Landscape Planning in the Ngong Hills of Kenya, an Integrated Approach

prepared by: J. Douglas Olson

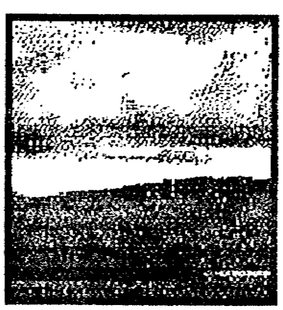
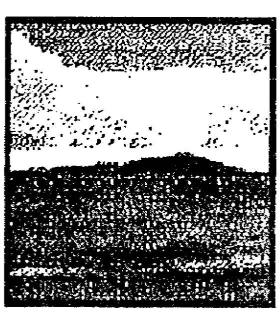
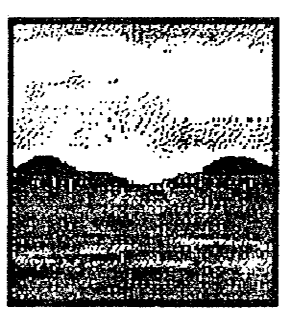
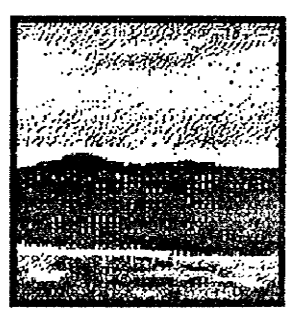
date: August, 1987

Submitted in partial fulfillment of the requirements for the degree of Master of Landscape Architecture to:

University of Manitoba, Canada
Department of Landscape Architecture

in association with:

University of Nairobi, Kenya
Department of Land Development


Permission has been granted to the National Library of Canada to microfilm this thesis and to lend or sell copies of the film.

The author (copyright owner) has reserved other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without his/her written permission.

L'autorisation a été accordée à la Bibliothèque nationale du Canada de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur (titulaire du droit d'auteur) se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation écrite.

ISBN 0-315-47902-7

LANDSCAPE PLANNING IN THE NGONG HILLS OF KENYA,

AN INTEGRATED APPROACH

BY

J. DOUGLAS OLSON

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF LANDSCAPE ARCHITECTURE

© 1988

Permission has been granted to the LIBRARY OF THE UNIVERSITY OF MANITOBA to lend or sell copies of this thesis. to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film, and UNIVERSITY MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

Abstract

The Ngong Hills represent a natural resource of significant importance to Kenya. The hills contain valuable agricultural, vegetational, hydrological, visual, recreational and wildlife resources. These support a number of land uses and a sizeable and quickly growing population. Settlement expansion and often inappropriate use of the resource base has threatened sustainability of production. The study undertakes to determine the degree to which existing land uses are destabilizing the environment and what changes in either land use or inputs are required. In addition, existing habitats and landscape elements are evaluated to ascertain their role in safeguarding desired functions with particular emphasis on the factors affecting primary production.

The study argues that an integrated approach to landscape planning; that is, holistically examining and responding to the biological, physical, cultural, and economic aspects of the environment, is necessary for truly sustainable rural development. In this way both conservation and development objectives may be achieved. A methodology is put forward that spatially relates information from various disciplines in order to design a course of action that is directed towards the optimum use of the land, consistent with the highest state of landscape integrity and economic and social feasibility. Agroforestry figures prominently in the plan.

Permission has been granted to the library of the UNIVERSITY of MANITOBA to lend or sell copies of this thesis, to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and lend or sell copies of the film, and the UNIVERSITY MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the thesis, nor extensive extracts from it may be reprinted or otherwise reproduced without the author's permission.

©1988

Acknowledgments

The author wishes to acknowledge the following persons and organizations who were helpful during the preparation of this study.

For their comments and direction throughout the course of the work, I am especially indebted to Dr. D. Rocheleau, Dr. G. King'oriah, Dr. M. Carvalho and Professor A. Rattray.

I am grateful to the Faculty of Architecture of the University of Nairobi for their advice, encouragement and hospitality.

For their untiring assistance in the field I am grateful to Ms. L. Omoro, Mr. E. Chamuchi and Mr. A. Ole Pello.

Special thanks are due to the International Council for Research in Agroforestry for their advice and information.

For the financial support received during the early stages of the work, the author gratefully acknowledges the University of Manitoba, Faculty of Graduate Studies.

Particular appreciation is extended to the Canadian International Development Agency without whose financial support this study would not have been possible. Thanks are also extended to the regional CIDA staff in Nairobi for their support and advice.

Finally I wish to thank the farmers of the Ngong Hills to whom this work is respectfully dedicated.

C O N T E N T S

Chapter **Page#**

1. INTRODUCTION 3

Purpose 5
Problem Statement 5
Previous Work and Literature Review 6
Objectives of the Study 18
Scope and Limitations 19
Research Methodology 20

2. THE CONTEXT 35

The National Context 36
Population and Employment 36
Land Tenure 37
Agriculture 38
Forestry 39
Tourism and Wildlife 40
Basic Needs 40
Development Strategy 43

The Historical Context 44
Land Use by the Maasai 45
Early Traders and Explorers 45
European Settlement and Maasai Reserves 47
1930 to the Present 49

3. THE BIO-PHYSICAL ENVIRONMENT 54

Geology 55
Previous Geological Work 55
Topography 56
Summary of Geology 56
Details of Geology 59

Climate 63
Seasonal Weather Patterns of East Africa 63
General Climate of the Kenyan Highlands 64
Detailed Climate of the Ngong Hills 66
Meteorological Observation Stations 67
Classification 67
Rainfall 67
Evaporation, Radiation, and Relative Humidity 73
Temperature 75
Winds 77
Summary 80

Hydrology 81
Geological Influences 81
Recharge to Groundwater 83

Hydrology con'd
Influence of Land Use on Water Resources.................................84
Forests..85
Grassland..87
Cropland...87
Agroforestry...88
Settlement...89
Planning and Management Implications.....................................89

Soils..93
Soil Survey Methods..93
Laboratory Methods...94
Cartographic Methods...94
Erosion..95
The Classification Units...97
Vertisols...97
Nitosols..98
Luvisols..99
Andosols..99
Regosols..99
Lithosols and Rock Outcrops...99
The Soil Mapping Units...100
Soils of the Ridges and Scarps...100
Soils of the Footridges and Footslopes...................................103
Soils of the Valley Bottoms and Volcanic Plains..........................107

Vegetation...110
Human Influence..110
Vegetation Classification..111
Undifferentiated Afromontagne Forest.....................................112
Dry Transitional Montagne Forest...115
Dry Montagne Forest of the Western Slopes................................116
Dry Wooded and Bush Grassland..116

Wildlife...118
Major Wildlife Species...119
Buffalo..119
Eland..120
Giraffe..121
Dik-Dik..121
Impala...122

Ecosystem Stability..124
Fire...126
Resource Stability Mapping...127
Summary..128

4. THE SOCIO-ECONOMIC ENVIRONMENT 130

The Socio - Economic Environment 131
Population and Labour Force 131
Employment and Economic Status of Households 134
Agricultural Costs and Prices 137
Credit Utilization and Costs 138
Agro Input and Commodity Prices 139
Infrastructure 140
Roads and Transport 140
Water Supply 142
Extension Services 143

Present Land Use 144
Cropland 145
General Cropping Characteristics 146
Land Utilization 147
Yields 148
Planted Trees and Woody Perennials on Farm 148
Capital Intensity 151
Labour and Power Intensity 151
Technical Knowledge and Attitude to Agriculture 152
Size and Shape of Farms 152
Access and Tenure 163
Production Constraints and Limiting Resources 164
Livestock 165
The Eastern Slopes 165
The Rift Valley 168
Forest Land 168
Human Influence 168
Reforestation Efforts 169
Grazing 170
Recreation 171
Human Settlement 171
Other Land Uses 172

5. DIAGNOSIS & DESIGN SPECIFICATIONS 173

Diagnosis of Major Land Use Problems and Potentials 174
Household Level Diagnosis 174
Food Production Subsystem 174
Cash Subsystem 174
Energy Supply Subsystem 175
Shelter Subsystem 176
Summary of Causal Factors and Constraints 178
Ecosystem and Community Level Diagnostic Summary 182

Design Specifications 187
General System Level Specifications 187
Summary Overview of Possible Interventions 190
Short List of Priority Interventions / Candidate Technologies 197
Technology Specifications for Selected Interventions 198

6. RECOMMENDATIONS AND CONCLUSIONS 202

Policy Set for the Ngong Hills 203
PreferencePolicies 203
Policies Related to High Density Settlement 203
Policies Related to Rural (low density) Settlement 203
Policies Related to Environmental Quality 204
Policies Related to Agriculture and Agroforestry 204
Policies Related to Horticulutre 204
Policies Related to Livestock 204
Policies Related to Forestry 205
Policies Related to Conservation 205
Policies Related to Recreation and Tourism 205
Policies Related to the Provision of Basic Needs 206
ExclusionRules 206

Prime Suitability 207
Land Utilization Types Under Consideration 207

Specific Management Recommendations 209
General Recommendations for All Areas 209
Small Holder Mixed Farming 210
Extensive Large Holders of the Western Slopes and Rift Valley 216
Ngong Township 219
Public Forest Land 223
ManagementUnits 223
General Planting Recommendations 228
Tourism and Recreation 229

Implementation 231
Model Farms and Demonstration Projects 231
Nurseries and Seedling Production 232
Planting 232
MajorProjects 233
The Forest Boundary Strip 233
The Kijiji Reservoir and Irrigated Specialty Crops 234
Extensive Silvopastoral System of the Rift Valley 234
Partial List of Organizations Offering Advice and / or Funding 234

FutureResearch 236

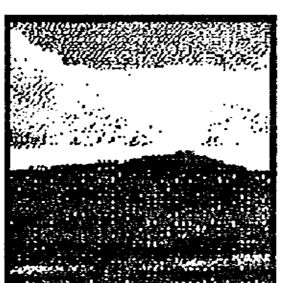
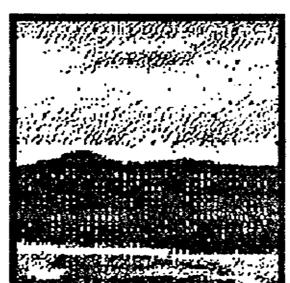
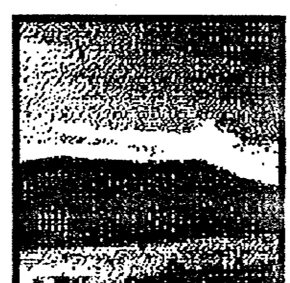
Conclusion 238

Bibliography 239

Appendices 247

Appendix 1, Laboratory Results of Representative Soil Profiles 249
Appendix 2, Farm Survey Questionnaire 279
Appendix 3, Map Reductions 291
Appendix 4, Sample Data Base Print Out 314

Chapter 1 Introduction

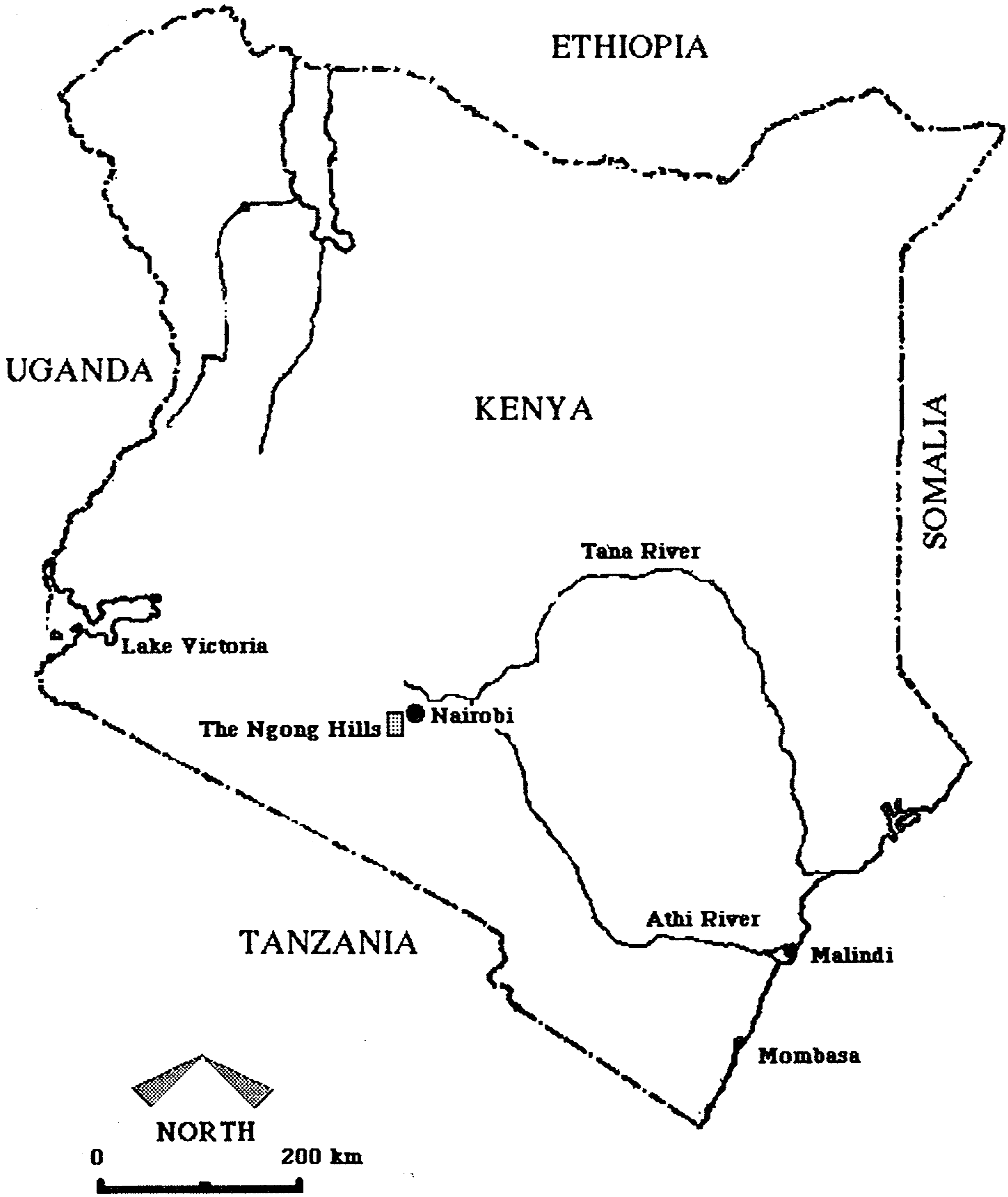


Figure 1, The Location of the Ngong Hills

1. INTRODUCTION

" The most urgent global problem today is to ensure the habitability of the earth's surface for man and his fellow species. With the present pressure of population this can only be achieved if men act as guardians of the earth in a role combining conservation and creation..... concerned equally with the conservation of natural life and the creation of environments where men can realize their potential for a full life in which beauty can be added to mere survival."

Dame Sylvia Crowe (1982)

There are few hill slopes that have not been touched by the problems of man induced ecological degradation. In developing countries particularly, the combined effects of growing populations, competition for scarce resources, and inappropriate land use, has led, all too commonly, to a downward spiral of decreasing environmental stability and diminishing levels of development.

With expanding populations, agricultural development has occurred in areas previously not subject to intensive cultivation. Land has been subdivided into plots, often with little regard for quality of soil, water availability, topography, existing vegetation, and susceptibility to erosion, with the result that plot size and fertility are often inadequate or marginal. Increasing numbers of inhabitants are attempting to extract their most basic needs of food, shelter, and fuel from environments whose balance, stability and equilibrium are threatened by those very attempts. Agrarian reform and adaptation to local physical and social conditions have not adequately followed the rapid increases in population and intensity of land use. A new ecological stability, responsive to this dynamic situation, is required, if the level and diversity of current development is to be sustained or improved.

Sustainable rural development will only be attained if planning efforts are in concert with the social, cultural, bio-physical, and economic forces at play in the environment. Human ecosystems are a complex web of various elements and the cause and effect of each must be considered in a holistic manner, if fully reasoned and comprehensive development proposals are to be made. Each element is inextricably woven with the others, and must be considered if the harmony and balance of the overall system is to be maintained. Therefore, an integrated approach to planning is required if the complexity inherent in the ecosystem is to be adequately addressed.

This approach is particularly applicable to the field of landscape planning which is " a hierarchial complex of a number of investigations leading to formulations in a number of disciplines " (Hills, 1974) and is necessarily concerned with the integration of man and his activities with natural processes and elements. Landscape is thus seen, not as purely natural space, but as the result of the manipulation of natural conditions by the work of man. It is the spatial expression of a particular social order. John Brinckerhoff Jackson has put it the following way:

> " A landscape is not a natural feature of the environment but a synthetic space, a man made system of spaces superimposed on the face of the land, functioning and evolving not according to natural laws but to serve a community..... for the collective character of the landscape is one thing that all generations and points of view have agreed upon. A landscape is thus a space deliberately created to speed up or slow down the process of nature. As Eliade expresses it, it represents man taking upon himself the role of time." (Jackson 1984)

It follows the understanding of this concept, that landscape planning seeks to understand and respond to the existing spatial organization of a locality, it's history, and the motivation for that structure (the formal political infrastructure, and the needs and aspirations of the inhabitants). A thorough comprehension of the bio-physical context is, of course, fundamental. In addition to this, the planner must evaluate the often conflicting demands placed upon the land and suggest ways of reshaping the landscape in such a way that it is more responsive to the requirements of the society. As sustainability of production is essential, the plan must be synchronized with the natural ecological processes that support it.

It is partly through an integrated approach to landscape planning; that is, holistically examining and responding to the biological, physical, social, cultural and economic aspects of the environment; that truly sustainable rural development may occur. Such a strategy should yield a landscape framework or infrastructure that both provides favorable environments for suitable land uses, and, is in accord with ecological processes that support them. In this way both conservation and development objectives may be achieved. This project seeks to apply this approach in the development of a landscape plan for the Ngong Hills of Kenya.

1.1 PURPOSE

The general purpose of the study is to evaluate the facts and processes that formed the landscape of the Ngong Hills, and to design a framework and course of action that is directed towards the optimum use of the land, consistent with the highest state of landscape integrity and economic and socialfeasibility.

1.2 PROBLEM STATEMENT

The Ngong Hills represent a natural resource of significant importance to Kenya. The area contains valuable agricultural, vegetational, hydrological, visual, recreational and wildliferesources. These support a number of land uses and a sizeable and quickly growing population. The threat to the natural resource base posed by recent settlement expansion and often conflicting and inappropriate land use, is serious, and, if left unanswered, may preclude sustainability of production. Conversion to small scale agricultural holdings and subsequent deforestation, has led to a decline in species diversity, visual quality, wildlife habitat, and water availability. Increased runoff, soil erosion, and declining fertility, associated with poor cultivation techniques and overgrazing, are further worsening the difficulties facing local farmers. Low income levels and under employment are common and the provision of basic human requirements is difficult for many families. Furthermore, the area is faced with the additional pressure of the urban expansion and population spill over of nearby Nairobi.

In light of these conditions, studies are required to determine the degree to which existing land uses are destabilizing the environment and what changes in either land use or inputs are necessary. In addition, an evaluation of existing habitats and landscape components is necessary to ascertain their role in compensating for the negative effects of the land uses in the area.

If more serious future problems are to be averted, measures must be taken which improve the stability and long term maintenance of the landscape by promoting practices which reflect a greater stewardship of the land.

1.3 PREVIOUS WORK & LITERATURE REVIEW

Landscape planning is a relatively new professional field and there are few comprehensive examples (in terms of a percentage of total land related planning efforts). The most notable work has been in Germany, the United States, Canada, the Netherlands, the British Isles and Israel (Weddle, 1978) and has occurred in the last thirty five years. In addition there have been some outstanding recent examples in developing countries.

Certainly, enlightened land planning and design has occurred in the more distant past, with such notable examples as the 18th and 19th century creation of the romantic English landscape by Brown, Repton and others. The work of Puckler-Muskau in 19th century Germany, although mostly confined to his estates, demonstrated " his profound grasp of a total ecology that included the human organism" (Newton, 1971). Fredrick Law Olmstead's work, particularly that of the Back Bay Fens and the Riverway in Boston, were significant in their ecologically sensitive treatment of degraded lands, not to mention their aesthetic importance.

Charles Elliot (1859-1897) made important contributions to the field of landscape architecture and planning, notably, his work on the Boston Metropolitan Parks system in which he demonstrated a site selection process based upon analysis of the historical and physical geography of the area. Elliot repeatedly called for "comprehensive studies" and "general plans" when dealing with land related development proposals (Elliot, 1896). In addition, his papers were among the first in the field of "landscape forestry" and indicated the requirement for advance planning in forestry operations to preserve scenic quality.

Other examples of early landscape planning are the efforts of the United States Soil Conservation Service which has done much to rehabilitate lands devastated by inappropriate agricultural practices. The establishment of conservation districts and the derivation of policies to guide land use in those areas was particularly significant. The Tennesee Valley Authority, formed in 1933, resulted in comprehensive planning for a large land area that was sensitive to the natural environment. The Resettlement Administration, established by President Roosevelt in 1935, combined agriculture and land conservation programs. The national park systems of both the United States and Canada and their subsequent planning efforts, have been outstanding in their attempt to conserve large tracts of public " unimpaired for the enjoyment of future generations ".

Although the importance of this historical work is undeniable, the details of the methodologies employed were often lacking or were rudimentary in nature. Planners and designers, although drawing on a broad range of disciplines, often worked intuitively and or neglected to be explicit in the descriptions of their analytical processes. As the problems and conflicts relating to land use increased in both number and complexity, the need for a comprehensive and defensible environmental planning process became more urgent. However, most of the environmental planning that has taken place to date has been directed towards problem resolution in a single field, ie. conservation, visual resources, forestry, hydrology etc. and only rarely have there been attempts to integrate the broad range of issues related to the use of land. Social and cultural influences are examined even less frequently.

Developments in the 1960's and early 1970's concentrated on the formulation of a systems model of planning (McLoughlin,1969; Chadwick,1971; Wilson,1972). This model postulates that it is possible to understand a system to such a degree as to formulate control mechanisms, and that the direct and indirect effects of such interventions can be forecasted, at least in the general sense of the impact on the entire system, it's people and their activities. (Hall,1979). The systems approach adopted a scientific, objective position in which the planner derived some of the goals and objectives from politicians and clients, as well as formulating objectives for the society by virtue of his training and examination of "the facts". Although the early systems planning models were often narrow in terms of the scope of issues under consideration, they indicated the value of analyzing the consequences, in both the short and long term, of existing and planned actions. Examples of landscape planning during this period that adopted a systematic and comprehensive approach include the seminal work of McHarg, 1969; as well as that of Weddle, 1967; Werkmeister, 1967; Steinitz *et al* 1968; Eckbo,1969; Hills, 1961,1970,1974; and Vroom *et al* 1970.

The work of A.G.Hills was particularly outstanding and is presented as it has influenced the methodology of the present study. It establishes a hierarchal framework for the ecological classification and interpretation of land units that allow for the identification of resources and patterns of use at different scales. The landscape planning procedure is seen to have six levels:

Level 1 - formulation of feature properties

Level 2 - formulation of feature gradient classes and ecosystem types

Level 3 - formulation of regional ratings of ecosystem types

Level 4 - formulation of the relative advantages of management alternatives

Level 5 - formulation of alternative landscape scenarios

Level 6 - formulation of the landscape plan (Hills,1974

Hills' methodology recognized that "all types of changes in the landscape must be considered in selecting the optimum landscape for any given area." (Hills, 1974) Using those features that interact transactionally to control production, (including social production ie. physical and mental health, changes in community lifestyle etc.) he derived his system for the classification, management and planning of the landscape. The various interrelationships between the parts of the ecosystem are explored. These relationships are seen not as isolated phenomena but always within the organism-environmental whole. The ecosystem is seen as a transactional whole or "circular causal system" (Hills, 1974). Following this concept, the ecosystems are described in terms of their parts or systems but in such a way that the relationships can readily be seen and explored. He classifies ecosystems as "production systems" of the following types:

1. **Biological**: eg. farm, forestry or fishery ecosystems

2. **Physiographic**: eg. mine, aquifer, or energy developing ecosystems

3. **Societal**: cultural ecosystems (Hills, 1970)

The objectives in levels 1-5 in the planning process are to identify those features which control production and which may form the basis for proposals in level 6.

Hills' method of landscape ecological inquiry is based on a complex of the following types of inference, which overlap to varying degrees: intuitive, inductive-deductive, transactional, iterative, evaluative, normative, and consensus. These combine to yield: an ecological method for investigating the ecosystem web, an areal organization of the system, and a method of "determining societal values of specific ecological relationships at two levels of landscape synthesis, viz. the natural and cultural landscapes" (Hills, 1974)

An understanding of the production potential of the ecosystems in the planning area is fundamental, as is a clear concept of the feasible management options, given the limits of the particular resource managers. Three types of evaluation were used:

1. **Capability**: the potential of the land for use in specified ways.

2. **Suitability**: the present suitability of the land for specified land uses.

3. **Feasibility**: incorporates socio-economic conditions into the above.

The matching of the management units to the needs of the society can only satisfactorily be accomplished if there is an understanding of which segment of the society is to be satisfied. Hills noted the necessity for intensive human ecological and anthropological investigations in landscape planning and called for a typological approach to human ecosystems (although his own work did not include it). The socio-economic and cultural information must be gathered in such a way as to allow it's integration with the physiographic and biotic information.

The importance of Angus Hills' work rests on his holistic approach to analysis and evaluation as well as his sound philosophical defence of the process. By gathering, analyzing, and synthesizing information in such a way that it reflects the transactional nature of the area under investigation, landscape decisions can be made based upon a matching of the societal, physiographic and natural determinants.

Ian McHarg's planning process is concerned with the integration of ecology and natural processes within the planning framework. Natural processes are seen to have inherent qualities which affect the productivity and ecological balance of the ecosystem. The misuse or mismanagement of the ecosystem has potential hazards. Accordingly, planning must respond to the implications to development that natural processes exhibit. "The plan can be developed only when there is adequate information on the nature of demand , it's locational and resource characteristics and, indeed the social goals of the community...........whatever the characteristics of the demand - the formulation of a plan....... should respond to an understanding of natural processes. It must plan with nature. " (McHarg,1969).

McHarg employed cartographic techniques based on an overlay process in which various combinations of maps could be superimposed and photographed to yield a composite. The technique also allows the weighting of the various component maps. Although transparent overlay techniques were being used by planners and designers for both analysis and presentation after 1950, (Whittle,1950; Lewis,1962; Alexander et al 1962) McHarg's presentations were among the most elaborate and had a great influence on the profession. Steintz (1976) and others have further refined the overlay method in such a way that it is suitable for either cartographic or computer analysis. In light of modern geographic information systems and computer assisted cartography, the principal value of the hand drawn overlay method lies in the approach to problem solving. It will, of course, continue to be used on small scale projects, or by those lacking access to more sophisticated systems.

Frederick R. Steiner (1981, 1984) has applied ecological principles to the planning of agricultural landscapes. Among other achievements, he has helped develop an agricultural land evaluation and site assessment system in an effort to preserve valuable farmlands.

The activity of landscape planning is well developed in Germany and there are several examples of notable work (Werkmeister, 1967, 1984; Steinert, 1985; Krinner *et al*; and others). However, that of Auweck, Schaller and Sittard (1979) is particularly interesting as it developed a well documented methodology that relates to the agricultural landscape. Adopting an integrated approach to the planning of a complex system, they sought to introduce the concerns of specialist fields. Equal weight was given the concerns of economists and ecologists with the overall aim being the "the stability and long term maintenance of land uses through minimizing the pressures on the environment (correct agricultural and forestry practices)" (Auweck *et al* 1979)

By superimposing and comparing specialist information for the planning area, they were able to determine areas of conflict. In the overall plan a balance between the various interests was attempted. Although there were no quantitative statements regarding the functioning of the system, there was an attempt to qualitatively describe the value (in terms of desired function conservation) of various elements in the landscape. These function conserving elements were matched with existing land uses which had been ranked in terms of their impact on the function of the land. Thus a map of the region was produced in which all areas fall into one of three classes: resource conserving, in equilibrium, or resource consuming. Although apparently lacking a social component, the study was important as it attempted to integrate multidisciplinary data to provide indicators for the planning of the agricultural landscape.

Although most of the preceding approaches to landscape planning acknowledged the importance of including a social component in the process, few have indicated, in a precise fashion, a social research methodology which responds to the level of detail required for design. The need for the integration of user requirements hopes and aspirations within the planning and design process has been recognized by a number of researchers (Chambers, 1983; Oliver, 1971; Heston, 1975; Hyden, 1983; Moore, 1976; Berger, 1978; Lynch, 1980; Low, 1981; FAO, 1979, 1981; Fortmann *et al* 1985; I.C.R.A.F. 1983; Muller, 1984; Campbell, 1984; Rocheleau, 1984; Chavangi *et al* 1985; Messerschmidt, 1985).

It is only through involvement that users will be able to meaningfully participate in the decision making processes that affect their lives. It is through active local peoples participation that planners will be able to ensure that indigenous expertise, traditional beliefs, taboos, norms, behavior details, alternatives, and priorities are incorporated into any development plans. As values are the fundamental sources of behavior, they must be fully understood and accounted for. The implications of changes in values, and therefore changes in behavior, must be explored if the intentions of plans or designs are to be realized. If there is a sufficient realization of cultural values and decisions planners can make allowances for them, or better yet, allow them to guide the plan.

Revision of cultural beliefs and traditions is often necessitated by the reality of a changing environment. People are forced to alter their values, expectations, and priorities in light of such imperatives as increased population,and scarcity of capital and resources. These are not simple changes as they often are closely connected to personal emotions and may lead to profound changes in personality, social status, societal behavior and satisfaction. (Pettman,1981)

One project that has adopted a culturally sensitive process is the Kenya Woodfuel Development Programme (KWDP) in Kakemega District. If successful, it will significantly improve the landscape of that area. The KWDP project is just getting underway, and an evaluation of it's success is not yet possible, however, the initial indications are encouraging. Certainly, the approach is a sensitive one that has implications for other development projects. A programme was developed based on a sound understanding of the cultural makeup of the community as well as the technical and economic considerations of the problem. In this way the requirements of the people both in a material and cultural sense, could be met in the least socially disruptive and most beneficial fashion. The taboos and cultural values of the people have been preventing them from reaching their development potential, and therefore, needed modification. A programme of mass awareness coupled with the use of local knowledge and skills, is starting to achieve this modification in a way that does not impose an external solution, but rather, builds on existing patterns of behavior.

The human ecological method of planning adopts the scientific, replicable approach to the determination of social requirements and beliefs. Anthropologists, working with planners, sociologists, ecologists and other disciplines evaluate human values, behavior, and requirements and analyze the cost/benefit or suffer/benefit results of varying planning approaches. Ethnographical and social analysis is used to define groups as well as identify problems and opportunities within the planning area. However, little attention has been paid to "the spatial aspects of social relationships and patterns of behavior" in African societies (Muller,1984). The scale of investigation varies according to study objectives, but it rarely is carried out at the level of detail required for small scale design (Low,1980). There are of course exceptions to this (I.C.R.A.F. 1983, Rocheleau,1984) in which investigations occur at varying scales in response to both the size of the management units and the larger contextual influences.

Setha M. Low (1980) has indicated a social science methodology that merges well with the landscape design and planning process. This methodology does not make a distinction between the physical and social environments. Recognizing five stages in the landscape design procedure (problem formulation, data collection, programme, physical design, design evaluation) , she identified the need for a recursive model with feedback loops that allows for re-evaluation in light of new information gained in subsequent stages. At each stage, with the exception of the physical design stage, social information, value decisions and interpretation is required. Social tasks required for each design stage are identified as are possible methods and techniques for accomplishingthetask.

A methodology that has been most successful in integrating social and cultural values with a comprehensive and systematic planning process is that developed by the International Council for Research in Agroforestry (I.C.R.A.F.) The "Diagnosis and Design" (D&D) methodology was developed to identify agroforestry technologies and research priorities that were based upon a diagnosis of the problems and potentials of land use systems. " The methodology is directed towards meeting the needs, solving the problems, or realizing the potentials of specific land use systems. The procedures ....lead to the design of one or more agroforestry technologies which appear to have the potential to effect realistic improvements in the target land use system." (I.C.R.A.F., 1983). The approach has been partially derived from Farming Systems Research (Collinson, 1981; Hildebrand, 1981; Zanstra et al, 1981; Shanner et al, 1982) and has adopted the rapid appraisal method (Chambers, 1981) for reasons of efficiency.

As the D & D process is thoroughly described elsewhere (I.C.R.A.F., 1983) only a brief outline will be presented here. Utilizing a multidisciplinary problem solving approach, the methodology may be divided into the following four stages (I.C.R.A.F., 1983):

PrediagnosticStage:

1. Environmental description of the study area
2. Differentiation of land use systems within the study area
3. Preliminary description of the selected land use system(s)

DiagnosticStage:

4. Diagnostic Survey
5. Diagnostic analysis
6. Derivation of specifications for appropriate technology

Technology Design Stage:

7. Technology appraisal
8. Technology design
9. Design evaluation

Follow up Planning Stage:

10. Research needs
11. Topicsrequiring further D & D attention
12. Projectimplementationplan

A wide range of issues in the agricultural, social, and natural sciences are examined in a systematic fashion and problem resolution is based on multidisciplinary synthesis.

The D & D methodology has been employed on many projects throughout the world . It has been combined with landscape analysis in the Kathama area of Kenya on a limited basis (Hoek *et al*, 1984)

Much of the I.C.R.A.F. methodology focuses on the individual farm and the household head as the farm manager. The logic of this approach is that, in many areas, this is the level at which most land management decisions are made. This emphasis on micro analysis is similar to work in human geography in the late 1960's and early 1970's. J. B. Jackson states: " Just as the elementary unit of mankind is the person, the elementary unit of the landscape is the individual dwelling.......This ordering of man's most intimate world is the prototype of how he orders his larger world" (Jackson, 1978). The importance of a micro level research orientation was recognized by others in theregional scienceprofession:

" Nothing truly general can be said about aggregate regularities until it has been made clear how far theyremaininvariatewith organizational differences atthe microlevel" (Hagertrand, 1970).

" A fruitful way to characterize a region is as a system of individual enterprises or organizations. The growth or decline of a single region is a summation of the growth or decline of it's components. Therefore the only meaningful way that any deep and perceptive understanding of regional change can be achieved is to focus attention on the change that occurs at the level of the individualenterprise" (Leigh, 1978).

The most most pressing need in this approach, is to integrate the micro level disaggregate findings with the regional or sub-regional findings and concepts. This is particularly true in landscape planning situations that must deal with a variety of problems or opportunities that occur at different scales in the landscape, but are nevertheless, transactionally related. The inventory, analysis, and synthesis of informationmusttherefore reflect theserelationships. (Rocheleau, 1984)

The D & D methodology lends itself to applications at variable scales (regional, community, ecosystem, farm,intra-household). This has been further detailed by I.C.R.A.F.(

Rocheleau,1984) and has been applied in several projects (Hoek *et al* 1984; Vonk,1984, Buck,1984). Different scales are considered separately and in various combinations in order to fully understand the operations and relationships of the systems under consideration. This sliding scale approach is particularly suited to regional and subregional development applications where the client group encompasses a wide range of users (Rocheleau,1984). Although the D & D methodology was developed specifically for the development of agroforestry technologies, it's comprehensive and problem solving approach makes it applicable to systematic landscape analysis and the derivation of a broad range of problem solutions, including options other than agroforestry.

Landscape planning has an ecological basis and is concerned with the establishment of stable ecosystems (Hackett,1971). Therefore an understanding of the factors affecting stability and their implications to development is essential. Work on various aspects of ecological stability as it relates to the human use of ecosystems (particularly mountain ecosystems) includes that of Ives *et al* 1984 ; B.Messerli ,1983 ; Getahun,1984; P.Messerli,1983; Glaser *et al*,1981; Gigon,1983; Winiger, 1983; and Hurni,1983. Much of this has centered on agricultural landscapes and methods of assessing stability with many examples from developing countries.

In recent years the concern for the visual quality of the environment has risen. In many areas it has become necessary to analyze the visual resource in order to provide a basis for it's management. As the Ngong Hills represent a valuable visual resource, both to local inhabitants and visitors, due consideration should be given it's management. Although there has been much work in the field of visual management (Appleyard;1963; Crowe,1966; Elsner,1979; Hizuchi, 1983; Litton,1971,1968; United States Forest Service, 1974, 1975, 1976; U.S. Bureau of Land Management, 1975; Zube,1975), there is considerable debate on the preferred methodology.

As land classification and evaluation are inevitable in landscape planning, the following works have been reviewed: Marsh,1983; Dent and Young,1981; FAO 1976 ; Young,1983,1984; Mitchell, 1973; Wiken,1979; Rowe,1979; Duffy,1979; Friend, 1979; Gimbarzevsky,1979; Quin,1979; Luff,1979. The work of McDonald *et al*(1984) provides a methodology for weighting suitability maps in terms of their degree of policy satisfaction.

An example of an approach to multiple land use that integrates the requirements for conservation with that of other resources is the Michiru Mountain project in Malawi.(Hough,1984). Government departments, local leaders, politicians and conservation volunteers, all were involved in the formulation of a plan to rehabilitate a degraded mountain environment. The local peoples needs were considered and a reasonable degree of success has been achieved.

The Integrated Project in Aridlands (I.P.A.L.) in the Marsabit area of northern Kenya, established by U.N.E.S.C.O. and U.N.E.P., is perhaps the most ambitious multidisciplinary study undertaken in that country. The aim of the project was to find " direct solutions to the most urgent environmental problems associated with desert encroachment and ecological degradation of arid lands." In an effort to provide a scientific basis for the rehabilitation and management of the lands in question, an integrated approach was adopted in which surveys and research were carried out in a number of different fields. The human ecology of the nomadic pastoralists of the area was studied and resource management models and plans were formulated. Although the project encompassed 22500 km^2 a great deal of data was generated and some detailed examples were put forward. The project is still underway under the auspices of the Kenyan government.

In terms of the broad objectives of the study, and the work accomplished in the Ngong Hills to date, there is a large and obvious gap. The only physical planning that has been carried out in the area is the Kajiado District Development Plan and this does not have an ecological or for that matter, resource based approach. It provides only a cursory look at the district as a whole and makes no attempt to understand it's functioning in a systematic way. The plan provides lists of completed or intended projects in the district as well as a brief assessment of programme success. It notes the "dismal" (Gov. of Kenya, 1984) performance of both the water development and soil conservationprogrammes.

The District Focus for Rural Development has emphasized the need for decentralized planning in Kenya. However, this has met with varying degrees of success in Kajiado District (Campbell, 1984; Gov. of Kenya, 1984). Although there has been widespread recognition of the need to integrate local resources, needs, and aspirations in the planning process, this has not been seriously addressed in district plans. The substantial human resources of the local population, in terms of agricultural expertise, and detailed knowledge of the area's problems and potentials, are thereforeunderutilized.

Other work in the area includes the following:

The Mazingira Institute, together with I.C.R.A.F., has done some agroforestry diagnosis and design work at Kibiko in the extreme northern end of the planning area (Buck, 1984). Local problems were identified and some possible solutions were designed. A school nursery was established and both public demonstration plots and on farm tests were established. This pilot project had many problems and met with limited success.

The Kenya Energy Non Government Organization (KENGO) has been actively involved in deseminating agroforestry information and is carrying out an afforestation programme in Kajiado District. Although not operating in the Ngong Hills, K.E.N.G.O. is a valuable source of related information.

The Kenyan Rangeland Ecological Monitoring Unit (K.R.E.M.U.) has examined some aspects of forest degradation in the Ngong Hills. They have noted general trends in vegetation change from 1967 to 1981 (K.R.E.M.U.,1981) but the classification is not of sufficient detail to be used for the present planning purposes.

The Department of Urban and Regional Planning (D.U.R.P.) did a development study of Kiserian on the edge of the study area. This project was limited in it's scope and did not adopt an ecologicallyorientedmethodology. (D.U.R.P.,1975)

Beatrice Khayota has conducted the most recent botanical investigations in the area with her MSc. work entitled "Taxonomic and Ecological Survey of the Orchid Flora of the Ngong Hills" (in preparation).

The Ministry of Agriculture has developed " Land and Farm Management Guidelines for Kajiado District" (1975) which contains some valuable information.

Dr. J. M. Ole Tameno, a Ngong Town veterinary doctor, has put forward a brief paper, " Ngong Hills- Proposals for Future Development"(1985), to the District Development Committee. This calls for increased development, including tourism, water development projects and environmental management. The paper is very general in nature.

The Ministry of Natural Resources has been carrying out a reforestation programme in the Ngong Hills. The University of Nairobi has contributed to this effort and a portion of the area has been named University Forest. Detailed direction is required if these efforts are to compliment other required strategies for the area.

The foregoing has discussed landscape planning and related work that has had a influence on the development of the methodology of this study. Most of the work has occurred outside the study area. It is not meant to be a comprehensive list of all recent work, but rather, to indicate that which is seen to be most relevant to the present project. Within this context, there is seen to be an existing methodological gap between any single work and the requirements of the project at hand. A methodology is required that has a strong social and cultural input, while at the same time maintaining an ecological and systematic stance that allows for investigation and incorporation of information at different scales. This process must also yield priorities and details of land use that satisfy both national and local people's objectives. In a country such as Kenya, where the economy and well being of the people is agriculturally based, it is imperative that the planning process address the ecological basis of such activity. This must be done at a scale and level of detail that yields practical examples as well as more general policies. Prior tp the present study, no such work has been done in the Ngong Hills. To accomplish this, and other study objectives, a synthesis of the methodological aspects of several of the studies reviewed, is necessary.

1.4. OBJECTIVES OF THE STUDY

The following are the broad objectives of the study. All are seen to be complementary.

1. To examine and analyze the characteristics and interactions of the various landscape factors in a systematicfashion.

2. To identify the type and spatial distribution of existing land uses.

3. To evaluate the suitability and environmental impact of existing and proposed land uses.

4. To identify and propose resolutions to land use conflicts.

5a. To make recommendations as to the role the Ngong landscape will play in the provision of timber, fuel, agricultural products, water, wildlife, tourism, recreation, and human settlements and to suggest an orderly arrangement of the land uses that is in accord with the ecological and social processes that sustain them.

b. To establish priorities of land use.

c. To suggest improvements in the environmental framework (eg. soil fertility, microclimate) within which appropriate new or existing technologies can operate.

d. To examine the role appropriate production technologies can play in improving the landscape (with particular emphasis on agroforestry).

