	120		0.71
	UTC1/DE		7,700	90		6,930	71		4,920	1,390		6.8	110		0.54	120		0.59	230		1.13
	VF2/LE		13,000	90		11,700	71		8,310	1,020		8.5	80		0.68	90		0.75	170		1.43
V	FY2/ED		14,970	90		13,470	33		4,450	600		2.7	50		0.22	50		0.22	100		0.44
	MN2/LE	8,190		75	6,140		33	2,030		1,920	3.9		150	0.31		120	0.24		270	0.55	
	MN4/EF	39,260		75	29,450		33	9,720		3,070*	29.8		250	2.38		190	1.85		440	4.33	
	MN2/EG	11,990		75	8,990		33	2,970		2,870	8.5		230	0.68		240	0.71		470	1.39	
	UT2/CD		15,520	90		13,970	33		4,610	1,010*		4.7	80		0.38	60		0.28	140		0.66
	UN2/ED		7,890	90		7,100	33		2,340	600		1.4	50		0.11	50		0.12	100		0.23
	UQ1/CD		480	90		430	33		140	730		0.1	60		0.01	60		0.01	120		0.02
	UU2/CD		3,940	90		3,550	33		1,170	1,010*		1.2	80		0.10	60		0.07	140		0.17
	UU2/CD		5,070	90		4,560	33		1,510	730		1.1	60		0.09	60		0.09	120		0.18
	UU3/CD	4,970		75	3,730		33	1,230		1,010*	1.2		80	0.10		60	0.07		140	0.17	
	UU3/CE	7,700		75	5,780		33	1,910		1,920*	3.7		150	0.30		120	0.23		270	0.53	
	VF/LE	5,010		75	3,760		33	1,240		1,020	1.3		80	0.10		90	0.11		170	0.21	
	TOTALS	125,750	231,600		94,330	208,620		46,080	134,520		131.3	215.80		10.50	17.29		8.34	17.80		18.84	35.09

Note: A = Advanced technology only; IA = Intermediate and advanced technology

* Higher costs due to stony soil

** Assumes 3.6 out of 4.0 ha. in ecozone II; 4 out of 5 ha. in ecozone III; 5 out of 7 ha. in ecozone IV; and 3 out of 9 ha. in ecozone V.

Table IV.2 continued

COSTS OF CUT-OFF DRAINS AND OTHER SOIL CONSERVATION MEASURES
ASSOCIATED WITH GRASS STRIPS FOR MACHAKOS-KITUI-EMBU

Eco Zone	Mapping Unit	Total Area ha	Area* Potential ha	Percent of potential to cropped***	Area of Potential to be cropped ha	Investment Unit Cost** shs/ha	Investment Total 000 shs	Annualized Investment Unit Cost shs/ha	Annualized Investment Total 000 shs	Annual Maintenance Unit Cost shs/ha	Annual Maintenance Total 000 shs	Total Annual Cost Unit Cost shs/ha	Total Annual Cost Total 000 shs
II	UFr2/BC	990	890	90%	800	150	120	12	10	10	8	22	18
III	UFr1/BC	1,650	1,490	80	1,190	150	179	12	14	10	12	22	26
	UFr2/BC	4,970	4,470	80	3,580	150	537	12	43	10	36	22	79
	UIr1/BC	2,310	2,080	80	1,660	150	249	12	20	10	17	22	37
	UNr1/BC	22,030	19,830	80	15,860	150	2,379	12	190	10	159	22	349
	UNr1/CD	4,030	3,630	80	2,900	80	232	6	19	10	29	16	48
	UU1/BC	4,600	4,140	80	3,310	150	497	12	40	10	33	22	73
	UU3/BC	750	560	80	450	150	68	12	5	10	5	22	10
	UU3/C	840	630	80	500	310	155	25	12	30	15	55	27
	UUC1/BC	2,110	1,900	80	1,520	150	228	12	18	10	15	22	33
	UQ1/BC	1,960	1,760	80	1,410	150	212	12	17	10	14	22	31
IV	UFd/AC	1,180	1,060	71	750	120	90	10	7	10	8	20	15
	UFr1/BC	2,770	2,490	71	1,770	150	266	12	21	10	18	22	39
	UFr2/BC	3,160	2,840	71	2,020	150	303	12	24	10	20	22	44
	UFr2/C	1,060	950	71	670	310	208	25	17	30	20	55	37
	UFr3/BC	790	710	71	500	150	75	12	6	10	5	22	11
	UIr1/BC	4,050	3,640	71	2,580	150	387	12	31	10	26	22	57
	UIr2/CD	5,870	5,280	71	3,750	80	300	6	24	10	38	16	62
	UNr1/BC	57,880	52,090	71	36,980	150	5,547	12	444	10	370	22	814
	UNr1/C	850	760	71	540	310	167	25	13	30	16	55	29
	UNr1/CD	12,090	10,880	71	7,720	80	618	6	49	10	77	16	126
	UNr2/BD	25,220	22,700	71	16,120	70	1,128	6	90	0	0	6	90

Table IV.2 continued

COSTS OF CUT-OFF DRAINS AND OTHER SOIL CONSERVATION MEASURES
ASSOCIATED WITH GRASS STRIPS FOR MACHAKOS-KITUI-EMBU

Eco Zone	Mapping Unit	Total Area ha	Area* Potential ha	Percent of Potential to be cropped**	Area of Potential to be cropped ha	Investment Unit Cost** shs/ha	Investment Total 000 shs	Annualized Investment Unit Cost shs/ha	Annualized Investment Total 000 shs	Annual Maintenance Unit Cost shs/ha	Annual Maintenance Total 000 shs	Total Annual Cost Unit Cost shs/ha	Total Annual Cost Total 000 shs
IV	UQ1/BC	17,130	15,420	71%	10,950	150	1,643	12	131	10	110	22	241
	UQ1/C	1,240	1,120	71	800	310	248	25	20	30	24	55	44
	UQ1CD	5,540	4,990	71	3,540	80	283	6	23	10	35	16	58
	UQ2/BC	3,420	3,080	71	2,190	150	329	12	26	10	22	22	48
	UU1/BC	32,240	29,020	71	20,600	150	3,090	12	247	10	206	22	453
	UU2/BC	30,330	27,300	71	19,380	150	2,907	12	233	10	194	22	427
	UU2/C	400	360	71	260	310	81	25	6	30	8	55	14
	UU2/CD	9,410	8,470	71	6,010	80	481	6	38	10	60	16	98
	UU3/BC	3,730	3,360	71	2,390	150	359	12	29	10	24	22	53
	UU3/C	1,890	1,700	71	1,210	310	375	25	30	30	36	55	66
	UUC1/BC	3,730	3,360	71	2,390	150	359	12	29	10	24	22	53
	UUC2/BC	9,280	8,350	71	5,930	150	890	12	71	10	59	22	130
	UUC2/C	6,290	5,660	71	4,020	310	1,246	25	100	30	121	55	221
	VXC/BE	13,002	11,700	71	8,310	30	249	2	20	0	0	2	20
V	FX*/BD	14,970	13,470	33	4,450	70	312	6	25	0	0	6	25
	UFC/AC	14,350	12,915	33	4,260	120	511	10	41	10	43	20	84
	UFd/AC	11,860	10,670	33	3,520	120	422	10	34	10	35	20	69
	UFr1/BC	7,880	7,090	33	2,340	150	351	12	28	10	23	22	51
	UFr3/BC	169,010	152,110	33	50.200	150	7,530	12	602	10	502	22	1104
	UFr3/C	11,740	10,570	33	3,490	310	1,082	25	87	30	105	55	192
	UFr4/C	12,000	10,800	33	3,570	310	1,107	25	89	30	107	55	196
	UFr4/CD	15,520	13,970	33	4,610	80	369	6	30	10	46	16	76

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Table IV.2 continued

COSTS OF CUT-OFF DRAINS AND OTHER SOIL CONSERVATION MEASURES
ASSOCIATED WITH GRASS STRIPS FOR MACHAKOS-KITUI-EMBU

Eco Zone	Mapping Unit	Total Area ha	Area* Potential ha	Percent of Potential to be cropped**	Area of Potential to be cropped ha	Investment Unit Cost** shs/ha	Investment Total 000 shs	Annualized Investment Unit Cost shs/ha	Annualized Investment Total 000 shs	Annual Maintenance Unit Cost shs/ha	Annual Maintenance Total 000 shs	Total Annual Cost Unit Cost shs/ha	Total Annual Cost Total 000 shs
V	UNr1/BC	84,003	75,600	33	24,950	150	3,743	12	299	10	250	22	549
	UNr1/C	2,360	2,120	33	700	310	217	25	17	30	21	55	38
	UNr2/BD	7,890	7,100	33	2,340	70	164	6	13	0	0	6	13
	UQ1/BC	20,610	18,550	33	6,120	150	918	12	73	10	61	22	134
	UQ1/CD	480	430	33	140	80	11	6	1	10	1	16	2
	UQ2/BC	1,010	910	33	300	150	45	12	4	10	3	22	7
	UQ2/CD	3,940	3,550	33	1,170	80	94	6	8	10	12	16	20
	UU1/BC	28,400	25,560	33	8,440	150	1,266	12	101	10	84	22	185
	UU1/C	3,980	3,580	33	1,180	310	366	25	29	30	35	55	64
	UU2/BC	72,980	65,680	33	21,670	150	3,251	12	260	10	217	22	477
	UU2/C	2,510	2,260	33	750	310	233	25	19	30	23	55	42
	UU2/CD	5,070	4,560	33	1,510	80	121	6	10	10	15	16	25
	UU3/BC	2,170	1,950	33	640	150	96	12	8	10	6	22	14
	UU3/C	4,470	4,020	33	1,330	310	412	25	33	30	40	55	73
	UUC1/BC	50,570	45 510	33	15,018	150	2,253	12	180	10	150	22	330
	UUC1/C	14,290	12,860	33	4,240	310	1,314	25	105	30	127	55	232
	UUC2/BC	10,560	9,500	33	3,140	150	471	12	38	10	31	22	69
	UUC2/C	8,270	7,440	33	2,460	310	763	25	61	30	74	55	135
		879,655	791,445		367,098		53,907		4,312		3,875		8,187

Table IV.2 concluded

COSTS OF CUT-OFF DRAINS AND OTHER SOIL CONSERVATION MEASURES ASSOCIATED WITH GRASS STRIPS FOR MACHAKOS-KITUI-EMBU

Eco Zone	Mapping Unit	Total Area ha	Area* Potential ha	Percent of potential to be cropped***	Area of Potential to be cropped ha	Investment Unit Cost** shs/ha	Investment Total 000 shs	Annualized Investment Unit Cost	Annualized Investment Total 000	Annual Maintenance Unit Cost	Annual Maintenance Total 000	Total Annual Cost Unit Cost	Total Annual Cost Total 000
Suitable for Advanced Technology Only													
V	UU3/CD	4,970	3,730	33%	1,230	80	98	6	8	10	12	16	20
	VXC/BE	5,010	3,760	33	1,240	30	37	2	3	4	5	6	8
		9,980	7.490		2,470		135		11		17		28

* Potential area for intermediate and advanced technology is 90% of total area; the comparable value for advanced technology is 75%.

** Unit costs apply to only that portion of the area with slopes between 5 and 8 percent, which are to supplied with cut-off drains and other facilities. No works are assumed for slopes less than 5 percent and unit costs for slopes above 8 percent are included as part of Table IV.2 on terracing. Consequently, unit costs per hectare for slopes CD, BD, BE must be added to those from the table on terracing to get overall costs per hectare. For example, overall costs for BD slopes comprise Shs. 80 per hectare for the grass strip area and Shs. 730 per hectare for the terraced area, giving a total of Shs. 810 per hectare.

Note: Total costs for each ecozone represent the maximum possible amount. Actual levels of investment would be less.

*** Assumed 3.6 out of 4.0 ha. in ecozone II, 4 out of 5 ha. in ecozone III, 5 out of 7 ha. in ecozone IV and 3 out of 9 ha. in ecozone V.

APPENDIX V

PROCEDURES AND RESULTS FOR THE QUANTIFICATION OF SHEET EROSION LOSSES IN THE MACHAKOS-KIT-EMBU AREA

This appendix describes the procedures and provides detailed results for the estimates of soil and production losses from sheet erosion in the Machakos-Kitui-Embu area. As mentioned in Chapter 5 the approach uses results of the universal soil loss equation and converts them into economic values in terms of equivalent uniform annual net returns to the area's farmers. As may be observed in reading the following description of procedures, a number of generalizations about specific conditions were made to keep the analysis within bounds. Notwithstanding, the results are believed to provide a clearer picture of the economic implications of sheet erosion for the area than other approaches. Moreover the analysis has served to identify factors deserving further investigation and consideration.

The method of analysis makes use of:

1. Soil classification and estimates of land use rates made by the study team's soil scientists;

2. The universal soil loss equation;

3. Information on cropping packages and profitabilities obtained from the study team's agricultural economists and agronomists;

4. Procedures of benefit-cost analysis. A description of each of these steps is presented next, followed by a table showing results for each mapping unit in the area.

V.1 SOIL CLASSIFICATION

The study's soil survey provided data on mapping units (general soil categories)* that include slope depth texture, other physical properties, location, amount, and types of land use. These are used in one way or the other in the universal soil loss equation and in the estimate of future net returns.

V.2 UNIVERSAL SOIL LOSS EQUATION

The universal soil loss equation, as the name implies, has wide ranging applicability. The equation makes it possible to estimate average annual soil loss from a given cropping system

*See "Soils of Machakos, Kitui-Embu Area: Legend" and the base soils map prepared by the study team's soil scientists, Report No. 10.

for a particular field.* Considerable research has been carried out in the United States in developing the factors going into the equation. According to Wischmeier and Smith, the soil-loss equation in its present form has been used in the United States for over 30 years, with the consequent development of data for use throughout the country.

The general form of the equation is:

A = R K L S C P, where

A is the resulting soil loss per unit area,
R is the rainfall factor,
K is the factor for soil erodibility,
S is the slope-gradient factor,
L is the slope-length factor,
C is the cropping management factor, and
P is the factor for the erosion control practice.

Results are in terms of annual tons of soil loss per acre, which are subsequently converted to tons per hectare.

Rainfall Factor (R): This factor is a measure of the erosiveness of rainfall and the extent to which soil particles are dislodged by rainfall. The factor is obtained from empirical data and is related to the total kinetic energy of rainstorms and their maximum 30-minute intensity. Observations from 181 key locations in the United States produce an average value of 168.** The Wenner report suggests a value of 200 as being the best estimate presently available for the project area.***

Soil Erodibility Factor (K): The soil erodibility factor is a measure of the susceptibility of soil particles to being dislodged and carried off by the runoff from rainfall. K values are based on the textural characteristics of basic soil types. Values typically range from 0.10 for loamy sand to over 0.60 for silt loam. The characteristics of the soils in the project area tend to bunch around 0.20 to 0.25, which is the range typical of sandy clays and sandy loams.

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* From Wischmeier and Smith. Other references include "Guidelines for Erosion and Sediment Control in California", Soil Conservation Service U.S. Department of Agriculture, Davis, California.January 1975; C.G. Wenner, "Soil Conservation in Kenya", Land and Farm Management Division, Ministry of Agriculture, Republic of Kenya, Nairobi, 1977; and S.H. Daines, Paul Njoroge and Karanja Njui, "Soil and Water Management, Final Report", Marginal/Semi-Arid Lands Pre-Investment Study, Nairobi, April 1978.

** See Table 11 in the Wischmeier and Smith Report.

*** C.G. Wenner,"Soil Conservation in Kenya",Land and Farm Management Division, Ministry of Agriculture, Republic of Kenya, Nairobi, August, 1977.

Slope-Length Gradient Factor (LS): The percent slope and length of slope are combined to give a single factor. The factor is a measure of the tendency for runoff to carry away particles dislodged by the rainfall. Values are read off charts that show the relationships between percent slopes, slope lengths and the LS factor. A chart for metric lengths is included in the Wenner report. For this analysis slopes are obtained from the descriptions of individual mapping units. Slope values used to enter Wenner's chart were taken as the average of the slope range as reported for each mapping unit. This approach understates somewhat the LS factor when the slope range is wide, but produces little error for the narrower ranges. Slope lengths were not recorded during the field survey. Upon the advice of the study team's soil scientists a standard length of 50 meters was selected. Because of the functional relationship between the factors, errors in estimating slope lengths are more dramatic for the higher slopes. Any follow-on work to this analysis would do well to obtain more precise estimates for the steeper slopes.

Cropping Management Factor (C): This factor defines the effectiveness of cropping and management practices in reducing soil loss relative to that which would occur if the land were tilled and left continuously fallow. Factors are specific to crops grown, the degree of protective covering offered by the crop canopy, management practices concerning crop residues, and the timing of annual erosivity caused by rainfall. For this study average C values for typical cropping patterns were based on data developed in the United States, since appropriate values have not been developed for Kenya. C values for different crops and conditions can be found in the aforementioned references. These values are combined with a rainfall erosion index, as presented by Wenner, that allows one to estimate the incremental C factor for each crop according to its phases of growth and the time of year for each phase. These phases include rough fallow, seedling, establishment, growing and maturing of crop, and residue or stubble.