6. To develop a planning strategy that integrates the basic needs, hopes and aspirations of the local inhabitants with the overall planning requirements.

7. To contribute to the environmental database of the area.

8. To provide a basis for locally directed support and to advise how the planning proposals might be implemented within the local framework.

1.5. SCOPE AND LIMITATIONS

The study area is 72 km^2 and is approximately twenty kilometers west of the Nairobi city centre and is in the Ngong Division of Kajiado District of the Rift Valley Province. It lies between longitudes 36° 37' 6" and 36° 40' 19" East and latitudes 1° 20' 49" and 1° 28' 9" South.

The main thrust of the project is the analysis and evaluation of the Ngong Hills landscape with the purpose of making reasoned recommendations for it's future use. Accordingly, emphasis in the study has been placed on those forces and elements that play a significant role in giving **physical form** to the landscape. Such areas as education, industry, political structure, health facilities, credit facilities etc. have only been investigated insofar as they contribute to form making. The town of Ngong itself has not be investigated other than to make recommendations as to it's peripheral growth areas and such matters that concern the environment outside of the town.

Due to the size of the study area, investigations have followed a hierarchal problem solving approach. The detail of investigation has not been equal in all areas, but increased in response to needs exposed in previous levels of inquiry. In this manner, needless accumulation of data has beenavoided.

Perhaps the greatest limitation to the study has been the withdrawal of research clearance by the Kenyan Government. Temporary research permits were granted for over a year and then withdrawn with no reason given and no possibility of appeal. Although most of the field work was completed by that time, considerable further consultation with local farmers and officials was to have taken place (as is explained more fully in the methodology section). Although the reasons for the denial of research clearance remain a mystery, the fact that the work will be of less value to Kenya, does not.

1.6. RESEARCH METHODOLOGY

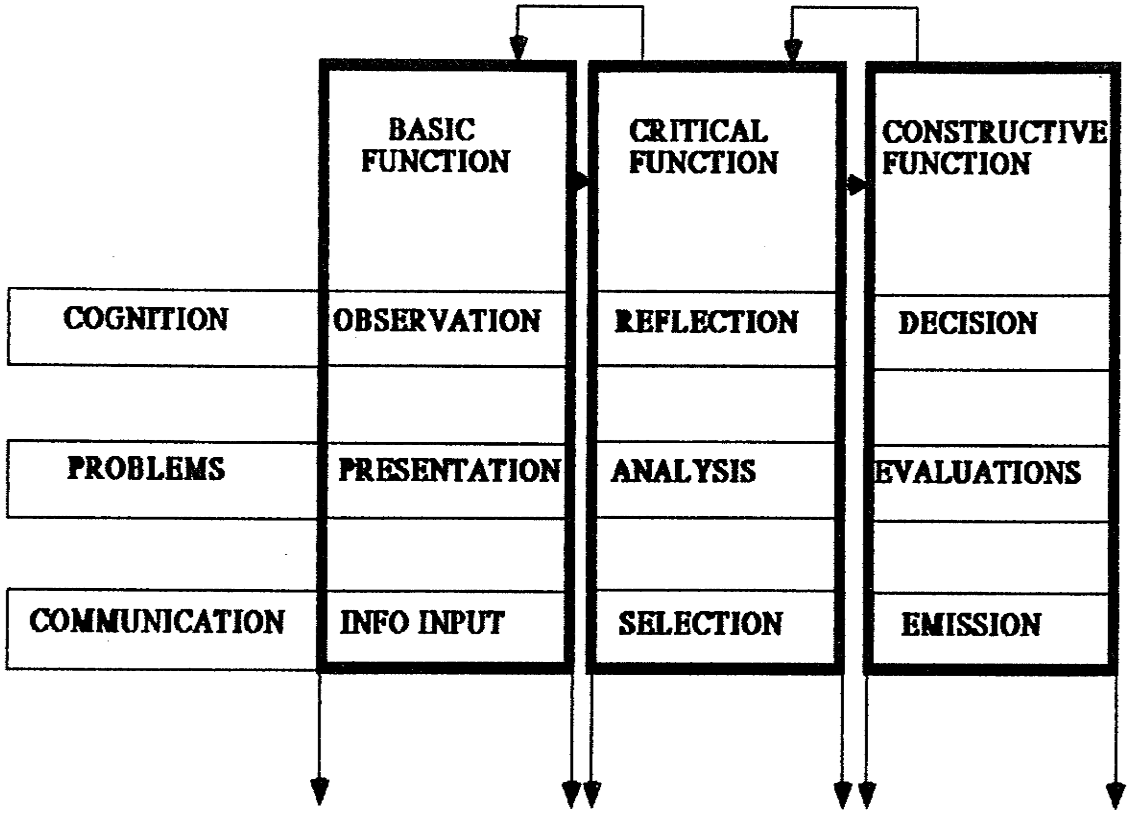
In response to the stated problem and broad objectives, the following methodology has been developed. It has been most influenced by the work of McHarg (1969); Hills (1974); Auweck *et a.* (1979); Low (1980); I.C.R.A.F. (1983); Rocheleau (1984); and McDonald *et al* (1984). Conceptually, the methodology (represented on the accompanying flow chart) can be broadly divided into the following three stages based on those in Engel's open theory of architecture :
"

Basic function: In this phase the problems are presented, concepts are defined, methods are formulated, and basic tests are carried out. In all, a tentative basis is established.

Critical function: In this subsequent phase previous assumptions are critically reflected upon, problems are analyzed, existing theories are assessed and evaluated. In all a set of criteria is formulated.

Constructive function: This phase is concerned with application of criteria in a broad sense. Not only are programs formulated and theories established but also physically is decided on form, method, design, and construction. In all: in this phase all criteria are translated in a concise form ...... in constructing a theory" (Engel, 1970)

The following chart indicates the breakdown of the functions. The importance of this conceptual outline lies in the fact that it contains feedback loops to allow for continuous improvement.



Source: Engel, 1970

The following methodology is an elaboration of this process and draws heavily upon the diagnosis and design (D&D) procedure of I.C.R.A.F. The prediagnostic stage belongs to the basic function, the diagnostic to the critical function, while design and recommendations are of the constructive function.

1.6.1 Prediagnostic Stage

After the generation of the initial problem statement and broad objectives of the study, previous work in the area was explored and government policies and programmes were examined. The study area boundary was finalized and the scale and methods of reproduction determined. A general environmental description of the area was carried out based upon reconnaissance visits and an inventory and examination of existing bio-physical and socio-economic information. The history of the area was assembled based upon literature review, archival research and interviews with Maasaielders.

In the Ngong Hills, very little baseline information existed, and additional surveys were required. Soil mapping at an appropriate scale was unavailable, and therefore, a semi-detailed soil survey was undertaken. The most recent available aerial photography was flown in 1978 but as significant changes have occurred since that time, the area was rephotographed at 1:10000 scale in 70mm. format.

The initial investigations were directed towards an ecological classification and interpretation of land units that allowed for the identification of resources and patterns of use at different scales. Physiographic site types (Hills, 1974) within the area were be delineated on the basis of homogeneity of physical characteristics (exclusive of present vegetation and artifacts) ie. soils, geology, landform, climate and hydrology. Land use types, which reflect the primary use of a tract of land eg. annual crops, tree and shrub crops, etc. were recorded. Management types, (those areas of similiar management characteristics ie. scale, social identity, labour sources, tenure, cultivation techniques, inputs, products and services etc.) were noted and combined with land use types plus physiographic site types to yield a typology of land use systems.

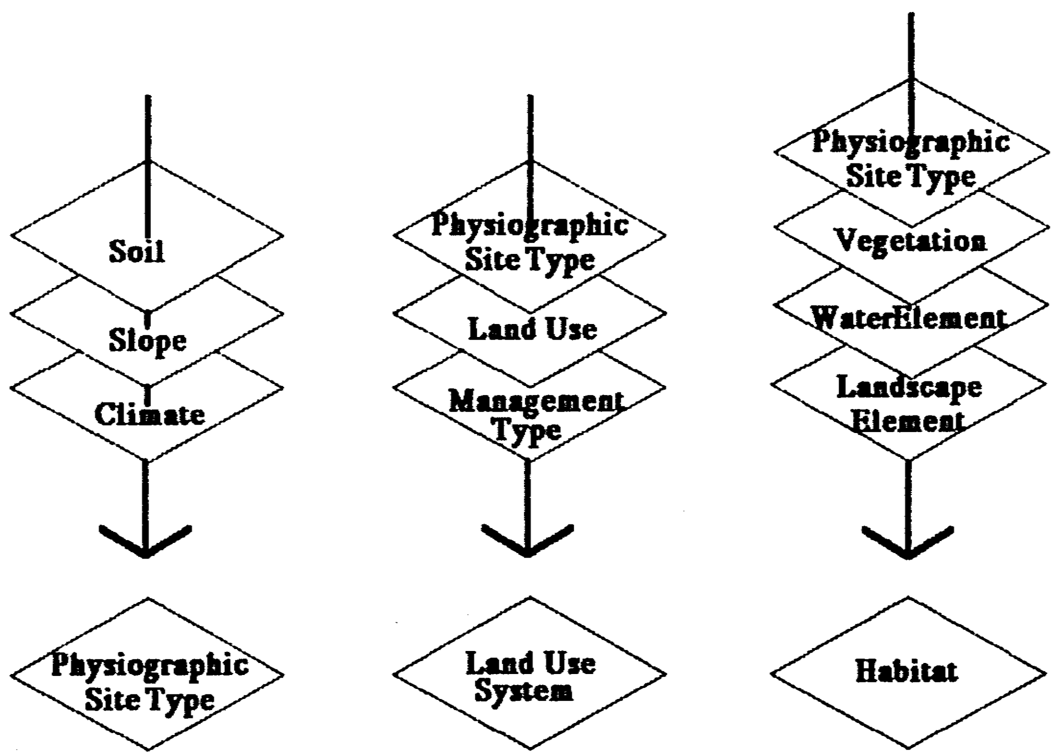


Figure 3: Typological Components

The management types were described in terms of the details of production ie. agriculture, forestry, livestock, agroforestry, etc. as well as the general sociological structure and function. Such subsystems as energy, food, water, shelter, raw materials for cottage industries, and cash were also examined. An ecological input - output analysis of the systems was undertaken and the sources and uses noted and related in diagrams. Following this, a preliminary identification of major land use problems and potentials occurred at several scales; ie. ecosystem, land use system and household levels. General trends were determined by an examination of statistics, aerial photography and reconnaissance surveys. Problems related to production, resource constraints, conservation requirements etc., were investigated and obvious potential solutions noted.

Priority systems for further attention in the following planning stage were selected from the land use system typology based upon:

1. The degree of representation of major land use systems in the region.

2. Amount of technical assistance required. (after I.C.R.A.F., 1983)

In addition, a wide range of units was selected to indicate the breadth of activities in the planning area. The identification of priority systems focuses attention where it is most required, thus eliminating unnecessary data accumulation.

Client definition was finalized at this stage with the client group (the inhabitants of the Ngong Hills) selected on the basis of:

"1. Functional criteria: present and future users, client utilization hierarchy.

2. Value based criteria: criteria to reflect norms and values of the local or regional community.

3. Economic criteria: based on costs of fulfilling client requirements."

(Low, 1980)

Detailed survey requirements and questionnaires were prepared at this stage.

1.6.2 Diagnostic Stage

The purpose of this stage was "to arrive at a diagnosis of the problems and potentials of the selected land use system(s) and to use this as the basis for derivation of design specifications for appropriate........interventions in the system or it's environment" (I.C.R.A.F., 1983)

Representative management units within various land use systems, selected in the previous stage, were examined in greater detail. Through participant observation and a series of surveys and interviews (both structured and unstructured) with farmers and other key informants (individual and groups) in the area, relevant diagnostic information was collected. A total of seventy-five randomly sampled, structured, detailed farmer interviews were conducted. This represented a sampling intensity of approximately 10.2% (732 farms were counted on the 1986 aerial photographs). The topics of interviews included details of system shortfalls (eg. shortage of water, fuel wood etc.), production constraints and sustainability problems, as well as their local solutions. Local needs and aspirations were identified and used to refine the study goals, objectives and policy set. Larger than farm scale (ecosystem, community) issues were assessed in detail with the aid of aerial photography and field surveys, eg. watershed management problems, regional fuel wood requirements, etc. The questionnaire results were computerized for analysis.

Each land use system type was evaluated and assigned an ordinal rank (0 to 5) in relation to the degree of impact on site productivity. Impact was judged by the long term effect of the land use system on the factors governing biological primary production. Primary production was used as an indicator as it makes no suppositions about future use (other than that the use will be related to plant production eg. arable agriculture, grazing, forestry, agroforestry). This allows for the unpredictability of future land use decisions. The rank was based upon the effect of the land use on such factors as : soil fertility, erosion, water (quantity and timing), microclimate, and species diversity of plant communities. Different factors received greater emphasis in different land use systems, eg.the impact of annual cropping on soil erosion would naturally be greater on a steeply sloping site with highly erodible soils than on a gentle slope with more stable soils. The evaluation was not limited to local specific effects but included the effects on the community or regional ecosystems. (eg. water availability to Kajiado)

Habitat mapping also commenced during the diagnostic period and covered the entire planning area. Habitat is used in the broad sense of: the place of abode of a plant or other organism, including man. It is an environmental niche, within which, essentials for development and existence are present (to a greater or lesser degree). This includes man made, physical, inorganic structures. It is the combination of the physiographic site type, the biotic site type and human artifacts. Different habitat types were identified based upon the existing landscape components, ie. amount, type, and crown density of cropland, pastures, trees, orchards, hedges, woodland, thickets, and water related elements. Originally the habitats were to include the presence or absence of soil conservation structures. However, due to the poor quality of the 1986 photography the structures were not identifiable on the photographs and were therefore not included.

The habitats were evaluated in two ways (see habitat evaluation chart). Firstly, an attempt was made to ascertain the "buffering capacity" of the various habitat types against the negative effects of existing uses in the area. This was based on the influence of the habitat components on the site productivity factors. These included soil fertility, erosion, water quantity and timing, microclimate, species diversity, and necessary inputs. These are the same factors used in the impact evaluation of the land use systems, and, as the same physiographic site types and mapping units were used, a spatially related correlation was possible.

Although precise quantitative results were not possible given the scope of the present study, an ordinal scale of the compensating effect of the habitats on the negative effects of the land use system was used. Habitats were placed within one of five groups with increasing compensating effect. In both the land use system and habitat evaluations, type related values are obtained and mapped. As both the habitats and the land use systems are, by definition, related to the physiographic site type, the environmental conditions within which the habitat components and land uses are operating, are accounted for. This is necessary as the same components and land uses have different values for different physiographic site types. Example: The value of a stand of trees to soil conservation would be directly related to slope angle and soil erodibility.

The impact ranked land use was then combined with the ranked habitats by numerical machine methods. In the evaluation matrix, (based on that of Auweck *et al* 1979) land use systems with increasing impact are placed opposite habitats with increasing conservation function (see evaluation matrix). A "theoretical compensation optimum" (Auweck *et al* 1979) is sought where the impact of the land use system is balanced by the conservation effect of the habitat. Following the numeric overlays (the procedure was repeated for effect on: soil erosion, soil improvement, microclimate, water availability, and species diversity and finally the total impact which encompassed all factors) all land units fall within one of three categories:

1. **Resource safeguarding area** - less favorable production conditions (including agricultural & livestock uses)

2. **Compromise area** - high degree of biological compensation effect with profitable or acceptable production

3. **Resource consuming area** - high level of production with negative effects

The maps resulting from this process (one for each factor plus one aggregate map) indicate the

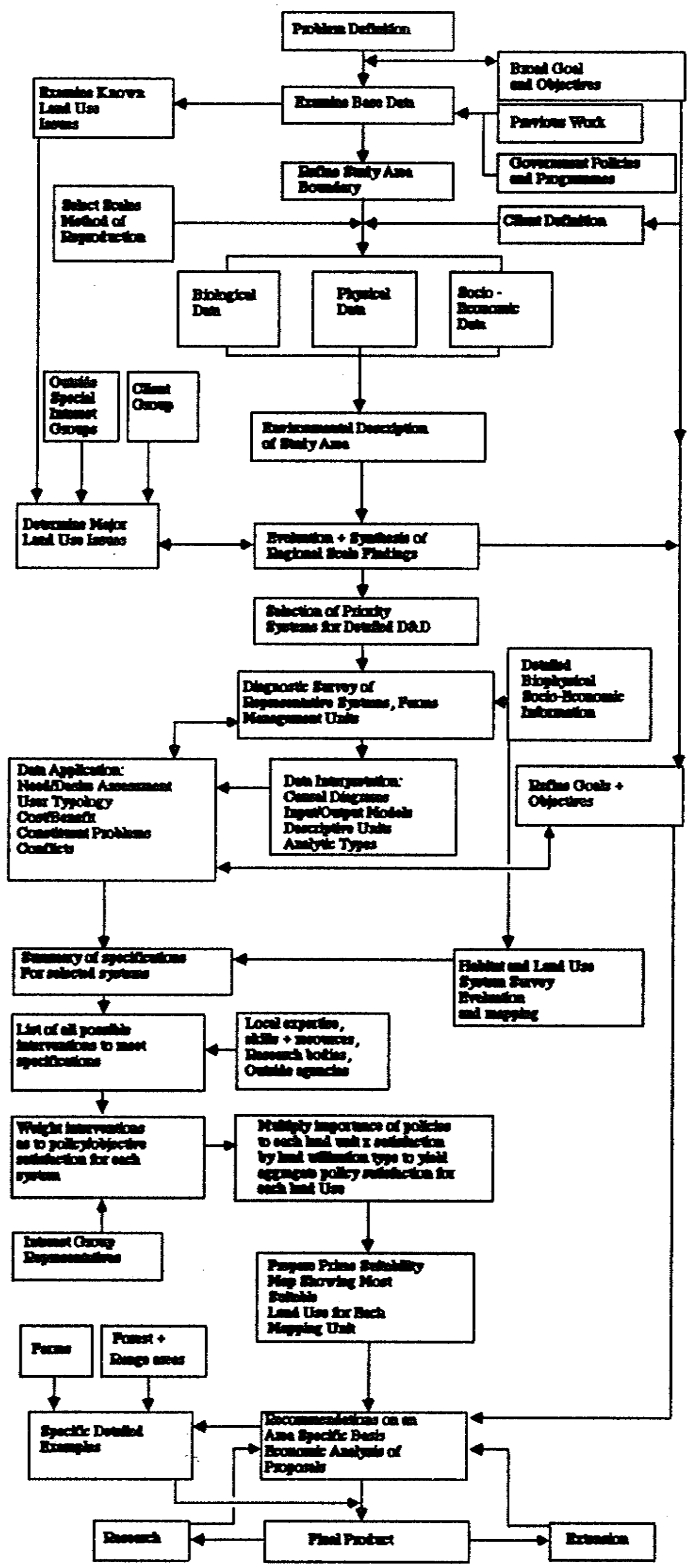


Figure 2, Methodology Flow Chart

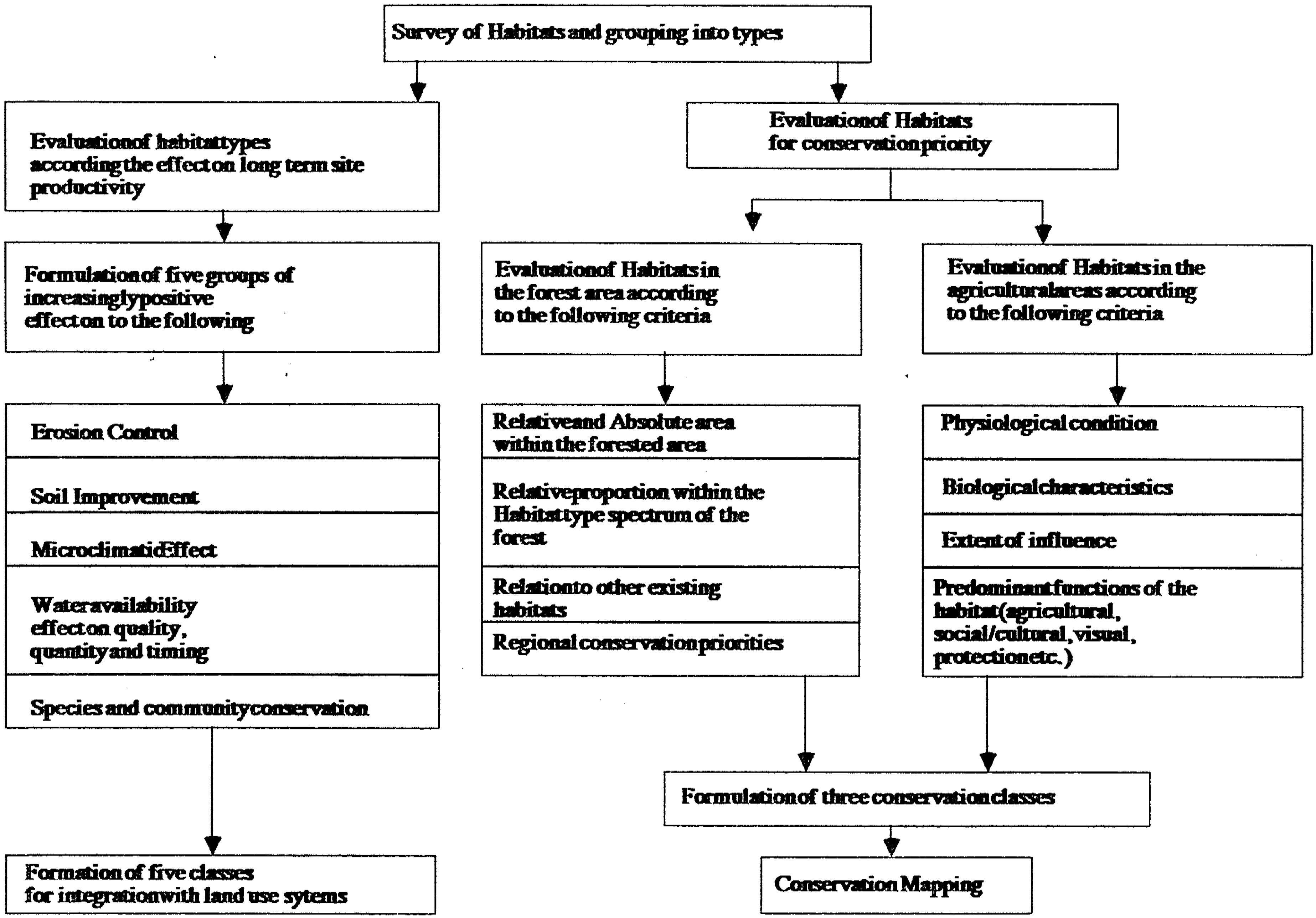
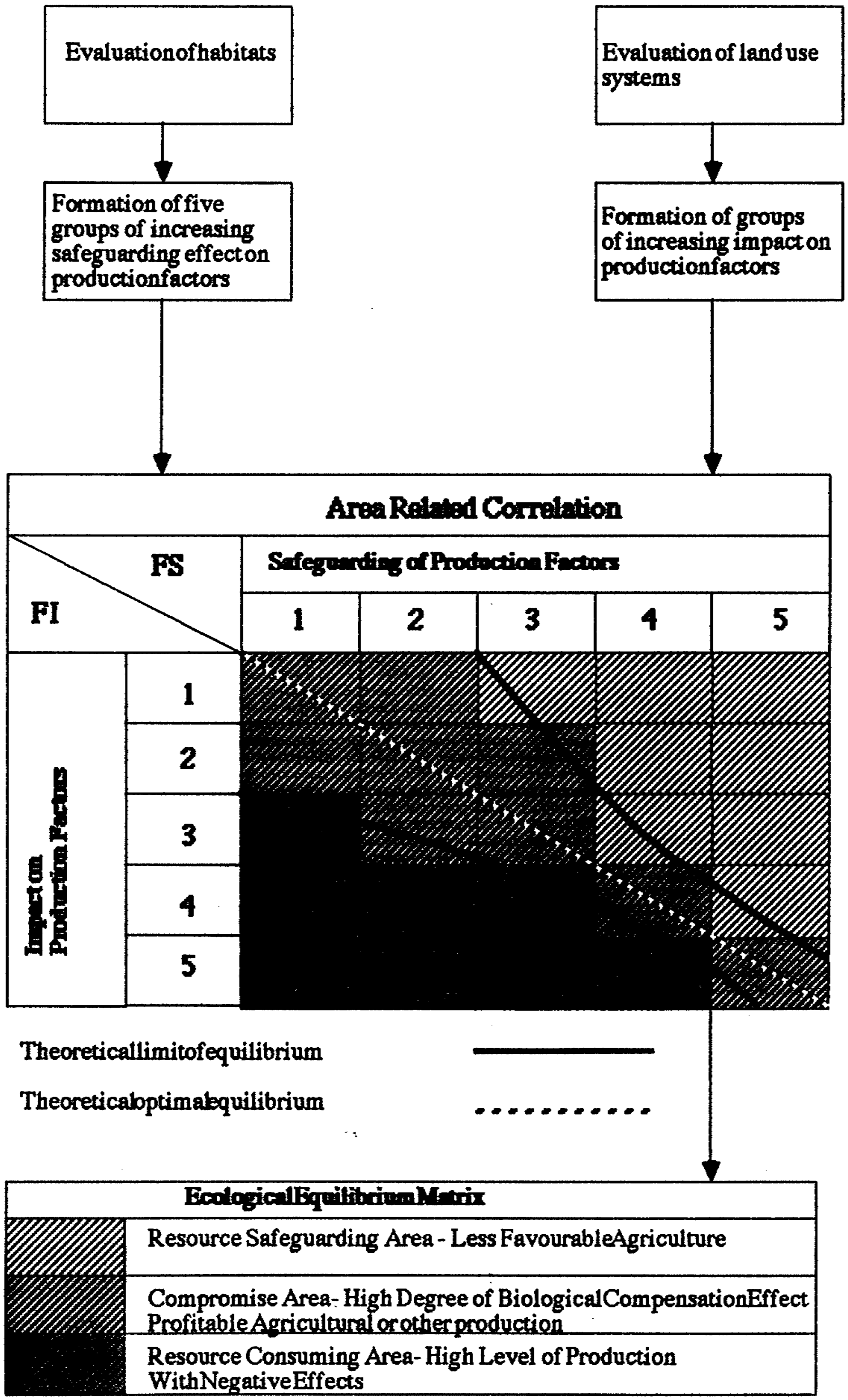


Figure 4, Habitat Evaluation and Mapping

Figure 5, Integration Model (After Auweck et al 1979)



spatial distribution of lands with three levels of resource stability. Changes in either habitat components, eg. vegetation, soil conservation structures, hedgerows, crown density etc. or changes in the land use will be necessary for those areas classified as resource consuming if long term production stability is to be achieved. These resource stability maps are most useful for selecting potential intervention areas. If, for instance, water availability is seen as an important issue, then those areas which are seen as presently resource consuming, should be selected as for improvement. The procedure helps direct scarce development funds to those areas where they are most needed.

The various intervention options were, of course, modified by the findings of the farm surveys of problems, needs, and opportunities. The farm surveys indicated the degree to which particular needs are being satisfied by the existing land use systems. Deficiencies do not necessarily imply resource degradation eg. the existing land use system may be ecologically stable but not providing needed materials for cottage industries and building. Therefore, the areas classified as resource consuming were combined with those where the present land use is not meeting needs and objectives to yield the areas requiring replanning.

The procedure also indicated the consequences of maintaining the *status quo*, at least in qualitative terms. It spatially delineated those areas which can be expected to degrade if modifications are not undertaken. The model does not provide quantitative information on ecosystem functioning at this stage. However as post project research continues it may become possible to assign quantitative values to the various types. A separate ranking of habitat conservation requirements was also made. This was based on an assessment of the function, form, and condition of the habitat's components. The importance attached to the various criteria used for the evaluation was related to the sphere of use. In the forest area particularly, the relative and absolute area of the habitat type, and it's rarity in the habitat spectrum, was considered. Three levels of conservation priority were assigned:

Conservation Priority 1: Those habitats requiring conservation of form and or function which are location specific.

Conservation Priority 2: Habitats requiring special management (eg. to avert soil erosion ore maintain aquifer recharge capability)

Conservation Priority 3: Common or large scale habitats.

All mapping units will be assigned a conservation priority. This priority were used to determine locations of conflict in the following planning stages and partly determined exclusionary uses in priority one areas.

Analysis of the diagnostic survey, as well as a review of the more general regional findings from the pre diagnostic stage, yielded the problems and potentials of the area, at scales ranging from intra-farmstead to regional. Design specifications for solutions at various scale were then derived which lead to land uses and technologies that "satisfy the problems and meet the potentials " (I.C.R.A.F., 1983) of the land use systems.

A four hectare (200m x 200m) grid cell was the unit to which all information was related. This was to facilitate spatial correlation and machine sorting and analysis. Utilizing Omnis 3 database management software, a geographic database was assembled for the area. Information on each grid cell is available simply by specifying the grid cell number (the number is the UTM coordinate number for the south west corner of the cell). Future managers in the area can refer to the system to gather information specific to the grid cell such as soil type, slope, climate classification, existing vegetation, crown density, existence of hedgerows, potential erosion, aquifer recharge importance, conservation value, land use, and management type as well as the impact of the grid cell's land use system, the safeguarding effect of the habitat and an integration of the two to yield the resource stability (see appendix for sample print out). Although the computer disks are not included in this report, they are available from the University of Manitoba, Department of Landscape Architecture.

1.6.3. Design Stage

The specifications for the design of the land use systems shown to be in need of replanning, were derived from the diagnostic surveys. All possible technologies and solutions that closely satisfy the specifications for the selected systems were assembled.

Some of the design solutions that meet these specifications, were required at a scales other than that of the problem analysis. eg. Desiccating winds, identified as a problem, in the individual farm surveys, may have a solution in a series of windbreaks extending far beyond the individual farm boundaries. The management and solution to this sub-regional problem may be community based, while the detailed design of the windbreaks occurring on-farm must respond to micro level problems and opportunities. This is, of course, oversimplified, but indicates that the resolution of problems at one scale (eg. farmstead) may be dependent on opportunities and constraints occurring within the larger system (eg. regional availability of labour, water, communal grazing lands etc.) The inventory, analysis, and synthesis must reflect these relationships. (Rocheleau, 1984)

Alternative land utilization types were derived from local expertise, research bodies, government sources, previous work etc., while preference policies (planning objectives) were obtained from the diagnostic surveys (bio-physical and socio-economic), the district and national development plans, various concerned government bodies, groups and individuals.

Originally, it was planned that representatives of interested parties (eg. development committees, forest and agricultural officers, chiefs, sub chiefs, local farmers and others) would be asked to assign an importance rank to each policy, for each of the land use systems. The aggregate vote of all individuals was to be used to assess the importance of each policy to each land use system. The planner was not to have a vote, but rather, to facilitate a clear exchange of information so that informed choices could be made. Unfortunately, research clearance by the Kenyan government was withdrawn late in the study, and this integral consultation was not possible. In order to test the model, the importance values for the policies was assigned by the author and not, as should have been the case, by the local peoples.

The fact that all policies did not apply to all land use systems limited the necessary evaluations. Exclusionary policies, restricting land use on a given land unit, (derived from the conservation ratings, existing government policies as well as judgement of the pragmatism of proposed land uses) were assembled at this time. The alternative land uses were then evaluated in a two dimensional matrix against the weighted preference policies for each land use system to determine the degree of policy satisfaction.

The policy importance value resulting from this process was multiplied by the degree of policy satisfaction of each land use. All policies were evaluated in this manner and yielded the aggregate policy satisfaction for a given land use in a given system. This portion of the methodology was heavily influenced by the LUPLAN model (examined by McDonald(1984) and based on the work of Ive (1980) and is presented below:

$$\text{Maximize}\, S_{ij} = E_{ij} * \Sigma R_{ijk} * V_k$$

Where:

	$i = 1,2 \ldots\ldots\ldots n$	= planning parcel or mapping unit
	$j = 1,2 \ldots\ldots\ldots m$	= feasible land use options
	$k = 1,2 \ldots\ldots\ldots p$	= preference policy whose satisfaction is to be maximized
	$E (E=0 \text{ or } 1)$	= exclusionary policy proscribing given uses for some parcels
	$R\ (0 \leq R \leq 1)$	= policy satisfaction rating or degree
	V	= policy weight or vote for a policy by given individuals
	S	= aggregate policy satisfaction for given use on a given parcel of land

A prime suitability map was then prepared based on the use that best satisfied the policies for each land unit and which was not eliminated by the exclusion rules. The prime suitability map reflects the spatial distribution of the land uses which are most socially and environmentally suitable (as the policy set is derived from those issues).

An alternative to this method would to prepare suitability maps based on policy weighting by individual interest groups eg. the Forestry Department, family farmers, landless people. The maps could then be overlaid to indicate areas of conflict and agreement between the various interest groups.

Detailed recommendations were then written for the major management types, based on this final analysis, as well as some location specific proposals. Examples of the proposals are provided and include detailed agroforestry systems, and species and planting recommendations etc.

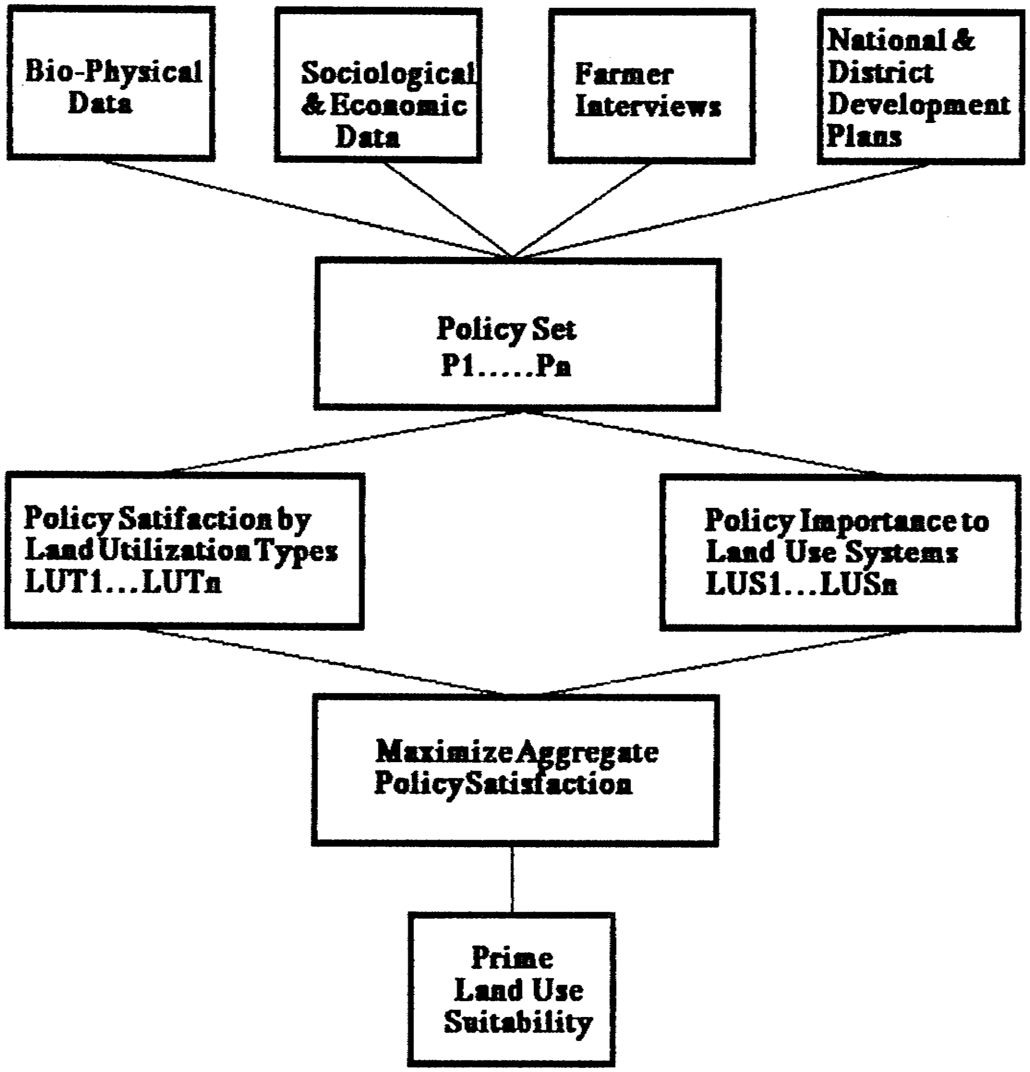


Figure 6. Prime Land Use Suitability Selection Process Flow Chart

1.6.4. Follow up

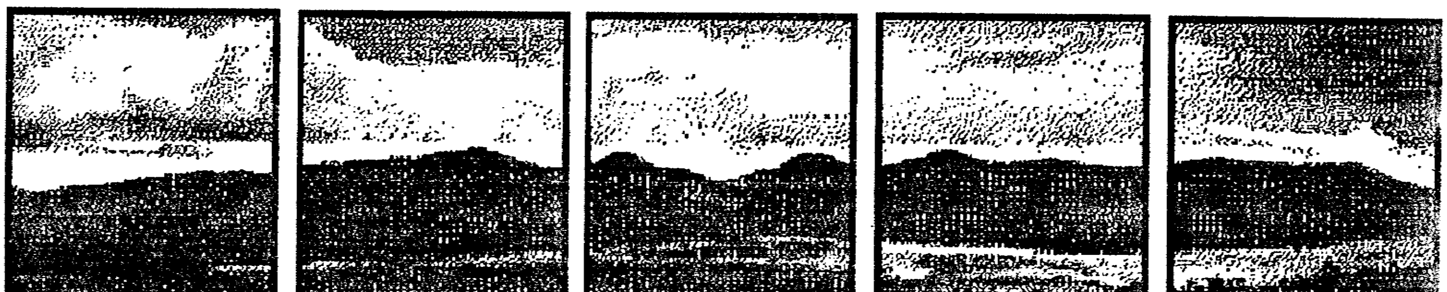
Methods of implementation through existing programmes, organizations, and groups were be explored and an implementation strategy proposed. Areas requiring further research were identified and the final report was compiled.

1.6.5 Summary

The methodology of this project provided for an evaluation of the effect of existing land uses and habitats on the sustainability of site productivity. As the same criteria and mapping units were used, a spatially related correlation between the negative effects of the land uses and the compensating effect of the habitats, was possible. A conservation priority rating was given to each mapping unit based upon it's form, function and condition. In addition a diagnostic survey of selected landuse systems was carried out which included detailed farmer surveys. Coupled with the land use / habitat evaluation model, the diagnostic survey indicated areas which require replanning as well as the problems and potentials of the land use systems.

A policy set for each land use system was assembled and ranked in importance for each land use system. This ranking was used to weight the final selection of feasible land uses. With this process a significant input by local people and agencies into both policy generation and land use selection is possible. The methodological approach is integrative, in that it responds not only to biological and physical considerations, but also, to the social, cultural and economic aspects of the environment. It is hoped that, in this way, both conservation and development objectives may be achieved.

Chapter 2 The Context



2.1. THE NATIONAL CONTEXT

The Republic of Kenya, having a total area of approximately 582,646 square kilometers, lies astride the equator in east Africa between latitudes 4° 30' North and 4°33' South, and longitudes 34° East and 42° East. It is surrounded by the Indian Ocean and Somalia to east, Ethiopia and Sudan to the north, Uganda to the west and Tanzania to the south.

West of the hot, humid, eastern coastal area of the country, lies very dry bush land, followed by the savanna grasslands and well watered highlands. Kenya is bisected in a north-south direction by the Great Rift Valley. In the south west the land descends from the western rim of the valley to the Lake Victoria basin, while in the west and northwest it is followed by the rugged Mt. Elgon and Turkana areas, respectively. The northeastern portion of the country is desert or near desert with a notable lack of distinctive features. Central Kenya has a mountainous core dominated by Mt. Kenya and the Aberdare range.

Kenya does not possess any significant mineral resources nor is it industrialized to any great extent. The wealth of the country therefore rests upon it's land resources and these resources are limited. Only 17% of the total land area or 99 050 square kilometers is suitable for rainfed agriculture and this area supports 80% of the population. Forest land covers approximately 3% of the total land area or 17 479 square kilometers, although it must be stressed that this is the total area classed as such and does not mean that the land is actually productive forest. Approximately 5% of the country has been set aside for wildlife protection and tourism in the form of national parks and reserves. Total water area is 13 396 or 2.3% of the country. The remainder of the land is dry and and only marginally productive.

Major urban centres include the capital Nairobi (pop. 1 500 000), Mombasa, Kisumu, Nakuru, Meru, Eldoret, Thika and Nyeri.

2.1.1. Population and Employment

The population of Kenya in 1987 was estimated at 21 824 650 based on the 1979 census and the official rate of increase of 3.8 % per year. This may be underestimated as the World Bank has estimated the rate of increase at 4.1% making it the highest in the world. The increases are due to a combination of declining mortality rates and increasing fertility rates. The average number of children born to women during their reproductive years has increased from 6.8 in 1969 to 7.9 in 1979 while the crude death rate has fallen from 20 per thousand population in 1969 to 14 in 1979.

The population structure indicates 51% is below the age of 15. (Gov. of Kenya, 1983)

The population structure and alarming rate of increase is putting added burdens upon land and natural resources in addition to having serious socio-economic consequences. Despite steady increases in Gross Domestic Product there has been an actual decline in per capita income due to population growth. Similarly, although there has been a marked growth in employment opportunities in the past ten years, the growth in the labour force has exceeded the opportunities, resulting in an ever increasing proportion of the population left unemployed. This, coupled with a high dependency rate (40% of the population has to support the remaining 60%), creates an untenable situation for many people.

Although the national population increase is listed at 3.8%, urban increases are far beyond this rate. Nairobi's population increase has recently been estimated at 10% which is putting an enormous strain on available resources.

2.1.2. Land Tenure

Land tenure is often complex in Kenya as three different systems are utilized. These are the traditional or customary system, the freehold system, and the leasehold system.

The traditional system is complex and varies greatly with ethnic groups. Common to many such groups, was the idea that land was controlled by chiefs, family groups or clans. The concept of individual land ownership was absent prior to the coming of the white man. The freehold system was introduced by the British and represents absolute possession of land by a group or an individual. In Kenya freeheld land is subject to the provisions of the Planning Law and Regulations , Local Authority Bylaws, the Land Control Act and the Land Planning Act. There are no restrictions on the amount of land an individual may hold in Kenya. Leasehold land implies an absolute interest in a parcel of land for a specified period of time. Regardless of the system of tenure, all property is strongly protected in law and may only be acquired by government through the Land Acquisition Act in the case of freehold and leasehold or by the Trust Act in the case of traditionally held land.

2.1.3. Agriculture

Agriculture is the backbone of the Kenyan economy, and is responsible for over one third of the Gross Domestic Product. Pastoral activities and smallholder agriculture engage the majority of the rural labour force for at least part of the year. Eighty seven percent of the population live in rural areas and in most regions agriculture is the only source of employment and there are few alternatives. The agricultural sector provides most of the national food requirements in addition to earning significant amounts of foreign exchange. Many smallholder plots, as well as the larger private and cooperative commercial farms, produce such important cash crops as coffee, rice, tea, cotton, pyrethrum, sugar cane, maize, wheat, sisal and horticultural products such as pineapples, flowers and vegetables. The staple food in the country is maize and national production exceeds demand in most years, allowing exports.

As much of the country is suitable for ranching, livestock production is significant and large quantities of beef are exported to countries in Africa as well as the mideast and Europe. In addition, there is a healthy dairy industry, particularly near large centres. The dairy market has rapidly grown and local production is exceeded by demand, thereby encouraging expansion. Kenya also produces large amounts of sheep, goats, pigs, and other agricultural products such as potatoes, beans, cashew nuts, macademia nuts, onions, wool and leather.

Government objectives in the agricultural sector have been stated in the Fifth Development Plan (1984-1988) and include the following:

> "............increased food production, growth in agricultural employment, expansion of agricultural exports, resources conservation.
>
> ....Most of the nation's food requirements must continue to be met from domestic supplies and, therefore, a major strategy of the Fifth Plan is to maintain broad self sufficiency in basic food stuffs. At the same time agricultural export earnings will be expanded by promoting exports of fruits, livestock and horticultural products, coffee and tea exports. Agricultural employment will be increased through more intensive husbandry, including zero grazing for dairy cattle, and a greater proportion of labour intensive crops and an expansion in agro-industrial processing activities. Resource conservation will be given a high priority through self help efforts, better management of the rangelands and promotion of labour intensive techniques. Poverty alleviation will be approached through the pursuit of employment, production and export objectives rather than by concentrating on direct Government action." (Government of Kenya, 1983)

2.1.4. Forestry

Although the forest reservations within the country are extremely limited, they are expected to contribute to the nation in a multitude of ways. There are however, a number of constraints to optimal forestry development, not the least of which is the conflict between potential uses of the land eg. forestry and agriculture or grazing. Multiple use management plans are lacking for most forests, as is the appropriate legislation to protect gazetted areas, resulting in over exploitation of resources. The demand for particular products such as fuelwood has outstripped production, resulting in serious resource depletion in many areas. Not only are the products in ever decreasing supply but the protection afforded to the environment by indigenous and/or well managed forests is diminished.

National forest policy objectives include:

> ".......reservation of land for forestry purposes; protection of forest resources; conservation and management of forests; development of agroforestry; continued establishment of forest estates; promotion of forestry and tree planting on identified trust as well as on private lands; promotion of forestry for public amenities and wildlife; ensuring continuing research in forestry; and conducting mass public education on the value of forestry" (Government of Kenya, 1983)

In order to accomplish these objectives the following strategies have been proposed by government:

> "New planting will be focused on private and communal lands because the availability of state owned land is becoming a constraint.
>
> Planting on private and communal lands will serve multipurpose uses such as fuelwood, wood for other domestic uses and the prevention of environmental degradation.
>
> Because arid and semi-arid regions are the most vulnerable to depletion of fuelwood these will be given special emphasis in allocation of resources.
>
> For the better control of exploitation of the existing forest resources field staff will be increased and infrastructure in forest areas improved." (Government of Kenya, 1983)

It is to be noted that the resources available to the country to supply industrial wood requirements, at least in the short term, appear to be adequate. The serious shortfalls are occurring in domestic products such as fuelwood. To address this problem national efforts have been focused in such programmes as the Forestry Plantation Development Programme, the Rural Afforestation and Extension Scheme, the Local Afforestation Scheme, the Chief's Nurseries, the Kenya Woodfuel Development Programme, the Kenyan Renewable Energy Development Programme and various integrated development projects. They have met with varying degrees of success.

2.1.5. Tourism and Wildlife

The tourism portion of the economy is strong and growing steadily. The capacity to generate much needed foreign exchange is considerable and the government " has pursued an active policy of involvement in all aspects in the industry" (Gov. of Kenya, 1983) The objective of the government is to considerably increase the number of visitors, thereby increasing both foreign exchange and employment. In order to realize this, new potential areas must be identified and these may be considered for parks or reserves. This is in keeping with the stated policy of undertaking measures "to conserve, protect and improve environment and wildlife" (Gov. of Kenya, 1983).

2.1.6. Basic Needs

The well being of the nation's people may be measured to some extent by the degree to which basic needs are satisfied. The Government of Kenya has pursued a policy of fulfilling the basic needs of the population. Given the rate of population increase, different needs have met with various degrees of satisfaction.

Food and Nutrition: Food is obviously the most basic of human needs. The availability of different products has fluctuated since independence as noted in the following table. Although the per capita availability of some products, notably milk, wheat, pulses, cassava, sorghum and millet has fallen since 1970, others such as maize, beef, eggs, rice, sugar, fats/oils, and potatoes has increased. The daily per capita nutrient availability has remained relatively stable and above the minimum requirements recognized by the World Health Organization. Available protein has risen since 1970. Although these average figures imply that minimum requirements are being met for the majority of the population, disparity exists, and considerable numbers of Kenyans are faced with insufficient nutrient intake. The government has indicated that up to one third of the population is " exposed to the risk of deficient nutrition " (Gov. of Kenya, 1983) The causes of this deficiency have been identified as inefficient production and marketing, poor food habits, as well as insufficientenvironmentalcleanliness.

Table 1. National Per Capita Availability of Selected Food Items
(kilos/year-period averages) source: Gov. of Kenya, 1983

PRODUCT	1965-1970	1971-75	1976-80
Milk	74.8	56.0	62.5
Beef	--	12.5	13.5
Mutton	--	2.5	3.6
Pork	--	0.5	0.3
Eggs	1.4	1.4	1.6
Poultry	--	--	1.9
Fish	3.1	2.5	2.8
Maize	95.1	97.4	100.1
Wheat	17.0	15.7	13.6
Rice	1.3	1.9	2.0
Pulses	25.9	22.6	17.2
Sugar	12.2	15.9	19.1
Fats/Oils	4.2	6.4	7.3
Potatoes	19.2	27.0	24.8
Cassava	59.8	53.3	49.9
Sorghum/Millet	8.0	6.7	5.6

Table 2. National Daily per Capita Nutrient Availability, 1965-1981
source: Gov. of Kenya, 1983

	Period	Calories	Protein (gm.)
	1965-70	2412	62.9
	1971-75	2453	65.6
	1976-80	2385	64.6
	1981	2428	72.6
Average	1965-81	2428	64.8

Shelter: Rapid increases in population naturally imply the need for a corresponding increase in housing. However, there has been a shortfall in housing over the last twenty years, particularly in the urban poor sector. It has been estimated that 30% of the urban population live in unplanned settlements (Gov. of Kenya, 1983). Despite the lack of adequate data on the status of rural housing, it is generally agreed that the problem in this area is one of quality rather than quantity. The rural households are expected to provide the initiative for improvement although some rural home improvement loans are available on a limited basis.

Health The provision of health services to the general population has received much attention and considerable funding. The improvements have been dramatic with death rates dropping as noted previously and the infant mortality rate dropping from 120 to 86 from 1963 to 1979. Life expectancy at birth was 54 years in 1982 compared with 40 years at independence. There have been considerable increases throughout the country in the number of hospitals, health centres, dispensaries, and health workers.

Water The water supply situation figures prominently in both the health of the population and the economic growth of the country. Efforts have been made to increase the availability of potable water as well as decreasing the distances of water sources from residences. It has been estimated that women in rural areas in 1975 (it is women who draw the water in most of Kenya) spent approximately one fifth of their time hauling water. Despite the government claim that " no region is more than 1.8 kilometers away from a water point" (Gov. of Kenya, 1983), this is clearly not the case in many areas, although considerable advancers have been made in recent years. The water developmentobjectivesinclude:

> (i) to provide potable water supplies to all rural and urban populations balancing these supplies between human needs, requirements for livestock development and the needs of the industrialsector.
>
> (ii) the management of water resources to achieve multipurpose development goals such as flood mitigation, hydro power developments, irrigation and drainage, recreation and wildlife conservation while minimizing deleterious environmental effects." (Gov. of Kenya, 1983)

A number of water development programmes exist including the Rural Water Supply Programme, the Livestock Water Supply Programme, and the Water Conservation Programme as well as government support for locally initiated self help projects. Water resource assessment and planning is carried out for the five main drainage basins in the country by the Ministry for Water Development.

Education The number of children attending primary school has risen dramatically both in total numbers and as a percentage of the total population. It is now estimated that 92% of eligible children are attending primary school as opposed to 60% at independence. There has been a corresponding increase in attendance at secondary and higher education institutions. However serious problems still plague the system, not the least of which is a shortage of qualified teachers. Pupil to teacher ratios in primary schools were 54:1 in 1981 and the percentage of untrained teachers rose to 48%.

2.1.7. Development Strategy

In July 1983 a new thrust in development policy came into effect in Kenya. Known as the District Focus for Rural Development, the policy resulted in a shift in the initiation, planning, and implementation of rural development projects from the centralized ministry headquarters to the districts. The districts are now responsible for identifying and coordinating development activities with the exception of those projects which span more than one district or have national implications. Such projects remain the responsibility of the ministries involved. The District Development Committee (DDC) under the direction of the District Commissioner is now the chief body in charge of development and all projects are supposed to be coordinated through them. This committee is comprised of the District Commissioner, District Development Officer, Ministry Department Heads, Members of Parliament, Chairmen of Local Authorities, Clerks of Local Authorities, Chairmen of Divisional Development Committees, Representatives of development related parastatals, and non-government development related organizations. Central to the concept of the DDC is strong local support for any project.

The District Focus is in concert with the stated theme of the current national development plan, namely, " mobilizing domestic resources for equitable development ". The resources available for rural development include ministry funds for district specific projects, multi district ministry programmes, local authority and town council resources, local self help, the Rural Development Fund, European Economic Community Micro Projects Programme, as well as other special projects and foreign funds. As economic pressures on the country increase, often beyond the ability of the government to address them with traditionally acquired funds, more and more emphasis is being put on the spirit of " Harambee " or self help.

> " When God had finished shaping the world he found he still had dirt between his fingers. He wiped this off upon the earth leaving the shape of the Ngong Hills."
>
> " A giant who was running across Africa tripped over Mount Kilimanjaro and in trying to save himself from falling crushed the earth to the shape of the Ngong Hills with one hand."
>
> " An enormous giant terrorized the land occupied by the Maasai, consuming vast numbers of their cattle for his normal sustenance. In desperation the Maasai approached various wild animals for help, asking in turn the lion, the buffalo, the elephant and the rhinoceros if they would rid them of this giant. Each of these animals was unable to help, but finally, when they approached the ant, help was obtained. Whilst the giant was sleeping all the ants in that part of Africa carried small particles of earth and buried the giant leaving only the knuckles of one hand above ground and these have since become the Ngong Hills"
> (Maasai Legends *in* Robson, 1969)

The Ngong Hills have long been considered Maasai land and indeed there is indication of their occupation of the area as early as the end of the seventeenth century (Harlow,1965). Evidence of earlier cultures is lacking and there are no known significant prehistoric sites in the hills (Leakey, personal conversation). The mountain is known in Maasai both as Doenyo Lamuyu (after the Maasai word Ilemuya " which is another name for the Enkidong'i or Oloiboni (ritual expert) clan" (Robson, 1969), and Oloo Laiserr, which refers to the group from which the Oloiboni descended.

The Ngong area has traditionally been the frontier between the Bantu Kikuyu and the Nilo-Hamitic Maasai. The relations between these two factions was, for the most part, hostile, and Ngong has been the site of several "fearful massacres" (Thomson, 1885). It is to be noted however, that agreements existed that allowed the women of either tribe to trade freely and in complete safety, despite the almost constant war. (Höhnel,1888; Leakey, 1963?) This is no doubt that this contributed to the intermingling of the two groups in later times.

Although the area was most definitely Maasai land, it was of great religious importance to the Kikuyu people who believed that this was the fourth sacred mountain used by God as one of his dwelling places on earth (in addition to Mt. Kenya, Donyo Sabuk, and the Aberdares). The Ngong Hills figure prominently in several Kikuyu prayers, including those at the dedication of sacred trees, the asking of blessing in marriage, at family sacrifices, thanksgiving for survival or childbirth, as well as invocations for rain. (Leakey, 1963?) The mountain was known to the

Kikuyu as Kiambi-ruiru, " the very black mountain ". This in reference to the dark appearance of the hill which is due to the forest cover and shadows cast by the north-south orientation.

2.2.1. Land Use by the Maasai

The nomadic, pastoralist Maasai controlled and utilized an extensive area of land in what is now Kenya and Tanzania. In Kenya this extended from the Tanzanian border to the foothills of Mt. Kenya and included much of the Rift Valley (especially the wooded grassland between the Mua Escarpment and the Aberdares) and the Athi-Kapiti Plains. Moving their large herds of cattle in accordance with grazing and climatological conditions, the Maasai managed the landscape in a cooperative and extremely successful fashion until the advent of the twentieth century when their cyclic movements began to be restricted by the colonialist powers.

The well watered Ngong Hills were used primarily as a dry season grazing area. Only goats were grazed on the upper sections of the hill, due in part to lack of adequate grass, but also because of the presence of disease bearing ticks associated with the wild game. Cattle were restricted to the valley bottoms and lowland areas where grass was more plentiful. These lower lying areas were burned at least every three years to remove the coarse cured grasses and to encourage new growth. Generally, the burn was carried out at the end of the dry season, resulting in high temperatures and comprehensive control of woody species.

The traditional land management was based on wet and dry season grazing areas. In very dry years these areas would be pooled with the approval of the clans involved. However, in the colonial period, with movement restricted to an area that the Maasai considered insufficient for their needs and both cattle and human populations increasing, these management options declined, and a progressive process of resource degradation ensued.

2.2.2. Early Traders and Explorers

Although the Eygptians, Phoenecians, Greeks, and Romans had been aware of East Africa, it was the Arabs, utilizing the seasonal monsoon winds to trade up and down the coast that were by far the most influential. (King'oriah, 1980) The Portugese, starting with Vasco de Gama in 1497, exerted their influence mainly on the coast, although their introduction of such foods as maize, bananas and sweet potatoes had a far reaching influence on the diets of the indigenous peoples. Competing with, and eventually forcing the withdrawal of the Portugese, the Arab traders ventured inland with large caravans (often as large as 1500 men) with the primary aim of securing ivory and slaves. The main caravan routes originated in what is now Tanzania and, if heading northeastwards, invariably stopped in the vicinity of the Ngong Hills at Ngongo Bagas (Ngong meaning "the eye or source" of the Mbagathi River). Here, before continuing, they replenished their provisions by trading with the Kikuyu. Leakey (1963) writes:

> " Foreign traders came to this part of the country a long time ago , but in those very early days they never used to enter the confines of Kikuyu territory. Instead they would go to Ngong and when they reached there they would fire guns as a signal. When the Kikuyu heard the noise they would go over to trade for such things as beads, cloth and brass wire...........the Kikuyu name for these Arab and Swahili traders was thukumu." (Leakey, 1963)

Then came the white explorers and hunters. Joseph Thomson writing in his book Through Maasai Land - a Journey of Exploration Among the Snowclad Volcanic Mountains and Strange Tribes of Equatorial Africa(1883-1884) notes the following while at the Ngong Hills:

> ".........finally camping at the base of a Kapte mountain named Lamuyu (Ngong Hills). On the way I shot no less than four rhinoceros. It was really glorious fun to see one of these brutes scattering the caravan before I gave it it's *quietus*." (Thomson, 1885)

Thomson describes the landscape as they reach the Kapte plateau from the Rift Valley at Ngong Hills:

> ".........a grand expanse of undulating country lay before us , the hollows knee deep in rich and succulent pasture, in which peeped forth familiarly the homelike clover. The ridges were covered with trees of moderate size, and markedly temperate in their aspect, though splendid Cape calodendrons formed an unwonted spectacle with their glorious canopy of flowers. The interspaces of the woodland were filled up with a dense mass of beautiful and fragrant flowering shrubs in great variety. These open spaces were the haunts of large herds of buffalo, and the feeding grounds of numerous elephants and rhinoceros, while in the grassy reaches could be seen vast numbers of elands, hartebeests, zebras, and ostriches." (Thomson, 1885)

He goes on to describe the killing of a sleeping Rhinoceros and then continues:

> "After this feat (the killing of the rhino), an hour of marching brought us to a beautiful depression, surrounded by wood capped ridges, and enclosing a glorious bubbling fountain of clear, cold water, which formed a charming pool in which ducks swam and water lilies reclined in vernal beauty. This was Ngongo-a-Bagas, the eye or spring of the Bagas, one of the chief headwaters of the Athi River of U-Kambani. A second of greater dimensions, the Ngare Murju, meets the Bagas a little to the east. It springs up, like the latter, in considerable volume at the base of the eastern side of Donyo Lamuyu" (Ngong Hills) (Thomson, 1885)

These descriptions underline the fact that the hills were well vegetated and very productive both hydrologically and faunistically. Ngongo Bagas has since been developed with a concrete retention structure and almost all the trees in the area have been cut. However, it is still the one of the origins of the Mbagathi River and an important water source to local residents. Sadly, the last Rhinoceros was seen in Ngong Hills fifteen years ago.

Count Samuel Teleki's exploring and hunting expedition to Africa in 1887-1888 passed through the Ngong Hills area and Ludwig von Höhnel, his companion, described the area as follows:

> We are now on the eastern side of Doenye Lamuyo, and the neighborhood was more hilly. The latter part of our march here had been partly between luxuriant woods and partly across beautiful meadows, or little watercourses fringed with soft green grass, all alike presenting a marked and delightful contrast to the dreary waterless plateau of Kapotei.
> We met with very few Masai and only saw natives in any number when we passed two Kraals on the edge of the wood.......many of the woman brought eleusine meal, tobacco, sugar cane and c.,which they had got from Kikuyu, and offered to sell them to us." (Höhnel, 1887)

2.2.3. European Settlement and Maasai Reserves

Although the Ngong Hills have never been settled to any extent by foreigners, the European expansion did have a tremendous effect on the area. This was due to the increased pressure placed on remaining Maasai areas such as Ngong which forced changes in traditional land management.

The mere presence of the Maasai in the Rift Valley was an indication of the suitability of the area for ranching. This coupled with the fact that the railway followed the Rift Valley made much of Maasai land attractive to foreign takeover and it was decided by the British that this would be allowed. Charles Elliot, the Commissioner of the East African Protectorate in 1904 states in the Kenya Land Commission Report 187 paragraph 642:

> ".........as a matter of principle, I cannot admit that wandering tribes have a right to keep other and superior races out of large tracts merely because they have acquired the habit of straggling over far more land than they can utilize."

Elspeth Huxley describes the attitude that was widespread among the white settlers at the time :

> "Civilization was good, savagery was bad. The logical corollary of this was that anyone who spread civilization was doing right, was confirming a belief on the people he helped

> civilize....There could be no question therefore, but that the white man was paramount and must remain so until the native became - if ever he did - the intellectual equal of the European." (Huxley, 1935)

Within this context large areas of the Rift Valley were taken from the Maasai. Indeed, the size of the acquisitions does lead one to wonder about the straggling the Europeans intended to do. At any rate, the European interpenetration continued until the concept of native reserves arose. In 1904 two Maasai reserves were established; one in the north and one in the south. This was agreed upon by certain leaders of the Maasai. In regard to the area around Ngong, the Land Commission Report of the 1904 treaty p.572 states:

> 'In addition to the foregoing, Lenana, as chief Laibon, and his successors, to be allowed to occupy the land lying in between the Mbagathi and Kiserian streams from Donyo Lamuyu to the point where both streams meet...." (KLC, 1904)

Although, it has been stated that the move of all people and stock to definite reservations was voluntary, the unity of the Maasai in this respect is somewhat questionable. Nevertheless, the agreement was to last " for as long as the Maasai as a race shall exist ." Seven years later the agreement was "renegotiated" and the northern reserve was much reduced in favour of an extension of the southern reserve. Many of the northern Maasai sections found land in the south, often usurping those who had lived there for many years. The exchange was certainly in the Europeans' favour, as the quality of the rich grazing lands in the north was clearly superior to the dry lands given in exchange. The white man's position in the Rift Valley was consolidated at the expense of theMaasai.

In 1913 the southern reserve was divided into two districts with the headquarters of the new eastern district located at Ngong until it's transfer to Kajiado in 1926. During this time the senior Laibon in Kenya, Lenana, resided in Ngong. Some of the major Maasai clans in the area at the time were: Lekokonyuki, Kaptai, Mataratu, Kangiri, Kisongo, Prugu, Roliaseri, Loita, Kekonyoge, Purka, Loidogelani, Matobatu, and Rekisongo.

Perhaps the finest literary descriptions of the landscape of the Ngong Hills in the first third of this century are offered by Karen Blixen, a Danish writer and author of the autobiography Out of Africa She lived in close proximity to the hills from 1914 to 1931. The following quotation gives a superb image of the land during this period:

> From the Ngong Hills you have a unique view, you see to the south the vast plains of the great game-country that stretches all the way to Kilimanjaro; to the east and north the park-like country of the foot-hills with the forest behind them, and the undulating land of the Kikuyu Reserve, which extends to

Mount Kenya a hundred miles away - a mosaic of little square maize-fields, banana-groves and grassland, with here and there the blue smoke from a native village, a small cluster of peaked mole-casts. But towards the west, deep down, lies the dry, moon-like landscape of the African low country. The brown desert is irregularly dotted with little marks of the thornbushes, the winding river-beds are drawn up with crooked dark-green trails; those are the woods of the mighty, wide branching mimosa trees, with thorn like spikes; the cactus grows here, and here is the home of the giraffe and the rhino.

The hill-country itself, when you get into it , is tremendously big, picturesque and mysterious; varied with long valleys, thickets, green slopes, and rocky crags. High up, under one of the peaks there is even a bamboo-grove. There are springs and wells in the hills; I have camped up here by them.

In my day , the buffalo, the eland and the rhino lived in the Ngong Hills; the very old Natives remembered a time when there were elephants there, and I was sorry that the whole Ngong Mountain was not enclosed in the Game Reserve. Only a small part of it was Game Reserve, and the beacon on the southern peak marked the boundary of it. When the colony prospers and Nairobi, the capital, grows into a big city, the Ngong Hills might have made a matchless game park for it. But during my last years in Africa many young Nairobi shop-people ran out into the hills on Sundays, on their motor-cycles, and shot at anything they saw, and I believe that the big game will have wandered away from the hills, through the thorn-thickets and the stony ground farther south.

Up on the very ridge of the hills and on the four peaks themselves it was easy to walk; the grass was short as on a lawn, with the grey stone in places breaking through the sward. Along the ridge, up and down the ridge, like a gentle switchback, there ran a narrow game-path. One morning, at the same time that I was camped in the hills, I came up here and walked along the path, and I found on it fresh tracks and dung of a herd of eland. The big peaceful animals must have been up on the ridge at sunrise, walking in a long row, and you cannot imagine that they had come for any other reason than just to look, deep down on both sides at the land below. "(Blixen)

2.2.4. 1930 to the Present

During this period the numbers of Kikuyu people in the Ngong area began to expand. This was in part due to squatting by Kikuyu as well as intermarriage with Maasai men. Bride payment to the Kikuyu families was often in the form of land. In addition, permission to cultivate was occasionally given by individual Maasai. The Colonial Secretary, H.M. Moore, referring to the Land Commission Report of 1933, stated;

> "2. Experience has shown that it is impossible to keep the Kikuyu out of the Maasai Reserve, even if it is desirable to do so, and I am only concerned with the regularizing of their occupancy of those parts of the reserve into which they have penetrated.
>
> 3. Section 662 refers to the precarious nature of their tenure. Kikuyu living at Ngong by a legal fiction are on Forest Squatter Agreements. I am practically certain that these agreements are invalid, but provided that some substitute can be devised for them, it is in everybody's advantage that the Kikuyu should remain there. In reference to changes in the Land Commission Report. Tenure, lease areas etc............ I greatly doubt if the Maasai will appreciate the reasons for any change, but they of course should be told. They are almost certain to object to any change, and I would again stress the necessity for overriding powers." (Moore, 1933)

By 1937 the District Officer at Ngong, summarizing the Officer in Charge, Maasai, wrote:

> ".........altho' interpenetration was recommended by the Land Commission Report, the Kikuyu immigration has increased so rapidly, being subject to no effective control that Ngong, an area highly prized by the Maasai but vacated on account of East Coast Fever was in danger of becoming a Kikuyu settlement.
>
> The Maasai were anxious to use the Ngong area, their only fear was that East Coast Fever would kill off their stock. They would make better use of the land in Ngong than the Kikuyu, and moreover they were the rightful owners of the land." (District Officer, 1937)

In the same year the District Officer presented a plan for the development of the Ngong Area by the Maasai in which he states " Now that the Kikuyu have been ejected from the Ngong area..." (District Officer, 1937) In the plan he outlined possibilities for mixed farming, dairying and ranching. He suggested the demarcation of small holdings of approximately twenty acres although he notes that if the area would allow larger holdings then the size should be increased. The division of the holdings were to be as follows:

> Grazing..........15 acres
> Crops................4 acres
> Homestead...1/2acre
> Trees............1/2acre
> ....It is suggested that the fifteen acres of grazing be planted with Rhodes grass or Paspalim, this would support five cows. The area would be paddocked, wattle seed being planted along the lines of division and bush being used as fencing until such time as the wattle grew large enough to support poles or wire. Later these wattle poles would be useful for building when thinning became necessary.
> ....On the four acres for cultivation, fodder crops, maize, potatoes etc. could be grown" (Johnston 1937)

The plan also included the encouragement of dairying and the provision of facilities for milking and the curing and storage of hides. Cattle dips and fencing were also to be constructed. It is interesting to note the input to this plan by the Agricultural Officer at Ngong. A copy of his memo to the District Officer in included in the Appendix. Had the recommendations which he put forth, including watershed protection measures, fodder production, small dam construction, firewood plots, controlled grazing etc., been implemented, the Ngong Hills might have had a brighter history. Very few of the recommendations were ever realized, due in large measure to a lack of any input by the indigenous peoples. This insensitivity not withstanding, it is noteworthy that many of the problems and possible solutions facing the Ngong Hills today were recognized fifty years ago.

A brief description of the vegetation on the hills was found in a 1937 government memo on East Coast Fever:

> " The hills themselves do not support a large permanent population but are used for grazing by the local herds. From about a mile outside the Boma along the old Kajiado Road the lower slopes are densely bushed for a distance of some five miles while the gullies running down from the upper parts are also bushed and in many places support trees." (Agricultural Officer, 1937)

The recognition of the obvious problems continued, together, it appears, with a lack of any real success in dealing with them. Both the District and Provincial Agricultural Officers write in 1951:

> " Although advice and warning and instructions have been given at frequent Baraza, little or no notice is being taken. I found several new shambas opened up, all on steep slopes where grazing is excellent......The speed of the ox ploughing greatly exceeds the ability of ordinary hand labour to dig and maintain terraces or to employ satisfactory cultural methods. First class grazing is rapidly being lost and I feel that a system of mining the land by absentee and other owners is gradually becoming a menace which must be stopped." (District Agriculture Officer, 1951)
>
> "As you know I was seriously perturbed at the vast increase in cultivation on the slopes of the Ngong Hills.........a large portion of these probably had no right to cultivate." (Provincial Agricultural Officer, 1951)

Meanwhile the problem of Kikuyu in the area continued. There are references in government memos to a large Kikuyu/Maasai battle in the area in 1947 but no details on the subject were found.

The government seemed to have had conflicting policy on the Kikuyu issue. In 1947 the District Commissioner of Kiambu removed all Kikuyu from Kibiko and several of these were resettled in

Ngong where they were required for the cultivation of large shambas. This is in contrast to the policy of a "closed district" which was reiterated in 1949 in the following memo:

> " The matter of illegal infiltration of Kikuyu was discussed and it was again stressed that no Kikuyu, or other alien, is allowed to settle in the reserve without the permission of the Local Native Council, and that an immediate report should be made if there was any such person. ......the practice of individual Maasai giving permission must stop." (District Officer, Ngong, 1949)

In conversation with local Maasai elders it became apparent that the situation with the Kikuyu was a cyclic one beginning with illegal squatting and those who received land for bride payment. Many Kikuyu were subsequently ejected from the area only to return in greater numbers. The final cycle seems to have begun around 1957 when land demarcation started in the area. Demarcation was accelerated after independence in 1963. Land was distributed mostly to Maasai and many of the Kikuyu were forced out at that time. However, with demarcation and title deeds came the right to sell, and since that time many people have sold their land. Most of the settlement in the area has been in the past twenty years.

The east side of the Ngong Hills is now predominantly Kikuyu, albeit with many remaining Maasai. Many of those who bought or received land since demarcation have subdivided it, and the average holding is now about seven acres with almost the entire east slopes (excluding the Forest Reserve) devoted to cultivation. An act of Parliament restricted subdivision size to a minimum of two acres. However, approximately 23% of the farms on the eastern slopes are less than two acres. Land demarcation in the Rift Valley portion of the study area was completed by 1980 and most land holders have title deeds for their land which ranges from 100 to 300 acres and the people have adopted a sedentary lifestyle. The traditional Maasai way of life is over in the Ngong Hills.

Illegal occupation of land continued throughout the hills after demarcation. On the 1978 aerial photography, buildings and clearing are scattered throughout the upper slopes and are present even on the ridge top. Serious forest clearing occurred and the evidence of this activity is still present in the form of pioneer and invader species. Wisely, the Government of Kenya, recognizing the hydrologic importance of the Ngong Hills, declared the present forest reserve, gazetted forest land, under proclamation order Number 90 in 1985. Those residing in the forest were removed. Included in the original concept of the forest reserve was the idea of resettling those landless people who had been in the forest, along a 400 meter strip on the inside of the reserve boundary. However, this proposal met with many problems and was withdrawn by the government. In the meantime however, several families moved into the boundary land, where they remain to this day.

The history of the Ngong Hills has been one of centuries of relative equilibrium followed by steady and relentless decline in the face of external and internal human pressures. Perhaps the most striking feature of the environmental degradation of the area has been the swiftness with which it has occurred. It has, after all, been less than thirty years since most plots were demarcated. It can only be hoped that this decline will soon be arrested and reversed, providing a stable platform for the future.

Chapter 3 The Bio-Physical Environment

3.1. GEOLOGY

The Ngong Hills are one of the most dominant topographic features of the Nairobi area, rising to an elevation of 2461 meters (8074 feet). They lie about twenty kilometers southwest of the city centre, immediately to the south of the Kenyan highlands (see location map). The hills form an impressive asymmetric ridge, approximately thirteen kilometers long and five kilometers wide. They are oriented slightly to the west of north and sit astride a major scarp on the eastern shoulder of the Gregory Rift Valley. They represent the eroded remnants of a former volcano, or string of volcanoes, that previously measured over eleven kilometers in diameter.

3.1.1. Previous Geological Work

Very little detailed geological work has been carried out specifically in the Ngong Hills, but the more general area has received attention. The first to give an account of the geology of the eastern rift valley was the German E. Suess who described it following his trip to the area in 1892. The now famous accounts of J. W. Gregory, after whom the Gregory Rift Valley is named, were published after his safaris of 1893 and 1919. He mentions the basic Ngong lava formations in his 1920 publication. He published several papers on the geology of the Rift Valley.

The geologists E.E. Walker (1903), G.L. Collie(1912), and Krinkel (1925) also made mention of the geology of the Nairobi area following trips to the region. Bailley Willis made a study of the Gregory Rift Valley in 1936. N. L. Bowen studied fine grained lavas from the Nairobi area and used these to illustrate his work "Petrology's Residue System" (1936)

H.L. Sikes (1939) made detailed surveys of the underground water resources of the Nairobi area during his work with the public works department. This work necessarily referred to the geology of the area with some reference to Ngong flows. This work was further refined and added to by E.L. Gevaets in the publications of the ministry of Works in 1969 (updated in 1970). William Pulfrey(1948) examined stone deposits of Ngong and Joubert included Ngong deposits in his report on building materials. F.J. Matheson(1966) worked in the southern end of the area while preparing the geological report for Kajiado.

Other more general works on Rift valley vulcanism include that of Nyamweru (1983).

The most detailed work in the area to date has been that of E.P. Saggerson, (1971) the former chief geologist of Kenya. This included an extensive report as well as mapping at 1:125000. The work (with the exception of the map) remains unpublished however.

3.1.2. Topography

The topography of the Ngong Hills reflects the asymmetrical nature of the overall landform. The hills represent the eroded remnants of a former volcano, or string of volcanoes, that previously measured over eleven kilometers in diameter. The volcano was bisected by a major north - south trending fault and the western half was down thrown several thousand meters and now lies beneath the floor of the Rift Valley buried under subsequent Limuru type lava flows. This down thrown section has been subject to repeated faulting as a result of rejuvenation of movement along the previous faults. The steep, boulder strewn western slopes have an average grade of over 25 degrees and are in marked contrast to the moderate slopes of the eastern flank which steepen towards the summit. The eastern portion is thought to represent the original undeformed lava surface that has been subsequently altered by water erosion (no less than fourteen tributary valleys may be counted). This suggests that the volcano had achieved a considerable height (much higher than it's present elevation) before the presently revealed lavas were laid down. The convex ridges and tributary valleys are moderately sloping with occasional steep sections. (See Slope and Relief Maps)

3.1.3. Summary of Geology

It is generally accepted that the geologic history of the area has been dominated by rifting and vulcanism associated with tectonic movements. In fact much of the landscape of East Africa has been the result of the processes of faulting and volcanic activity (Nyamweru 1983). The formation of the Ngong Hills in particular is best understood in the context of the overall system of which they are a part, namely the East African Rift System.

The African rift system stretches from the Afar depression in northern Ethiopia to the mouth of the Zambezi River in Mozambique with a total length of 5600 kilometers. The Rift system is a depressed and faulted zone running across the African continent and is very prominent in some areas. Consistent with the theory of plate tectonics, it is an area of extension and crustal

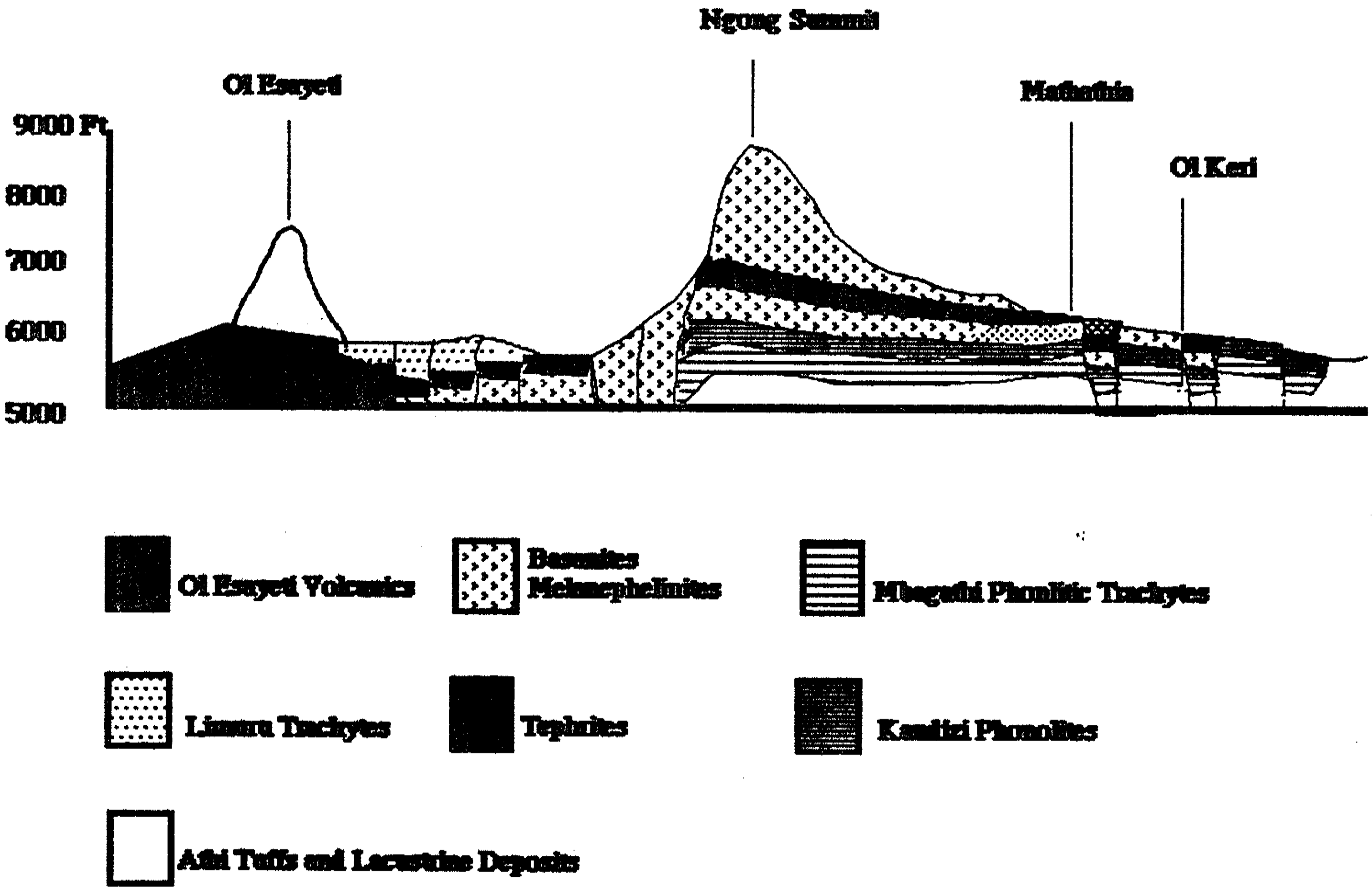


Figure 7, Geological Section of the Ngong Hills instability. Gradually, the land on the eastern side of the rift is moving eastwards away from the mass to the west. The land mass of Africa is splitting apart along the Rift system and volcanic rock from below (often basaltic) issues forth to fill the resultant void. This is precisely what has occurred in the formation of the Ngong central volcano which is associated with the eastern rim of the fault zone. It's several outpourings of lava were both preceded and followed by tectonic movements. With the exception of the Ngong volcano and it's associated satellites of Ol esayeti and Ngoroi no other vents in the immediate vicinity have been found or inferred and it is thought that the majority of the lava in the Nairobi area of the Rift has been derived from fissure types of eruption.

Study of the fracture zone of the Rift indicates that the Ngoirobi fault and the north - south Kedong fault are the two major fault lines. These have helped form the steep walled, impressive features of the Ngong Hills. The geological history of this area of the Rift system has been of normal faulting and subsidence with local tilting of small blocks. These have often been accompanied by sub-parallel faults. Saggerson (1971) noted the following three periods of faulting occurring in the Nairobi area of the Rift system:

"1. Major faults formed before out pourings of volcanic rocks when the generally north - south fracture pattern was established.

2. Grid faults formed in the mid Pleistocene at the close of the main volcanic episode.

3. Cross faults and minor faults that have affected all other structures."

When the Ngong volcano subsided into the Rift it appears that the most elevated part of the area was associated with the largest single displacement. The cause of this great subsidence was due both to the accumulation of extruded material on the surface, as well as the structural weakness in the deep zone of continuous tension. H.L.Sikes (1926) describes the subsidence as follows:

".....the former highlands comprising the major centres of dispersion of the group II series (Ngong Basic Series) were down thrown along the Ngong main fault and the Ngong cross fault, forming a basin into which the lavas of the fourth group subsequently flowed from the northward. It is clear that the formation of the basin occurred in the region where the volcanic ejecta of the second group of vulcanism was accumulated at it's greatest thickness - namely over the vents which gave rise to it......."

Despite the fact that this is a dated description and rock series names have changed, later authors appear in agreement with it's substance (Gevaerts 1970, Saggerson 1971).

Although the topography of the hills indicates the focus of the eruptions was along a north - south line, it is very difficult to determine whether the several peaks that form the horizon today were in fact volcanic centres, or if there was but one massive centre and the undulating ridge line is the result of subsequent erosion. The actual volcanic vent has not been located but detailed mapping of" the stratified lavas, tuffs, and agglomerates with pyroclastic ejectamenta predominating in the western face may reveal the necessary evidence"(Sikes,1939) One vent has been confirmed; that of a "minor eruptive centre at Kandizi where ultrabasic lavas" (Saggerson,1971) have exited the Ngoroi vent. Many flows have issued from the Ngong volcano and can be recognized where they have created spurs on the eastern aspect of the mountain. The steep western side is deeply dissected and strewn with scree and boulders making individual bands difficult to see.

The rise to the rift, as the shoulder of the valley is approached from the east, is due not only to the accumulation of volcanic rock from numerous eruptions along the edge of the system, but also, to the uplifting and doming of the earth's surface that took place prior to the original faulting. The central volcano of Ngong erupted in association with the formation of the Gregory Rift valley. The volcanic rocks began accumulating in mid-Miocene times and continued into at least the upper Pleistocene. (Saggerson 1971) Subsequent to the main period of volcanic activity, strong normal faulting occurred resulting in the dissection and down thrusting of the western portion of the volcano and it's burying by Limuru trachytic lavas as previously described. Subsequently this too was faulted resulting in the formation of grabens to the west and east of the main ridge (see section). These troughs were formed between near parallel faults. The sections show relatively small scale grabens while the Gregory Rift Valley itself exhibits typical graben form on a grand scale.