The annual C factor for ecozones two, three and four is 0.278. Crops grown in these three regions are assumed to be predominantly maize and beans in equal amounts. Coffee is grown in ecozone two. But this is a tree crop and not considered as cropped land. The proportion of land estimated as being cropped is accordingly reduced to account for portions planted in coffee. The C factor for ecozone V is 0.413. Crops grown in this zone are assumed to be sorghum and cowpeas. C. values for cowpeas were not found in the literature, so the value for beans was substituted as being a reasonably close approximation.

Erosion Control Practice (P): Various erosion control practices reduce the rate of soil loss. Most prevalent according to the literature from the United States are contour tillage, strip cropping on the contour, terracing, and grassed waterways. These procedures are suggested for the project area as part of area-wide conservation measures. Although soil conservation, such as terracing, is practiced in parts of the

project area, the absence of accompanying facilities limits the effectiveness of these measures. As a general rule, no effective conservation practices are assumed to exist in the area. This overly negative assumption is believed to offset some other tendencies in the earlier estimates that have understated the rate of erosion. The factor for P under no conservation practice, where cultivation is up and down the hill, is 1.0. Contour practices from simply farming across the slope to full contour, strip farming will reduce the factor to values ranging from 0.95 to 0.25, depending on conservation practice and slope.

V.3 RESULTS OF THE SOIL-LOSS EQUATION

Rates of soil loss for each of the mapping units in ecozones II through V are shown in Table V.1 Values range from 4 to 705* tons per hectare per year. Fortunately, the extremely high rate of 705 is an area (mapping unit MNrDG in ecozone V) in which only 5 percent of the area is assumed cropped. The lowest rates of soil loss are on mapping units LId and UQ2 with A (0-2%) and AB (0-5%) slopes, respectively.

Values of soil loss per hectare were converted to centimeters of loss per year by using a bulk density of 1.2. Bulk densities on soil samples collected by the soil scientists team were not run, so that a presentative value was used for all of the soils. The resulting losses in centimeters per year are also shown in Table V.1.

V.4 CROPPED AREA

One of the observations of the soil survey was the extent of land under crops. Land previously cropped but presently fallow was also categorized as being cropped. Rates of land use for crops were listed by the soil survey team as being over 50 percent, 25 to 50 percent, 10 to 25 percent, and under 10 percent. General knowledge concerning pressure on the land according to soil quality and ecozone was applied to give a more specific estimate of land use on each of the mapping units. Table V.2 gives estimates of the amount of land continually under crops. The rates for ecozone II for the over 50 percent category are less than for ecozone III due to part of the area being in coffee. Values in the table generally decrease from better to poorer soil classifications and from wetter to drier ecozones. For ecozone V land used for actual cropping is less than that

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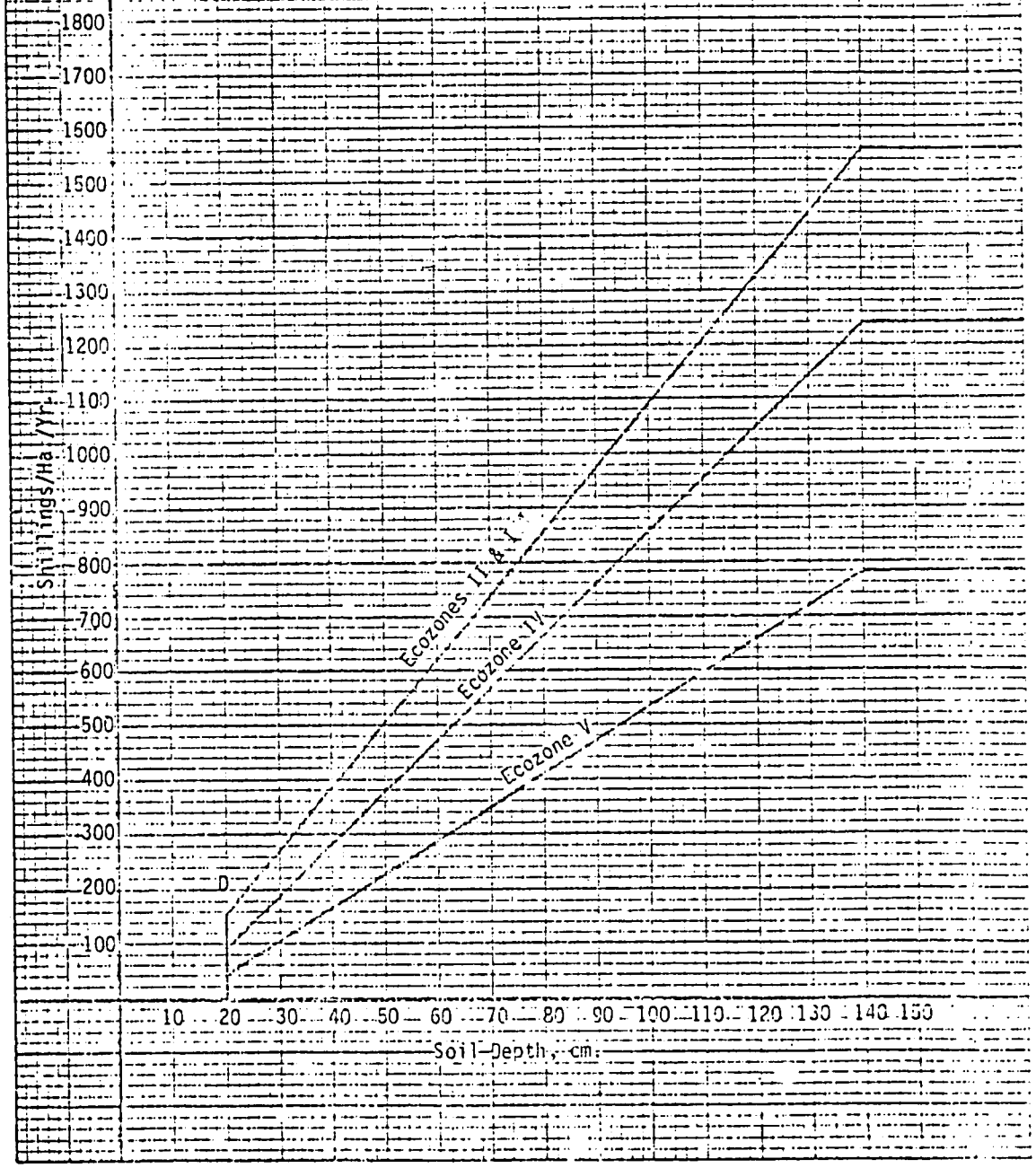
*Note: This rate of soil loss is extremely high considering that practice in the United States attempts to limit annual soil loss to no more than 11.5 metric tons per hectare. Whether or not rates are actually this high needs confirmation from further analysis and field study.

Figure V.1

ANNUAL NET CROPPING RETURNS
AS A FUNCTION OF
SOIL DEPTH AND ECOZONES



Best Available Document

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indicated in the general heading because of the distinction between land actually being cropped and that which is both cropped and fallow. No significant cropping is considered as taking place in ecozone six. Finally, these cropping rates were multiplied by the estimates of total area within each mapping unit to arrive at the number of hectares being cropped.

Table V.2 ESTIMATES OF LAND PRESENTLY BEING CROPPED IN THE MACHAKOS-KITUI-EMBU AREA

Ecozone	Soil Class	Land Use Rates (Both Cropped and Fallow)			
		Over 50%	25-50%	10-25%	Under 10%
II	A and B	75	45	20	5
	C	60	35	15	5
	D	50	25	10	0
III	A and B	85	45	20	5
	C	70	35	15	5
	D	60	25	10	0
IV	A and B	75	45	20	5
	C	60	35	15	5
	D	50	25	10	0
V	A and B	50	40	15	5
	C	30	25	10	0
	D	25	10	5	0

V.5 NET RETURNS FUNCTION

Net annual operating returns from cropping were estimated for each ecozone and soil class. Returns exclude the costs of family labor and do not take into account costs of periodic investments. These estimates are based on the predominant cropping package in each zone: namely, maize and beans with some cotton in ecozones two and three; maize, sorghum and beans with some sunflower in ecozone four; and maize, sorghum, sunflower and cowpeas in ecozone five. It may be noted that more simplified cropping mixes were assumed for estimating the C factors as part of the soil loss equation.