3.1.4. Details of Geology

The rocks of the Ngong area consist mainly of lavas and pyroclastics of Pliocene age which have been laid down over an eroded and slightly undulating system of crystalline basement rocks. The composition of this Precambrian foundation of largely schists and gneisses from within the Mozambique belt, indicates that they were metamorphosed by earth movements involving folding, probably more than 500 million years ago. It is believed that they were mainly sediments that metamorphosed to their present condition due to the combined forces of intense heat and pressure as well as the intrusion of granitic material.

Rocks of a similar nature form the crystalline basement system covering much of eastern Kenya. Boreholes in the area indicate that the surface of this material was undulating and had been subject to erosion prior to it's burial by later depositions. These crystalline rocks are rarely exposed, particularly in the Ngong area where they are below hundreds of meters of lava. However they have been found in some of the lavas extruded from the Ngong volcano and now exposed in the Olohia area. These contain fragments of hornblende and quartz feldspar gneisses and indicate that the ancient metamorphic rocks were "penetrated at depth during the formation of the Ngong vent."(Saggerson 1971). No other lavas in the area have been found to contain fragments of precambrian rock of such size as found in the Ngong agglomerates.

Between the late pre-Cambrian and Tertiary times the geological record for central Kenya is lacking with the exception that following the folding and metamorphism of the basement system, the area was subjected to various erosion cycles that resulted in the formation of a peneplain. The history of deposition during this period has been lost and it is not until the Pliocene that a clear record emerges. It was at the beginning of this period that the deposits of Athi tuffs and lacustrine sediments were laid down. These two types of materials, although of a very different nature, were grouped together by Shackelton(1945) and subsequent scholars have maintained this classification (Saggerson 1971). This is probably because the extent of the interbedding of the lacustrine material and the pyroclastics and tuffs is unknown as borehole evidence in the area is incomplete.

Volcanic activity began to play a major role in the area starting with the outpourings of Kapiti phonolite onto the already eroded peneplain in the late Miocene. These deposits abut the Ngong area but do not extend over it. In the early Pliocene Mbagathi phonolitic trachytes, originating in the Ngong volcano, covered the Athi tuffs and lacustrine deposits. The thickness of the flows (there appear to have been two or three) varies, with the maximum accummulations occurring nearest the source on the shoulder of the Rift. This lava was typically brown or greenish brown to pinkish brown. It often exhibits striking feldspar laths set in a grey brown matrix. The outward flows were of a relatively uniform thickness and boreholes in the Karen - Langata area show thicknesses of this material ranging from 250-400 feet.. The eastern extent (near Kabete) is marked by erosion scarps.

After each period of volcanic activity there followed a period of relative dormancy during which the pressure built, firing later eruptions. The subsequent deposits are to varying degrees interstratified with weathered pyroclastics. The majority of all the Ngong eruptions occurred in the late Cainozoic period over a duration of about 12 000 000 years.

Kandizi phonolites of a dark blue to black colour overlie the Mbagathi phonolitic trachytes. These probably also had their origin in the Ngong vent. They formed a lava apron around the northern and eastern flanks of the volcano. This flow extended across the Karen area where it is finally hidden beneath subsequent flows of Nairobi phonolite of different origin.

The Ngong basalts which were laid down over the Kandizi phonolites have been differentiated into upper and lower basalts by Gevaerts(1970) although he admits there is no hard evidence to support this and the presence of the older lower basalts is only inferred. Saggerson (1971), however, has mapped the Ngong volcanics in a more detailed fashion. He states that the oldest Ngong lavas are probably those encountered in boreholes in the Karen - Langata area where they have been noted between Nairobi trachyte and Kandezi phonolite. In terms of exposed lavas found at Ngoroi, however, the basic lavas clearly overly both the Mbagathi phonolitic trachyte and the Kandizi phonolite. Later flows from the main Ngong vent(s) cover the floor of the Kandizi valley and reach Ngoroi. The extent of the Ngong lava apron has been clearly shown by borehole information. While thousands of feet of lava have accumulated on the shoulder of the Rift the thickness drops to 67 meters (220 feet) at Mbagathi Springs and to 20 meters (66 feet) at west Langata. The lava was absent immediately east of this point.

The Ngong lavas are typically dense blue-black to black with yellow amygdaloidal varieties in the northwestern flows. They form a group of lavas which range from ultrabasic to basic and consist of the following types that are listed in stratigraphic order (Saggerson 1971):

1. Basanites, tephrites, atlantites, and tannbuscites (Lamwia, Wireless station)

2. Basanites (eastern slopes)

3. Tephrites (Ololua and Ol Keri)

4. Basanites (Ol Keri)

5. Tannbuschites, melanephelinites and ankaratrites (Ngoroi)

The western slopes below Kipruti are formed of tephrite overlain by basanites but their location in the geological sequence is imprecise. The foregoing main rock types are of variable makeup and range " from basanite to nepheline on the one hand and tephrite to atlantites on the other"(Saggerson 1971). On weathering most form distinctive rocks, a fine example of which is found near the Magadi road where melanocritic basanites containing titanaugite crystals can be found.

Basanites are the most common rocks of the Ngong area. They form not only the most easterly slopes of the volcano at Ol Keri and Kiserian but also the upper slopes of the hills. The lavas were basic, alkaline and contained olivine and are often found interbedded with tephrites. At Kipruti, which is the most northern extension of the flows, both atlantites and melanocratic basanites have been noted. Augitites and nephelinite flows are also represented.

Detailed mapping has confirmed Ngoroi as the site of a former volcanic vent on the southern bank of the Kandizi River near the Kandizi stone quarries. Ankaratrite (biotite-olivine melanephelinite) and tannbuschite (feldspar bearing melanephelinite) form the small conical hill found on the site. It was from this vent that ultrabasic lavas were extruded onto an eroded surface. The ankaratrites are strongly porphyritic and contain olivine in sizes up to 1 cm. in length which frequently has an orange alteration rim around it composed of alterations varying from serpentine to chlorite.

Tannabuschites, a similar rock, is found in the lava flows to the east of the Magadi road as well as on the north bank of the Kandizi River. These are very similar rocks to the ankaratrites with the major difference being the presence of feldspar. Just to the east of Ngoroi there is a deposit of a particularly melanocratic rock composed of copious amounts of titanaugite and olivine phenocrysts set in a fine grained ground mass.

The basanites are dense blue black rocks that often contain phenocrysts of brown pyroxene up to 1 cm. in length set in a fine grained ground mass of augite, magnetite and nepheline. These rocks are extremely variable and contain greater or lesser amounts of feldspar, biotite, analcime, olivine, chlorite, serpentine and titan augite. Specimens that contained very small proportions of nepheline were referred to as atlantites.

Almost continuous exposures of tephrites occur along the eastern margin of Ngong from the Veterinary Station in the north to Kiserian in the south. Similar rocks are displayed on the steep western scarp. The tephrites are similar in character to the basanites but do not contain the mineral olivine. However, tephrite does contain phenocrysts of orange brown barkevikite. The rocks vary in the amount of feldspar present and are less basic than the basanites.

Only a few dykes have been reported in the area. Sikes (1939) reported two vertical dykes, composed of Basanite and basanitoid, that were exposed on the western slopes. Saggerson (1971) also found "thin tephritic dykes.....in the Kandizi Valley associated with the Ngoroi vent."

3.1.5. Summary

In summary the geological history of the Ngong Hills has been dramatic and has resulted in impressive landforms. Volcanic eruptions produced a series of alkaline lava flows and associated tuffs which began accumulating in mid-Miocene time and continued into the Pleistocene. This activity occurred during a period of faulting and crustal instability in the time of the formation of the Rift Valley. The resulting formations, modified by various processes, are now affecting the lives of the people making use of the land. The fertility, drainage, stability and ultimate productivity of the land has as it's fundamental basis, geological processes set in motion millions of years ago. It is this violent process of rifting and outpouring of lava that has given the Nairobi area it's most prominentfeature.

3.2. CLIMATE

The climate of the Ngong Hills must be considered in the context of the more general weather patterns existing in East Africa as a whole. Therefore, this section will first examine the general meteorological conditions prevalent throughout Kenya, and will then look at the more specific conditions of the Kenyan Highlands. Finally, the detailed meso and microclimatic patterns of the Ngong Hills themselves will be discussed.

The importance of a thorough climatological understanding of an area considered for landscape planning, cannot be overstated. This is particularly true in the highlands of Kenya where weather patterns are extremely variable, often within very short distances. Winds, rainfall (timing, quantity, intensity, variation), and temperatures are dependent to a large degree on elevation, aspect, topography and vegetative cover.

3.2.1 Seasonal Weather Patterns of East Africa

Findlater (1973) has noted that the seasonal weather patterns and general atmospheric circulation in East Africa " is not completely understood " and that generalizations can be misleading, as the effects of local modifiers may be dramatic. However, such generalizations are necessary to provide a overall understanding of the conditions.

The trade wind systems from both hemispheres converge on the equatorial trough. Low level winds move towards this trough and produce significant upward movement which in turn leads to condensation, cloudiness and precipitation. This intertropical convergence zone lies close to the "overhead position of the sun" (Findlater,1973). This zone determines the rainy seasons by it's annual movements which follow the sun between the tropics (with a lag time of about five weeks). Although ascent in this zone generally leads to precipitation or cloudiness, Cocheme (1973) writes " Although the intertropical convergence zone appears to determine the rainy seasons by it's annual movement, it must not be thought of as a moving belt of rain but rather as a moving zone within which, or in the vicinity of, some of the mechanisms which produce rain operate more effectively". The recent rain failures in Kenya underline this statement.

The convergence zone follows the path of the sun and lies approximately above the tropics at the solstices, while it is above the equator at the equinoxes. As rain is associated with the convergence zone, there are generally two such seasons near the equator (as the trough passes it twice a year), while there is only one at the tropics. Generally speaking, rainfalls are at a maximum when the area is closest to the convergence zone, and at a minimum when at the furthest distance. This simplistic explanation is, of course, greatly modified by local conditions ie. altitude, and geographic features. Findlater(1973) notes that the meridional orientation of the east African coastline and highland areas has given rise to winds that are more meridionally oriented than most other equatorial areas. This has caused some distortion of the convergence zone resulting in areas of divergence or enhanced convergence. This distortion has been used to explain the existence of the arid area of eastern Kenya, which is one of the few equatorial areas with sparce rainfall.

In January, the zone of convergence and the associated increase in rainfall, is found south of east Africa. At this time the rains are beginning in southernmost Tanzania. Studies of surface pressure have shown that while the flow is convergent on the areas to the south, it is divergent in areas to the north, notably Kenya, Somalia, and parts of Ethiopia. (Findlater, 1973). By late March or early April the rains have moved northwards into northern Tanzania and Kenya and the divergence from northeast Africa is lessened, with an accompanying drop in wind speeds. The most northerly position of the rain belt is reached in July, when it influences the highlands of Ethiopia. The south easterly monsoon, which blows from April to October, has little effect on rainfall in Kenya at this time, as the the flow is not generally subject to convergent lifting. This south easterly flow may however, be influenced by orographic lifting and occasionally gives rise to cloud and precipitation on wind facing slopes. In October and November the rains begin their move southward and start to affect Kenya. The winds shift more to the east and northeast. As these are more convergent, lifting occurs and precipitation increases, at first on the coast and then progressing inland. The cycle is completed by January.

Although giving a general picture of the climate of the area, this explanation does not adequately account for the great variation that occurs throughout the area. Variations in seasonal and yearly rainfall totals are common and can be partially explained by large scale circulation changes. In the drier areas of Kenya, long term monthly rainfall means are not always a good guide to expected values, as reliability of the rains is often low. Furthermore, local variations within very short distances are common especially in the highland areas.

3.2.2. General Climate of the Kenyan Highlands

The climate of the Kenyan highlands has been described by some as the finest in the world in terms of human comfort. While this may be true, it is nevertheless, highly variable over both time and space. It is this fact that is of great concern to farmers in the area. The variability may be traced to several factors, including elevation, aspect, vegetative cover, and topography, although altitude, more than any other, has the greatest effect, as it strongly influences temperature and rainfall.

Without a doubt, the single most limiting climatological factor is rainfall. The vast majority of the rain falls within the two rainy seasons which occur between the monsoons; April to May and November to December. These two periods are known locally as the "long" and "short" rains, respectively. This bimodal pattern is particularly strong in the Nairobi (including Ngong), Thika, and Machakos areas. These areas are the most marked in this respect in all of the highlands (Ondingo, 1971). The northeast monsoon (December to March) delivers more precipitation than the southeast monsoon (June to September). (Kenyan Met. Dept., 1980)

The highland areas characteristically have high rainfalls due to orographic lifting which encourages precipitation. The highlands also act as high level heat sources, promoting air parcel lifting and subsequent condensation. Nieuwolt (1973) has shown that the degree to which each of these factors affects rainfall is dependent on season and aspect. Orographic lifting is responsible for much of the rainfall in November and December (when winds are high). During the April - May rains, the winds are of a lower velocity and convection is responsible for much of the lifting. Precipitation, is therefore, very much affected by aspect especially during November and December when those slopes facing the winds receive more rain. Aspect takes on less significance during April and May when the winds are not as strong.

Variations in rainfall over space can be very great as " air masses .... are conditionally or convectively unstable, so that only a slight uplifting can result in large amounts of rainfall being released." (Nieuwolt, 1973). Rainfall generally increases with elevation to an approximate maximum of 2500-3400 meters where this trend reverses (Nieuwolt, 1973). This reversal is due the combined influence of the amount of water available for precipitation and the effectiveness of the increased elevation in causing precipitation. At a certain altitude the optimum combination of these two opposing factors is reached, beyond which, it decreases. The increase in rainfall is usually due to increased rainfall frequency rather than increased intensity. Studies also indicate that rainfall is more continuous at higher altitudes. Elevation does not appear to have an effect on seasonal rainfall distribution.

The importance of the rainfall quantity, distribution, and reliability to agriculture is paramount. As the rainy seasons are separated by up to five months of dry weather, the implications are severe. The period of drought nullifies any high yearly rainfall values, as crops are restricted to one or the other of the two seasons, unless they are able to withstand the intervening conditions. Therefore, although yearly totals may indicate the possibility of growing a particular crop, the seasonal rainfall values and the drought hardiness of the crop must be taken into account. Tree crops, including coffee and sisal, which are able to withstand the drought, are commonly grown in the highlands. In some areas the climate does not permit arable agriculture and livestock grazing is common.

Also significant to agricultural activities, is the reliability of the rainfall. In this respect, certain areas are notoriously variable and unreliable, based on the monthly, seasonal, and yearly totals. The reliability in some areas is such that mean values cannot be relied upon for planning purposes. In the Ngong area, six out of twenty years receive less than 750 mm of rain giving a high chance of crop failure and severely reduced yields (Odingo, 1971). Seasonal reliability calculations are seen to more valuable to the farmer than simply yearly calculations. Calculations on a seasonal basis have been made for most of the highlands (GTZ,1983) but the Ngong Hills area were excluded from the study. Generally speaking, the long rains are more reliable than the short rains.

It has also been established that there is a definite correlation between altitude and temperature in the highlands (East African Meteorological Dept., 1959). Temperature, however, is not generally an agriculturally limiting factor in the highlands (certainly not in the Ngong Hills), other than choice of crops. Frosts are uncommon below 2500 meters. One aspect of temperature that has management implications is that as temperature and radiation is high year round, the removal of shade greatly increases soil temperatures. This increases the rate of organic matter decomposition and results in greater nutrient leaching. This also lowers the moisture holding capacity of the soils and increases erosion by both wind and water.

3.2.3. Detailed Climate of the Ngong Hills

Meteorological investigations in the Ngong Hills area have been limited to rainfall measurements at several stations. All of these are within 15 kilometers of the study area although most are much closer. More detailed observations have been made at the Nairobi- Dagoretti Corner Station which is approximately 14 km. from the study area. Unfortunately, none of the observations have been made at elevations greater than 2042 meters. Considering the height of the hill (2460 meters), and the almost certain variations in rainfall that this implies, estimates on climatological probabilities are necessary. Another limitation is that the only measurements available for the western side of the hill are at Kisamis which doesn't receive the full effect of the hill, (although it is definitely in a rain shadow). Vegetative indicators as well as assumptions based upon general observations and farmer interviews have been used to estimate the climate.

3.2.3.1. *Meteorological Observation Stations*

Station	Latitude	Longitude	Elevation
Nairobi - Dagoretti Corner	1° 18'S	36°45E	1799m
Ngong Forest Station	1° 18'S	36°44E	1890m
Ngong District Office	1° 22'S	36° 39'E	2042m
Maasai Rural Development Centre	1° 28S	36° 38E	1762m
Kibiko "A", Gathakos Farm	1° 20S	36° 38E	1752m
Kisamis Primary School	1° 29S	36° 38E	1707m
Apostles Seminary (Kiserian)	1° 26S	36° 41E	1829m

3.2.3.2. *Classification*

The climate of this highlands area can be classified as IV 5, III 5 and III 6 (strongly modified by the topography) according to the agroclimatic zone map of Kenya. The lower Rift Valley portions of the area can be classified as zone V4 and V5, depending on elevation. These are fairly cool highlands dominated by grassy, open woodlands with some closed forest and woodland at higher elevations (in their natural state). The climate varies from semi-humid at higher elevations on the eastern aspect to semi-arid at the northern and southern ends of the hills as well as on the west slopes.

Parts of the area also fall within the criteria for selection as LH3 M+S: Lower Highland Zone (maize zone) with one medium and one short growing periods. Portions also fall within the LH4 s/m + s/vs : cattle, sheep, barley zone with one medium to short growing period and one short to very short season.(GTZ, 1983). The Köppen classification for the Ngong DO station is Cw2 : Highland subhumid with two wet seasons.

3.2.3.3. *Rainfall*

Rainfall measurements have been analyzed from seven stations. This shows great variability with the highest values recorded at Dagoretti Corner with a mean yearly total of 1049 mm. This was followed by the Ngong Forest Station with 938.2 mm., Apostles of Jesus Seminary at Kiserian with 825.7 mm., the Ngong District Office with 820.6 mm., the Maasai Rural Development Centre with 648.5 mm., Kibiko "A" with 599.3 mm., and finally, the very low value of 477.8 mm. at Kisamis in the Rift Valley. The last five stations are included, or are very close, to the study area. The beginning of the both rainy periods appears uniform to all stations with the long rains starting near the end of March and the short rains near the end of October.

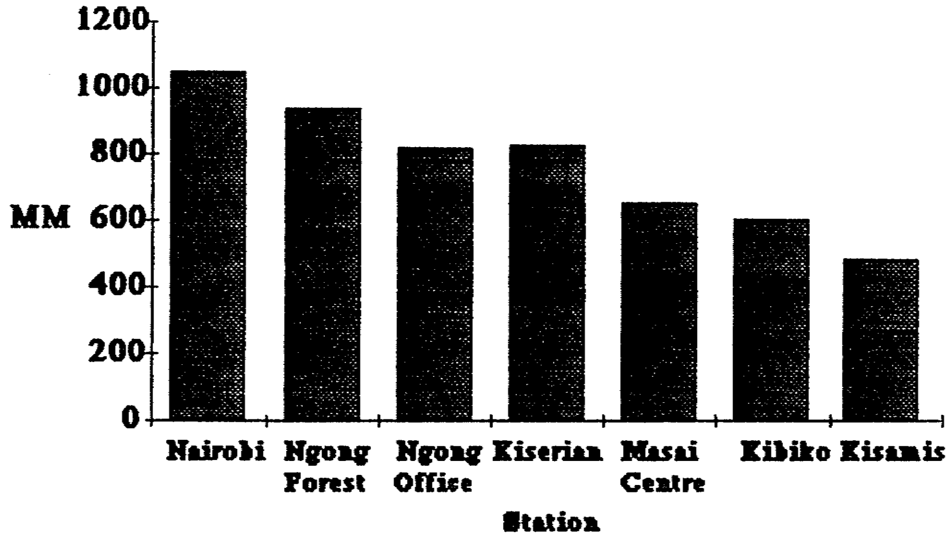


Figure 8. Mean Annual Rainfall

The variation in values is high considering the small distances between stations. The low values at Kibiko can at least partially be attributed to its position in that it does not receive much orographic lifting during either rains and may be partially shadowed by the hills during the November to December rains. The Maasai Centre does not receive appreciable lifting at anytime of the year. It appears that Kiserian (Apostles of Jesus Station), at the edge of the hills, receives the benefit of orographic lifting during the short rains of November to December when winds are stronger than during the long rains. The mean values for the two rain periods shown in the following charts indicate the greater relative amounts received by the Kiserian area during the short rains. This may be extrapolated to the entire southeastern face of the hills (albeit with some uncertainty) and indicates that the short rains may be relatively more advantageous for planting in that area.

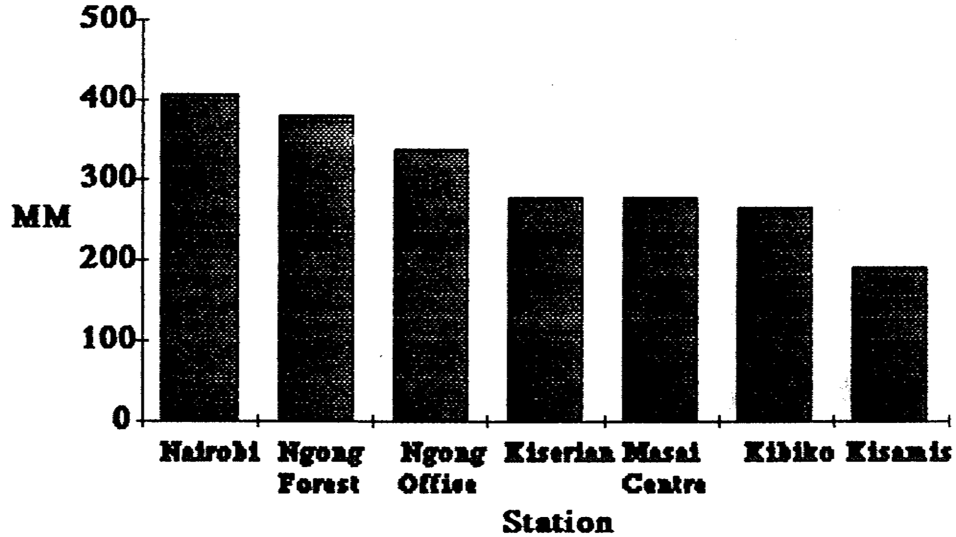


Figure 9. Mean Rainfall, April - May

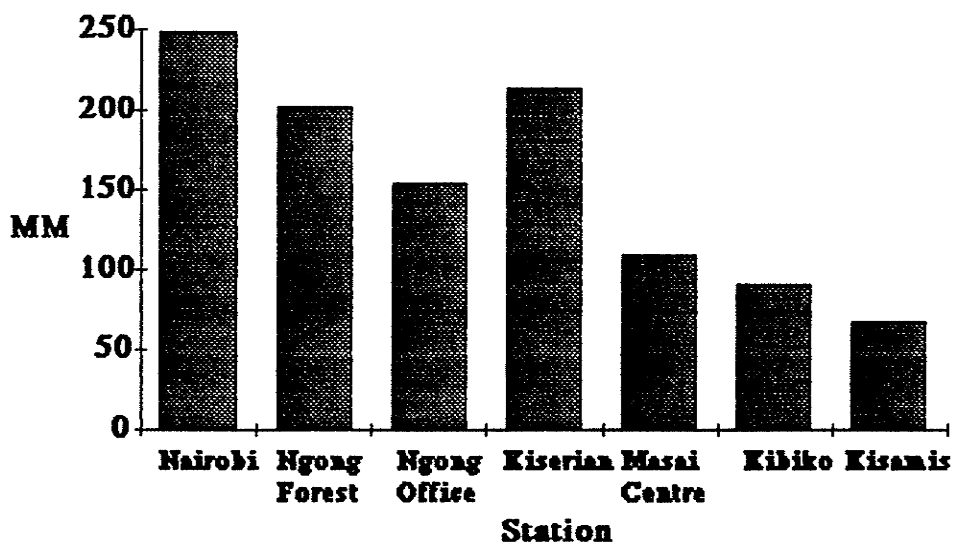


Figure 10. Mean Rainfall, November - December

The values for Ngong Office Station on the other hand indicate greater values during the long rains. If resources for forestry planting are limited and both areas can't be planted during both rains, priority should be placed on the south eastern flank during the short rains and on the northeastern flank during the long rains. Further observations are required to confirm this. Note the difference in rainfall between Kiserian and Kisamis, a distance of only 6 km. Also note the difference between Ngong District Office and Kibiko. A drop in rainfall of over 200mm per year occurs over a distance of only 3 kilometers.

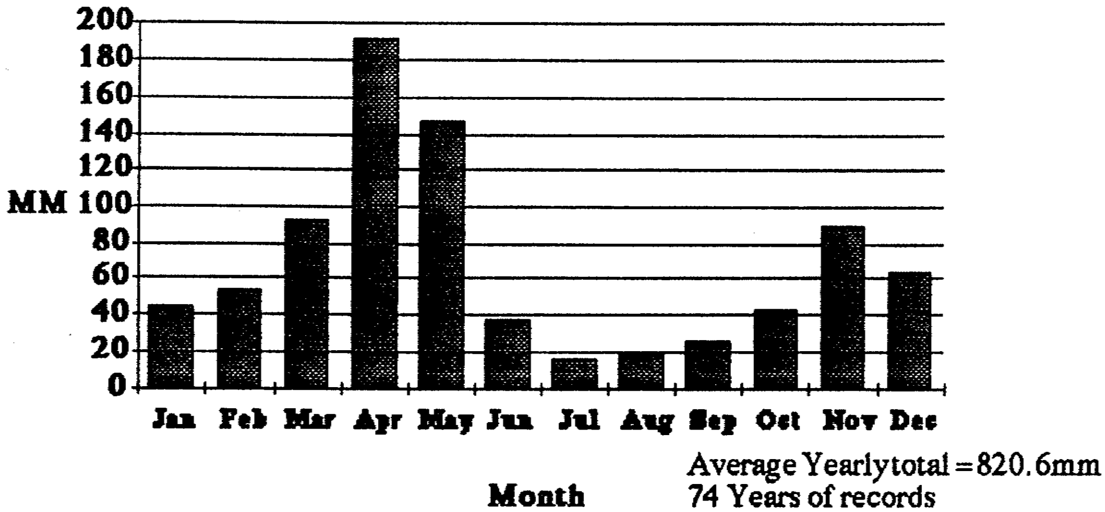


Figure 11. Mean Monthly Rainfall, Ngong District Office

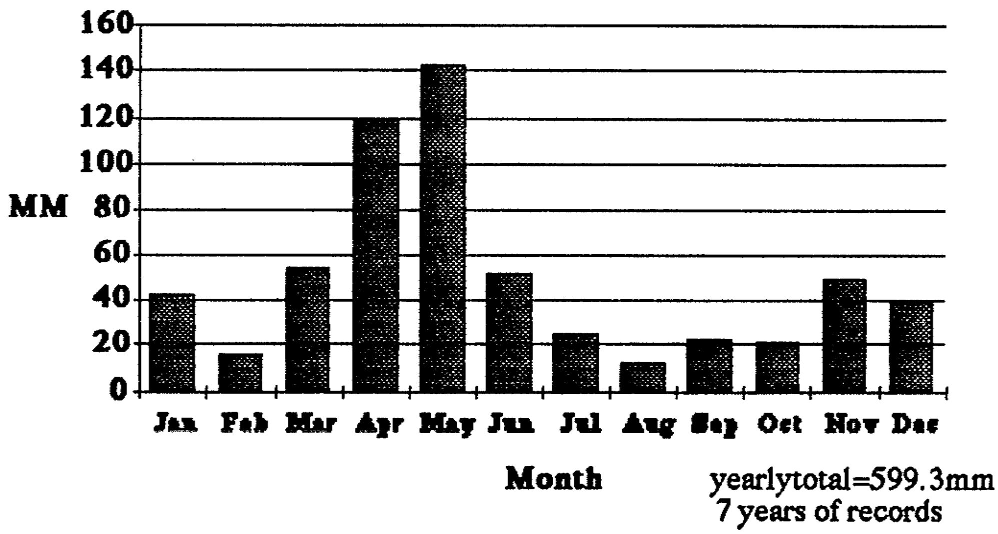


Figure 12. Mean Annual Rainfall, Kibiko "A", Gathakos Farm

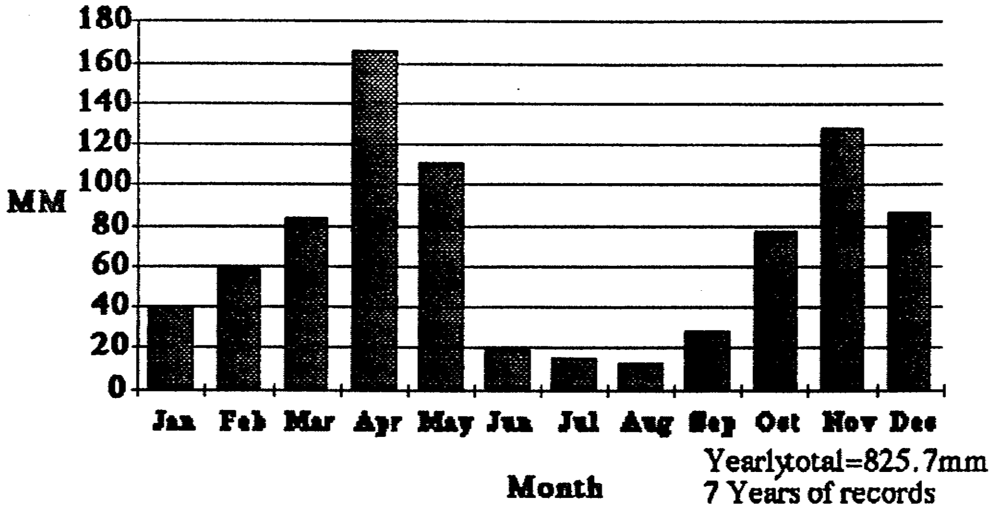


Figure 13. Mean Annual Rainfall. Apostles of Jesus Seminary (Kiserian)

Rainfall extremes for Dagoretti Corner indicate a gap of 979mm. between the highest yearly values and the lowest which are 1632mm and 653mm., respectively. The graph of monthly rainfall extremes underlines the extreme variability. Reliability studies indicate that the area receives less than 750mm. six years out of twenty. The long rains are generally more reliable than the short rains.

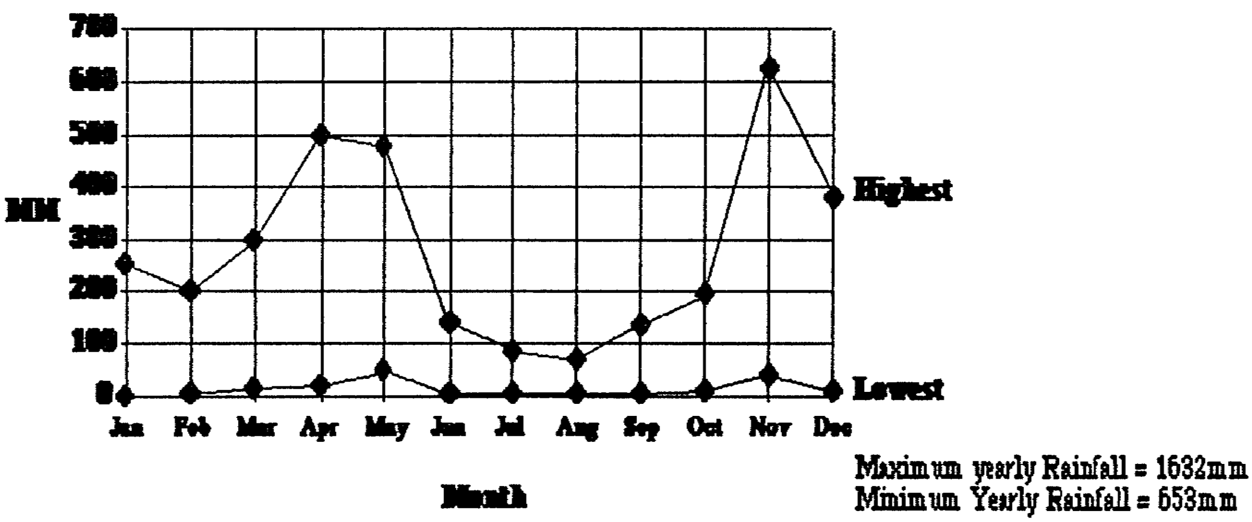


Figure 14. Rainfall Extremes

Maximum 24hr. rainfalls have only been recorded at Dagoretti with the highest single value of 139.1 mm. This has implications for water retention and erosion structures.

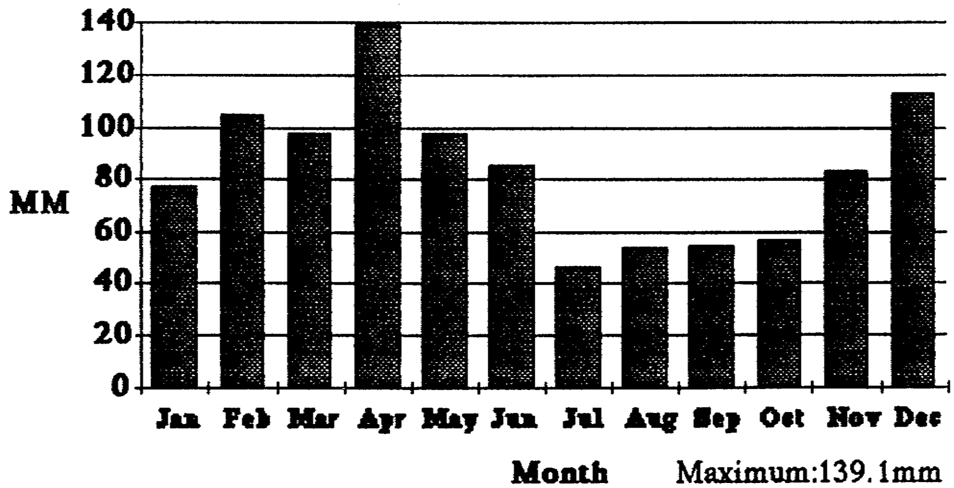


Figure 15. Maximum 24hr. Rainfall. (Nairobi, Dagoretti Corner)

As noted previously, no observations have been made either above the elevation of 2042 meters or immediately to the west of the hills. It is however, obvious from vegetative indicators that these areas are at variance with the available stations. The higher elevations receive more precipitation, although precisely how much more, is difficult to say. Mist and heavy fog is much more common at higher elevations and this contributes to the overall water budget. The general observations on the relationship of rainfall to elevation previously discussed are assumed to hold true for the Ngong Hills. However, it is not possible with the available data, to quantitatively assign rainfall values to these higher elevations. It can only be said that they are undoubtably higher, and at one time, were capable of sustaining a robust dry montane forest.

In contrast, the west side of the hill is far drier than it's eastern counterpart (see chart for Kisamis below). This is due mainly to three factors:

- it faces away from the prevailing rain bearing winds and is therefore in the rain shadow.

- the slopes on the west side are very steep (averaging over 25°) and runoff is accelerated, giving littletimeforinfiltration.

- the west facing slopes receive the hottest and most drying rays of the sun.

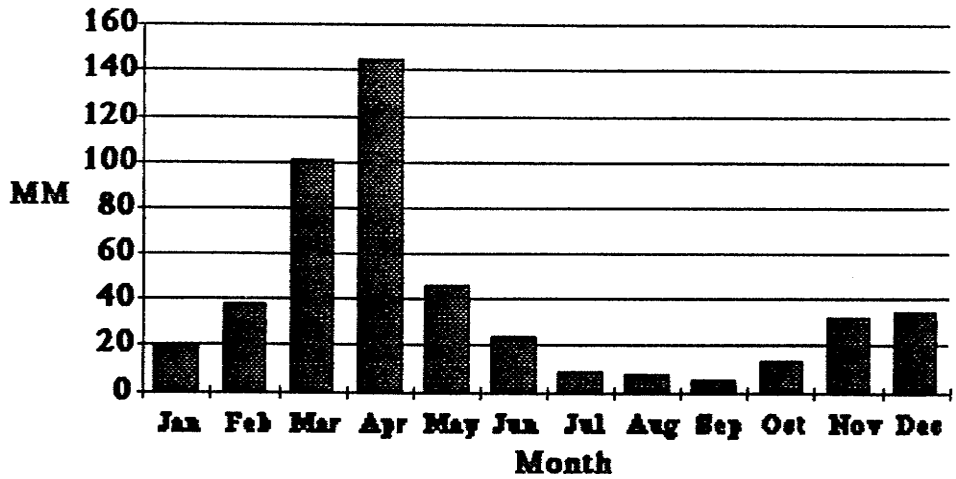
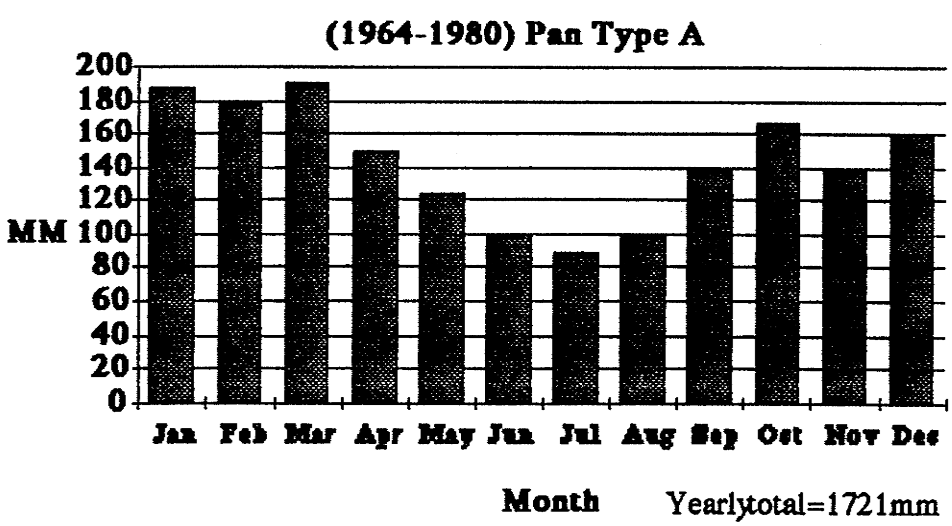


Figure16. Mean Monthly Rainfall. Kisamis Primary School Yearly Total = 477.8mm

3.2.3.4. *Evaporation, Radiation, and Relative Humidity*

Evaporation measurements are only available for Nairobi-Dagoretti Corner. Evaporation is generally less variable than rainfall regimes (Darnhofer, 1983) and this is demonstrated by the graph of evaporation extremes. It is apparent from the graph for mean monthly evaporation, that the peak evaporation values are during March, followed by January, February and October. The mean yearly evaporation is 1721mm. The highest annual evaporation was 1951mm. while the lowest was 1519mm.



Yearlytotal=1721mm

Figure 17. Mean Monthly Evaporation, Dagoretti Corner, Nairobi

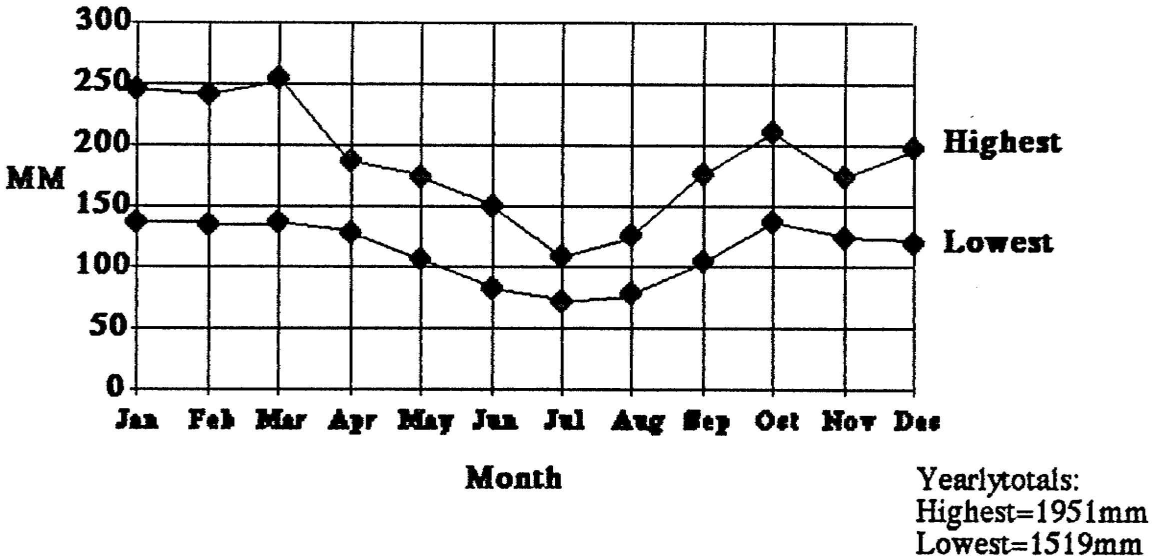


Figure 18. Monthly Evaporation Extremes, Dagoretti Corner, Nairobi

Average daily radiation figures show February to have the highest values, followed by January, March and December. The mean daily radiation over the entire year is 455 langleys. The mean daily sunshine in the area is 6.9 hours.