Estimates from the team's agronomists and agricultural economists showed a rather uniform decrease from high to poor quality soils that could be related to soil depth. Part of the decrease in yields associated with shallower soils is related to the general loss in fertility as soils are eroded and become shallower. Another cause of reduced yields is the lesser water holding capacity such soils.

The overall result of these estimates and relationships produced the set of curves shown in Figure V.1. A certain amount of liberty was taken in drawing these curves, mainly to simplify subsequent calculations. This shows up in the linear relationship between soil depth and returns and the abrupt breaks at 20 and 140 centimeter depths. Nevertheless, their general shape and magnitude are believed realistic.

V.6 EQUIVALENT ANNUAL NET RETURNS

The functions from Figure V.1 can now be used with the rates of soil loss in centimeters per year to arrive at the degradation in net returns over time. The accumulative effect of soil losses on net returns can be measured by converting future values to their equivalent annual amounts. This result compared with annual net returns as of the present give the reductions in yield due to erosion over the long term.

The steps in carrying out these calculations are as follows:

1. Soil depth for a part[illegible] mapping unit located in one of the ecozones is taken [illegible] the average of the depth range for those soils less than 140 centimeters deep. For example, mapping units with soils ranging from 50 to 80 cms are assumed to all be of 65 cms depth. For soils ranging above 140 cms, values are broken into two parts: those above and below 140 cms. The average of both parts are then taken as being representative of the soil groups and are weighted according to the percentages in each part. To illustrate, UFr3 soils have depths between 50 and 200 cms.* Sixty percent (i.e., $\frac{140-50}{200-50}$) are assumed to be 95 cms deep (i.e., $\frac{140 + 50}{2}$) and the remaining 40 percent as being 170 cms deep.

2. Time to soil exhaustion is the length of time it takes for the average soil depth to reach 20 cms. For soils less than 140 cms deep, this amount of time is the average soil depth divided by the rate of soil loss. Thus, for an average soil depth of 65 cms and a rate of soil loss of 0.32 cm per year, 203 years would elapse. Separate calculations of time to exhaustion for the portion of soils above 140 cms were not made because results are rarely dependent on this value.

3. The time shape of annual yields is not known. Yields are assumed to progress uniformly from their present value to the terminal level at 20 cms. These ultimate values as shown in Figure V.1 are shs. 150 per hectare, shs.90 per hectare and Shs.40 per hectare for ecozones II and III, IV and V, respectively. The negative slope of the yield curve is the amount of loss in net returns divided by the length of time to exhaustion. No production is considered beyond this terminal date.

4. The final step is to simultaneously integrate and discount the area under the yield curve to obtain a present worth of all future net returns. The present worth is subsequently converted to equivalent equal amounts by applying the capital recovery factor. For the long time periods associated with these calculations, this factor is simply the discount rate: namely, 8 percent.

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*Note: Deep soils were rated by the soil scientists simply as being over 120 cms. Actual depths cannot be deermined without taking deeper samples. Their judgement, however, indicates that these deep soils probably average two meters

The expression to obtain the present worth values is

$$\int_{o}^{n} ye^{-ix}\, dx.$$

Where: y is the linear function for net returns and takes the form a + bx where a is the value of net returns at the outset and b is the annual rate of reduction in net returns,

e^{-ix} is the continuous discount factor,

e is the exponential function,

i is the discount rate, and

x is the time scale.

Integrating this function gives a present worth function of:

$$\frac{a}{i}\left(1 - \frac{1}{e^{in}}\right) + \frac{b}{i^2}\left(\frac{in}{e^{in}} + \frac{1}{e^{in}} - 1\right)$$

The equivalent annual net returns for an infinetely long time period are obtained by multiplying the above expression by i, which becomes:

$$a\left(1 - \frac{1}{e^{in}}\right) + \frac{b}{i}\left(\frac{in}{e^{in}} + \frac{1}{e^{in}} - 1\right).$$

An example should clarify the procedure. Mapping unit UNr2/BD has slopes ranging from 2 to 16 percent, depths ranging from 25 to 80 cms. and a K factor of 0.20. For the unit in ecozone four, maize and beans are assumed as the dominant crops. The C factor for this area and cropping pattern is 0.278. Other factors for the soil loss equation are: R = 200, L = 50 meters, and P = 1.0. The LS factor, obtained from page 26 of Wenner's report, is 1.6 using an L of 50 meters and an average slope of 9 percent. The annual rate of soil loss is:

A = R K L S C P

= 200 x 0.20 x 1.6 x 0.278 x 1.0

= 17.8 tons per acre per year

= 40.0 metric tons per hectare per year

At bulk density of 1.2, the rate of 40 tons per hectare per year is equivalent to 0.33 cms. per year. (At 1.2 tons per cubic meter of soil and 10,000 square meters per hectare, one cm.-hectare of soil weighs 120 tons.) Thus, 40 tons per year is 1/3 of a cm. (i.e., 40/120).

This rate of soil loss can now be compared with the average soil depth of 53 cms. The length of time (n) to reach the assumed exhaustion rate of 20 cms. (see Figure 1) is

100 years (i.e., (53-20)/0.33). The other necessary values can also now be obtained from Figure 1. The initial (1977) level of net returns ("a" factor) is Shs. 410 per hectare per year. (Enter curve for ecozone IV at 53 cms.) The rate of decline ("b" factor) is 3.20 (i.e., (Shs. 410 - Shs. 90/100). Finally, "i" is 8 percent. The equivalent annual net returns can now be found:

$$410 \left(1 - \frac{1}{e^{100 \times 0.08}}\right) + \frac{3.20}{0.08} \left(\frac{0.08 \times 100 + 1}{e^{100 \times 0.08}} - 1\right) =$$

409.9 - 39.9 = Shs. 370 per ha. per year

V.7 ANNUAL NET RETURNS IN YEAR 2000

The level of annual net returns by the year 2000 are obtained by multiplying the annual rate of soil loss by 23 (years between 1977 and 2000). This amount of loss is subtracted from the present average soil depth to arrive at the average depth in 2000. The value of net returns is read directly from the appropriate curve in Figure 1.

V.8 RESULTS

Results of these two calculations are listed by ecozones in Table V.1. The first seven columns give information on soil type, location, characteristics, and areas. The next two columns show the rates of soil loss as estimated by the universal soil loss equation. The next six columns give the results of the analysis in terms of amounts and percentages of loss in production measured as reductions in the quivalent annual net returns. Finally, the last four columns show the level of annual output in year 2000 and the percentage reduction.

As noted earlier, a discount rate of eight percent was used in computing the equivalent annual net returns. A similar calculation was also made using a discount rate of four percent. These results are not shown in detail, since the procedures do not vary from those using an eight percent rate of discount.

ble V.1

REDUCTION IN ANNUAL NET RETURNS TO CROPPING UNDER TRADITIONAL AGRICULTURE
DUE TO SHEET EROSION FOR MACHAKOS-KITUI-EMBU

Eco Zone	Mapping Unit	Soil Characteristics: Depth, cm.	Slope %	Total Area, ha.	Rate of Present Use* %	Cropped Area, ha.	Soil Loss Rate: Tons/ha./yr	cm./yr	Equivalent Annual Net Returns from Cropping: Present Rate (sns/ha./yr)	Future Rate (sns/ha./yr)	Total Present (Millions of sns/yr)	Total Future (Millions of sns/yr)	Loss** (Millions of sns/yr)	Reduction (%)**	Annual Net Returns in Year 2000: Rate yr 2000 (sns/ha./yr)	Total yr 2000 (millions of sns/yr)	Loss** (Millions of sns/yr)	Reduction (%)
II	MU2	25-50	3-50	10,525	10	1,050	151	1.59	160	161	0.28	0.17	0.21	55	0	0	0.38	100
	MU1	50-200	8-50	4,840	60	2,910	254	2.11	1,240	1,062	3.61	3.09	0.52	14	899	2.62	0.99	28
	UFr2	50-200	2-8	990	75	740	20	0.18	1,365	1,372	1.09	1.02	0.00	0	1,360	1.01	0.01	1
	Sub-total			16,350		4,700					5.01	4.28	0.73	15		3.63	1.38	28
III	MU2	25-50	8-50	17,930	10	1,790	191	1.59	160	151	0.64	0.79	0.35	55	0	0	0.64	100
	UU3	25-80	2-8	750	15	110	22	0.18	540	513	0.06	0.06	0.00	0	487	0.05	0.01	17
	UU3	25-80	5-8	850	15	130	29	0.25	540	504	0.07	0.07	0.00	0	468	0.06	0.01	14
	UU1	50-120	2-8	1,250	15	190	22	0.18	920	893	0.27	0.26	0.01	4	864	0.25	0.02	7
	MU1	50-200	8-50	16,240	70	11,370	251	2.11	1,240	1,069	14.10	12.07	2.03	14	639	10.22	3.85	28
	UU1	80-120	2-8	4,600	65	3,010	20	0.17	1,090	1,085	4.26	4.16	0.10	1	1,044	4.08	0.18	4
	UUr1	80-120	5-16	4,000	70	2,820	49	0.41	1,050	1,031	3.07	2.91	0.16	5	980	2.76	0.31	7
	UUC1, UFr2, UFr1, UUr1, UUr1 ***	50-200	2-8	33,070	78	25,810	20	0.17	1,390	1,373	35.88	35.44	0.44	1	1,361	35.13	0.75	2
	UUC2	80-200	5-16	1,700	60	1,020	63	0.52	1,390	1,347	1.42	1.37	0.05	3	1,314	1.34	0.08	6
	UUr1	80-200	8-30	3,500	70	2,450	139	1.17	1,350	1,299	3.41	3.18	0.23	7	1,225	3.00	0.41	12
	Sub-total			84,620		49,700					63.18	59.81	3.37	5		56.89	6.29	10
IV	UUr2	25-80	2-16	25,217	60	15,130	40	0.33	410	370	6.20	5.60	0.60	10	339	5.13	1.07	17
	UU3	25-80	2-8	3,777	15	560	22	0.18	410	388	0.23	0.22	0.01	4	374	0.21	0.02	9
	UU3	25-80	5-8	1,872	15	280	29	0.25	410	380	0.11	0.11	0.00	0	359	0.10	0.01	9
	UU2	25-120	0-5	803	5	40	4	0.04	600	595	0.02	0.02	0.00	0	595	0.02	0	0
	YUC	25-120	2-30	13,002	10	1,300	97	0.81	600	503	0.78	0.65	0.13	17	427	0.56	0.22	28
	UUr2	50-80	0-5	13,950	20	2,790	11	0.09	530	519	1.48	1.45	0.03	2	508	1.42	0.05	4
	UUr2	50-80	5-16	5,873	15	880	58	0.49	520	470	0.47	0.41	0.06	13	420	0.37	0.10	21
	MMr	50-80	5-40	25,342	10	5,600	475	3.97	530	204	2.97	1.14	1.83	62	0	0	2.97	100
	MMr2	50-120	8-30	13,376	10	1,337	139	1.17	720	579	0.75	0.60	0.15	20	482	0.45	0.27	36
	MU1	50-120	2-8	17,150	15	2,570	22	0.18	720	698	1.85	1.79	0.06	3	678	1.74	0.11	6
	UU1	50-120	5-16	5,512	15	820	58	0.49	720	661	0.60	0.55	0.05	8	610	0.51	0.09	15
	UUr1	80-120	5-16	17,093	50	7,250	49	0.40	860	812	6.24	5.89	0.35	6	773	5.61	0.63	10
	UUC1	40-200	8-30	8,060	60	4,830	157	1.30	1,100	1,073	5.31	4.94	0.37	7	955	4.62	0.69	13
	MU1	40-200	8-50	3,613	35	1,430	254	2.11	1,100	975	1.57	1.34	0.43	11	827	1.97	0.60	21
	UFd, UUC1, UFr3, UUr1, FIr	40-200	0-5	18,950	50	9,430	9	0.07	1,100	1,097	10.37	10.34	0.03	0	1,090	10.28	0.09	1
	UUr1, UU1, UU2, UFr2, UUC1, UUr1, UFr1, UFr2																	
	UUC2	80-200	2-8	144,150	72	104,210	22	0.18	1,100	1,089	114.63	113.48	1.15	1	1,078	112.34	2.29	2
	UUC2, UU2	50-200	5-14	41,160	55	23,030	53	0.43	1,100	1,071	25.39	24.72	0.67	3	1,044	24.10	1.29	5
	UU1	50-120	5-8	1,240	15	190	29	0.25	720	690	0.14	0.13	0.01	7	663	0.13	0.01	7
	LId	80-120	0-2	250	35	90	4	0.04	840	855	0.08	0.08	0.00	0	851	0.08	0	0
	UFd	50-200	0-8	1,180	35	410	16	0.13	1,100	1,092	0.45	0.45	0.00	0	1,084	0.44	0.01	2
	UUC1	80-200	2-5	6,710	60	4,020	16	0.13	1,100	1,092	4.42	4.40	0.02	0	1,084	4.36	0.06	1
	UUC2, UFr2, UUr1, UU2	50-200	5-8	8,450	58	4,952	31	0.27	1,100	1,084	5.45	5.37	0.09	1	1,069	5.29	0.16	3
	Sub-total			406,027		197,917					191.71	185.68	6.03	3		180.76	10.95	6
	UU1	50-80	2-3	29,608	10	20,060	34	0.29	320	297	0.66	0.61	0.05	8	277	0.57	0.09	14
	YUC	25-120	2-30	5,000	5	250	141	1.19	360	272	0.09	0.07	0.02	22	197	0.05	0.04	45
	MMr	25-80	8-80	11,970	5	600	705	5.88	240	59	0.14	0.03	0.11	77	0	0	0.14	100
	UFr4, UUC2, UU3	25-80	5-8	24,750	10	2,490	38	0.31	240	217	0.60	0.54	0.06	10	199	0.49	0.11	18
	UUr2	25-80	2-16	7,594	25	1,970	61	0.52	240	201	0.47	0.40	0.07	15	169	0.33	0.14	29
	UUC2, UU3, UFr4	25-80	5-16	113,550	6	6,310	94	0.79	240	181	1.51	1.14	0.37	24	129	0.81	0.70	46
	UUC2	25-80	2-8	13,722	10	1,380	38	0.31	240	217	0.33	0.30	0.03	9	195	0.27	0.06	17
	UU3	25-80	4-30	7,701	5	390	213	1.77	240	127	0.09	0.05	0.04	44	0	0	0.09	0
	UUC2	25-80	0-5	2,298	10	230	18	0.16	240	228	0.06	0.05	0.01	17	221	0.05	0.01	17
	UU1	50-80	0-2	5,068	10	510	9	0.07	320	315	0.29	0.29	0.00	0	309	0.29	0.01	3
	UU1	50-80	5-16	452	10	50	85	0.72	320	264	0.02	0.01	0.01	50	215	0.01	0.01	50
	FIr	50-200	2-16	14,562	10	1,550	41	0.32	610	593	0.92	0.88	0.04	4	572	0.86	0.06	7
	UFr3	50-200	2-5	1,155	25	290	13	0.16	610	605	0.18	0.18	0.00	3	603	0.17	0.01	6
	UFr3	50-200	2-8	163,010	25	41,250	29	0.25	610	601	25.77	25.34	0.38	1	595	25.14	0.63	2
	UFr3	50-200	5-8	11,729	25	2,930	38	0.31	610	593	1.79	1.75	0.04	2	590	1.73	0.06	3
	LID	80-120	0-2	7,515	25	1,880	7	0.07	530	525	1.00	0.99	0.01	1	524	0.99	0.01	1
	UU1, UU2, UUC1, UFd	80-200	0-5	163,247	33	54,133	16	0.13	650	645	35.13	38.45	0.28	1	642	38.29	0.45	1
	UFC, UFd	80-200	0-8	26,229	25	6,560	22	0.18	690	683	4.53	4.48	0.05	1	679	4.45	0.08	2
	UFr1, UUr1, UU1, UU2, UUC1	80-200	2-8	164,230	41	68,293	34	0.29	690	679	47.12	46.37	0.75	2	671	45.82	1.30	3
	UUr1, UUC1, UU1, UU2	80-200	5-8	44,350	29	12,725	43	0.34	690	676	8.78	8.60	0.18	2	666	8.47	0.31	4
	UU2	80-200	5-16	[illegible]	50	2,525	73	0.63	670	665	1.75	1.69	0.07	4	665	1.63	0.12	7
	Sub-total			841,654		211,715					134.53	132.26	2.27	2		129.49	4.43	3
	TOTALS			1,335,003		459,027					394.71	382.03	12.70			371.68	23.25	

* Present (1977) and potential land use rates are based on field observations and recommendations from the soil survey team.