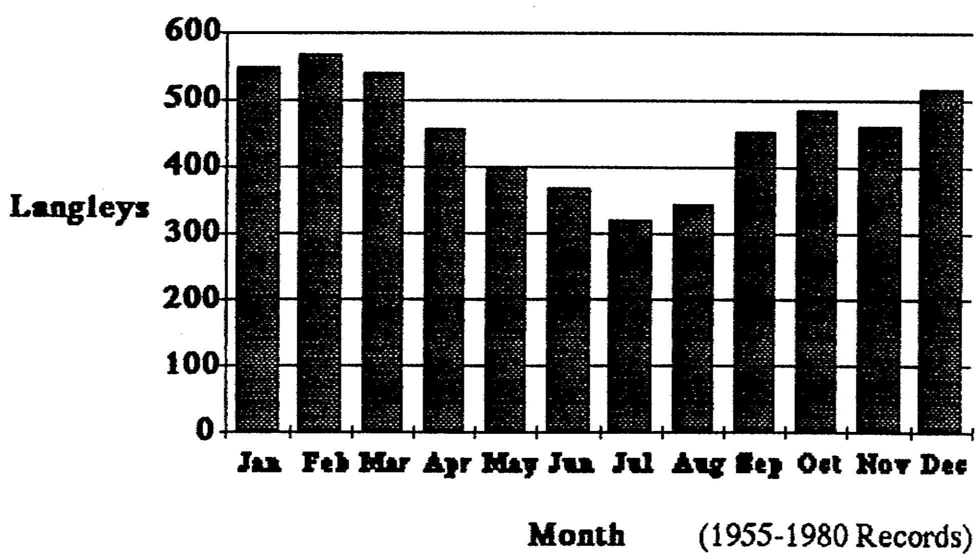


Figure 19. Average Daily Radiation, Dagoretti Corner, Nairobi

Average relative humidity is consistently above 90% at 0600 hrs., while at 1500hrs. the values range from 36% in April to 61% in May. The yearly average for 600hrs. and 1500hrs. is 93% and 50% respectively. Using these two values the average relative humidity for the entire year is 72%. Heavy mist is a frequent occurrence, particularly at higher elevations.

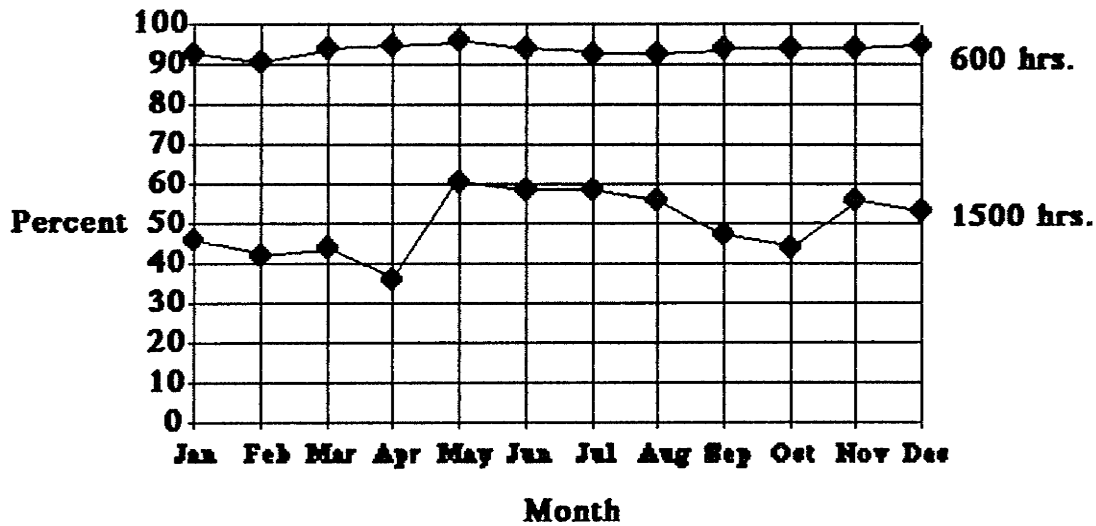


Figure 20. Average Relative Humidity, Dagoretti Corner, Nairobi

3.2.3.5. *Temperature*

Temperatures are fairly constant throughout the year, with average monthly temperatures varying no more than a few degrees. The average temperature at Dagoretti (1799m) is 17.6°C. Using a lapse rate of .55°C per 100m in elevation change, the average temperature at the summit of the Hills (2460m) is calculated to be 14°C. Frosts are uncommon in the agricultural zone but do very occasionally occur at the highest elevations. The highest temperatures occur in March while the lowest are recorded in July. The greatest daily range of temperature occurs in February.

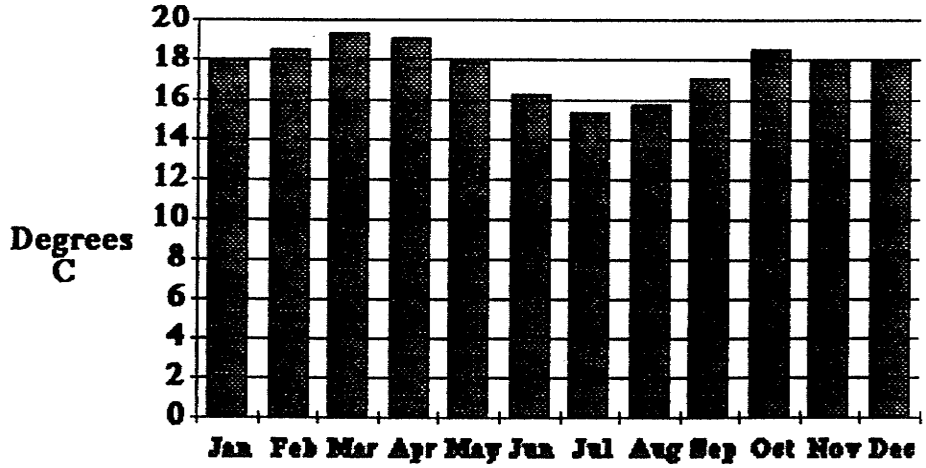


Figure 21. Average Temperatures. Dagoretti Corner. Nairobi

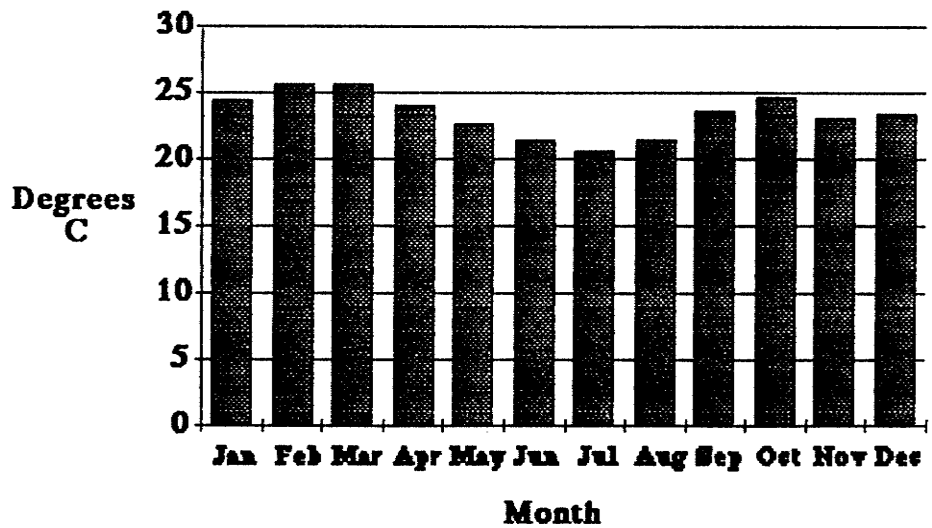


Figure 22. Mean Maximum Temperature. Dagoretti Corner. Nairobi

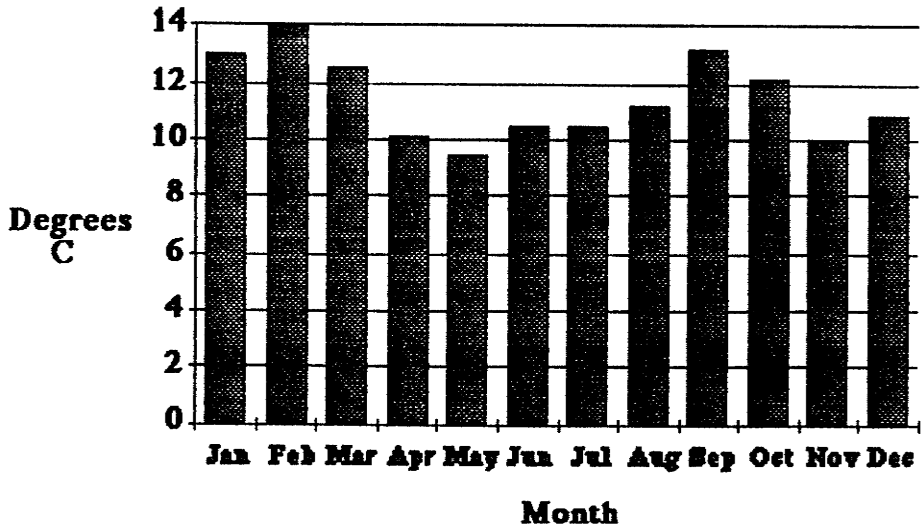


Figure 23. Mean Minimum Temperature, Dagoretti Corner, Nairobi

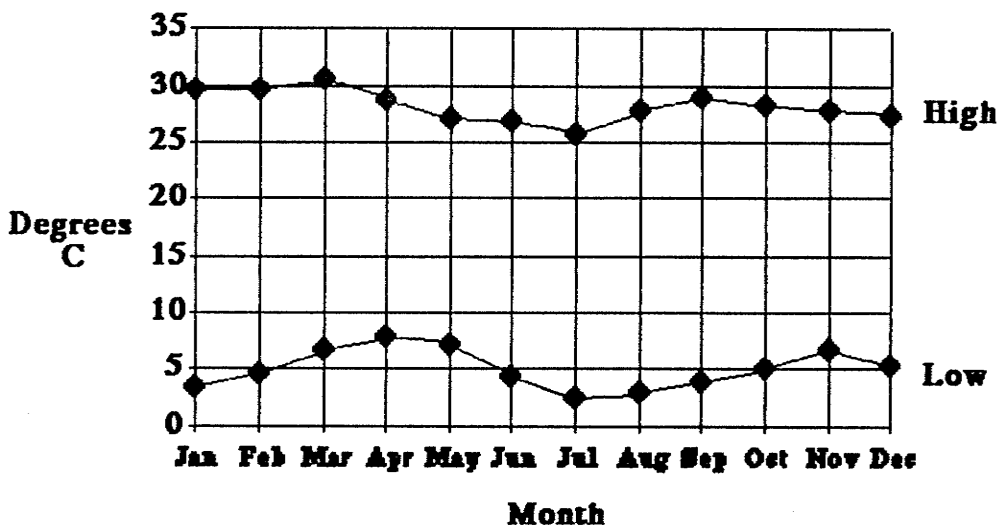


Figure 24. Temperature Extremes, Dagoretti Corner, Nairobi

3.2.3.6. *Winds*

Wind data is only available from the Nairobi-Dagoretti Station. From this it is apparent that both daily wind run and mean wind speed are at a maximum in December. Winds remain high during January , February and March, which coincides with the period of highest potential evaporation. November winds are also relatively strong.

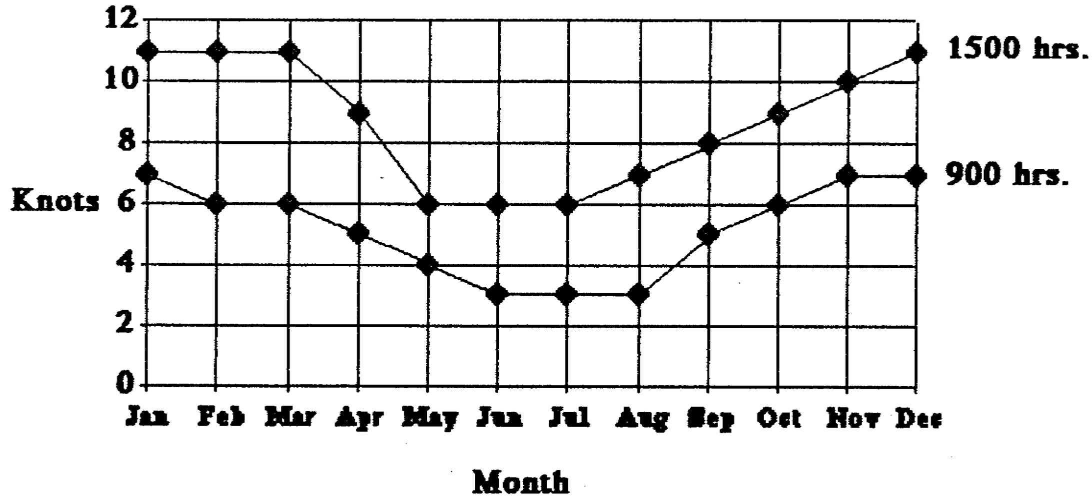


Figure 25. Mean Wind Speed, Dagoretti Corner, Nairobi

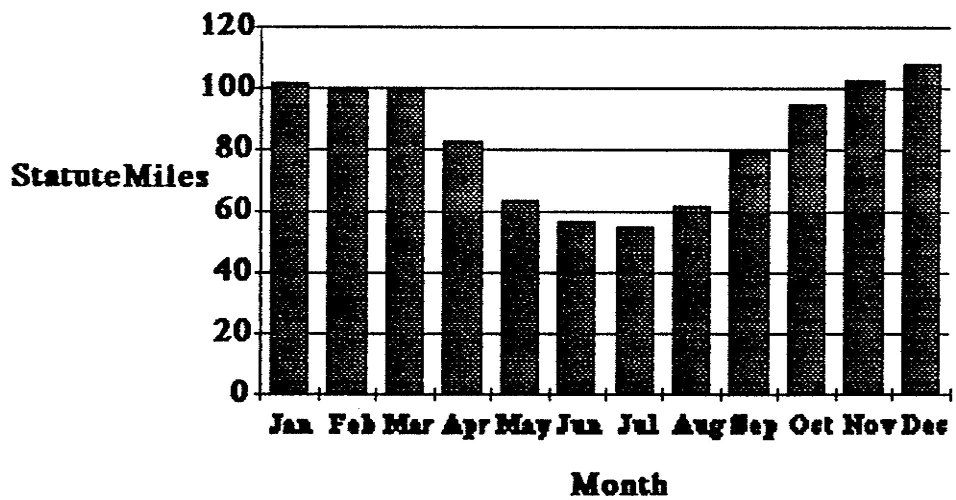
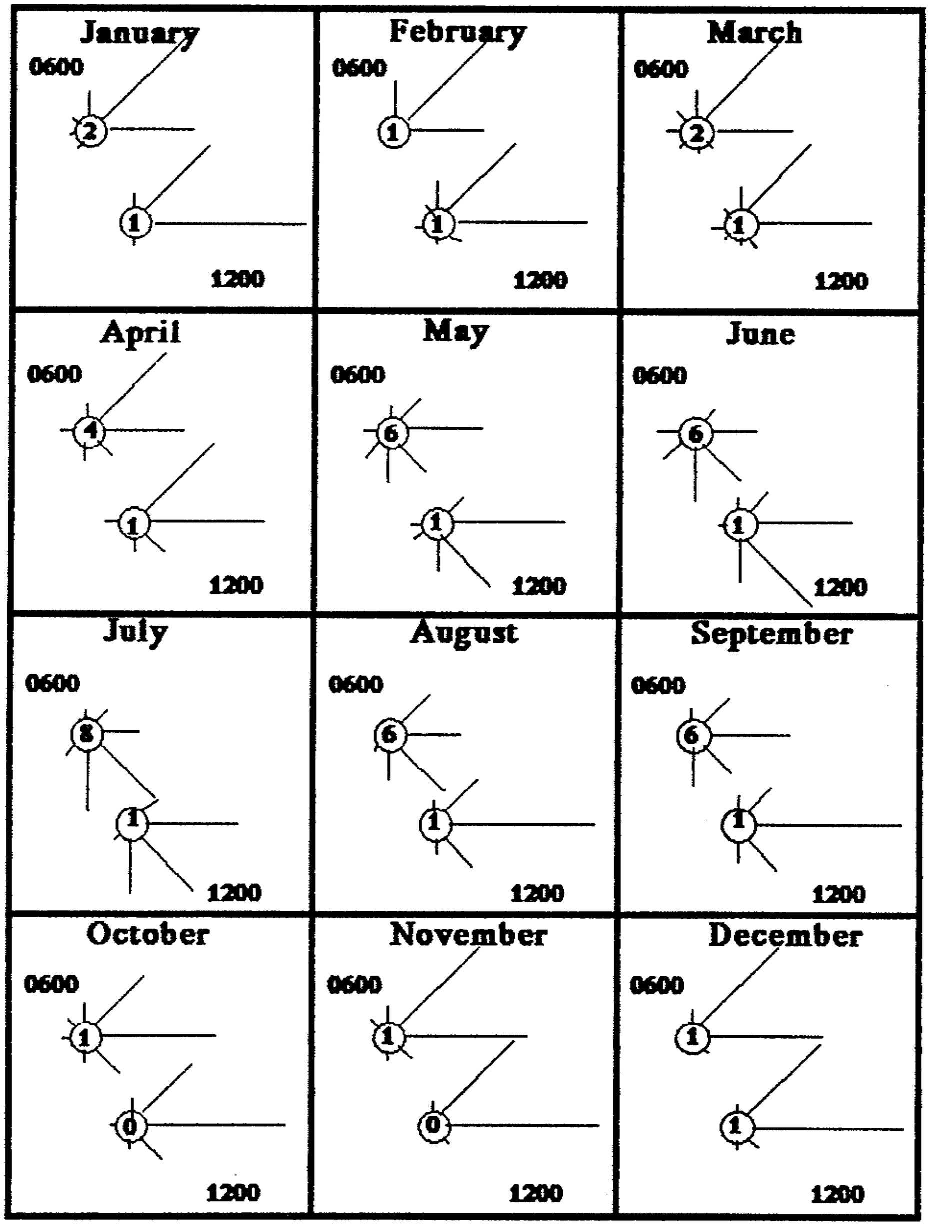


Figure 26. Daily Wind Run, Dagoretti Corner, Nairobi

Wind direction is modified by the prevailing monsoons, and is predominantly northeast to east in October to April, while it is east to southeast the rest of the year. The following chart of wind roses indicates the relative frequency of wind direction (represented by line length).

The general winds in the area, represented by the Nairobi data, are strongly modified by the topography and vegetation of the Ngong Hills. As the orientation of the hills is north-northeast, the prevailing northeasterly to southeasterly winds often strike the hills perpendicularly, maximizing the effect of the topography. The prevailing winds blow straight up the many side valleys. This does not generally allow the development of convective slope and valley winds that might otherwise occur.



NOTE: Line length represents relative frequency of observation. Numbers in circles are calms.

Source: Kenya Met. Dept.

Figure 27. Wind Direction by Month, Dagoretti Corner, Nairobi

Topography and changes in elevation affect winds in several ways. Winds, that in adjacent areas are aloft, become surface winds at higher elevations. This is evident in the Ngong Hills as the wind speed rises with elevation and strong winds are almost always present near the summit. The "corner effect " is also noticeable on the Ngong Hills . As the mountain stands as a relatively isolated massif, airflow tends to move not only over it, but around it. The resultant pressure differential causes the wind to both speed up and "wrap around" the corners of the hill. This effect contributes to the excessive winds at both the southern shoulder of the hills, and the Kibiko area at the northern end of the study area. This is coupled with a lack of significant vegetative cover. The flow is therefore unrestricted and high, greatly contributing to desiccation. Flow over the mountain produces some turbulence and eddying on the steep lee side. This turbulence decreases with distance from the summit and winds are significantly lower than on the windward side.

3.2.4. Summary

The climate of the Ngong Hills exhibits extreme variability, mainly as a result of topographic influence. Rainfall patterns cause some of the area to be classified as semi-arid while the higher elevations of the eastern flank are sub-humid. This variability naturally has implications to future planting plans. The average temperatures decrease with elevation, and, although this not strongly limiting to plant growth, it does affect species selection.

As wind speed is a major factor in the drying rate, it must be addressed in the landscape plan. The very drying northeasterly and easterly winds should be modified. This is particularly true for the northern shoulder which experiences strong winds due to it's position. This has been aggravated by forest clearing. A reduction in wind speed can appreciably increase both available moisture and crop yields. As evidenced by the existing vegetation on wind sheltered sites in the hills, seemingly slight improvements in shelter can make a large difference in growth rates and seedling establishment.

In summary, the major climatic constraints to agriculture and silviculture are low and unreliable average rainfalls and high winds. These factors will have to be addressed by farmers and foresters if the full potential of the area is to be realized.

3.3. HYDROLOGY

The importance of the water resources of the Ngong Hills cannot be over emphasized. The springs, surface waters and both deep and shallow aquifers, supply many thousands of people and animals with their water requirements. In addition to the rural settlement areas in the hills themselves, domestic water from the Ngong Hills is supplied to Ngong Township, Bulbul, Kibiko, Kiserian and Kajiado (see Infrastructure - Water Supply). Countless other people outside of the study area, depend upon water having its origin in the Ngong Hills including, to some extent, those drawing from the Karen-Langata aquifer which is thought to be contiguous with the Ngong aquifer and recharged from that area. Water demand is rising in concert with population increases and already serious shortages are occurring. Water rationing is occurring in all the piped water schemes in the study area as well as in Ngong Town itself.

There are no major rivers in the study area although the hills contribute to the Mbagathi, Nol Choro, Kandis, rivers to the east and the Loodo Ariak River to the west. No less than twenty-five small streams have their origins high in the hills on both the eastern and western flanks. Almost all the springs and surface water is seasonal. Whereas, several years ago there were ten permanent springs on the hill, now there are only two.

3.3.1. Geological Influences

The hydrology of the Ngong Hills is dominated by the underlying geology and topography of the area. The flows of the watercourses are complex, with many streams originating as springs high in the hills, flowing more or less permanently in the upper most regions, then disappearing in the lower sections only to re-emerge downstream. Erosion in the stream beds is not significant as flow in most streams has reached the lava sheet. The sheets are often stepped due to minor faulting, and alluvial material has built up behind these changes in level until grade is reached.

Boulders and other alluvial materials have been accumulated in the many V-shaped valleys. It is into these permeable materials that the streams percolate, giving rise to considerable subsurface flow. In the alluvial plains and basins at the base of the slopes, flows are most likely in buried stream channels and gravel seams overlain by silt. Faulting and subsurface dipping of the underlying lava flows creates underground storage areas and sizeable shallow aquifers. In many locations where the alluvial basin is approaching grade, small swamps and springs are present. It is evident that a considerable water volume is available from shallow sources such as trenches and wells in streambeds, particularly at the toes of the hills. Currently the shallow wells in the area are seldom completely dry although this situation has been deteriorating in recent years and water level recovery times (after pumping), are increasing.

Because of these subsurface flows in porous material, stream gauging in the area does not give an adequate representation of the water available. Stream observations, carried out in 1974 during a study of the Ngong water supply, were "highly variable" (Bell, 1974) and inconclusive. For this reason they have not been used in any calculations.

As previously stated in the geology section, the series of lava flows that occurred in the Ngong area were separated by periods of time sufficiently long to allow the formation of soil layers, as well as the accumulation of ash from nearby volcanic eruptions. These layers, intercalated between lava flows, provide the basis for substantial deep aquifers. " These dip to the west in the vicinity of Ngong village and progressively change to a shallow dip to the east, south towards the Magadi Road." (Halse, 1974)

A drilling programme, initiated in 1976 to investigate the potential of tapping the deeper aquifers in the area, confirmed that the area of greatest potential lies near the major north -south trending fault which lies close to the lower road from Ngong to Kiserian (just outside the study area). The Drilling Report #1 for the Ngong -Kajiado Water Supply Project states:

> "......it can be established that the ground water potentials of the Ngong-Kiserian area are highly promising depending on the penetration of the deeper confined aquifers. The deeper aquifer is of a fluviatile nature and has approximate yields of 15-20m^3/h. All other aquifers above this yield are approximately 5-10m^3 ....According to records available for borehole No. C3937, it is evident that a high yielding aquifer exists at depth in the project area. Tests carried out at this borehole revealed increasing yield with depth. The yields were 2.3m^3/h, 2.7m^3/h, and 35.7m^3/h at depths of 127m, 221m, and 260m respectively.
>
> It can be noted that the deeper confined aquifer in the Ngong - Ololua area is most productive. However, the aquifer becomes less productive southwards probably due to reduction in it's thickness.
>
> It is not possible to estimate recharge due to lack of information from the few existing boreholes and hence safe yield cannot be assessed satisfactorily. However, an abstraction rate of 20m^3/h, which remains to be proven by further exploration in the whole area seems reasonable enough to maintain ground water balance."
>
> (Ministry of Water Development, 1976).

3.3.2. Recharge to Groundwater

An estimate of the amount of water going to recharge subsurface water reserves is necessary if accurate estimates of water availability for plants are to be made, not to mention estimates of safe ground water withdrawals for other uses. The water balance equation is as follows:

$$P = E + S + Ro$$

where:

P = Precipitation
E = Evapotranspiration
S = Change in soil water storage
Ro = Runoff

However, such estimates are difficult in the Ngong Hills for a number of reasons:

1) Stream gauging is inconclusive and variable.

2) Rainfall at higher altitudes is only estimated as no permanent gauges are in place. (see Climate)

3) Evapotranspiration values are only available for Dagoretti Corner (Nairobi) and do not accurately account for the Ngong Hills environment in which mist and cloud are frequent thereby lowering the evaporation rate.

4) Soil water storage capacity is only estimated (using 100 mm as maximal values of soil water reserves).

5) Computations have been made on a monthly basis only while a ten day period would have been more valuable if data was available.

Despite these limitations, the water balance for the area has been calculated and is shown in Table 4. Rainfall records from the Ngong divisional headquarters have been used in the calculations as they are the most lengthy and reliable figures for the area. The results indicate that only in the month of May is sufficient water available, (after soil reserve recharge), for ground water recharge. Only 32.2 mm is available at this time. For most of the year a soil moisture deficit exists and absorbs all precipitation. Groundwater recharge theoretically occurs only during the long rains.

The results indicate that there are not great amounts of water available for extraction. In fact the amount available for safe extraction will soon be exceeded by requirements (according to these calculations and the demands projected by Ministry of Water Development consultants). If 30 km^2 is used as the area of recharge, the total water quantity available is 32.2(mm) x 30 x 10^3 m^3 = 966,000 m^3 per year. The demand on the resource will be 965 060 m^3 per year by 1990 and 1,531,540 m^3 per year by 1995 (Min. of Water Development, 1978). These are only estimates but indicate the critical importance of conservation of water resources. The current water shortages and lowering of borehole water levels in the Ngong area, underline the importance of such measures.

As most of the soils over the aquifer immediately to the east of Ngong are vertisolic (black cotton soils) with low water permeability, the majority of the groundwater recharge must take place in the hills, where soils and faulting etc. are more favorable. Therefore, every effort must be made to increase water retention and to decrease evaporation within the hills. In light of the above calculations, the establishment of more forests in the gazetted forest area and the encouragement of land use systems with significant water conservation components, should be given extremely high priority. These efforts should concentrate on those areas with highest potential for improvement. The accompanying Hydrology map indicates the relative importance to aquifer recharge (both shallow and deep) of the various land units. Those areas indicated as having extremely high aquifer recharge importance should, naturally, be considered.

Further studies are required to confirm these results. A network of rain gauges throughout the hills should be established to provide a more accurate measure of rainfall patterns. At the very least, a gauge should be established at the antennae station at the top of the hill.

3.3.3. Influence of Land Use on Water Resources

Generally speaking, the basic aims of watershed management coincide with those of soil conservation. An area well managed in terms of it's soil resources, ie. protection of the soil forming processes, improvement of nutrient composition and protection and enhancement of soil structure, usually is also reaping the benefits of improved quantity, quality, and timing of stream and subsurface water flows. Pereira has stated that:

> " the basic tenets of the soil conservation discipline are that the soil surface should be maintained in a receptive condition for the infiltration of rainfall and that surface water should be led along gentle gradients without reaching erosive velocities. Where a steep fall is necessary, concrete or other revetment should be provided.........prepared drainage routes should be provided ......and kept free of obstructions." (Pereira, 1973)

Although often related, the coincidence of soil and water conservation objectives is far from universal. A particular conservation structure may reduce soil erosion but not reduce total overland flow, eg. cut off drains which, although they keep water off individual fields, do not encourage water infiltration. In another example, water impoundment projects may lead to concentrations of stock and subsequent soil degradation. The interrelationship of soil and water conservation issues demands an integrated approach to solution generation.

The influence of land use on the hydrologic balance is extremely variable, particularly in tropical regions, where highly seasonal and intensive rainfall is followed by extended dry periods. Clearing of forests, and increases in cultivation, grazing and urbanization, often lead to negative influences on water resources. Fire, trampling by stock, poor cultivation techniques, and the hardening of surfaces such as roads and residential areas, have contributed to a reduction in the ability of the soil to absorb water. Overland flows are increased, producing larger and more frequent peak or spate flows, leaving little for aquifer recharge. The resultant decrease in subsurface reserves leaves less water available for discharge through springs and boreholes, and, as in the case of the Ngong Hills, these tend to dry up. There is also a decrease in soil moisture retention, as concentration times are decreased. In some cases surface runoff is so accelerated that field capacity is not reached during short rainfalls.

The coefficient of runoff changes with land use and land cover. The following chart indicates the variability. These are broad generalizations and vary with cultivation practices, forest type, slope (angle and length) and soil structure.

Table 3. Coefficients of Runoff for Various Land Covers

Land Cover	Overland flow	Recharge flow	Coefficient of Runoff
Forest	10 - 20%	80 - 100%	0.1 - 0.2
Cultivated	50 - 60	40 - 50	0.5 - 0.6
Residential	40 - 50	50 - 60	0.4 - 0.5
Urban	90 - 100	0 - 10	0.9 - 1.0

(source: Marsh, 1983)

3.3.3.1. *Forests*

It has been repeatedly stated by many authors that there is no evidence that forests can effect the total amount of precipitation an area receives. (Pereira, 1973; Penman, 1963) However, the myth persists and it is interesting to note that many people in the Ngong area say that one of the major reasons they plant trees is "to increase rainfall" (see farm questionnaire results) Of course, there are hydrologic benefits of forests, but these are related to the disposition of the precipitation that does fall. As the previous table shows, runoff is decreased and subsurface infiltration is increased. In undisturbed forests, water infiltration to the soil is predominantly through the macro pores which dominate the total pore space (Humbel,1975). Overland flow is considerably reduced , even in areas of very high rainfall.

Molehanov (1960) summarizing extensive Russian research, states that shelterbelt forests along the contour provides maximum water yields. If only 6% of the watershed area is forested in this manner, overland flow is halved. If 30 to 40 percent of the watershed is so treated, " the entire surface runoff is transferred to subsoil and erosion is thereby prevented." (*in* Pereira, 1973)

The total water vapour loss in a watershed is equal to evaporation plus transpiration. The effect of a forest on this loss must be calculated on the basis of the individual characteristics of the forest type involved (canopy closure, foliage characteristics etc.). It has been reported that forests transpire up to 10% more water than most grasslands, although some deep rooted grasses, like *Cynadon dactylon*, have higher rates. In addition, evaporation rates from the soil surface are significantly lower in forests with complete canopy closure than in grasslands due to a reduction in wind speed, radiation, andtemperature.

Although total precipitation amounts are not increased, it has been shown that forests do influence the presence and frequency of slight rainfalls and mists (Parsons, 1960), a common occurrence in the Ngong Hills. Water vapour condenses on foliage and stems and subsequently drips to the ground. The benefit of mist is threefold; firstly, it reduces transpiration rates; secondly, there is some absorption and utilization through the foliage; and thirdly, in prolonged and heavy conditions, there is soil moisture recharge.

It has been stated that light dry season rains:

> " falling on a forest canopy with transpiration restricted by dry soils will greatly increase the rate of loss of water vapour. However, the same rate of light rainfall in calm misty conditions on a cold wet landscape................will have little effect on the rate of vapour loss since neither heat energy to evaporate more water nor air movement to remove more vapour is available."(Pereira, 1973)

Despite the increase in rainfall interception and transpiration, it has been conclusively shown that forests tend to absorb heavy rainfall and allow it's infiltration to the soil through the forest floor litter. Such infiltration and storage of water reserves for slow release, reduces rain season spate flows and improves the water timing regime. The benefits of the forest in the upland collection areas are often realized by downstream water users in the form of more permanent streams, shallow wells and springs, as well as higher water quality.

3.3.3.2. *Grassland*

There appear to be two opposing factors at play in the effect of grazing and grassland management on the hydrologic cycle. Firstly, if erosion and rapid overland runoff is to be avoided, the grass sward must be kept in such a condition that soil surface protection is maintained. Overstocking and excessive trampling must be minimized in order to allow optimum sward development. On the other hand, the denser and more productive the grassland is, the more water is consumed by the plants and the less is available for other purposes. Rates of water use by African grassland species vary tremendously. Very deep rooted species such as *Cynadon dactylon* often produce and maintain soil moisture deficits, which in drier areas can preclude groundwater recharge. The optimal timing of subsurface flow, and the protection of soil and water quality through reduction of peak overland flows, has a price, namely the substantial use of potential water reserves by the vegetation.

If it is to provide maximum benefit, the management of an area for both grazing and water, must strike a balance between optimal vegetative growth and fodder production. Generally, water yields are directly related to grazing intensity, but this may be offset by increases in sediment loads and long term reductions in vegetative productivity due to soil erosion. In several areas of the Ngong Hills overgrazing, attributable mainly to poor stock distribution, is causing excessive amounts of bare ground and subsequent erosion. A system of rotational grazing which excludes stock during periods of maximum vegetative growth is necessary. In addition, stock and game trails are often poorly located and maintained, contributing to the velocity of overland flow.

3.3.3.3. *Cropland*

The effect of arable agriculture on the hydrologic resources of the region are many and complex. Although cultivated crops have water requirements which seasonally reduce soil moisture reserves, these are often less than the natural vegetation they replaced. The majority of annual crops in the Ngong Area have much shorter growing seasons and use less water than the herbs, shrubs and trees that once grew in their place. The exception to this is where the area was natural open grassland.

The distribution of rainfall to overland flow and soil infiltration, is the area of greatest concern. Overland flows are considerably increased in the absence of suitable precautions. Repeated tillage changes surface soil structure, reducing it's infiltration capacity, while at the same time, increasing it's tendency to be transported by water and wind. Sheet, rill and gully erosion are often the result. As most annual crops do not completely cover the soil surface, particles are exposed to the full and substantial kinetic energy of impacting rain droplets. This force can dislodge particles and destroy soil aggregates. The effect is to both reduce surface porosity, leading to "puddled" and compacted soils, and to increase sediment loads in streams and reservoirs.

The degree of impact that cultivation has upon the hydrology of an area is dependent on the particular crops involved, the cultural practices and the structures or landscape elements (terraces, micro catchments etc.) present on the farm. Wisely practiced cultivation, utilizing a high degree of plant coverage of the soil surface, proper crop rotation, contour tillage, terracing, and low velocity grassed waterways (as required), can contribute positively to the overall hydrologic characteristics of a region. Those cultivations which leave the soil surface completely covered for most or all of the year, such as zero tillage or zero grazing crops (napier grass etc.), reduce hydrologic damage even further. As in grassland management, deep rooted crops give conflicting results. They may produce vigorous growth but at the cost of greater water consumption, although this may be soil moisture not otherwise available for agriculture. The cost therefore, is not to the individual farmer but to the local subsurface water reserves.

3.3.3.4. *Agroforestry*

Agroforestry " is a collective term for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either under the same form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions between the different components. " (Labelle, 1983).

Agroforestry has the potential to address many water related issues. The effects, of course, are highly variable as the scope of possible interventions is large. Many of the previously mentioned advantages of croplands, grasslands and forests, can be realized with agroforestry systems. Such improvements as reduction of evaporation losses by increasing shade and reducing windspeeds; improvements in soil structure and fertility; the creation or reinforcement of water retention/harvesting structures; rehabilitation of erosion features and other degraded lands; utilization of deeper soil water reserves; and reduction of pressures on critical protection areas by more intensive production elsewhere, are among the possible benefits. In the application of agroforestry systems there are often conflicting results, eg. the utilization of deep rooted water loving tree crops raises the issue of local utilization of water reserves vs. regional benefits of ground water recharge. As with other possible interventions, priorities must be established.

3.3.3.5. *Settlement*

The effect of settlement on the hydrologic regime is often extremely negative. As previously shown runoff and spate flows are dramatically increased as infiltration rates are reduced. Not only are recharge rates reduced but the quality of both surface and groundwater is usually lowered due to pollution. In the Ngong Hills, pit latrines are the most common form of sewage disposal. While this is acceptable throughout most of the area, it is not advisable in the stream conveyance zones as the risk of pollution of shallow aquifers is substantially increased. In the conveyance zones, pump out tanks or gas digesters should be encouraged.

In the high density settlement areas of Ngong Township more serious problems exist. The sewage system of the town should be rehabilitated and all new buildings should be connected to it. The Kijiji settlement has no proper sewage system and this presents a threat to water resources not to mention the health hazard.

3.3.4. Planning and Management Implications

> "As the Incas and their descendents have successfully demonstrated with their irrigation systems, soil and water management requires simple skills and discipline rather than complex and expensive techniques." (Pereira, 1973)

The Ngong Hills have under gone rapid change in land use patterns and this has resulted in a lessening in available water for both agriculture and domestic use. A rapidly expanding population is making ever increasing demands on a dwindling resource. As mentioned previously there are a number of options in water management and priorities have to be placed. Available water can be directed towards soil moisture reserves for utilization by local agriculturalists, it can be impounded in storage reservoirs for use by livestock or humans or, it can be directed towards groundwater reserves for withdrawal by more distant users. Clearly, in the Ngong Hills, the widespread importance of the water resources demands that the solution encompass all of these options.

Great demands are being placed upon the groundwater reserves by the regional population. An extensive water pipe infrastructure has been installed and is under expansion. Such demand and investment cannot be ignored and implies a concerted effort towards deep aquifer recharge as the piped water is supplied by boreholes. However the opportunity cost involved in making the collection area strictly a watershed protection forest is far too high for a nation such as Kenya to absorb. The area must serve other production objectives and the water considerations must be integrated with those of other uses. Therefore groundwater recharge should receive highest priority in those areas where it would be most effective and where it doesn't conflict with other demands. This is in the collection zones of the gazetted forest reserve area, particularly in the vicinity of faults and in areas of deep porous soils. A programme directed towards increased infiltration, integrated with wildlife, grazing, fuelwood, and recreational concerns is required for that area.

Measures have been identified by the government to alleviate the situation and efforts have been made to reforest the area. However, success has been less than satisfactory and a more concerted effort is required. Species selection will have to be more rigorous and planting techniques more appropriate if establishment is to occur under the difficult conditions.

Soil moisture reserves are seasonally depleted and 96% of all farmers report unreliable timing of rains and mid season moisture stress. Poor crop yields are almost universally blamed on water shortages. As the land under agricultural production is the primary support of a great number of people, this issue should be addressed in the water management of the area. It is obvious from the calculations that there will never be enough water in the area for extensive irrigation even if suitable areas could be identified. The greatest potential for improvement lies in small scale water harvesting and reduction of evaporation. Improvements in soil structure and composition (organic matter % etc.) would also improve the soil moisture regime. Windbreaks have enormous potential for reducing evaporation rates particularly in the Kibiko area.

Water impoundment in the valleys near the forest reserve boundary, as proposed in the Ole Tomeno brief may be very difficult given the nature of the basins. Very few are water tight and, while the topography may be appealing for dam construction, detailed investigations are required to ensure that the dams will not leak through geological faults or subsurface porous material. Failure to carry out detailed investigations could result in much wasted effort. Impoundment is more practical on the vertisolic soils at the very toes of the foot ridges. These sites could be used for a number of purposes including limited irrigation of specialty crops or nurseries.

The benefits from proper water management are realized by many others outside of the area. For this reason farmers who invest both time and capital to bring about conservation should not be expected to bear the full costs for projects which will benefit the public. Indeed, if they are they probably won't carry them out as the return on investment may not be sufficient. Credit and other incentives are required.

In summary watershed management in the area must be multi-facetted, addressing not only hydrological concerns in a number of ways, but also other local and regional requirements. In this way scarce resources will be used in the most efficient manner.

Table 4, Water Budget for the Ngong Hills

Period	ET	Prec.	WD	WS	EL	GCH	GST	Ro	Ep	P/Eo	Class	Ep/Eo
January	140	44.0	96.0					0	44.0	.24	SA	.24
February	134	53.2	80.8					0	53.2	.30	SA	.30
March	143	92.5	50.5					0	92.5	.48	SH	.48
April	112	191.2		79.2		79.2	79.2	0	112.0	1.28	H	.75
May	93	146.0		53.0		53	132.2	32.2	60.8	1.18	H	.49
June	74	37.6	36.4			-36.4	95.8	0	74.0	.38	SA	.76
July	67	15.4	51.6			-51.6	44.2	0	67.0	.17	A	.75
August	75	19.0	56.0			-44.2		0	63.2	.19	A	.63
September	104	25.2	78.8					0	25.2	.18	A	.18
October	125	42.6	82.4					0	42.6	.26	SA	.26
November	105	90.1	14.9					0	90.1	.64	SH	.64
December	120	63.8	56.2					0	63.8	.40	SH	.40
Total/Avg	1292	820.6	603.6	132.2		X	X	32.2	788.4	.48	SH	.49

Eo = Potential Evaporation (pan type) in mm
ET = Potential Evapotranspiration in mm (0.75 x Eo)
P = Precipitation in mm
WD = Water Deficit= ET P
WS = Water Surplus = ET P
EL = Evaporation Loss (small quantities which cannot be used by crops)
GCH = + Ground Charge - Ground Discharge
GST = Ground Storage (Maximum assumed to be 100mm)
Ro = Runoff (surplus after 100mm ground charge)
Ep = Effective Rainfall: Ep = P-EL - Ro - GCH
P/Eo = Water availability ratio without ground water reserves (climatic hygro period)
Ep/Eo = Water availability ratio with ground water reserves (edaphic hygro period)

A = Arid
SA = Semiarid
SH = Subhumid
H = Humid

*** Altitude= 2042 meters   Latitude 1° 18' S   Longitude 36° 45' E**

3.4. SOILS

The varied topography of the Ngong Hills has contributed to the development of several soil types in the area. Although the soil genesis was no doubt influenced by the former climate (which was much more humid), it is the nature of the country that is the dominant force. The rock formations, their altitude, the manner in which they have been dissected and eroded, the effects of the fauna and flora, slope, and time, have all contributed to the formation of the present soils of Ngong.