** Compared with present values.

*** Where soils are grouped, soil loss rates are based on the weighted averages of "k" factors for each mapping unit.

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APPENDIX VI

TABLE: VI.1 MODEL FARM BUDGET TRADITIONAL TECHNOLOGY

	Soil Suitability		
	A	B	C
Zone III 5 Ha Farm			
Returns Net of out pocket costs			
Crops			
Maize		2380	1048
Beans		1792	1608
Cotton		262	158
Total Crops		5434	2804
Livestock and Livestock Products		170	85
Total Returns		5604	2889
On-Farm Investment costs:			
Livestock			
(Cattle Kshs. 692.55 plus Goats Kshs. 81 @ 8% perpetual)		61.88	
(Cattle Kshs. 333.45 plus Goats Kshs. 39.60 @ 8% perpetual)			29.84
Tools (Kshs. 100 for 2 years @ 8%)		56.08	56.08
Total annualized Investment cost		117.96	85.92
Net to Famit Labour and other Resources		5486.04	2803.08
(per Hectare)		(1097.20)	(560.62)

Cropping patterns assumed:

Zone III 3 Ha under crop: 3/7 Maize, 3/7 Beans, 1/7 Cotton
balance rough grazing (2ha)
(Cotton two season others single season)

TABLE: VI.1 (contd.) MODEL FARM BUDGETS TRADITIONAL TECHNOLOGY

	Soil Suitability	
	B	C
Zone, IV 7 Hectare Farm	Kshs.	Kshs.
Returns Net of out of Pocket costs		
Maize	1508	781
Beans	1687	1505
Sunflower	697	362
Total Crops	3892	2648
Livestock and Livestock Products	168	130
Total Returns	4060	2778
On - Farm Investment Costs		
Livestock		
B: (Cattle Kshs. 656.90 plus Goats Kshs. 79.20 @ 8% perpetual)	59.69	
C: (Cattle Kshs. 513.00 plus Goats Kshs. 61.20 @ 8% perpetual)		45.94
Tools (Kshs. 100 2 years @ 8%)	56.08	56.08
Total annualized Invest ment costs	115.77	102.02
Net to Family Labour and other Resources	3944.23	2675.98
(per Hectare)	(563.46)	(382.28)

3 Ha under crop: 3/7 Maize, 3/7 Beans, 1/7 Sunflower,
Balance (4 Ha) Rough Grazing.

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TABLE: VI.1 (contd.) MODEL FARM BUDGETS TRADITIONAL TECHNOLOGY

	Soil Suitability	
Zone V 9 Ha Farm	B Kshs.	C Kshs.
Returns Net of out of Pocket Costs		
Maize	305	201
Sorghum	1186	896
Cowpeas	403	363
Sunflower	421	358
Total Crops	2309	1818
Livestock and Livestock Products	52	39
Total Returns	2361	1847
On - Farm Investment Costs Livestock		
B: (Cattle Kshs. 207.76; Goats Kshs. 21.60 @ 6%)	18.35	
C: (Cattle Kshs. 153.90; Goats Kshs. 16.20 @ 8%		13.61
Tools (Kshs. 100 @ 6% for 2 yrs)	56.08	56.08
Total Annualized Investment Costs.	74.43	69.69
Net to Family Labour and other resources	2286.57	1777.31
(per Hectare)	(254.06)	(197.48)

3 Ha under Crop 1/6 Maize, ½ Sorghum. ½ Cowpeas, 1/6 Sunflower

Cowpeas two seasons, Others single season

6 Ha Range.

TABLE: VI.2

MODEL FARM BUDGETS: INTERMIDIATE TECHNOLOGY

	Suitability A	Suitability B	Suitability C
Zone III			
Sale of Crops	7740	7390	2700
Sale of Livestock & Livestock Products			
Milk	3000	3000	6000
Cult. and surplus livestock	1720	1720	3320
Gross Receipts	12460	12110	12020
Deduct out of pocket costs:			
Crops	1320	1260	580
Livestock	2500	2500	5080
Hired Labour	830	820	610
Repairs and Maintenance	50	50	50
Total Out of Pocket	4800	4730	5320
Net Operating Income	7660	7380	5700
Deduct Investment Costs (Annualized at 6%)			
Ox (cost 850, salvage 600; 5 years)	111	111	111
Plough (500 for 15 years)	29	29	29
Jembes and Yokes (130 for 2 years)	73	73	73
Pangas, Chains etc. (120 for 5 years)	30	30	30
Dairy Equipment (1600 for 10 years)	238	238	476
Bana grass stand (250 for 4 years)	75	75	150
Range stock, (1200 perpetual)	480	480	960
Range Renovation (100 perpetual)	8	8	8
Total annualized Investment	1044	1044	1837
Net before terracing costs	6616	6336	3863
(per Hectare)	(1,323.20)	(1,267.20)	(772.60)

Assumes 5 + Ha Farm
1 Ha Maize each season
1 Ha Beans each season
1 Ha Cotton each year on A & B. Soils, none on C
1 Ha Bana grass or similar forage on A & B soils 2Ha on C.
1 Ha natural pasture.

TABLE: VI.2 (contd.)

MODEL FARM BUDGET - INTERMEDIATE TECHNOLOGY

	Suitability		
	A	B	C
Zone IV			
Sale of Crops	6610	6000	4260
Sale of Livestock Products:			
Milk	2770	2770	2770
Cult. and surplus Dairy animals	1720	1720	1720
Gross Receipts	11100	10490	8750
Deduct out of Pocket costs:			
Crops	1490	1260	940
Livestock	2500	2500	2500
Labour	1290	1280	1270
Repairs and Maintenance	50	50	50
Total Out of Pocket Costs	5930	5190	4860
Net Operating Income	5670	5300	3890
Deduct On = Farm Investment Costs (annualized at 8%)			
Ox (cost 850; salvage 600; 5 yrs)	111	111	111
Plough (500; 15 years)	29	29	29
Jembes and Yokes (130; 2 years)	73	73	73
Pangas, Chains. etc. (120; 5 yrs)	30	30	30
Dairy Equipment (1600; 10 yrs)	238	238	238
Livestock (6400 perpetual)	512	512	512
Bana grass stand (250 for 4 yrs)	150	150	150
Range Renovation 200 perpetual	16	16	16
Total annualized Investment	1159	1159	1159
Net before Terracing costs	4511	4031	2731
(per Hectare)	(644.42)	(575.85)	(390.14)

Assumes: 7 + Ha Farm
1 Ha Sorghum each season
1 Ha Beans each season
1 Ha Sunflower each season
2 Ha Bana grass
2 Ha Improved Range.

TABLE: VI.2 (contd.)

MODEL FARM BUDGET - INTERMEDIATE TECHNOLOGY

	Soil Suitability		
Zone V	A	B	C
Sale of Crops	5430	5010	3750
Sale of Livestock	160	160	160
Gross Receipts	5590	[illegible]	3910
Deduct out of Pocket costs:			
Crops	1480	1240	930
Livestock	135	135	135
Hired Labour	760	750	740
Repairs and Maintenance	50	50	50
Total out of pocket	2425	2175	1855
Net Operating Income	3165	2995	2050
Deduct on-farm Investment costs (annualized at 8%)			
Ox (cost 850; salvage 600; 5 years)	111	111	111
Plough (500 for 15 yrs)	29	29	29
Jembes and Yokes (130 for 2 years)	73	73	73
Pangas, Chains etc. (120 for 5 yrs)	30	30	38
Livestock (80 perpetual)	6	6	6
Range Renovation (600 perpetual)	48	48	48
Total annualized Investment	297	297	297
Net before Terracing costs	2868	2698	1958
(per Hectare)	(318.67)	(299.78)	(195.33)

Assumes: 9 + Hectare Farm
1 Hectare Sorghum 1 season
1 Hectare Beans both seasons; 1 Hectare 1 season
1 Hectare sunflower both seasons
6 Hectares improved range.

TABLE: VI.3

MODEL FARM BUDGETS: ADVANCED TECHNOLOGY

Zone III[1/]	Soil Suitability A	B	C
	Kshs.	Kshs.	Kshs.
Returns from:			
Crops	11170	10390	3080
Milk	6000	6000	12000
Cult. and surplus Dairy stock	2050	2050	4100
Gross Receipts	19220	18440	19160
Deduct out of Pocket costs			
Crops	2580	2450	910
Livestock	3700	3700	7400
Hired Labour	1350	1310	1275
Repairs and Maintenance	100	100	100
Total out of pocket costs	7730	7560	9685
Net Operating returns	11490	10880	9455
Deduct on farm investment costs (annualized at 8%)			
Dry land Tiller (850; 10 years)	117	117	117
Harness and Yoke (250: 5 years)	63	63	63
Hand tools (250: 5 years	63	63	63
Bana grass stands (250 per Ha for 4 years)	75	75	75
Dairy Equipment (2000 per Ha bana: 10 years)	298	298	596
Dairy stock) 8000 per Ha bana - perpetual)	640	640	1280
Total annualized on Farm Investment	1256	1256	2269
Net before Terracing costs	10234	9624	7226
(per Hectare)	(204680)	(19248)	(144520)

1/ assumes 5 Hectare farm.

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TABLE: VI.3 (contd.)

MODEL FARM BUDGET - ADVANCED TECHNOLOGY

	Soil Suitability		
	A	B	C
Zone IV 1/			
Returns From:			
Cropping	8650	7620	5500
Livestock and Livestock Products			
Milk	5000	5000	5000
Cult. and surplus Dairy animals	2050	2050	2050
Gross Receipts	15700	14670	12550
Deduct out of pocket costs			
Cropping	2630	2220	1490
Dairy	3280	3280	3280
Repairs and Maintenance	100	100	100
Labour Hired	1500	1470	1440
Total Out of Pocket costs	7510	7070	6310
Net operating Returns	8190	7600	6240
Deduct on Farm Investments (annualized at 8%)			
Dry land tiller (100; 15 years)	117	117	117
Harness and Yoke (250; 5 years)	63	63	63
Hand tools (250; 5 years)	63	63	63
Range Renovation (100 perpetual)	8	8	8
Bana Grass stands (250 for 4 years)	150	150	150
Dairy stock (8000 perpetual)	640	640	640
Dairy Equipment and Building (2000; 10 years)	298	298	298
Total annualized Investments	1339	1339	1339
Net before terracing	6851	6267	4901
(per Hectare)	(977.71)	(894.42)	(700.44)

1/ assumes 7 Ha Farm.

TABLE: VI.3 (contd.) MODEL FARM BUDGETS
ADVANCED TECHNOLOGY

	Soil Suitability		
	A	B	C
Zone V 1/			
Returns from:			
Crops	7230	6630	4860
Livestock and Livestock Products	3100	3100	3100
Total Returns	10330	9730	7960
Deduct out of pocket costs			
crops	2440	2240	1540
Livestock	1440	1440	1440
Hired Labour	1550	1500	1450
Repairs (10% of Implement cost)	100	100	100
Total out of pocket costs	5530	5280	4530
Net operating returns	4800	4450	3430
Deduct on - Farm investment costs (Annualized at 8%)			
Dry land tiller cultivation or (1000: 15 years)	117	117	117
Harness and Yoke (250; 5 years)	63	63	63
Hand tools (250: 5 yrs)	63	63	63
Range Renovation (600 perpetual)	48	48	48
Livestock (4000 perpetual)	320	320	320
Total annualized Investment costs	611	611	611
Net before terracing	4189	3839	2819
(per Hectare)	(465)	(425)	(313)

1/ Assumes 9 Hectare Farm

TABLE VI.4 LABOUR ANALYSIS - INTERMEDIATE TECHNOLOGY (CLASS B SOILS)

	Maize /ha	Beans /ha	Cotton i/ /ha	Bana i/ /ha	TOTAL	Family	Hired	Cost K.shs
ZONE III								
Plough) Plant) Fertilizer)	21.4	28.6	23.2	10.3	133.5	80	53.5	321.00
Dusting Spray	4.3	6.4	6.4	-	23.2	23.2		
Weeding ii/	14.3	14.3	14.3	14.3	85.8	80	5.8	34.80
Harvest, Threshing	29.4	26.4	44.4		126.2	80	46.2	277.20
Dairying (2 cows plus replacement)				(per yr)	77.1	51.4	25.7	152.40
Cutting grass			-	18.6	18.6	12.5	6.1	36.60
TOTAL					464.4	327.1	137.3	822.00
ZONE IV	Sorghum 1 ha	Beans 1 ha	S/Flower 1 ha	Bana 2 ha				
Plough) Plant) Fertilizer	26.7	28	16.4	20.3	150.5	80	71.5	429.00
Spraying	6.4	6.4	2.1	-	14.9	14.9		
Weeding	14.3	14.3	14.3	28.6	114.4	80	34.4	206.40
Harvesting, threshing	26.5	26.4	17.8		141.4	80	61.4	368.40
Scaring birds	35				35	23.4	11.6	69.60
Cutting grass				25	25	16.8	8.2	49.20
Dairying (2 cows plus replacement)					77.1	51.4	25.7	152.90
TOTAL					558.3	346.5	212.8	1275.50
ZONE V iii/	Sorghum	Beans	S/Flower					
Ploughing Plant Fertilizer	21.7	28	16.4		138.5	80	58.5	357
Spraying	6.4	6.4	2.1		29.8	29.8	0	
Weeding	14.3	14.3	14.3		85.5	80	5.8	34.80
Scaring birds	35				35	35		
Harvest, threshing	26.5	26.4	17.8		141.3	80	61.3	367.80
					75	75		
TOTAL					505.1	379.8	125.6	753.60

i/ Cotton and Bana are Annual Basis, others single season

ii/ Assumes plough used in weeding all single season crop weighted equally

iii/ Weighted in total at ration of Sorghum 1, Beans 3 and S/Flower 2 in line with recommendations in proposal for the Machakos District Integrated Rural Development Programme substituting beans for cowpeas.

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TABLE VI. 5 LABOUR ANALYSIS ADVANCED TECHNOLOGY (CLASS B SOILS)

ZONE III

ACTIVITY	MAIZE 1 ha	BEANS 1 ha	COTTON 1 ha	BEANS 1 ha	TOTAL	FAMILY	HIRED	COST @ KSHS.
Ploughing								
Planting								
Fertilizing	26.4	28.6	25.6	11.1	146.7	80	66.7	400.20
Spraying								
Dust	4.3	8.6	6.4	-	32.2	32.2		
Weeding	14.3	14.3	14.3	14.3	85.8	80	5.8	34.80
Harvesting & threshing	33.6	27.1	48.2	18.6	188.2	80	108.2	649.20
Dairy					115	77	38	228.00
TOTAL					567.9	349.2	218.7	1312.20

ZONE IV	SORGHUM 1ha	BEANS 1ha	S/FLOWER 1ha	BANA 2ha	Total	Family	Hired	Cost @ Kshs
Ploughing								
Planting	20.7	28.6	16.7	21.2	153.2	80	73.2	435.20
Fertilizing								
Dust Spray	8.6	8.6	2.1	-	38.6	38.6		
Weeding	14.3	14.3	14.3	28.6	114.4	80	34.4	206.40
Harvesting & threshing	27.2	27.1	22.9	25	179.4	80	99.4	596.40
Dairy					115	77	38	228.00
TOTAL					600.6	355.6	245	1470.00

ZONE V	SORGHUM (1ha/ season)	BEANS (2ha season 1ha / season	S/FLOWER (1ha season)	SORGHUM (for cattle 2 ha/each)	TOTAL	FAMILY	HIRED	COST @ KSHS.
Planting								
Ploughing	20.7	28.6	16.7	20.7	214.8	80	134.8	808.8
Fertilizing								
Dust Spray	8.6	8.6	2.1	4.3	55.8	55.8		
Weeding	14.3	14.3	14.3	7.0	113.8	80	33.8	202.80
Harvesting & threshing	27.2	27.1	22.9	18.0	226.4	152	74.34	446.40
Dairy					90	90	-	-
					700.8	457.8	243.0	1458.00

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APPENDIX VII

Relative Land Use Suitabilities

Table VII.1

Relative Land Use Suitabilities

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Rainfed Arable Mixed Farming Technology Level Tradit./Interm/Advcd			Large Scale Arable Farming	Irrigation Suitability Small Holder	Irrigation Suitability Large Scale	Forestry Potential
	E C O L O G I C A L					Z O N E		II
HQb/EF	1,200	D	D	C	D	NR(1)	NR(1)	B
MQ1/DF	4,840	D	C	B	D	NR	NR	B
MQ2/DF	10,520	D	D	D	D	NR	NR	A
UFr2/BC	990	B	A	A	B	NR	NR	A

Table VII.I (continued)