The soils of the area have had a complex evolution and often the profiles reveal that they are the result of the weathering of volcanic ash that fell on well developed soils. In several routine auger samplings, layers of ash have been found interspersed with soil, indicating that a sufficient length of time passed between ash falls to allow soil development. Ash has been found on both ridges and valleys, proving the ash fell on an uneven previously eroded land surface (Pulfrey, 1948). William Pulfrey (1948) in an unpublished report on the stone deposits of the Ngong area noted the ridges have much less ash than the valleys, which, he claimed, were filled with deep layers of the material. The present soil survey has found common evidence of ash fall throughout the study area, although never in the copious amounts reported by Pulfrey.

The most common soils of the area are andosols, luvisols, regosols, and nitosols on the ridges; nitosols and luvisols on the eastern flank; andosols, lithosols and rock outcrops on the western flank; and vertisols with some phaeozems in the valley bottoms and plain areas. The soil depth is highly variable, ranging from less than 10 cm. in many areas on the western slopes to the extremely deep (often over 2 meters) nitosols on the eastern slopes. As the soils have been developed over impervious lava sheets they often exhibit slight seasonal impeded drainage.

3.4.1. Soil Survey Methods

As an initial literature search revealed, there had been no soils investigations in the Ngong Hills other than the reconnaissance survey for the entire country done at a scale of 1:1 000 000. Clearly this was inadequate for planning purposes and a semi- detailed survey was carried out by the author. Black and white aerial photography from 1978 at a scale of 1:12 500 was acquired, and an uncontrolled mosaic assembled. In addition the area was rephotographed in 70 mm black and white format at a scale of 1:10 000. An uncontrolled mosaic was also assembled from that photography. Using both the mosaics and stereoscopic photo pairs, an initial interpretation based on landforms was done. Preliminary land units were identified and routine soil auger hole locations were selected. The density of augerings was variable with the highest number being placed in the cultivated areas on the eastern slopes below the forest reserve. The logic in this approach is obvious, namely that management intensity should determine sampling density. Therefore, sampling densities in the cultivated lands approached one augering per ten hectares, while in the forest reserve and western areas, they dropped substantially to one in fifty hectares.

A total number of 450 routine auger holes were drilled with a dutch auger to a depth of 1.2 meters (as soil conditions allowed). The Food and Agriculture Organization (FAO) Guidelines for Soil Profile Descriptions were employed. General observations at each augerhole included: geology, landform, macro and micro relief, slope, position on slope, drainage, present erosion, rockiness, land use, human influence, presence of sealing/crusting/cracking, vegetation type, composition and percent cover of trees, shrubs, herbs, grasses and bare ground. Each horizon in the sample profiles were described in terms of: depth, colour (based on the Munsell Colour Charts, 1971) when dry and moist, mottling, concretions, texture, and consistence. Following completion of the augerhole sampling, soil mapping units were delineated. Representative locations from each mapping unit were selected and soil pits to a depth of 1.5 meters (as soil conditions allowed) were dug and described.

The types of information acquired at the routine augerholes were described at each soil pit, but in greater detail (see soil profile and routine augerhole description forms, appendix 1). Additionally, soil structure was examined and soil samples from each horizon were collected for laboratory analysis. Although thirty such pits were dug and described, only twenty were analyzed in the laboratory and presented in this report. This was due to duplication of soil types and financial limitations on laboratory analysis.

3.4.2. Laboratory Methods

The chemical and physical analysis of the selected soil samples was carried out by the Department of Soil Science at the University of Nairobi. Soils were analyzed for texture, pH, % C, % N, P(ppm), and cation exchange capacity. The methods employed in the analysis followed those specified by the National Agricultural Laboratories of the Kenyan Ministry of Agriculture. Interested readers are referred to the ministry publication Physical and Chemical Methods of Soil Analysis Editors: Hinga, Muchena, and Njihia (1980) for further details.

3.4.3. Cartographic Methods

The soil mapping unit boundaries were finalized on the mosaic at a scale of 1:10 000. This was then photographically reduced to a scale of 1:20 000 and the information transferred to the base map. Information was generalized to the four hectare grid cell used throughout the project. Where mapping unit boundaries on the mosaic bisected a grid cell, the cell was assigned the soil unit with the greatest area. As all information was correlated to the grid, it was logical to graphically present it in this manner. The photo mosaic has been provided in order to maintain the more accurate boundaries should future users require them. Although every effort was made to relate the reduced mosaic to the base map, it must be restated that the original mosaic was uncontrolled and some map registration inaccuracies are bound to have occurred because of this. Slope classes were not identified on the soil map as this was taken into consideration in the delineation of the physiographic site types elsewhere in the plan.

3.4.4. Erosion

The long term sustainability of agriculture and, to a large degree, the prosperity of the people of the Ngong Hills, will rest on the stability of the resource base. Instability in the form of soil erosion presents a serious threat to agricultural yields both in the long and the short term. As soil type and topography vary within the study area so does the erosion potential. Soils with different characteristics such as water holding capacity, particle size,and structural stability are more sensitive to cultivation and will react differently to the same management practices. The most sensitive areas should therefore be left uncultivated or be managed in such a way that is responsive to the particular characteristics that make the soil sensitive.

The major factors affecting soil erosion are:

1) **Topography:** The degree and length of slope determines the amount and rate of runoff.

2) **Rainfall** The frequency and intensity. (heavy storms produce the most severe erosion)

3) **Soil Type:** The resistance of the soil to breakdown and transport by raindrops or running water is a function of particle size, organic matter content, permeability, and degree of aggregation.

4) **VegetativeCover:** Vegetative cover, including crop residues and canopy protection by trees, protects the soil from the impact of raindrops and retards runoff and soil movement.

Erosion has been identified as an important issue in several areas in the hills. Many farmers are well aware of the seriousness of the situation and have taken decisive measures to combat it. Typical conservation measures taken include : the construction of fanya juu terraces, and the installation of rock wash stops, gabions (rare), grass bunds, and cut off drains. Other farmers, equally aware of the problem, have reacted to a lesser degree for a variety of reasons including:

feeling of lack of benefit for work on common land, lack of available labour and technology, lack of security of tenure (in the case of leasehold land), or most commonly, lack of appropriate seed and tree seedlings. There is little use of vegetation for rehabilitation of degraded lands although preventative measures are becoming more common.

Soil erosion is occurring on cultivated lands, road right of ways, and to a lesser degree on grazing lands and around watering points. Erosion is of course occurring to some degree on all soils due to the influence of rainfall and associated waterflows in streams, field furrows, ditches and across slopes. Sheet, rill, and gully erosion are the most common kinds occurring in the area. Sheet erosion, although not as obvious as the other two types, may in fact be the most serious, as it occurs over all sloping lands (with varying consequences) in a quiet, insidious fashion. The lack of obvious signs of sheet erosion often lulls farmers into a sense of false complacency, little aware of the physical and economic costs associated with such processes. In contrast, rill and gully erosion are very much evident, particularly on the steeper slopes. In some locations (eg. many of the farms on steep slopes), the magnitude of the current erosion is alarming and steps must be taken to arrest it if sustainability of production is to be maintained. In the drainage gully below Kijiji, erosion is so severe that it will soon wipe out the access road to the village.

The following are contributing to continued or accelerated erosion:

1) **Cultivation on excessively steep slopes:** In some areas notably on the east side of the hill, farmers are cultivating steep slopes with no protective measures (such as terracing etc).

2) **Cultivation with no regard to contour:** The simple conservation measure of ploughing along the contour is often disregarded with the result of increased erosion.

3) **Cultivation of drainage channels:** Many farmers are cultivating seasonal drainage channels thereby exposing unprotected soils to water flows. In time gullies are formed and the land is rendered useless without remedial measures. Permanent vegetation must be preserved in all channels.

4) **Cultivation of shallow soils:** If cultivation occurs on shallow soils the soil particles are more easily transported when the ground becomes waterlogged and surface flow commences.

5) **Roadway and trail degradation:** Many trails and roads in the area unintentionally serve as drainage channels. Often water is not diverted off the track frequently enough and flows down slope for considerable distances. Not only does erosion occur along the road or trail but once the water eventually is released, the accumulated flow can cause considerable damage in adjacent fields.

6) **Uncontrolled removal of trees for fuel:** As the use of firewood is prevalent ,tree removal is of course inevitable. However, the lack of a concentrated regeneration program has resulted over the years in a considerable reduction in the number of mature trees. The effects on erosion are multi-fold; large trees bind soil particles and help prevent soil movement; in number, trees reduce windspeeds therefore reducing moisture loss and increasing the vigour of existing protective vegetation; tree canopies reduce rainfall impact; the removal of trees puts greater pressure on other lands for fodder, fuel etc. and may lead to further degradation elsewhere and long term productionreduction.

7) **Overgrazing** The lack of a coordinated grazing management plan for the area is contributing to a progressive decrease in palatable species , therefore putting greater pressures on ever decreasing lands. This concentration of stock often creates bare patches of soil which are then subject to erosion. On common lands outside of the forest reserve, rights of access (including stocking numbers), and responsibilities (for herding, pasture rehabilitation etc.) are not clearly defined and thus are leading to degradation. Within the forest reserve, there is no grazing managementplan

8) **Distance to stock watering point.** Many farmers are forced to drive their stock long distances to watering points. As stock both trample and graze vegetation en route and at the water source, these areas are subject to much pressure and, over time, vegetation is removed, soils are compacted and erosion ensues. This further reduces possible grazing areas as well as impacting vulnerable stream sides which in turn degrades the water resource. (siltation etc.)

3.4.5. The Classification Units

The FAO and UNESCO soil map legend (FAO/UNESCO,1974) has been used on the project as this is standard practise by the Kenya Soil Survey (KSS) as well as being in common usage throughout Africa. The classification of the soils was based upon the following types:

3.4.5.1. *Vertisols*

Often referred to as "black cotton soils", vertisols are commonly found in lower lying, imperfectly drained areas, namely in valley bottoms and in the Rift Valley portion of the study area. They are, typically, dark, heavy clays with very distinct large cracks, usually to a depth of at least 50 cm. and at least 1cm. wide for part or most of the year. They lack distinct horizons because of the process of mixing and churning of the soil due to their very strong shrinking, swelling and cracking characteristics. The common presence of slickensides (polished and grooved surfaces produced by one mass sliding past another) is indicative of this process. Vertisols have poor engineering characteristics due to their swelling and shrinking.

The percentage of montmorillonite clay determines to a large degree the amount of swelling and this is variable between the mapping units. In several of the units, particularly in the extreme west, swelling of the soil when wetted is truly spectacular, and one sample "blossomed" to about 125% of it's original volume. While the cracks allow water infiltration during initial wetting, the swelling characteristic causes the cracks to quickly disappear as the rains continue. The high clay content makes the soils only slightly permeable, and the majority of the rains are directed overland. (see table ?) The water holding capacity of the soil is very high but it is held tightly by the clay and much is unavailable to plants. Farmers commonly complain of waterlogging.

The workability of vertisols may be described as horrendous. When wet they are extremely sticky and make hoe culture very difficult. When dry they are extremely hard and farmers speak of the jembe (hoe) bouncing off the concrete like peds. The shrinking and cracking characteristic causes air pruning and breakage of most roots and few crops do well in unirrigated situations, despite the relatively high fertility of most vertisols.

3.4.5.2. *Nitosols*

These deep, red, moderately weathered soils are common on the eastern flank of the hills and generally coincide with the most productive agriculture. Most of the nitosols in the area have been developed under forest cover. They are friable to very friable clays to clay loams and have excellent physical characteristics. The percentage of clay does not decrease by as much as 20 percent within 150 cm. of the surface and some of the ped faces are shiny. Structure is generally moderate, fine to medium, sub angular blocky. The nitosols have weak surface capping, a stable structure, and are porous throughout the profile. These latter characteristics give them a tendency to resist erosion. They have very good moisture holding capacity and most of that moisture is available to plants or percolates to subsurface reserves. For this reason the nitosols are extremely important to the hydrologic management of the area and offer the best opportunities for recharge improvement.

Workability is very good and the soils present no problems in this regard. Soil fertility, although initially quite high, is quickly depleted by continuous cultivation and requires inputs to maintain fertility. These inputs occur to some extent as many farmers are adding manure to the soil. Very few of the farmers are using chemical fertilizers and the amount of manure added is seldom adequate to maintain fertility. Declining yields have been reported by the majority of farmers cultivatingnitosols.

3.4.5.3. *Luvisols*

The luvisols in the study area are moderately weathered with a clear sequence of horizons. An argillic B horizon with a base saturation of over 50% underlies an A horizon. Texture is generally clay and the structure is moderate to strong sub angular blocky. The soils are moderately deep with some cases of saporitic rock within 60 cm. of the surface. Some surface cracking is evident and there is slight surface sealing. They are less permeable than the nitosols and therefore allow greater surface runoff.

Consistence is sticky when wet, firm when moist and hard when dry, leading to some problems in workabilityfor arable agriculture, and compaction if overgrazed.

3.4.5.4. *Andosols*

Andosols are characterized by a low bulk density and are derived from volcanic ash. Texture is usually loam and the soils are highly permeable with little or no surface sealing. Andosols have good moisture holding capacity but they are only moderately deep and often overly rock. Consistence is non-sticky when wet, friable to very friable when moist, and soft when dry. Although they present no workability problems, none of the andosols occur outside of the forest reserve and are therefore not subject to cultivation. Because of their low bulk density and position (often on the steep western slopes) they may be subject to erosion if disturbed. The andosols in the study area are very dark grey and are moderately fertile.

3.4.5.5. *Regosols*

These are soils from unconsolidated materials and are found on the south end of the western scarp. They lack diagnostic horizons and in the study area consist of gravelly material in a matrix of clay. Although the clay is fairly fertile, the position of the regosols (on steep slopes) and their high stone content make them unsuitable for agriculture.

3.4.5.6. *Lithosols and Rock Outcrops*

By definition lithosols are very shallow soils with continuous and coherent rock within 10 cm. of the surface. However, this has proved to be somewhat impractical in the tropics and it is acceptable to use rock within 25 cm. as diagnostic. This is the case with many of the lithosols in the Ngong Hills. They have an A,R sequence of horizons with no B horizon. They are found predominantly on the main ridge and the western slopes, often mixed with rock outcrops (non soils) and occasional pockets of deeper soils. They have poor potential for any agriculture and should be maintained as grassland or forest.

Table 5. Hydrologic Characteristics of Various Soils

Soil Type	Subsoil bulk density [1]	Subsoil Wt. % Field capacity	Subsoil Wt. % Available Moisture	Topsoil Infiltration [2] Dry soil	Topsoil Infiltration [2] Wet soil
Nitosol	1.10	27.0	10.5	2.0	1.2
Luvisol	1.53	18.0	7.7	9.1	5.6
Vertisol	1.22	39.2	10.5	_	_

[1] = gm/cc [2] =mm/minute Source: KARI (1979)

Table 6. Soil Types and Summary of Characteristics

Soil Type	Natural fertility	Drainage	Available H_2 Holding capacity	Erosion potential
pellic Vertisol	High	V. Poor	V. High	Medium
orthic Luvisol	Medium to High	Imperfect	Medium to High	Medium
Lithosol	V. Low	Excessive	Low	V. Low
dystric Nitosol	Medium	Gen. Good	High	Medium to High
eutric Regosol	Medium	Fair	Medium	Medium
luvic Phaeozem	Medium	Gen. Good	Medium	Low
vitric Andosol	Medium to High	Good	High	Medium to High

3.4.6. the Soil Mapping Units

The soils of the Ngong area are highly variable but may be generally described according to the landforms occurring in the area. These are, broadly speaking, ridges and scarps, footslopes and footridges, valley bottoms and volcanic plains. The entire study area is volcanically derived. For details of representative soil profiles refer to appendix 1.

3.4.6.1. *Soils of the Ridges and Scarps*

Mapping Unit: RS1

Parent Material:	undifferentiated basanites, tephrites, atlantites, ankaratrites
Relief Macro:	undulating ridge top (convex in X-section); slopes 0 - 30%
Relief Micro:	locally dotted with small rock outcrops
Vegetation:	grassland, thickets and forest patches
Landuse:	Wildlife, recreation, grazing
Soils, general:	moderately deep to very shallow soils overlying saporite and volcanic rocks. Transition to **R** is abrupt.
colour:	**A** horizon predominantly Dark brown (7.5YR 3/4) **B** horizon brown to dark reddish brown (5YR 3/4)
Texture:	Sandy loam to Clay loam with inclusions of clay.
Consistence	Slightly hard when dry, friable when moist, slightly sticky and plastic when wet.
Chemical properties:	A horizon: CEC about 29 me/100g.; soils are slightly acidic pH 5.9; Organic C is about 3.4%; N about 0.5%; P about 0.8ppm
Soil classification:	orthic LUVISOLS, with inclusions of LITHOSOLS

For the description of representative profiles see appendix 1, profiles #3 and #5.

Mapping Unit: RS2

Parent Material:	undifferentiated basanites, tephrites, atlantites, ankaratrites
Relief Macro:	Steep faulted western scarp; slopes 30 - 100%
Relief Micro:	irregular and rugged, rock outcrops and stony ground
Vegetation:	*Themeda*, *Hyparrhenia*, *Acacia* bushed grassland, forest patches near ridge top
Landuse:	Wildlife, grazing

Soils, general: shallow soils overlying volcanic rocks. Transition to **R** is abrupt and generally within 15cm. This is highly variable and there are many pockets of deeper soils resulting from small landslides and microrelief.

colour: **A** horizon predominantly Dark brown (7.5YR 3/2)
Deeper soils generally very dark grey to black

Texture: Clayloam

Consistence: Slightly hard when dry, friable when moist, slightly sticky and plastic when wet.

Chemicalproperties: A horizon: CEC about 30.6 me/100g.; soils are near neutral, pH 6.9; Organic C is about 1.9%; N about 0.07%;
P about 102 ppm.

Soilclassification: LITHOSOLS, with inclusions of shallow eutric REGOSOLS and vitricANDOSOLS

For the description of representative profiles see appendix 1, profiles #3, #15 and #23.

Mapping Unit: RS3

Parent Material: Ol Esayeti Oligoclase Tephrites

ReliefMacro: western slope of fault line; slopes 25 - 75%

ReliefMicro: irregular and rugged, rock outcrops and stony ground

Vegetation: *Acacia* bushed grassland,

Landuse: Wildlife, extensive grazing

Soils, general: extremely shallow soils overlying volcanic rocks with many rock outcrops with no soil at all. Transition to **R** is abrupt and generally within 10 cm.

colour: **A** horizon predominantly Dark brown (7.5YR 3/2) moist

Texture: Clayloam

Consistence: Slightly hard when dry, friable when moist, slightly sticky and plastic when wet.

Chemicalproperties: A horizon: CEC about 30 me/100g.; soils are near neutral, pH 6.9; Organic C is about 1.9%; N about 0.07%;
P about 102 ppm.

Soilclassification: LITHOSOL

For the description of representative profiles see appendix 1, profile #3

Mapping Unit: RS4

Parent Material:	undifferentiated basanites, tephrites, atlantites, ankaratrites
Relief Macro:	Steep faulted western scarp; slopes 30 - 100%
Relief Micro:	irregular and rugged, rock outcrops and stony ground
Vegetation:	*Themeda*, *Hyparrhenia*, *Acacia*, *Euphorbia* bushed grassland, very small forest patches near ridge top
Landuse:	Wildlife grazing
Soils, general:	shallow soils overlying volcanic rocks. Transition to **R** is gradual with greater percentage of gravels and rock occurring with depth. Horizon definition is based on rock content and slight change of colour. Otherwise little definition in unconsolidated material. Transitions are smooth and gradual. Soil depth is highly variable as there are pockets of deeper soils resulting from small landslides and micro relief. There are inclusions of LITHOSOLS and to a lesser degree, ANDOSOLS in this unit.
colour:	**A** horizon predominantly Dark grey (10YR 4/1) **B** horizon Very dark greyish brown (10YR 3/2) often mottled with yellowish brown (10YR 5/6) resulting from the breakdown of parent material.
Texture:	Clay
Consistence	Very hard when dry, firm when moist, sticky and plastic when wet.
Chemical properties:	A horizon: CEC about 30.6 me/100g.; soils are near neutral, pH 6.9; Organic C is about 1.9%; N about 0.07%; P about 102 ppm.
Soil classification:	eutric REGOSOLS with inclusions of LITHOSOLS, and very occasional shallow ANDOSOLS. The main difference between this unit and RS2 is the higher percentage of REGOSOLS in this unit.

For the description of representative profiles see appendix 1, profiles #3, #15 and #23.

3.4.6.2. *Soils of the Footridges and Footslopes*

Mapping Unit: FS1

Parent Material:	undifferentiated basanites, tephrites, atlantites, ankaratrites
Relief Macro:	slopes 10 - 55% steepening and becoming more convex towards the summit, Footridges running perpendicular to main ridge 500 - 800 meters in width.

ReliefMicro: generally smooth with very occasional rock outcrops

Vegetation: *Themeda, Pennisetum*, grassland, occasional forest patches *Dombeya, Albizia*, in forest reserve, annual crops in farming area

Landuse: Wildlife, grazing in upper portions, smallholder mixed farming on lower slopes

Soils, general: Welldrained, very deep, moderately weathered soils with excellent physical characteristics for arable agriculture. Common shiny ped faces; The horizon transitions are gradual and smooth; the soils are moderately rapidly permeable.

colour: **A** horizon predominantly Dark reddish brown (5YR 3/4) dry

B horizons vary from dark reddish brown (5YR 2.5/2) to Yellowish red (5YR 4/6)

Texture: Clay to clay loam

Consistence: Slightly hard when dry, friable when moist, slightly sticky and plastic when wet.

Chemical properties: A horizon: CEC about 20 me/100g.; soils are slightly acidic to neutral, pH 6 - 7; Organic C is about 1.1%; N about 0.14%; P about 1.8 ppm.

Soil classification: dystric NITOSOL

For the description of representative profiles see appendix 1, profiles #4 and #9.

Mapping Unit: FS2

Parent Material: undifferentiated basanites, tephrites, atlantites, ankaratrites

ReliefMacro: slopes 10 - 55% steepening towards the summit,

ReliefMicro: generally smooth with very occasional rock outcrops

Vegetation: *Themeda, Pennisetum*, grassland, occasional forest patches *Acacia, Euphorbia*

Landuse: Wildlife, grazing in upper portions, some arable agriculture in lower sections

Soils, general: A complex of moderately well drained, moderately deep, moderately weathered soils, interspersed with deep soils.

The horizon transitions are gradual and smooth with the exception of an abrupt transition to **R**; the soils are moderately permeable.

colour: **A** horizon predominantly Dark reddish brown (5YR 2.5/2) dry (5YR 3/2)

B horizons vary from dark reddish brown (5YR 2.5/2) to (5YR 3/3) to dark red (2.5YR 3/6)

C if present Dark reddish brown (5YR 3/2)

Texture: Clay to clay loam

Consistence: Hard to extremely hard when dry, firm to extremely firm when moist, very sticky and very plastic when wet.

Chemical properties: A horizon: CEC about 38 me/100g.; soils are neutral, pH6.7 - 7.3; Organic C about 1.7%; N about 0.28%; P about 1.7 ppm. (also See FS1)

Soil classification: Complex of vertic and orthic LUVISOLS with a few inclusions of NITOSOLS

For the description of representative profiles see appendix 1, profiles #11 and #14

Mapping Unit: FS3

Parent Material: undifferentiated basanites, tephrites, atlantites, ankaratrites

Relief Macro: Convex Footridges running perpendicular to main ridge 500 - 800 meters in width. Slopes 15 - 55% steepening towards summit.

Relief Micro: generally smooth with occasional rock outcrops

Vegetation: *Themeda, Pennisetum,* grassland, occasional forest patches of *Dombeya, Albizia,*

Landuse: Wildlife grazing,

Soils, general: A complex of shallow well drained soils interspersed with moderately deep and deep soils. The horizon transitions are gradual and smooth with the exception of an abrupt transition to **R**; the soils are moderately permeable.

colour: **A** horizon predominantly Dark reddish brown (5YR 2.5/2)

B Dark reddish brown (5YR 2.5/2)

Texture: Sandy clay loam

Consistence: Slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet.

Chemical properties: A horizon: CEC about 34 me/100g.; soils are slightly acidic,

pH5.6 -6.5; Organic C 3.9%; N about 0.33%;
P about 2.7 ppm.

Soilclassification: orthic LUVISOLS with inclusions dystric NITOSOLS

For the description of representative profiles see appendix 1, profiles #18 and #9.

Mapping Unit: FR1

Parent Material: undifferentiated basanites, tephrites, atlantites, ankaratrites

ReliefMacro: Convex Footridges running perpendicular to main ridge 500 - 800 meters in width. Slopes 5 - 45% steepening towards summit.

ReliefMicro: generally smooth with very occasional rock outcrops

Vegetation: *Themeda, Pennisetum,* grassland, occasional forest patches *Dombeya, Albizia,*

Landuse: Wildlife, grazing in upper portions,

Soils, general: A complex of well drained, deep, moderately weathered soils interspersed with moderately deep soils. The horizon transitions are gradual and smooth with the exception of a clear transition to **C** and abrupt transition to **R**; the soils are moderately permeable.

colour: **A** horizon predominantly Dark reddish brown (5YR 3/4) dry or very dark greyish brown (10YR 3/2)

B horizons vary from dark reddish brown (5YR 2.5/2) to Yellowish red (5YR 4/6)
or Dark brown (10YR 4/3) to Yellowish brown (10YR 3/4)

C if present Dark brown (10YR 4/3)

Texture: Clay to clay loam

Consistence: Slightly hard to hard when dry, friable when moist, sticky to slightly sticky and plastic to slightly plastic when wet.

Chemicalproperties: A horizon: CEC about 20 me/100g.; soils are slightly acidic, pH5.6 -6.7; Organic C varies from 1.3 - 4.1%; N about 0.35%; P about 1.5 ppm. (also See FS1)

Soilclassification: Complex of orthic LUVISOLS and dystric NITOSOLS

For the description of representative profiles see appendix 1, profiles #9 and #20.

Mapping Unit: FR2

Parent Material:	undifferentiated basanites, tephrites, atlantites, ankaratrites
Relief Macro:	Convex Footridges running perpendicular to main ridge 500 - 800 meters in width. Slopes 5 - 45% x
Relief Micro:	generally smooth with very occasional rock outcrops
Vegetation:	annual crops, *Eucalpytus, Croton* etc. in farming areas.
Landuse:	mixed farming
Soils, general:	Moderately well drained, moderately deep to shallow soils The horizon transitions are gradual and smooth with the exception of a clear transition to **C** and abrupt transition to **R**; the soils are moderately permeable. Occasionally exhibit vertic characteristics.
colour:	**A** horizon predominantly Dark yellowish brown (10YR 3/4) dry or very dark grey (10YR 3/1) **B** horizons are commonly dark reddish brown (5YR 3/4) **C** horizon Dark brown (10YR 4/3) mottled with very dark greyish brown (10YR 3/2)
Texture:	Clay to clay loam
Consistence	very hard when dry, very firm when moist, sticky to slightly sticky and plastic to slightly plastic when wet.
Chemical properties:	A horizon: CEC about 27 me/100g.; soils are slightly acidic to neutral, pH5.6.6 -7; Organic C is about 2.3%; N about 0.23%; P about 5 ppm.
Soil classification:	orthic LUVISOLS

For the description of representative profiles see appendix 1, profiles #2 and #7

3.4.6.3. *Soils of the Valley Bottoms and Volcanic Plains*

Mapping Unit: VB1

Parent Material:	Limuru Trachytes
Relief Macro:	Volcanic Plain; Slopes 0 - 5%
Relief Micro:	generally smooth with occasional termite mounds, Often rocky surface
Vegetation:	*Acacia, sp.* in bushed grassland.
Landuse:	extensive range, wildlife

Soils, general:	Imperfectlydrained, very deep,moderatelyweathered soils. The soils show little profile development and the horizon transitions are diffuse and smooth; there is distinct and very deep cracking; soils have extreme swelling characteristics.
colour:	**A** horizon predominantly Black (10YR 2/1)
	AC horizon Black (2.5YR 2/0)
Texture:	Clay
Consistence:	extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet.
Chemicalproperties:	A horizon: CEC about 50 me/100g.; soils are neutral, pH about 7.5; Organic C is about 1.7%; N about 0.16%; P about 2 ppm.
Soilclassification:	pellicVERTISOL

For the description of representative profile see appendix 1, profile #13

Mapping Unit: VB2

Parent Material:	undifferentiatedbasanites,tephrites,atlantites, ankaratrites
ReliefMacro:	Valley bottom; Slopes 0 - 5%
ReliefMicro:	generallysmooth and flat, occasional gilgai relief
Vegetation:	*Acacia, sp.* in *Themeda*grassland.
Landuse:	grazing, arable cropland
Soils, general:	Imperfectlydrained, very deep,moderatelyweathered soils. The soils show little profile development and the horizon transitions are diffuse and smooth; there is distinct and very deep cracking; soils have swelling characteristics but not as extreme as VB1.
colour:	**A** horizon predominantly Very dark grey (10YR3/1)
	AC horizon Black (10YR 2/1)
	C horizon very dark grey (10YR 3/1)
Texture:	Clay
Consistence:	extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet.
Chemicalproperties:	A horizon: CEC about 52 me/100g.; soils are slightly acidic on

the surface, becoming neutral with depth. neutral, pH about 5.7 (A) and 7 (AC); Organic C is about 3.3%; N about 0.05%; P about 3 ppm.

Soilclassification: pellicVERTISOL

For the description of representative profile see appendix 1, profile #1

Mapping Unit: VB3

Parent Material: Phonolites

ReliefMacro: Volcanic Plain; Slopes 0 - 5%

ReliefMicro: generally smooth with occasional termite mounds

Vegetation: *Acacia, sp.* in bushed grassland.

Landuse: extensiverange, wildlife

Soils, general: moderatelydrained, moderately deep soils with gradual and smooth horizon boundaries.

colour: **A** horizon very dark greyish brown (10YR 3/2)

AB horizon Dark brown (10YR 3/3)

B horizon Very dark greyish brown (10YR 3/2)

Texture: Clay loam and Clay

Consistence: very hard when dry, very firm when moist, sticky and plastic when wet.

Chemicalproperties: A horizon: CEC about 24 me/100g.; soils are nearly neutral, pH about 6.8; Organic C is about 1.7%; N about 0.19%; P about 9 ppm.

Soilclassification: luvicPHAEOZEM

For the description of representative profile see appendix 1, profile #17

3.5. VEGETATION

The vegetation of the Ngong Hills is reflective of the topographic position, soils, climate and human influence, and thus, is highly variable. It is therefore necessary to describe the vegetation in sections, which correspond to altitudinal zones, as well as aspect. As the inventory of the vegetation has been at a reconnaissance to semi detailed level, and little detailed research has been carried out in the area, only a general description is possible. As there has been considerable vegetation change in the area due to human influence, the included species lists include those that may occur in the area, based on information from similar areas. (Confirmed species in the area are differentiated from those that are might occur by an asterisk.) This is considered reasonable as it has been stated that the " floristic differences between extremes on a single mountain are usually greater than the differences between the afromontagne assemblage as a whole on that mountain and the assemblage found on nearby , or indeed distant mountains." (Unesco, 1978)

The various classification systems used by different authors (Greenway, 1973; Pratt et al, 1966; the Yangambi system , 1956; and Unesco, 1978) leads to some confusion in the application of a classification typology. Indeed, even within publications of the same organization, (Unesco, 1978, 1979) significant disagreement among typology exists.

3.5.1 Human Influence

The indigenous vegetation has been heavily impacted by humans and few if any "untouched " areas remain. K.R.E.M.U. (1981) has indicated an average annual loss of 18 ha. of indigenous forest, generally replaced with grassland and/or lower quality bushland. In 1980 only 156 ha. of forest remained in the 3077 ha. forest reserve. This is less than half of what was estimated in 1965. Perhaps the most profound human influence has been fire (see Fire section) but gathering for fuelwood and charcoal burning is also having an enormous effect. Although illegal, 71% of those surveyed admitted gathering at least some of their fuelwood requirements from the forest. On the lower northeast slopes almost every acacia over 7 cm. dbh has been cut recently, and there are many remains of charcoaling piles. The law is obviously not being adequately enforced.

Although the intent of the forest department has been to re-establish an indigenous forest, germplasm is difficult to obtain, and the following are the species in the nursery to be planted out this year (I indicates indigenous species):

Eucalyptus saligna
Luceana sp.
Erythninus sp.
Eucalyptus maculata
Alberia caffra
Cupressus lustanica
Croton megalocarpus (I)
Acrocarpus Fraxinifolia
Casuarina equisetifolia
Schinus molle
Pinus patula

Other species grown at the Ngong nursery which appear promising to the department and may be planted in future, include:

Jacaranda nimisoides
Ekebergia ruepelliana
Sterculia acutifolia
Erythrina tomentosa
Markhamia hildebrandtii (I)
Acacia sp. incl. xanthophloea
Spathodeacampanulata
Eleodendron
Marcunia
Cordia abyssinica

As few of the above are indigenous, or have had extensive field trials, the long term survival is uncertain. Indeed, even the short term survival is compromised, both by species/site incompatibility, as well as often inappropriate planting techniques. The establishment rate for the seedlings planted out to date has been low (personal observation).

The natural forest has been **completely** destroyed in the agricultural area on the eastern and northern slopes. Very few indigenous species exist, with the exception of some outstanding examples of *Ficus* as well as some *Euphorbia, Croton megalocarpus and Olea spp. Croton megalocarpus* is extensively planted by local farmers. Almost all of the other trees in the agricultural area are Eucalyptus spp., Grevillea and Cypress. The most common annual crops are maize, pulses, potatoes and horticultural crops. Some citrus, paw paw and bananas are also grown. (for details of domestic vegetation see land utilization section)

3.5.2. Vegetation Classification

The variety within the following broad vegetation classifications is large, and varies not only according to species composition, height and density, but also in other particulars of growth form (ie. branching pattern etc.) The generalities ascribed to a particular class are just that, and great variability in the architecture of stands, supposedly of the same type, exists. The complexity of the forest types are further complicated by the composition of the intermediate types which link areas of more discreet composition. This implies that further study of the profiles of the stands in addition to the diameter, height, and species information should be carried out. This was not possible during the present study.

3.5.2.1. *Undifferentiated Afromontagne Forest*

According to local elders, the Ngong Hills were once completely forested, with the exception of open areas near the ridges and occasional glades. The importance of such a forest to the ecology of the area is illustrated in the following figure.

Undifferentiated afromontagne forest (Unesco, 1979) presently exists on the eastern flank from approximately 2000m to the summit at 2460m. This type is by no means contiguous over the area, and is interspersed with large areas of grassland, chiefly *Themedatriandra*. Species found or able to grow in the afromontagne area include:

* denotes those species confirmed in the Ngong Hills

Acokanthera schimperi *
Aprodytes dimidiata
Brucea antidysenterica
Canthium fresiorum *
Caseria battiscombei
Cassopourea congoensis
Clausena anisata
Clematis hirsuta *
Cynoglossm caeruleum
Diospyros abysinnicus
Dracaeana afromontana *
Ekebergia capensis *
Embelia schimperi *
Euphorbia cussoniodes
Euphorbia candelabrum *
Grewia similis
Halleria lucida
Juniperus procera
Lepidottrchchilia volkensii
Maytenus heterophylla *
Nuxia congesta *
Ocotea kenyensis
Olea capensis
Oxyanthus speciosus *
Prunus africana *
Podocarpus falcatus
Psychotria orophila *
Rhytignia sp. *
Strychnos mitis
Xymalos monospora
Allophylus kilimanjarica *
Biospyros abysinica
Buddleia polyschya *
Canthium oligocarpum *
Cassia didymobotrya
Cassipourea malosana *
Clerodendrum myricoides
Cussonai holstii *
Cyperus ajax *
Dombeya goetzenii. *
Ehyretia cymosa*
Elaendendron buchananii *
Erhata erecta *
Euphorbia obovalifolia
Ficus hochstetteri
Hagenia abyssinica
Ilex mites
Kiggelaria africana
Maesa lanceolata *
Nuxia floribunda
Ocotea bullata
Olea africana *
Olinea usambarensis
Peperonia abyssinica *
Phytolacca dodecandra *
Podocarpus latifolious
Rapanea melanophloeos
Schefflera volkensii *
Widdington cupressoides

As previously mentioned the form of these stands is extremely variable. Towards the upper, heavily windblown slopes, forest vegetation is sparce, lower and more contorted than on the midslopes (often *Maytenusheterophylla* and *Nuxia congesta* are conspicuous). Towards the northern end of this zone, forest vegetation is now almost completely absent and only the odd single stem remains. This further exacerbates the harsh climatic conditions and makes reforestation even more difficult.

There are a few small remnant stands of bamboo, *Arundinaria alpina,* indicating that the area received over 1200mm rain per year at the time of establishment. It also is an indicator of deep soils. The bamboo is in great danger of extinction in the area and only two stands have been noted in field surveys. Other species known to be threatened in the afromontagne include several epiphydic orchids, living on mosses and lichens in the forest (they are indicators of environmental quality). Not only has the forest itself been removed or degraded, but the trees are being stripped of moss by people gathering for the local florists. This is removing the habitat of the orchids. In her study of the orchids of the Ngong Hills, Kahyota (1986) noted the following species to be present (11 species noted present in earlier studies were not found in 1986):

Aerangis thomsonii
Angraecum erectum
Bolusiella iridifolia
Diaphananthe montana
Diaphananthe sub-simplex
Disperus kilimanjarica
Polystachya campyloglosa
Polystachya spatella
Raerangis amaniensis
Angraecopsis breviloba
Angraecum sacciferum
Chamaeangis orientalis
Diaphananthe rutila
Diaphananthe sp.
Eulophia streptopetala
Polystachya cultriformis
Polystachya transvaalensis
Stolzia repens

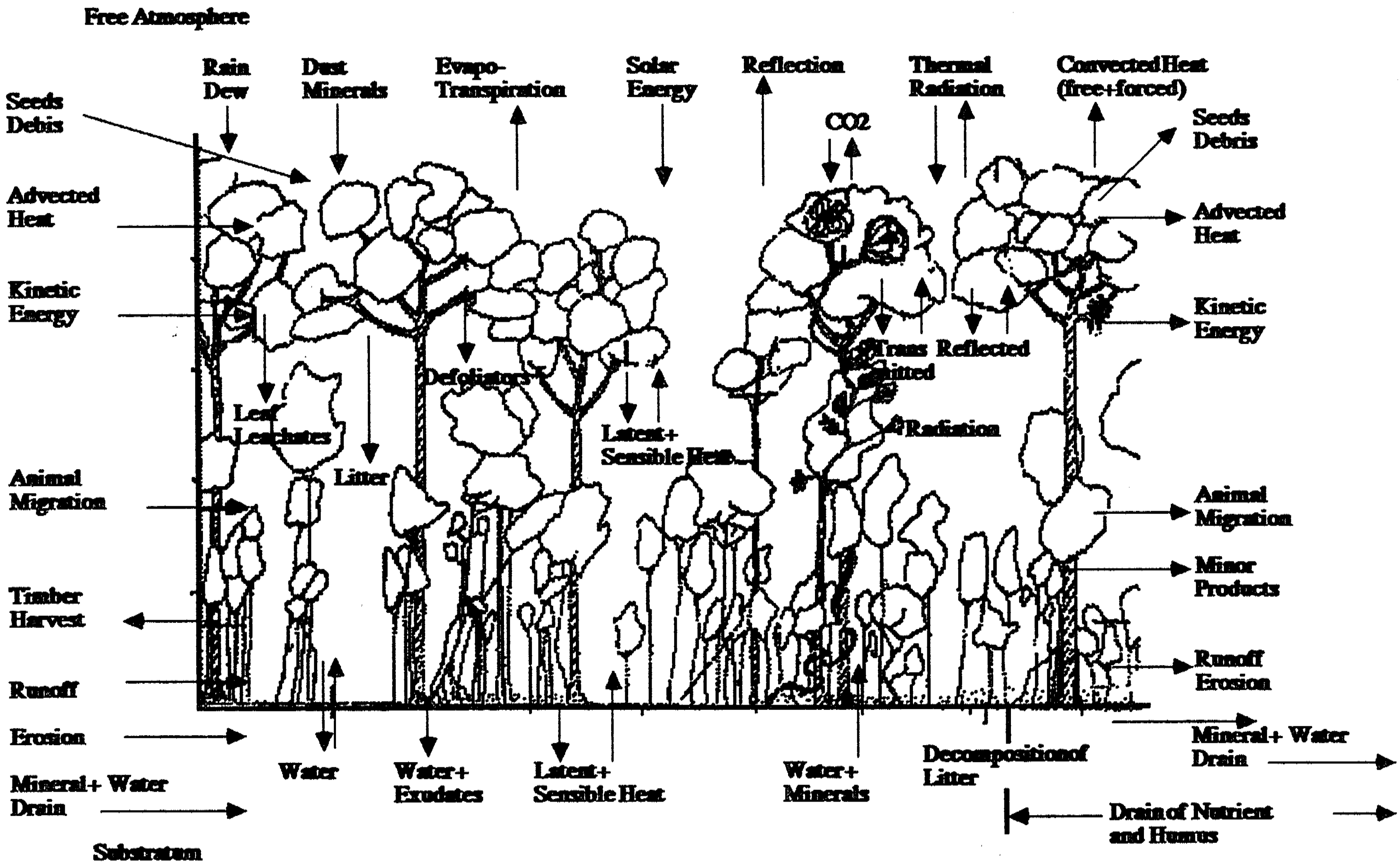


Figure 28. Inputs and Outputs of a Tropical Forest Ecosystem

Source: UNESCO, 1978

3.5.2.2. Dry Transitional Montagne Forest

This zone merges with the dry transitional montagne forest lower on the slopes, although a precise boundary is difficult to delineate. This type formerly covered most of the area now in agricultural production and includes species from both the afromontagne and non afromontagne spectrum. Common species of this type include:

Albizia gummifera (near streams)*
Apodytes dimidiata
Bromus uniloides *
Carissa edulis *
Cassine buchananii *
Chaetacmearistata
Croton megalocarpus
Diospyros abyssinica
Dovylis abyssinica *
Ehretia cymosa *
Euclea divinorum
Grewia similis *
Manilkara obovata
Newtonia buchananii (near streams)
Phyllanthus discoides
Strychanos usambarensis
Teclea spp. *
Tricholadus ellipticus
Warburgia salutaris (ugandensis)
Acokanthera longiflora *
Brachylaena discolor
Calodendrum capense *
Cassia didymobotrya *
Cassipourea congoensis
Chrysophyllum riridifolium
Cyathula polycephala *
Dombeya goetzenii *
Drypetes gerrardia
Erythrina abyssinica
Fagaropsis angloensis
Hypoestes verticillaris *
Markhamia hildebrandtii *
Olea africana *
Schrebera alata
Suregada procera
Rutaceae spp.
Uvariodendron anisatum

The grassland areas of the eastern slopes include the following species:

Ajuga remota *
Bothrichloa insculpta *
Cineraria grandiflora *
Cynadon dactylon
Cynium volkensii *
Digitaria scalarum *
Helichrysum odoratissimum *
Satureia biflora *
Stipa dregeana *
Thumbergii alata *
Verbascum brevipedicellatum *
Aspilia pluviseta *
Carissa edulis *
Clutia abyssinica *
Cynodon nlemfuensis *
Digitana abyssinica *
Gutenbergia cordifolia *
Pennisetum clandestinum *
Solanum indicum *
Themeda triandra *
Thumbergii gregorii *
Verbascum scrophularifolium *

On the lower slopes of the gazetted forest zone and indicative of disturbance, over grazing and fertility depletion, stands of the following species have developed:

Solanum indicum *
Acanthus eminens *
Aspilia mossambicensis *
Leonotis mollisima *
Ocimum suave *

Thickets of the following species have also developed on the lower slopes of the forest reserve:

Abutilon longicuspe *
Abutilon mauritianum *
Crotalaria agatiflora *
Lantana trifolia *
Lippia ukambensis *
Marytenus heterophylla *
Rhus natalensis *
Rhus vulgaris *

3.5.2.3. *Dry Montagne Forest of the Western Slopes*

The vegetation of the dry western slopes is in marked contrast to that of the eastern flanks of the hills. Montagne forest exists only in a few of the highest and most sheltered areas. The remainder of the west aspect is composed of thornbush scrub and grassland. The dry conditions of the slopes are due to the rainshadow of the hill, aspect, shallow soils and steep slopes. The latter accelerates runoff thereby lessening infiltration. The main species in this area are *Acacia spp.* and *Tarchoanthus sp.* with scattered *Euphorbia spp.* *Themeda triandra* and *Hyparrhenia cymesarii* are the dominant grasses at higher elevations. Growth is slow in this zone and establishment of new seedlings is problematic. Common species of the montagne forest of the dry western slopes are:

Acacia spp.
Bersama abyssinica*
Cussonia holstii*
Euclea divinorum*
Euphorbia candelabrum*
Euphorbia nyikae*
Heteromorpha trifoliata*
Noxia congesta*
Olea europeana*
Senecio syringifolius*
Senecio petitianus*
Tarchoanthus comphoratus
Teclea nobilis*
Teclea simplicifolia*
Vangueriatrifoliata*

3.5.2.4. *Dry Wooded and Bush Grassland*

Dry bushland and grassland is the most common type of the western slopes. Commonly observed speciesinclude:

Aloe spp.
Acacia drepanolobium
Acacia mellifera
Acacia seyal
Acacia tortillis
Acaia xanthophloea
Aspilia mossambicensis
Carrissa edulis
Commelina sp.
Crassula granvikii
Cynodon dactylon
Cyperus sp.
Cyphostemma rievense
Digitaria scalarum
Dodonaea viscosa
Erythrina abyssinica
Hibiscus fuscus
Hyparrhenia cymesaria

Kalanchoe densiflora
Ocimum suave
Rhus vulgaris
Scutia myrtina
Themeda triandra

Maytenus spp.
Rhus natalensis
Rumex usambarensis
Tarchonanthus camphoratus

3.6. WILDLIFE

The Ngong Hills once supported a large and diverse wildlife population, including the now absent elephant and rhinoceros. The decline in both the relative area and diversity of suitable habitat, has led to a corresponding reduction in game. However, significant resources still exist in the area. Buffalo are commonly observed in the forest, and eland, baboons, leopard and various antelopes including impala, bushbuck and dikdik, are among the local species. Giraffe are often present at the foot of the western slopes. Lion, although once common in the area, are now very rare. A wide variety of bird life is present with swifts and several species of birds of prey, including the crowned eagle, being conspicuous. There have been no game counts in the area, nor has there been any attempt to identify species, habitat condition, or to establish a wildlife management plan. Generally speaking, the area has received little attention from the Ministry of Tourism and Wildlife despite the considerable potential to generate foreign exchange through additional wildlife based tourism.