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Arable Mixed Technology Tradit./Interm/Advcd		Rainfed Farming Level	Large Scale Arable Farming	Irrigation Suitability Small Holder	Large Scale	Forestry Potential
	E C O L O G I C A L					Z O N E		III
HNr1/DE	3,500	D	C	B	D	D	C	B
HQb/EF	15,950	D	D	C	D	D	D	C
MPr/DF	1,610	National		Park				
MQ1/DF	16,240	D	C	B	D	D	C	B
MQ2/DF	17,930	D	D	D	D	D	D	B
UFr1/BC	1,650	B	A	A	B	A	A	A
UFr2/BC	4,970	B	A	A	B	A	A	A
UIr1/BC	2,310	B	A	A	B	A	A	A
UNr1/BC	22,030	B	A	A	B	A	A	A
UNr1/CD	4,030	C	B	A	B	C	B	B
UQ1/BC	1,960	C	C	B	B	B	B	B
UU1/BC	4,600	B	A	A	B	A	A	A
UU3/BC	750	D	C	B	C	D	C	B
UU3/C	840	D	C	B	C	D	C	B
UUC1/BC	2,110	C	B	B	B	B	B	A
UUC2/CD	1,700	D	D	D	D	D	D	C

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Table VII.I (continued)

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Arable Mixed Technology Tradit./Interm/Advcd	Rainfed Farming Level		Large Scale Arable Farming	Irrigation Suitability Small Holder	Irrigation Suitability Large Scale	Forestry Potential
	E C O L O G I C A L					Z O N E IV		
HNr1/DE	350	D	C	B	D	D	C	B
HNr2/DE	10,370	D	D	C	D	D	D	B
HQb/EF	32,690	D	D	D	D	D	D	C
LIC/AB	2,350	D	C	C	C	C	B	B
LId/A	250	C	B	A	A	B	A	B
MNr/DG	55,960	D	C	C	D	D	D	B
MQ1/DF	9,810	D	C	B	D	D	C	B
MQ2/DF	6,410	D	D	D	D	D	D	C
(2) PIC/AB	11,890	D	D	D	D	D	C (3)	C
(4) PIr/AB	2,390	B	A	A	A	A	A	B
UFd/AB	3,520	C	B	A	B	C	A	B
UFd/AC	1,180	C	B	A	B	C	B	B
UFr1/BC	2,770	B	A	A	B	A	A	B
UFr2/BC	3,160	B	A	A	B	A	A	B
UFr2/C	1,060	B	A	A	B	B	A	B
UFr3/AB	7,550	C	B	A	B	A	A	B
UFr3/BC	710	C	B	A	B	A	A	B
UIr1/BC	4,050	B	A	A	B	A	A	B
UIr2/AB	13,950	B	A	A	A	A	A	B

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Table VII.I (continued)

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Arable Mixed Technology Tradit./Interm/Advcd		Rainfed Farming Level	Large Scale Arable Farming	Irrigation Suitability Small Holder	Irrigation Suitability Large Scale	Forestry Potential
	E C O L O G I C A L Z O N E IV							
UIr2/CD	5,870	C	B	A	B	C	B	B
UNr1/AB	3,170	B	A	A	A	A	A	B
UNr1/BC	57,880	B	A	A	B	A	A	B
UNr1/C	850	B	A	A	B	B	A	B
UNr1/CD	12,090	C	B	A	C	C	B	B
UNr2/BD	25,220	C	C	B	C	C	B	C
UQ1/BC	17,130	C	C	B	C	B	B	C
UQ1/C	1,240	C	C	B	C	C	B	C
UQ1/CD	5,540	D	C	B	C	D	C	C
UQ2/AB	870	D	D	D	D	D	C	C
UQ2/BC	3,420	D	D	D	D	D	C	C
UU1/BC	32,240	B	A	A	B	A	A	B
UU2/AB	4,240	B	A	A	A	A	A	B
UU2/BC	3[illegible],330	B	A	A	B	A	A	B
UU2/C	400	C	B	A	B	B	A	B
UU2/CD	9,410	C	B	B	C	C	B	B
UU3/BC	3,730	D	C	B	C	D	C	C
UU3/C	1,890	D	C	B	C	D	C	C
UUC1/AB	2,310	B	B	B	B	B	B	B

Table VII.I (continued)

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Arable Mixed Technology Tradit./Interm/Advcd	Rainfed Farming Level		Large Scale Arable Farming	Irrigation Suitability Small Holder	Irrigation Suitability Large Scale	Forestry Potential
	E C O L O G I C A L					Z O N E		IV
UUC1/B	6,710	B	B	B	B	B	B	B
UUC1/BC	3,730	C	B	B	B	B	B	B
UUC1/DE	7,700	D	C	B	D	D	C	B
UUC2/BC	9,280	D	C	C	D	D	D	C
UUC2/C	6,290	D	C	C	D	D	D	C
UUC2/CD	32,050	D	D	D	D	D	D	C
VXC/BE	13,000	D	C	C	D	D	D	C

Table VII.I (continued)

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Arable Mixed Technology Tradit./Interm/Advcd	Rainfed Farming Level		Large Scale Arable Farming	Irrigation Suitability Small Holder	Irrigation Suitability Large Scale	Forestry Potential
	E C O L O G I C A L Z O N E V							
AX1/AB	35,300	C	B	A	A	B	A	B
FXr/BD	14,970	C	C	C	C	C	B	C
HNr2/DE	8,190	D	D	C	D	D	D	C
HQb/EF	34,470	D	D	D	D	D	D	C
LIC/AB	37,040	D	C	C	C	B	B	C
LId/A	7,520	C	B	A	A	C	A	B
MNr/DG	12,000	D	D	C	D	D	D	C
MQ2/DF	10,870	D	D	D	D	D	D	C
PFb/A	27,480	C	B	A	A	A	A	B
PFr/A	136,330	C	B	A	A	A(5)	A	B
PIC/AB	3,650	D	D	D	D	D	D	C
UFC/AC	14,350	C	B	B	B	C	B	B
UFd/AB	37,730	C	B	A	B	C	A	B
UFd/AB	11,860	C	B	A	B	C	B	B
UFr1/BC	7,680	C	B	A	B	A	A	B
UFr3/B	5,960	C	B	A	B	A	A	B
UFr3/BC	169,010	C	B	A	B	A	A	B
UFr3/C	11,740	C	B	A	B	B	A	B
UFr4/C	12,000	D	D	C	D	D	D	C
UFr4/CD	15,520	D	D	C	D	D	D	C

Table VII.I (continued)

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Arable Mixed Farming Technology Level Tradit./Interm/Advcd			Large Scale Arable Farming	Irrigation Suitability Small Holder	Irrigation Suitability Large Scale	Forestry Potential
	E C O L O G I C A L Z O N E V							
ULb/D	1,550	D	D	D	D	D	D	C
UNr1/BC	84,000	C	B	A	B	A	A	B
UNr1/BC	23,590	C	B	A	B	B	A	B
UNr2/BD	7,890	C	C	B	C	C	B	C
UQ1/A	9,070	C	B	A	B	C	B	C
UQ1/BC	20,610	C	C	B	C	B	B	C
UQ1/CD	480	D	C	B	D	D	C	C
UQ2/AB	9,150	D	D	D	D	D	C	C
UQ2/BC	1,010	D	D	D	D	D	C	C
UQ2/CD	3,940	D	D	D	D	D	C	C
UQ2/E	280	D	D	D	D	D	D	C
UU1/AB	7,450	C	B	A	A	A	A	B
UU1/BC	28,390	C	B	A	B	A	A	B
UU1/C	3,980	C	B	A	B	B	A	B
UU2/AB	4[illegible],540	C	B	A	A	A	A	B
UU2/BC	72,980	C	B	A	B	A	A	B
UU2/C	2,510	C	B	A	B	B	A	B
UU2/CD	5,070	C	B	B	C	C	B	B

Table VII.I (continued)

1	2	3	4	5	6	7	8	9
Mapping Unit	Area ha	Small Holder Rainfed Arable Mixed Farming Technology Level Tradit./Interm/Advcd			Large Scale Arable Farming	Irrigation Suitability Small Holder	Large Scale	Forestry Potential
	E C O L O G I C A L					Z O N E		V
UU3/BC	2,170	D	C	C	C	D	C	C
UU3/C	4,470	D	C	C	C	D	C	C
UU3/CD	4,970	D	D	C	D	D	C	C
UU3/DE	7,700	D	D	C	D	D	D	C
UUC1/AB	76,270	C	B	B	B	B	B	C
UUC1/BC	50,570	C	B	B	B	B	B	C
UUC1/C	14,290	D	C	B	C	B	B	C
UUC2/AB	2,300	D	C	C	D	D	D	C
UUC2/BC	10,560	D	C	C	D	D	D	C
UUC2/C	8,270	D	C	C	D	D	D	C
UUC2/CD	90,120	D	D	D	D	D	D	C
UXC/BE	5,010	D	D	C	D	D	D	C