Wildlife depredation is a major issue in the area. Wild pigs are causing an extraordinary amount of crop damage on the eastern slopes and many farmers reported complete crop loss. Fifty five percent of the surveyed farmers reported depredation by pigs , while twenty eight and twenty five percent reported damage by buffalo and porcupines, respectively.

The possibility of increasing the wildlife carrying capacity of the area through habitat enhancement, has been explored in the landscape plan. The seasonal habitat requirements of the various species have been examined to determine the feasibility of providing a greater mosaic than presently exists. Such a strategy will help maintain a diversity of game by both providing additional habitat, as well as minimizing niche competition, especially during the dry season. During the wet season, both the amount and palatability of grasses and browse are at their maximum and serious competition is rarely a problem. It is in the dry season that the greatest ecological separation of species takes place. This must be addressed in the type of habitat provided by such efforts as reforestation and grassland enhancement, if species diversity is to be increased.

As many species of game are hosts to disease (particularly East Coast Fever) carrying ticks, utilization of the forest reserve for grazing by domestic stock or fodder production presents major problems. The Ngong Hills are extremely problematic in this regard, as several different varieties of the diseases are present. A research programme is underway in the area to find methods of immunizing cattle against ECF. Local buffalo are captured and a serum is prepared from their blood. This is subsequently injected into domestic stock, protecting them from the disease. The programme has been extremely successful and, given the potential for dairying in the area, is very important and should be continued and expanded.

3.6.1 Major Wildlife Species

The following section discusses the characteristics and planning implications of the major species found in the study area. A partial species list is included.

3.6.1.1. ***Buffalo*** *(Synerus caffer)*

Buffalo are the among the most conspicuous wildlife species in the Ngong Hills and range over a considerable portion of the study area. Although confined for the most part to the forest reserves there have been frequent complaints by local farmers of buffalo caused crop depredation. For the most part, the problems have occurred only during very dry seasons and drought when the animals are under considerable stress. A fence was established along the forest boundary but both the original design and maintenance have been insufficient to keep the beasts out of the farming area.

Although buffalo in other areas commonly congregate in herds of up to 400, there are nowhere near that many animals in the Ngong Hills. Reliable estimates by either local officials or farmers have not been available and a proper count was not included in this study. A *rough* estimate of the number of buffalo in the forest reserve would be about sixty, as occasionally there are reports of a herd near that size. The author, however, has never encountered such a herd, and generally small bands of five or six individuals are the norm. Single animals have also been encountered. Herds are quite stable and will usually stay within a range of three to twenty kilometers although occasionally they will go farther. In the hills they tend to prefer the higher altitude forest, small meadows, and thickets within close range of springs. This fact often brings them in conflict with humans gathering firewood or water in the area. There is occasional conflict with tourists but there have been no reported buffalo caused deaths in the Ngong Hills.

Although buffalo will browse, they are predominantly grazers (Pratt, 1977) and prefer especially green grass near water courses as they drink daily. Their habit of wallowing frequently enlarges small ponds allowing greater water storage when rains fall. Lamprey noted the following feeding observations of Buffalo: " 94 per cent were grasses, 1 percent other herbs and 5 percent shrubs. Of the grass species eaten in Tarangire Reserve, 21 per cent *Cenchrus ciliaris* and 12 per cent

Eragrostis superba. These observations have been confirmed and extended by Sinclair and Gwynne (1972). (*in* Pratt, 1977). In areas where the densities are high enough, the grass sward is kept short and this allows other smaller grazing species to find suitable feeding niches.

3.6.1.2. ***Eland** (Taurotragus oryx)*

Eland are common in the Ngong Hills, particularly on the southwest slopes and the south end of the main ridge where herds of up to eighteen are often seen. Population data is currently unavailable but given the importance of the species, the biologist at Ngong should do a complete count of eland, if not for all the large mammals in the area.

The eland is the largest member of the antelope family in Kenya with adult males reaching 839 kg., a shoulder height of 160 cm. and a length of 317 cm. (Meinertzhagen, 1938). Although large herds have been observed in other areas, generally in the hills, they do not exceed the congregation of a few family groups (10-18 individuals). Individual adult males are often seen in the steeper, more inaccessible areas. The gestation period is 262 days with a single calf usually born during the long rains.

The feeding habits of eland have been observed by Lamprey (1963) who recorded the following vegetation utilization (in the Taragire Game Reserve): grasses, 70%; other herbs, 9%; shrubs, 9%; trees, 12%. Their influence on habitat is generally considered to be beneficial (even on domestic ranches) due to their tendency to reduce woody species.

Preferred species:
Grasses: Cynadon nlemfuesis, Cenchrus cilaris, Themeda triandra and Digitaria milanjiana
Trees: Dalbergia melanoxylon and Kigelia africana (K. aethiopum)

Eland can tolerate fairly dry conditions and are often found considerable distances (up to 40 km.) from water sources. Hence, their preference for the western slopes where, although water is scarce, their preferred food species are present, human harassment is less than on the east slopes and there is a greater amount of escape terrain.

The eland is a gentle creature by nature and poses little danger to visitors in the area. The reverse is more likely the case with heart and metabolic rates no doubt increasing with human encounters. This occurs even if the animal doesn't flee. However, the eland may become habituated to human presence and they are one of the most promising species for domestication. Several such experiments have been carried out in Kenya and indicate the species is capable of good growth and reproduction rates while under domestication. The resistance to disease has been found to drop considerable when the animals are confined (Pratt, 1973). The hardiness of the free ranging animal in the face of several tick related diseases in the area has been attributed to it's diverse diet of browse and grasses.

Particular attention should be paid to eland habitat enhancement, as it is not only a major attraction to visitors in the area, but has some, albeit limited, game cropping potential should existing laws prohibiting such activity be changed.

3.6.1.3. Giraffe (*Giraffa camelopardalis*)

Giraffe are present in the study area although they are limited to the western and southwestern semi-arid fringes of the hills. The animals do not extend into the eastern, northern or steeper portions of the study area. Herds of up to twenty individuals are common at the base of the hills although solitary individuals are frequently seen. While no population data is available, densities in the aforementioned areas do not appear to be excessive. Due to their browsing nature, giraffe are not in direct conflict with the local cattle, although there is some competition with goats. Giraffe reach a shoulder height of between three and four meters and weigh up to 1000 kg. Gestation period is about fifteen months with a single calf the norm.

Wooded or bushed grassland or riparian woodland is considered ideal habitat. Due to their height they do not enter dense forest. Giraffe are browsing animals and their favorite species are *Acacia spp.* and *Balanites spp.* The closely cropped form of these species is due in most part to giraffe. The canopy area and tree height of the preferred species are restricted by browsing, although canopy density usually increases. The reduction in mature *Acacia* and *Balanites* species, primarily by fuelwood gatherers and charcoal burners, combined with poor regeneration due to overgrazing, is leading to a reduction in giraffe habitat.

3.6.1.4. Dik-Dik (*Rhynchotragus kirkii*)

The small dik-dik antelope is common throughout the hills and may be observed singly or in groups of two or three. As the animal does not require free water it is often found on the drier western slopes where it both grazes and browses. Due to it's adaptability, the dik-dik is able to withstand fairly heavy human influence and often survives in overgrazed areas. Gestation is four months leading to a single young born in the rains.

3.6.1.5. ***Impala*** *(Aepyceros melampus)*

Limited numbers (personal observation) of impala are found in margins of the hills. Most of the animals are found in the southeastern portion of the study area, particularly in those areas with accessible water, limited steepness, some bushland and few humans (eg. University forest). As in all of the species mentioned there have been no counts made. The author has only made one observation of impala in the area in addition to finding a recent skull. Although the animals generally occur in groups it is appears that this is rare in the Ngong Hills as reported sightings have beenlimitedtoindividuals.

Impala are both grazers and browsers and Lamprey (1963) has observed the following distribution of diet: 92% grass; 6% tree and shrub foliage; and 2% herbs and sedges. Other studies have shown lower percentages of grasses, (Talbot and Talbot, 1961). *Cynadon* is a preferred grass species while *Acacia tortilis* fruits are also eaten. In well watered areas impala do not require free water but, rather, derive their requirements from green grasses and dew. They are not generally considered in competition with domestic stock and are not known to detrimentally effect vegetation (Pratt, 1973). Gestation period is 196 days and birth is given to one young, generally in thick cover. Adult males are 63-73 kg., while adult females are 43-48 kg. Shoulder height is approximately 87-95cm.

Major Large Mammals of the Ngong Hills

* denotes those present at one time but now absent

Common Name	ScientificName
Buffalo	*Syncerus caffer*
Bushbuck	*Tragelaphus scriptus*
Dik-dik	*Rynochotragus kirkii*
Eland	*Taurotragus oryx*
Elephant*	*Loxodonta africana*
Gazelle, Grant's	*Gazella granti*
Gazelle, Thomson's	*Gazella thomsonii*
Giraffe	*Giraffa camelopardidlis*
Klipspringer	*Oreotragus oreotragus*
Kudu, Greater*	*Tragelaphus strepsiceros*
Kudu, Lesser*	*Strepsiceros imberbis*
Leopard	*Panthera pardus*

Lion	*Panthera leo*
Monkey, putty nosed	*Cercopithicusnictitans*
Monkey, black and white Colobus	*Colobus abyssinicus*
Ostrich*	*Struthia camelus*
Rhinoceros*	*Diceros bicornis*
Warthog	*Phacochoerus aethiopicus*
Zebra, Burchell's*	*Equus burchelli*

3.7. ECOSYSTEM STABILITY

Change is inherent in any given ecosystem; species composition, diversity and complexity are all subject to variation over time. Yet ecosystem stability may be retained in spite of (and often because of) this variability. It is, however, important to understand where the boundaries are to this cyclic stability, for once exceeded, the ability of the system to recover to it's former state may be threatened. Human perturbations often push an ecosystem beyond it's natural cyclic boundaries and a new cyclicity may be imposed, often with very different production characteristics. If the pre-perturbation stability is to be re-established, inputs (eg. energy), will be required to move the system back within the original boundaries

The use of the term stability can be problematic as it is, " a value loaded concept and is closely related to the notions of *equilibrium* and *balance*. It conjures up images which are at once utopian and profoundly nostalgic." (Ives, 1984) However, the concept is useful in that it gives some indication of the condition of an ecosystem. Winiger(1983) has used the terms stability and instability in relation to various systems of agricultural use, which are applicable in the investigation of the Ngong Hills ecosystems. A distinction is made between natural ecosystems, adapted agricultural systems, compromise agricultural systems, and disintegrated agricultural systems. (see chart) Each system requires different types of inputs to maintain stability. The adapted and compromise systems are the most likely to be found in the Ngong Hills. Stability is used here to indicate a condition which allows for sustainability of production. Sustainability is seen to be maintenance of production over at least two generations. Damages caused by the land-man relationship (erosion etc.) are also repaired within that period.

In the Ngong Hills the ecosystem has been negatively impacted. The former closed circuits of nutrient recycling in the tropical forest ecosystem (see following figure) have been modified into semi-open ones, in which the flow of resources is leaving the system (in the form of fuelwood, fodder etc.) and is not being replaced by other inputs. The result has been ecological degradation. If now left to recover, there is no guarantee that the system will return to it's pre-perturbation state and, given the new demands that are being placed on the area, it probably isn't desirable that it does.

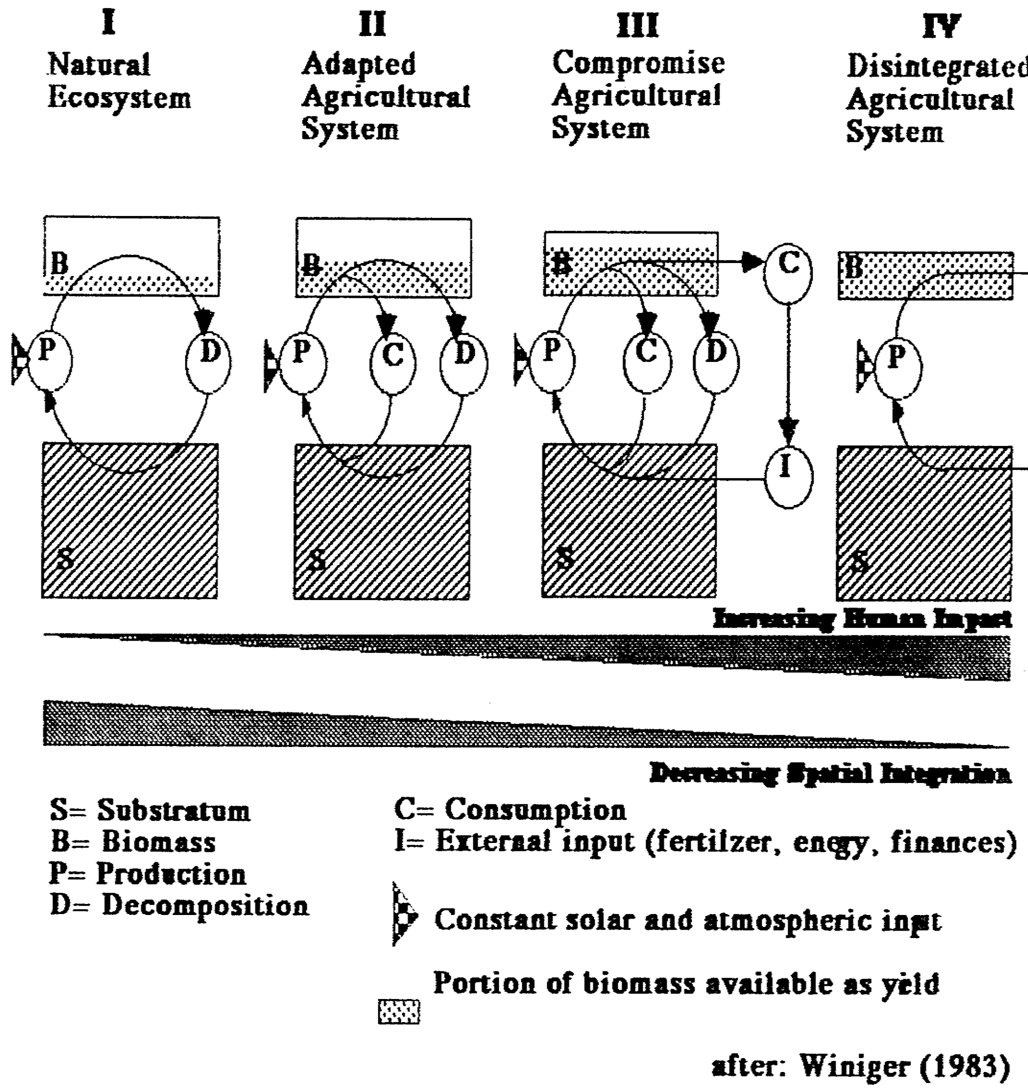


Figure 29. Different Levels of Production & Related Flows of Substances & Energy

An understanding of the natural succession and the possible shortcuts to the desired seral stage is desirable if cost effective management interventions are to made. If pre-climax stages must be maintained in order to meet management objectives (eg. fodder production), energy inputs will be required. If climax forest is seen as desirable, then those areas that will succeed most quickly to that stage should be selected for initial investments. These include: well watered sites with some existing woody shrub cover and those areas in close proximity to existing indigenous stands which should be used as a major source of germplasm. The rate of succession to climax forest will be determined, to a large degree, by the amount of human intervention, in the form of planting and site preparation, grazing management, and fire control.

The stability of the purely agricultural areas is determined by the cycling of substances and energy. The higher the demands placed upon the system, in terms of biomass removed, the higher the necessary energy inputs to maintain stability and sustain production. The design of systems that meet these energy demands from within the system itself (adapted and compromise systems), is important in areas such as the Ngong where external inputs are generally not affordable by local farmers. The necessary inputs may include human labour or "home grown" fertilizer produced by nitrogen fixing trees intercropped with annual crops or grass/browse species.

3.7.1. Fire

The influence of fire has probably been most responsible for the establishment of grassland in the area and the subsequent inhibition of succession. Early burning by Maasai pastoralists to improve the amount and quality of fodder undoubtably influenced vegetation composition. The timing of the burning also has also had a marked effect. Fires towards the end of the dry season tend to more fierce and make greater incursions into the non grassy areas. As the trees and shrubby component are consumed, the species composition changes towards a grass species preponderance. As the grass content increases, the danger posed by the fine fuels to the remaining relatively fire tolerant species increases, and eventually, even they are destroyed. A pure grassland remains (often dominated by *Themedatriandra* or *Hyparrhenia spp.*) This is precisely what has occurred in the Ngong Hills. Repeated burning (as part of the original Maasai management of the area) coupled with more recent fuelwood gathering and clearing for cultivation has left the majority of the area *Themeda* grassland.

The effects of burning and the timing of the burn is subject to debate. Some researchers claim that burning late in the dry season causes little erosion as it leaves the soil exposed for only a short period of time before the rains start and growth resumes (Cook, 1965). However, given the erosive capability of the rains in hill country such as Ngong, (maximum 24 hour rainfalls approach 140 mm) a considerable amount of erosion can occur in a short time. In addition there is substantial evidence that hot burns, late in the dry season, can consume organic matter, thus reducing the water holding capacity of the soil. (West, 1964). Micro flora and fauna as well as soil structure may also be damaged by repeated or intensive burns. In light of the possible negative effects both on soils and forest establishment, and the present fire control capability of the Forest Department, it is suggested that all burning be discontinued in the area and that a fire control plan be prepared. This would include the establishment of a vegetative fire break at the forest boundary which would not react quickly to ignition.

It is not suggested that grassland be completely eliminated from the forest reserve, but rather, that it be significantly reduced. The grasslands have been very important to local pastoralists acting as dry season reserves. In addition, the diversity of habitat and the "edge effect" provided, is important to wildlife. The complete withdrawal of grazing rights may have serious consequences to adjacent ecosystems where the additional pressure will have to be accommodated. As it has been found that the effect of mowing is similar to fire (in terms of most aspects of succession inhibition), it may be possible to establish cut and carry grasslands in the lower reaches of the forest. This would have the dual benefit of providing much needed fodder, as well as reducing the danger of fine fuel ignition and subsequent forest damage. A cut and carry system would also reduce the damage to planting stock by grazing animals.

3.7.3. Resource Stability Mapping

The stability of the resources affecting primary production has been examined utilizing the methodology previously described. The result has been the series of stability maps. These indicate which areas may be considered *resource consuming, inequilibrium,* or *resource conserving.* They also illustrate in a relative sense, the total impact of current land uses throughout the area. Eg. As would be expected, the high density settlement in Ngong Town has a very high impact on the resources examined. Farming on the eastern slopes, under current management techniques, is also extremely resource consuming on some physiographic site types, whereas, extensive grazing in the Rift Valley is less so.

It must be stressed that these maps indicate trends under the common management techniques of the area and are **not** quantitative. Nor do they express the precise conditions on each land unit. For example, an area may be indicated as being resource consuming in terms of soil erosion. The methodology does not account for soil conservation structures and assumes they are not present (which is the case throughout much of the area). The condition of resource consumption holds true, if indeed, no conservation structures are present, but may be otherwise if they are on site. Currently, the maps indicate risk areas and local land manager's will have to assess the success of any structures on an individual basis. The original methodology was to include an assessment of the safeguarding provided by soil conservation structures but the quality of the most recent aerial photography did not allow for the necessary interpretation.

Perhaps the most useful application of the maps is an indication of which areas should receive priority attention given scarce development funds.

3.7.3. Summary

Although presented in a segmented fashion, the ecology of the Ngong Hills must be considered in a holistic manner. Manipulations within one part of the system will bring about corresponding changes in others, eg. soils, microclimate and water availability etc. Whatever the systems used by local peoples and other resource managers in the area, they must respond to the realities of nutrient and energy cycling. If the level of demand placed upon the system exceeds the internal and external inputs, instability arises and sustainability of production is surely threatened.

The Ngong Hills is a varied and diverse landscape with a correspondingly diverse land use spectrum. If land use is to be sustainable, it must be guided, to a large degree, by the ecological processes at play in the environment.

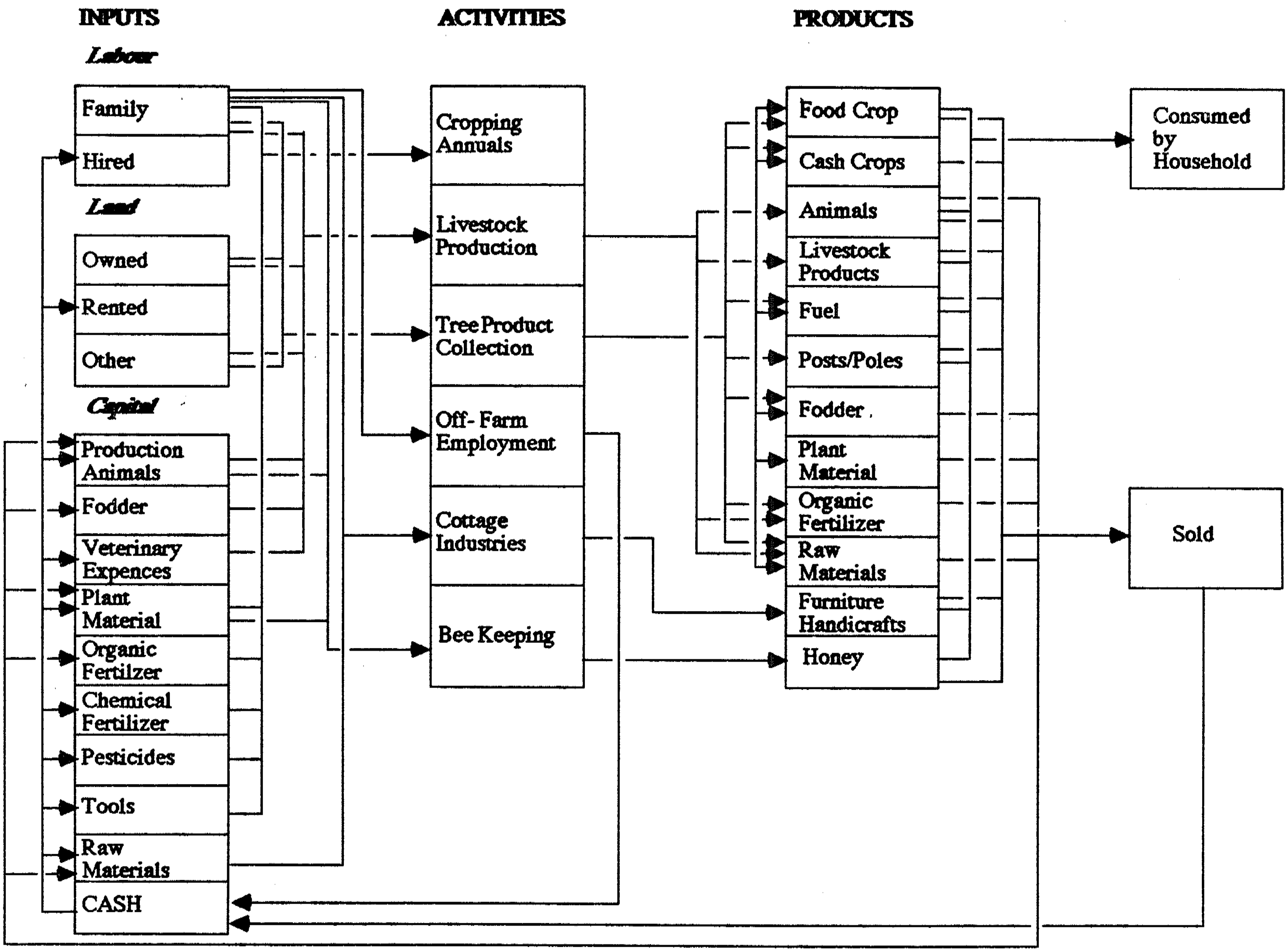


Figure 30. Input - Output Model of a Farm on the Eastern Slopes of the Ngong Hills

Ch. 4 The Socio-Economic Environment

4.1. THE SOCIO-ECONOMIC ENVIRONMENT

The landscape of the Ngong Hills has been changed and adapted over time by local peoples in an attempt to meet their needs and aspirations. The enormous changes that have occurred, have had, as their driving force, the strivings of people to take or nurture from the land those resources they can use. The present landscape reflects that force, and, at least a partial understanding of the landscape, comes with an understanding of the sociological structure.

4.1.1. Population and Labour Force

The latest population enumeration was the census of 1979. However, due to the lack of coincidence of census and study area boundaries, as well as the considerable change in the last eight years, the 1979 results were used only for Ngong township (adjusted for an annual growth rate of 5%.) The 1979 census was 3997 people and the 1987 estimate is 5605. For the remainder of the area, the average number of individuals per farm was determined from the farm survey results and this figure was multiplied by the number of farms.

The survey indicated an average number of 9.8 individuals per farm (not necessarily family units). Counts from the 1986 photography indicated a total of 732 farms. This yields a total population in the area of 12780 including Ngong Township. With an average farm size of 2.83 ha., the population density in the farming area of the eastern slopes is 346 persons per square kilometer. On the western slopes , densities are far lower and are estimated at less than 20 persons per square kilometer. The age class distribution is presented in figure 32. The female to male sex ratio was 0.98 : 1. Fully 69.1% of the population is below the age of 25, indicative of extremely high future growth.

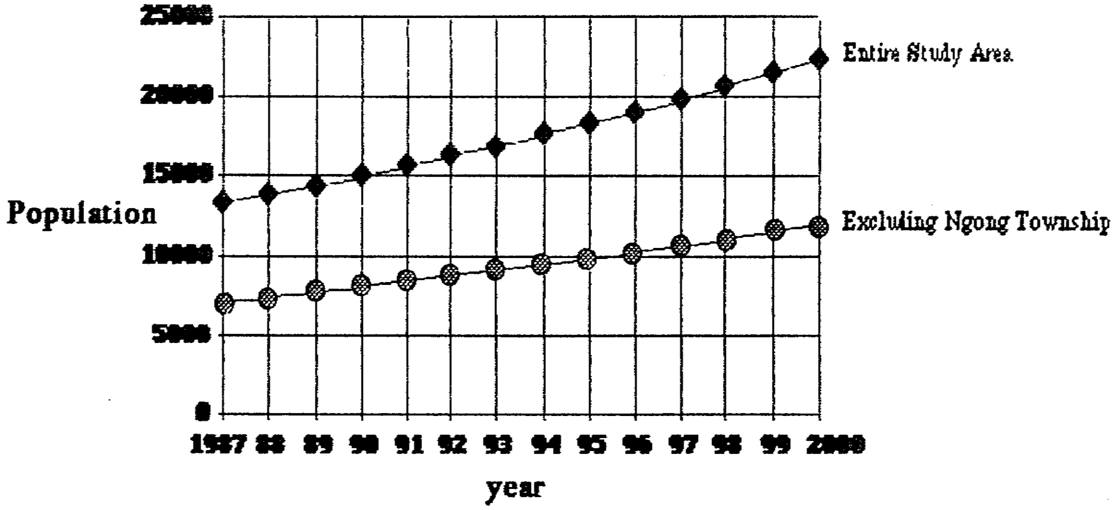


Figure 31. Population Projection to the Year 2000

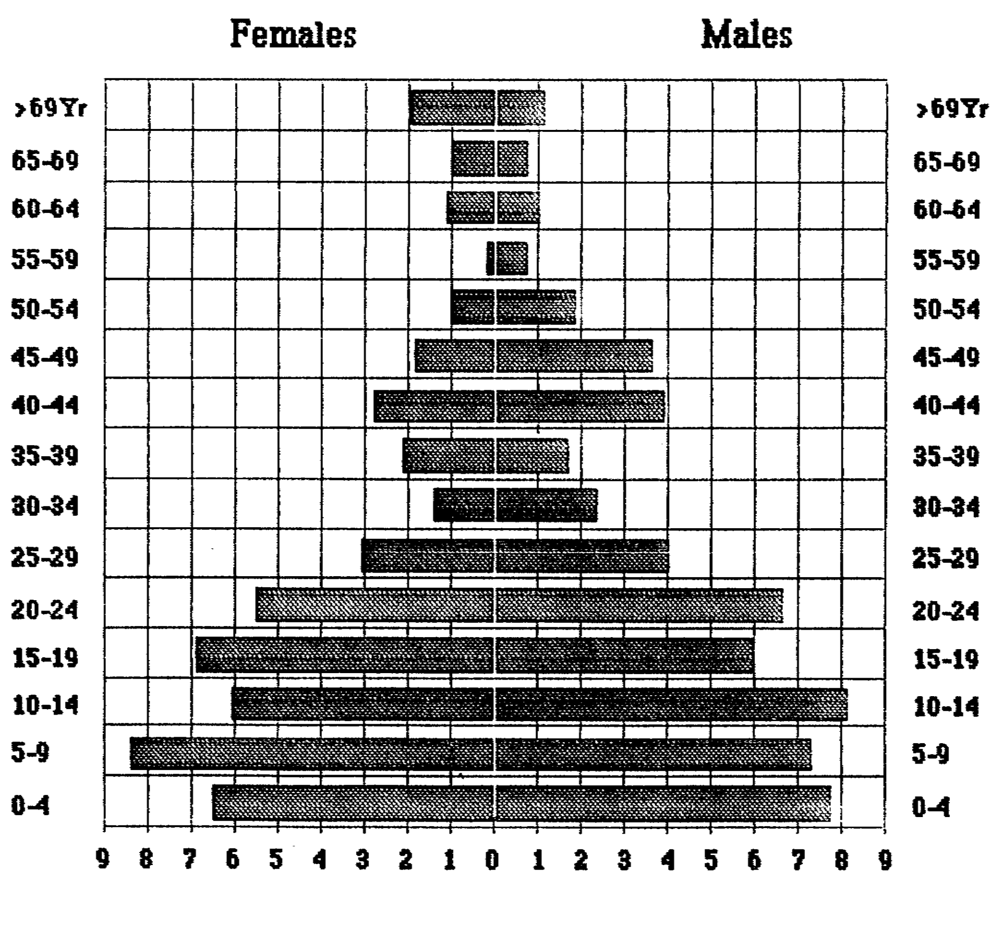


Figure 32. Population Distribution by Age Group

If the 15-54 age group is considered the primary work force, the dependency rate is 1 potential worker to 0.84 dependents. This can be considered reasonable given the national context. However, these are averages for the area and do not indicate the labour situation on individual farms. In many cases children and elders contribute significantly to on farm labour. Survey results indicated that, on average, there were 0.8 adult males and 1.2 adult females available for farm work (per farm). The difference in males to females is attributable to the off farm employment opportunities for each sex. An average of 0.7 males and 0.2 females per farm work off the farm. Many of these individuals are working in Nairobi. These figures indicate that a majority of the farm labour falls on the shoulders of women. This, coupled with the traditional division of labour, puts an enormous burden on the women of the area. The following division of labour is typical of many farms.

Table 7. Division of Labour on a Typical Smallholding

ACTIVITY	MALE	FEMALE
Water Collection & Transport		*
Fuelwood Collection & Transport		*
Fodder Collection & Transport	•	*
Cooking and Domestic chores		*
Childcare		*
Crop Husbandry	•	*
Animal Husbandry	*	•
Off Farm Employment	*	•

Primary responsibility * Secondary responsibility •

Fifty four percent of farms hire extra labour for at least part of the year. The average number of full time workers (or equivalent) is 1.4 per farm. The average total available labour would therefore be 3.4 full time workers. Considering the average farm size of 2.83 ha., this number is sufficient for intensive farming systems for most of the year. Using only these averages for labour problem diagnosis gives a misleading picture, as 39% of the farms reported seasonal labour shortages, particularly during planting and harvesting periods for maize/beans. The cost of labour in the area is 15-25 Ksh./day and this is a problem for many farmers with limited cash resources. There is no question that labour is available if the cost can be met.

Lack of education contributes to a maintenance of both the traditional division of labour and farming methods. The average length of education of the questionnaire respondents was 5 years but there were many instances of complete lack of education.
Attendance at school is now compulsory for children and educational levels are rising considerably.

4.1.2. Employment and Economic Status of Households

Determination of income was difficult as many respondents were either reluctant to reveal their income or kept no records and couldn't give an accurate estimate. Only 61% of respondents felt they could estimate their income and these tended to be in the middle and upper income groups (relative to the sample population). Those that couldn't or wouldn't respond often were at the very lowest end of the income spectrum. The following chart of population distribution by income group does not include this group. Similarly, the average income per farm of 2836 Ksh. per month is higher than it would be if all farmers in the survey were able to respond. However, even with this bias 60% of the population earn less than 2000 Ksh. per month per farm unit and this sum must support an average of 9.8 persons. The average income amounts to 3472 Ksh. per person per year. Savings of any kind (including savings in the form of livestock or other farm investments) are only possible for 31% of the farms.

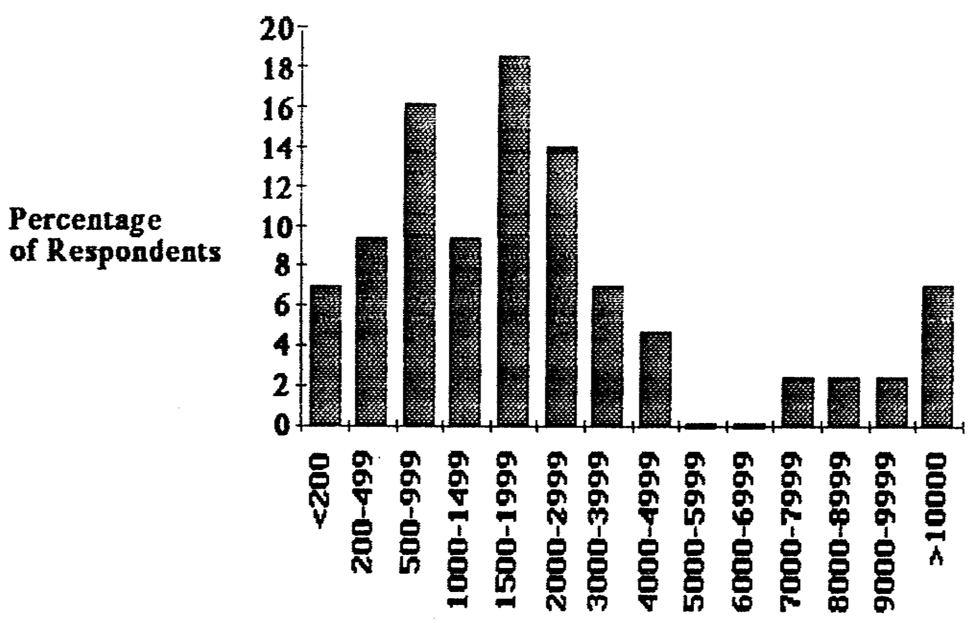


Figure 33. Population Distribution by Income Group per Farm Unit

Note: This chart illustrates only the distribution of those people who were willing and able to estimatetheirincome.

By far the greatest amount of cash for most farms comes from off farm employment which amounts to over 70% of the reported income. The balance is made up of sales of: cash crops (11%), surplus foods (7%), livestock related products (11%) and gifts or remittances (1%) (See figure ?). As the total income of the farm rises, a greater percentage comes from off-farm employment. The importance of off-farm employment is partially attributable to the proximity of Nairobi where there are employment opportunities. It is also indicative of the low degree of market orientation of the farms.

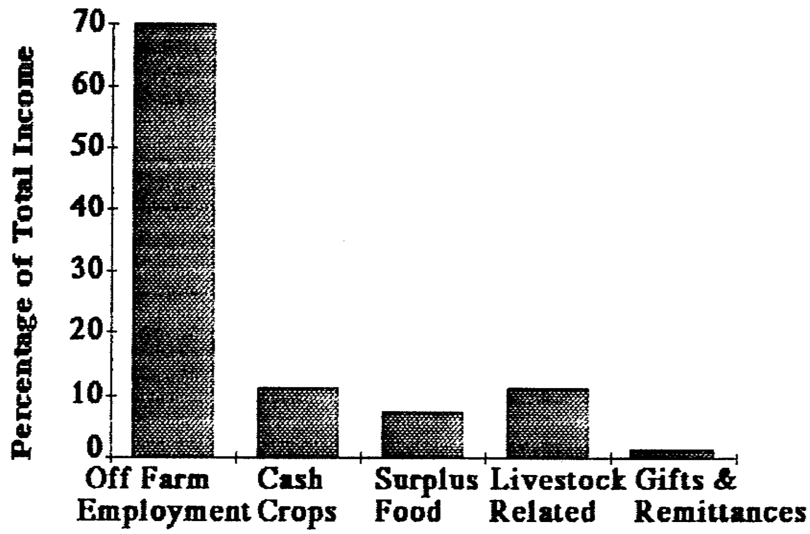


Figure 34. Sources of Earned Income

Although 19% of farms reported some type of cottage industry, the generated income was invariably low. Types of cottage industries included: spices and condiments, leather goods, hand made sisal products, embroidery and furniture manufacturing and repair.

Although the cash generation figures indicate the relatively small cash importance of agricultural activities to the economic well being of the farm unit, the subsistence level of most farm activities must be recognized. With limited employment opportunities there are few alternatives to agriculture for most people. Farming is still providing most people in the area with much of their food. Although 76% of the farms are near self sufficiency in food production, 86% still report seasonal shortages of staples. Of those reporting seasonal shortages, 47% report them only in bad years, while 15% note them in most years and 37% experience shortages even in good years. Clearly, there is need for production improvement in order to adequately meet this basic need. Lack of cash for inputs such as fertilizers and improved seed is a major constraint (See land utilization types for additional production constraints).

Livestock related products are currently about equal to arable agricultural activities in terms of cash generation. This area has great potential for improvement in the Ngong area. There is a large and expanding market for milk and farmers can easily sell all they produce. Although there is a dairy co-operative, milk collection and marketing is a problem for many producers. In addition, payments are often delayed causing cash bottlenecks. Other constraints to improved milk and livestock production are: fodder shortages, inadequate credit facilities for purchase of grade cattle, and disease and veterinary problems.

Wood products, including building posts, poles, and fuelwood do not figure prominently in either cash generation or production for on farm use. This is another area for potential improvement. The market for such products is substantial and well developed in the Nairobi area and producers would have little difficulty selling. In addition, scarce cash resources could be diverted to other uses if farms produced more, or were self sufficient, in these products. Fuelwood in particular has potential as a cash crop.

Cash crops and surplus food sales account for about 17% of the total farmer income. Coffee is grown on only a few farms as it requires cash inputs for chemicals etc. Although the area is a marginal coffee area it has not met with a great deal of farmer acceptance. Similarly, pyrethrum which was grown in the area in past years, has fallen from favour, due mainly to market difficulties. The main agricultural cash generators are maize, beans, and potatoes, followed by irrigated horticultural crops such as tomatoes, cabbages, onions, and spinach grown for the Nairobi market. As the risk of maize failure is high (25%) and few farmers have any irrigation, the need for alternative cash crops, particularly those that require little cash outlay, is great.

The average expenditure pattern of farm units in the area is presented in the following chart. Despite the fact that a large proportion of the respondents said they were at or near self sufficiency in food, expenditures in this category are still the highest. This variance may be attributable to the fact that the chart reflects only those who could estimate their expenses and this group has a higher income and tends to rely more on off-farm employment. In addition, there may have been a tendency for respondents to exaggerate their self sufficiency and downplay production deficits.

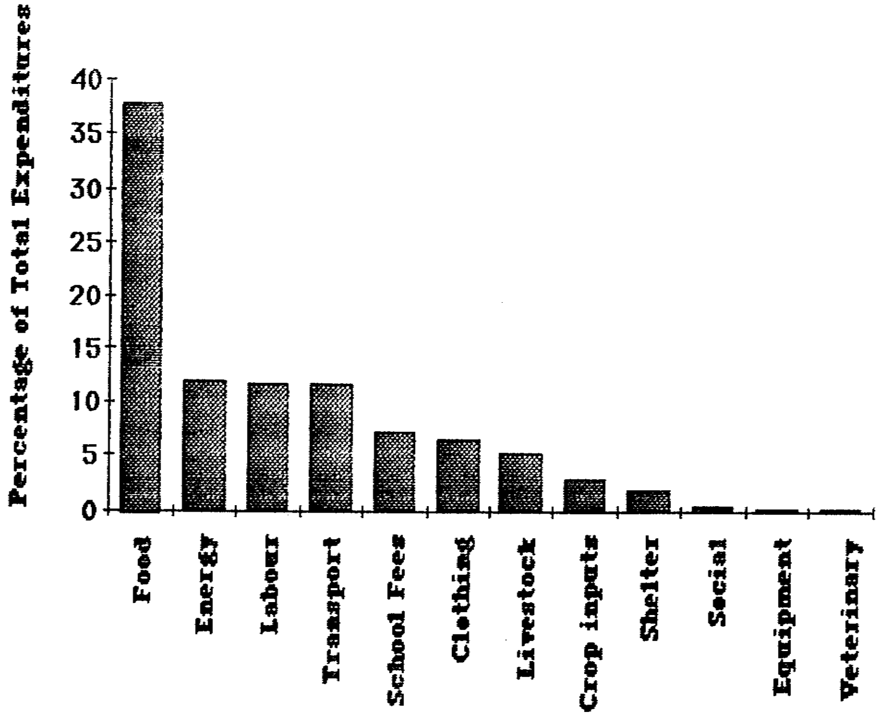


Figure 35. Expenditure Pattern

Those farmers who couldn't estimate their expenditures were most often in the lower income groups. These individuals were asked to rank their expenditures as either major, moderate or minor. From this ranking energy emerged as the most consistently major expense followed by shelter, crop inputs, food and clothing. The relatively high ranking of shelter may be the result of a greater percentage of individuals in the lower income groups who rent their land. It would also appear that the lower the income, the greater the reliance on self produced food. Energy expenditures as a percentage of income necessarily go up for this group.

4.1.3. Agricultural Costs and Prices

The possible options open to local farmers are determined in large measure by the economic reality. The following section summarizes some of the key areas.

Credit utilization was difficult to elicit but is estimated as low. Financial institutions lending to local farmers include the Kenya Commercial Bank, the Cooperative Bank For large co-op operations),

the Agricultural Finance Corporation as well as private banks in the area. Loans are occasionally made for farm improvements and stock upgrading (see below). Title deeds to land are generally required for collateral.

The Agricultural Finance Corporation is the most commonly utilized credit institution. The types of loans they will consider are presented below:

Table 8. Types of Loans Available

Type of Loan	Repayment Period (yr)$_1$	Interest Rate$_2$	Minimum % Down Payment	Remarks/Security$_3$
1)LAND PURCHASE	up to 20	12	20 - 40	
2)DEVELOPMENT	5 - 10	12	varies	Secured by title deed
2a) Dairy loan (cattle, sheds, dips)	5 - 10	12	-	Repayment through I.R.O.(irrevocable)
2b) Ranch loan i. development	20 years	12	20	Repayment at sale of animals. Working capital provided at full amount for first 2 years Then sliding scale for 8 years. May be 4 year grace period on development loans.
ii working capital	2 years	13		
2c) Sheep Loan (breeding stock, dips, pasture improvement, fencing	5 Or 10 years	12		Only justified when farmer can warrant higher stocking rate. Must be mixed farm.
2d) Pig Loan i. development	3 - 5 years	12		intended market must be shown

Type of Loan	Repayment Period (yr)[1]	Interest Rate[2]	Minimum % Down Payment	Remarks/Security[3]
ii. working capital		13		
2e) Poultry Loan (chicks, feed, working capital)				Restricted to areas with localmarketing advantage. Minimum size layer:500Broiler:1000
i. Feed	2 years	13		
ii Others	4 years	12		
2f) Pasture Improvement Loan (leyestablishment, paddocking fencing)	5 years	12		Total loan based on # of animals to be kept.
2g) Coffee loan				
i) working capital	1 year	13		Must have coffee
license				
ii processing etc.	5 - 10 years	12	25	May be 3 year grace
2h) Water Loans (tanks, damsetc)	5 - 10 years	12	25	Must have water permit Must have installed eq.
2i) Seasonal Crop Loans formaize/wheat	1 year	14	20	Financed at the rate of Ksh. 1 360 per acre.
2j) Other Seasonal Crop Loans (maize, cotton, wheat, sunflower, potatoes, horticultural crops)	2 years	13	25 Ksh. 1 000 per acre	Financed at the rate of Secured by title deed.

Notes:

1. Unless stated otherwise a grace period of 1 year after loan disbursement is granted.
2. Interest rates are bound to change from time to time.
3. Most AFC loans are secured by title deeds; limited unsecured credit of up to 50 000 Ksh. can be granted where appropriate security is not available.

Source: A.F.C. Development House, Nairobi and Farm Management Handbook of Kenya Vol. IIIB

4.1.3.2. *Agro Input and Commodity Prices*

This topic has been dealt with in a very detailed manner in the Farm Management Handbook of Kenya Vol. IIIB (Ministry of Agriculture, 1985). Readers are referred to that publication for further information.

4.1.4. Infrastructure

In relation to the rest of the country, The Ngong Hills area is very well served by a developed infrastructure. This however, is not to say that it is optimal, and there is much scope for improvement.

4.1.4.1. *Roads and Transport*

The road network in the study area is adequate in terms of it's extent, but is in need of additional

upgrading and maintenance. The Settlement and Infrastructure map illustrates the road network by type and condition. The best roads in the area are the main Ngong to Nairobi Road, the Ngong to Kiserian Road and the Magadi Road, all of which are hard surfaced.

The upper circular road, which is the major spine of the study area, is unsurfaced and difficult for two wheel drive vehicles to negotiate after heavy rains. The road width and alignment are satisfactory given the present and anticipated levels of use. Drainage structures (culverts, channels and ditches) are often blocked, giving rise to over road flows and subsequent running surface damage. Sidehill cuts need stabilization in several locations if future high maintenance costs are to avoided.

The aesthetic quality of the upper circular road is very high and the route is a popular pleasure drive for Nairobi residents, particularly in combination with the route around the hills. The alignment follows the contours and wraps gracefully around the many footridges of the hills. Running, as it does, between the 1900 and 2100 meter contours, framed and open views are afforded of both the skyline of the ridge and the hills below the road. Although contributing significantly to the spatial variety of the alignment, the roadside planting could be greatly improved and better coordinated. Presently, the roadside is underutilized and in need of rehabilitation. Improved planting in this large niche could add, not only to the scenic quality of the road, but, more importantly, to the functional requirements of the right of way (ie. erosion control and sidecut stabilization, provision of shade, fodder and fuelwood).

The many side roads and small tracks throughout the farming area provide both vehicular (often only 4x4) and pedestrian access to the farms. Generally, these are located along the ridge tops and in the valley bottoms. Maintenance on these tracks appears to be close to nil and many are nearly impassable to two wheel drive vehicles, even in the dry season. Large volumes of water run down the roadways and serious gully erosion is evident in many locations. Diversion ditches are desperately needed along most of these routes but these must be placed in such a way as to prevent large discharges into adjacent farmers' fields. Although too narrow in some places to allow planting, there are many presently unutilized locations that would be suitable for additional plant material.

A similar situation has developed on the main road to the top of the hill at the north end of the ridge. Inadequate initial design and poor maintenance has resulted in erosion so severe that the road had to be relocated parallel to the original route. In places, the second road is below surrounding grade by as much as 2 meters and it too will soon reach the condition of the first alignment.

Because of this the hill top is no longer accessible to saloon vehicles for most of the year. As this is the main access and the local council is charging admission to vehicles, there are economic as well as ecological reasons for improving and then properly maintaining this road. The road ends at the radio beacon but a smaller track proceeds beyond this point for more than a kilometer. In addition to disturbing hikers, four wheel drive vehicles have caused considerable vegetative damage along this route.

Access to the ridge from the south is via a 4x4 track from the Magadi Road. No maintenance is carried out on this track either and there are several locations of serious erosion. The road makes its way to a point just below the highest summit from which a foot trail proceeds for several kilometers along the ridge to the north access road. Views from both of the ridge access tracks are spectacular and varied.

The road network in the Rift Valley portion of the area is limited to the western circular route and unimproved 4x4 tracks branching from it. Many of the latter are impassable in all but the driest seasons. Erosion on many of the tracks is causing the development of parallel roads which in turn also degrade.

While the distribution of roads appears to adequately serve the populus, the condition of many tracks renders them unsatisfactory. Farmers who do have vehicles can often not use them and those that don't have to haul their produce on foot to a point that public vehicles can reach. The lack of public transport on all but the hard surfaced roads means that most of the people in the area have to walk very long distances to reach transport. This affects not only the transport of produce to available markets but also the possibility of finding and taking work elsewhere. It also contributes to the number of absentee members of families who live and work off farm. A matatu (privately operated small bus) service along the upper circular route would greatly improve the situation for many people. However, matatus would not be able to operate in wet weather given the current condition of the upper circular road.

4.1.4.2. *Water Supply*

The Ngong Hills have traditionally been a plentiful source of water. Indeed, the very name "Ngongo" refers to the eye, spring or source of water. Unfortunately, shortages of water are now the norm for many local residents. Water rationing occurs in virtually every part of the study area that has piped water including Ngong town itself. Most schemes turn the water on every three

days. Increasing populations have brought about an ever increasing demand which given present resources is not possible to optimally satisfy (see hydrology section). This demand has led to a number of developments.

Several water projects have been initiated in the area in recent years. Many have been completed or are nearly so while several others are in the planning and construction phases. The infrastructure map indicates the location of piped water projects. In addition several new boreholes are planned to help meet the demands of Ngong Town and adjacent areas.

Many of the projects have been developed on a harambe or self help basis, with the government providing matching funds as well as technical advice. Several springs have been tapped in the hills but these are often shallow sources and are at their production/utilization limits. Their are many private boreholes in the area and these serve not only the owners but very often the population in the immediate vicinity. There are few retention dams in the area, although there is great potential for more. Water points including piped water schemes are located in the areas of greatest population density namely the eastern slopes and their is very little to serve those in the west. The following is the percentage of farmers who report their main source of water to be:

Borehole	19.7%
Piped water (within 1 Km.)	57.6
Trucked(delivered)	4.5
Spring	18.2

38% claimed their drinking water supply was inadequate and 48% had difficulty securing adequate water for their stock. 62% have some water storage facilities and 48% are employing some form of waterconservation.

4.1.4.4. *Extension Services*

Extension services are provided mainly by the Department of Agriculture who maintain a District

Agricultural Officer with a staff of 11 working from the Ngong office. Advice on arable agriculture and livestock development is available and their are a few model farms in the area. The department also has a bee keeping extension service that visits the area. The Ministry of Energy (Kenya Woodfuel Development Programme) has a few agroforestry demonstration plots in the area. The agricultural finance corporation also offers financial advice.

The local Veterinary Clinic provides services. In most instances the farmer must come to Ngong Town for advice although the agricultural extension officers do visit the farms.

4.2 PRESENT LAND USE

The Ngong Hills have undergone dramatic and extensive changes in land use, particularly over the last thirty years. The following percentages of farmers reported the original land use at the time of occupation to be:

Arable agriculture	24.2 % of respondents
Forest products	11.4
Grazing	71.4

The previous vegetative cover at the time of occupation was reported to be:

Cultivated crops	15.7 % of respondents
Grassland	28.6
Forest	40.0
Bush and Thicket	15.7

These percentages are in marked contrast to the present conditions where arable agriculture now accounts for almost 100% of the eastern slopes outside of the forest reserve. The natural forest has been completely destroyed in the farming areas . Considering the average length of residence is only 16 years, the rate of change has been very high. This has had a profound effect upon the ecology and production characteristics of the area.

While mixed small scale farming is widespread on the eastern slopes, extensive grazing is the still the most common land use in the western and southern portions of the study area. The gazetted upland forest area is used for the grazing of domestic stock, fuelwood and fodder gathering, watershed protection, and recreation as well as for wildlife protection and research. The distribution of major land utilization types (LUT's) is illustrated on the map. Land use A summary of the major land use categories and areas is found in the table and chart below. Details of the land utilization types follow, together with plans and sections of several representative farms. Although most of farms in the area are mixed agriculture operations, the cropland and livestock components are presented separately.

Major Land Use	Hectares
High Density Settlement	56
Forest Reserve	3077
Large Holder Extensive Grazing Lands	1679
Small Holder Mixed Farming	2388
Total	7200

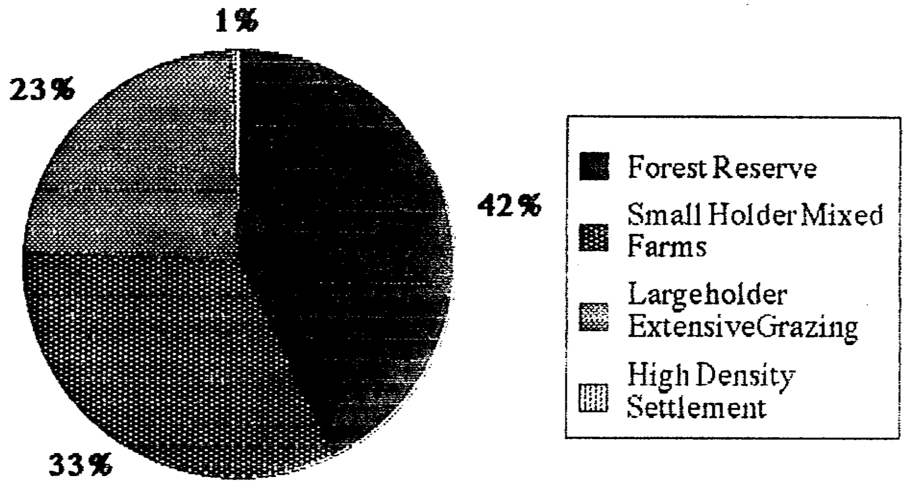


Figure 36. Major Land Uses as a % of the Total Study Area

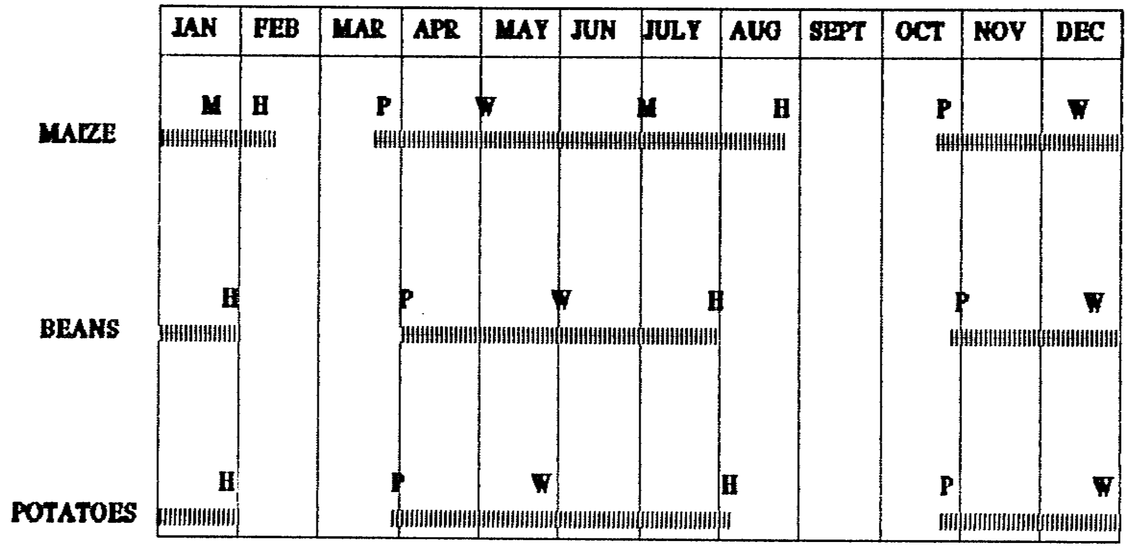
4.2.1 Cropland

Cropland accounts for a large portion of the study area and most people in the area derive at least some of their basic needs from it. Details of this major land use follow.

4.2.1.1. *General Cropping Characteristics*

Most of the arable cropland in the study area occurs on the eastern slopes below the forest reserve. Small scale, non-mechanized, rainfed, subsistence farming with little commercial orientation is the norm. Maize, intercropped (both mixed and row) with beans is almost universal as the major crop component, followed by English and sweet potatoes, and peas, which are also intercropped with maize. Crops are planted twice a year on the same land at the beginning of the long and short rains.

Maize grown in the short rains runs a 25% risk of crop failure. Despite this, many farmers continue to plant this staple as it is difficult to obtain and transport legally otherwise (due to maize transportation regulations). Failures are used for livestock fodder. Occasionally, the maize/beans combination is replaced by potatoes/beans in the short rains. The following generalized cropping calendar indicates the distribution of farming activities for the three major crops.



P = preparation and planting **W**= Weeding **H**= Harvesting

Figure 37. Cropping Calendar

Only 10% of farmers fallow any of their land and those that do, rest only a very small portion and the period of fallow is usually only a few months. Pastures are not generally rotated with cropland. The average cultivation factor which is " the number of years under cultivation as a percentage of the total cultivation , non-cultivation cycle....... a measure of the intensity of arable use of a soil. " (FAO, 1984), is estimated at 67% for the entire farm (cultivated land / (fallow land + productive land + cultivated land). The cropping index which is : " The number of crops harvested in relation to years in the cropping cycle " (FAO, 1984) is 200%, indicative of double cropping per year.

The production level may be classified as Level 1 according to the Farm Management Handbook of Kenya. Farmers employ traditional production techniques, do not apply appreciable amounts of fertilizers and do not utilize plant protective agents with the exception of coffee. (although 77% of farmers apply some manure to their land and the amount only averages about 50 kg./ha./yr.) Use of improved seed is usually limited to maize of which 612 and 613 are the popular varieties.

4.2.1.2. *Land Utilization*

The following chart illustrates the land utilization by use and crop type on the average farm.

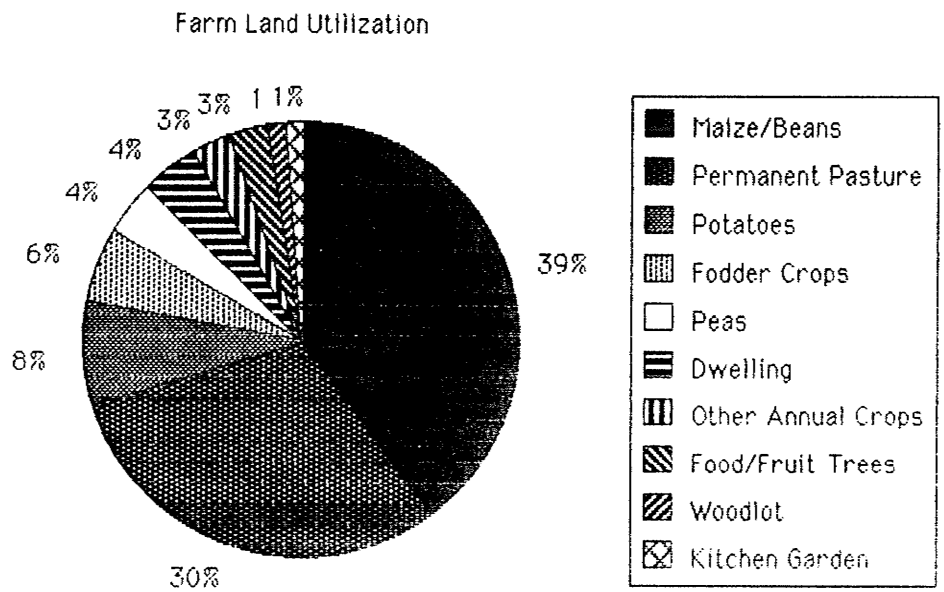


Figure 38. Farm Land Utilization

The following table lists the various crops grown and their average areas:

Table 9. Land Utilization on Small holdings

Land Use	Acres	Hectares
totallandsize	7.0	2.83
rainfedcropland	3.8	1.54
maize/beans(intercropped)	2.9	1.17
peas	0.3	0.12
potatoes	0.6	0.24
other crops*	0.2	0.08
fodder crops (incl. napier)	0.4	0.16
fruit/foodtree/shrub	0.2	0.08
permanentpasture	2.2	0.89
other trees (woodlot)	0.1	0.04
kitchengarden	0.1	0.04
dwellingplace	0.3	0.12

* other common crops include: millet, sorghum, wheat, cabbages, sweet potatoes, sugar cane, kale, tomatoes, soya beans, carrots, parsley, onions, sunflowers.

4.2.1.3. *Yields*

Actual yields are difficult to determine as most of the produce is consumed on farm and few farmers keep accurate records. However, estimates based on farmer interviews indicate yields for maize range from less than 800 kg./ha. to about 1600 kg/ha. per year, all of which are below the predicted yields for this zone and level of management. According to similar areas, yields without fertilizers should be approximately 2000 kg./ha. With fertilizers and higher management levels, yields of up to 4000 kg./ha. are possible (Ministry of Agriculture, 1983).

Results of trials in Kajiado district indicate yield increases of 31 Kg. per hectare for each kilogram of 60-60-0 fertilizer added per hectare. Significant yield increases could therefore be expected in the LH3 (III-3) zone of the Ngong Hills if fertilizers could be added. Increases in the drier zones would be far less.

Yields for beans are very difficult to estimate probably runs around 600 kg/ha. at production level 1. Sunflower, although not common in the area could do well at about 600 kg./ ha. Potatoes and cabbages are subject to tremendous variation with the level of management. Yields are around 5000 kg/ha for potatoes and 2000 kg./ha. for cabbages, but yields of far higher are possible.

Napier grass yields are unknown but similar areas report yields of 2500 kg. of total digestible nutrients (TDN)/ha without fertilizer.

4.2.1.4. *Planted Trees and Woody Perennials on Farms*

The on farm woody component has undergone fluctuation and change over the years. Almost all the native forest that was in the farming area has been removed. In its place are cropland, pasture land and planted trees and woody perennials. The following is the percentage of farmers who felt the number of trees in the area (in the past five years) had:

Increased	69%
Decreased	31%

If felt to have **increased** the following percentages cited these reasons:

Protected by local people	2
Protected by government	2
Population not increased	0
New Plantations established	96

If felt to have **decreased** the following percentages cited these reasons:

Population increased	0
Cultivation increased	15
Uncontrolled cutting	71
Overgrazing	5
Fire	0
More than one answer	9

Tree planting on farms has been well accepted and the number of trees on private farms has increased significantly over the past five years (as opposed to the number of trees on public lands). This is very evident when the 1978 photography is compared with the present situation. 89% of farmers plant trees on their land while only 34 % plant outside of their farm boundary. The most commonly planted trees in the area are: *Croton megalocarpus, Grevillea robusta, Eucalyptus saligna, Cupressus lusitanica, Casuarina equisetifolia,* and *Schinus molle.*

Unfortunately, most of the above mentioned species are not very suitable for intercropping (given present management practices) as they are excessively competitive with crops for both light and, especially in the case of the *Eucalyptus*, water. The very large numbers of *Eucalyptus* that have been successfully established in the area are a problem in several ways. A mature specimen will transpire up to 400 gallons of water a day, which is a serious blow to local soil moisture reserves, not to mention groundwater recharge. In addition, the leaves contain toxins which accumulate in the soil and can preclude future maize production. The brittle nature and extremely tall growth form of this tree make it a dangerous species to plant in the very densely populated areas.

The major source of seedlings (65%) is the government MOE nursery at Ngong. Other sources are: private nursery (19%), on farm nursery (7.9%), and transplants from farmer's own land (7.9%). Only 50% of farmers felt they could get the species they wanted.
When asked for which reasons they would plant trees next year, the following percentages of farmers cited:

Reason	**Percent of Farmers**
Fuelwood	32
Fruit / Food	21
Building Posts and Poles	20
Shade	9
Windbreaks	8
To increase rainfall	5
Fencing	2
Erosion Control	2
Charcoal production	1

In recent years there have been several agroforestry initiatives in the Ngong Hills. The Kenyan Renewable Energy Development Programme (KREDP) has provided some farmers in the area with both advice and seedlings. From their trials they are recommending the following species for the area. *Leucaena leucocephala, Sesbania sesban,* and *Calliandra calothyrsus,* planted along contours or on terrace edges together with Bana or Napier grasses. The suggested in-row spacing is 0.25 - 0.5 m. with 4 - 8 meters between rows. Other recommended species include: *Erythrin. abyssinica, Cordia abyssinica, Acacia sp., Markhamia sp.*, and *Grevillea robusta.* They also are recommending that farmers plant in an east west orientation wherever possible. This last point is far too general however and does not fully consider the local wind variation due to topography.

The Mazingira Institute together with I.C.R.A.F. did some work with local people in the Kibiko area in 1983. A cursory Diagnosis and Design was conducted and several on farm trials were conducted. The trial species included *Leucaena leucocephala, Grevillea robusta, Casuarina equisetifolia, Sesbania grandiflora, Marcharium tipu, Prosopis chilensis, Ceasalpinia spinosa, , Mimosa scaburella, Zyziphus mauritania.* Success on the experimental trials was limited due in most part to inadequate water supply.

The percentage of farmers who feel that the main reasons for seedling mortality are:

WaterDeficiency	88%
Goats	3
Mole Rats	3
Insects	2
Wrong Species	2
Other Pests (incl. wildlife)	2

The following are the possible niches for trees identified in the farming area (listed in decreasing order of occurrence and present degree of utilization):

Table 10. Possible Niches for Trees (Occurrence & Present Utilization)

Occurrence	Degree of Utilization
1. Cropland	1. Property boundaries
2. Around homes	2. Hedgerows
3. Property boundaries	3. Field boundaries
4. Field boundaries	4. Around homes
5. Roadsides	5. Cropland
6. Hedgerows	6. Roadsides
7. Pastures	7. Pastures
8. Drainage channels	8. Perennial Orchards (incl. napier)
9. Terraces	9. Gullies
10. Perennial orchards (incl. napier grass)	10. Woodlots
11. Gullies	11. Terraces
12. Woodlots	12. Drainage channels
13. River/stream banks	13. River/stream banks
14. Rangeland	14. Rangeland
15. Waterholes	15. Waterholes

4.2.1.5. *Capital Intensity*

Capital intensity of the operations is low (see income section) and most farmers are not able to afford agricultural inputs such as fertilizers and pesticides. This combined with other factors, such as poor soil management, have lead a majority of farmers to complain of declining yields. This is to be expected as most of the soils were developed under forest cover and the initial fertility has been depleted in the absence of affordable inputs.

4.2.1.6. *Labour and Power Intensity*

The labour intensity on the farms is high with approximately 5.4 man months per hectare per year (or 3.2 full time adult workers per farm) available on the average farm. Despite this, some farmers report shortages of affordable labour at peak periods. Power on the farm is almost entirely human labour and few people use draught animals with the exception of donkeys for hauling water. There is very little use of machinery although some of the larger farms do hire custom operators for ploughing. The common hand tools used are pangas (machetes), and jembes (hoes).

4.2.1.7. *Technical Knowledge and Attitude to Agriculture*

The technical knowledge and attitude towards agriculture of farmers in the area is extremely variable, ranging from several outstanding examples of model farms to many that are less than adequate. Generally speaking, the farmers have at least primary school education and are receptive to beneficial innovation. Most farmers are aware of the dangers posed by poor management and have made at least some effort to improve their land.

Ethnic composition affects farmer attitude towards agriculture. The Kikuyu farmers have more cultivation experience than many of the Maasai people who have only recently adopted farming. This is by no means universal and some of the finest farms in the area are operated by Maasai.

4.2.1.8. *Size and Shape of Farms*

Farms are generally laid out parallel to the crest of the ridges (where there is usually a road or improved track) and often run from the ridge crest to the valley floor. At the end of a ridge the farms are usually laid out radially. The average farm size is seven acres (2.83 ha.) and the mode falls in the 5.1 - 10 acre class. Farm size ranged from one to one hundred acres on the eastern slopes, and up to three hundred acres on the ranches in the western portion of the study area. The following table lists the percentage of farms in the various size groups:

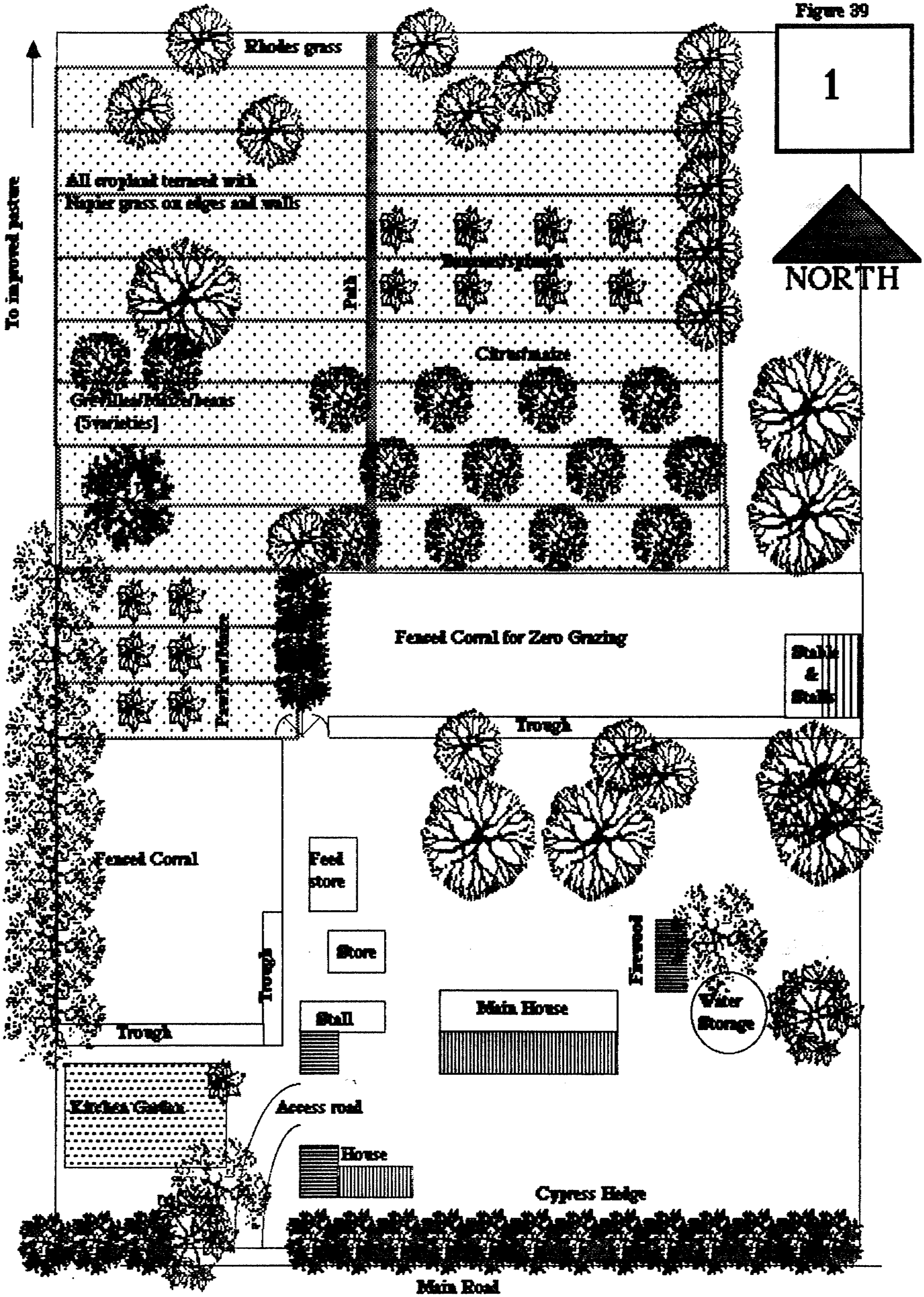
Table 11. Size Distribution of Sampled Farms

Size	Percentage of Sample
< 2 acres*	22.9%
2.1 - 5 acres	28.6
5.1 - 10	32.8
10.1 - 15	5.7
15.1 - 20	4.3
20.1 -50	4.3
> 50 acres	1.4

* Subdivision under 2 acres illegal by act of parliament!

The following plans and sections are of typical farms sampled. The first farm illustrated, is that of an old Kikuyu woman who had the finest farm the author visited. She demonstrated a wealth of agricultural and agroforestry knowledge and was making over 3500 Ksh. per month off her 6 acres. Few farms came close to this and most of the others were far from it in terms of production andsustainability.

Figure 39


1
NORTH
To improved pasture
Rhodes grass
All cropland terraced with
Napier grass on edges and walls
Path
Citrus/maize
(5 varieties)
Fenced Corral for Zero Grazing
Stable & Stalls
Trough
Fenced Corral
Trough
Trough
Feed store
Store
Stall
Main House
Firewood
Water Storage
Kitchen Garden
Access road
House
Cypress Hedge
Main Road

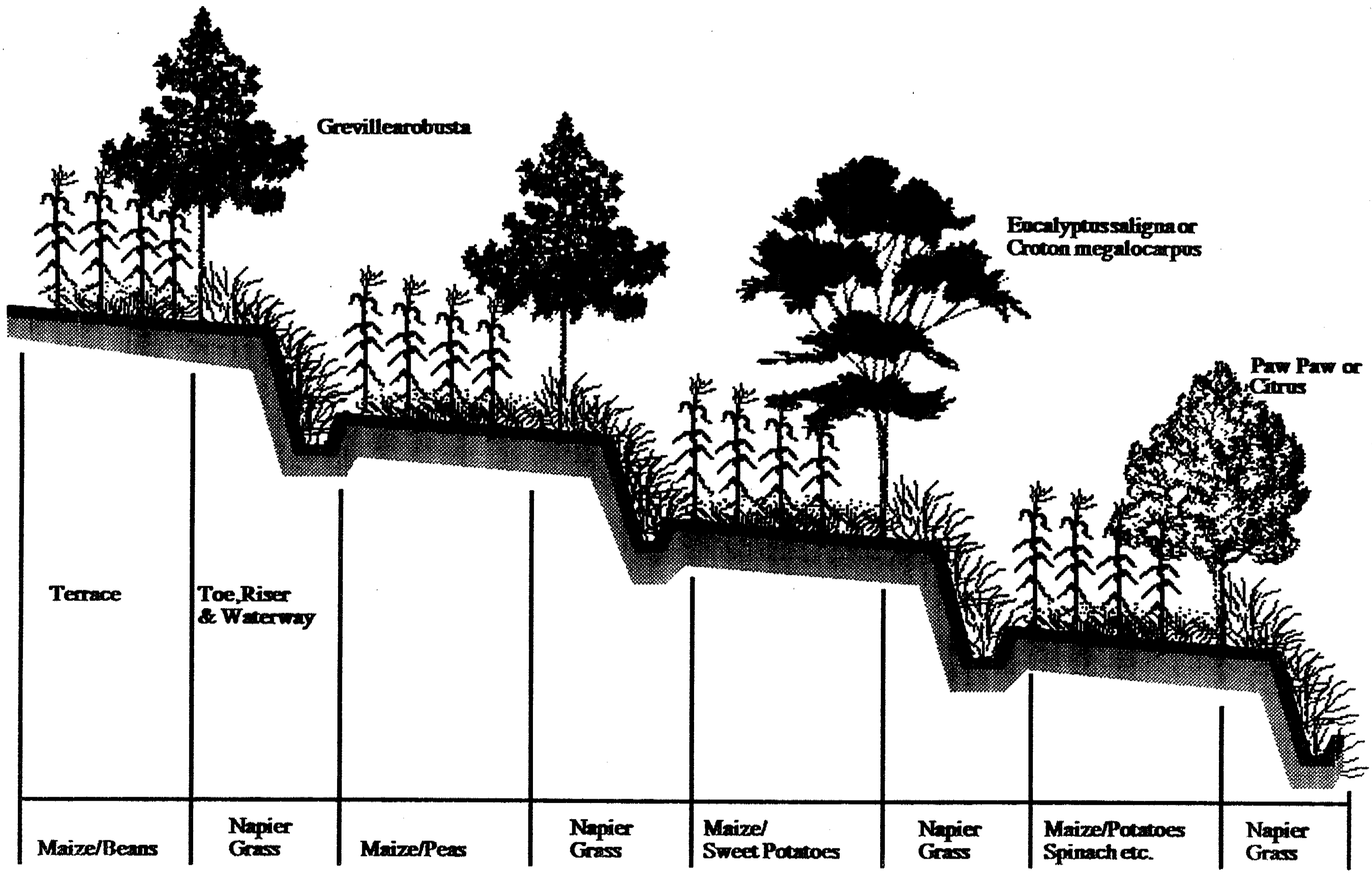
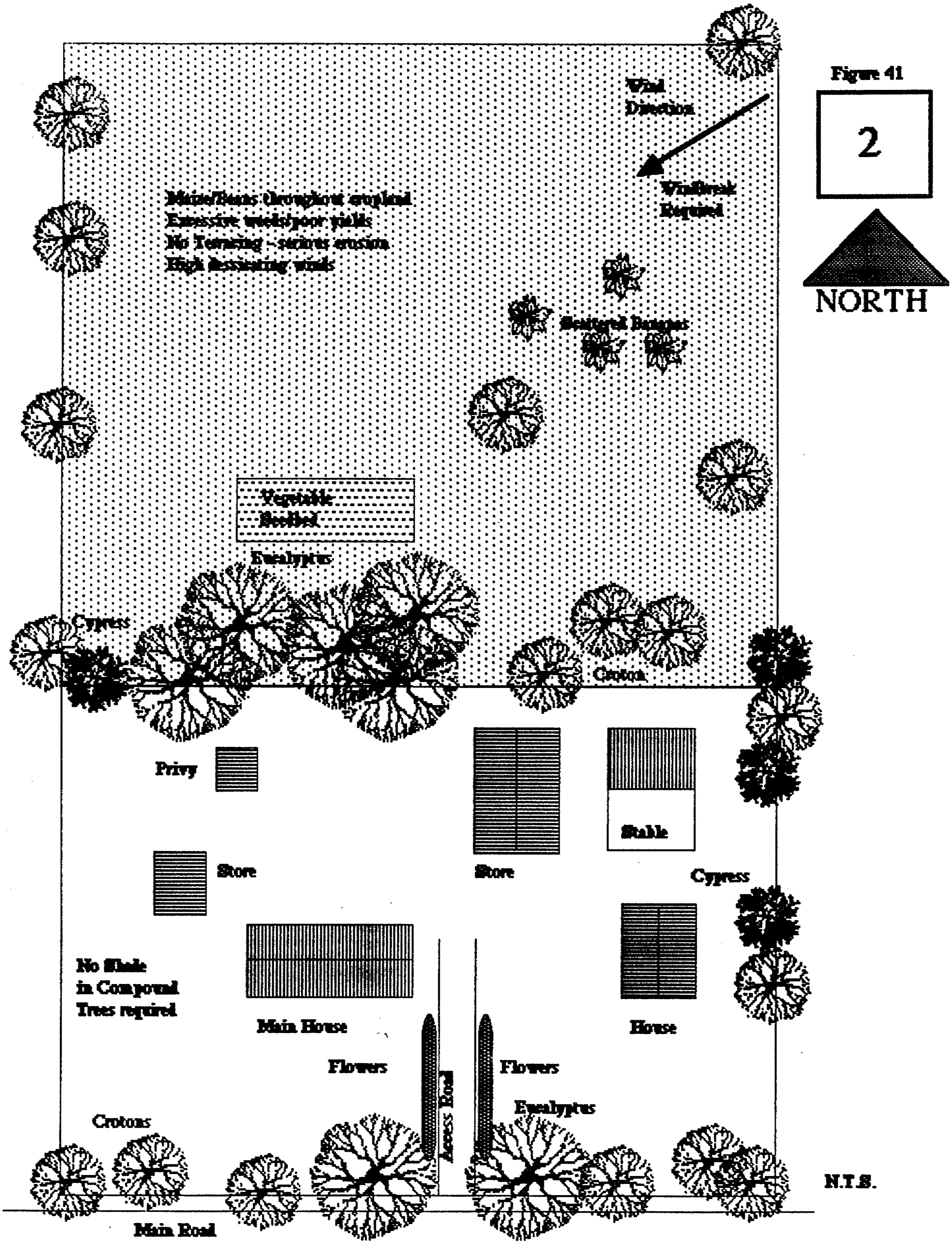


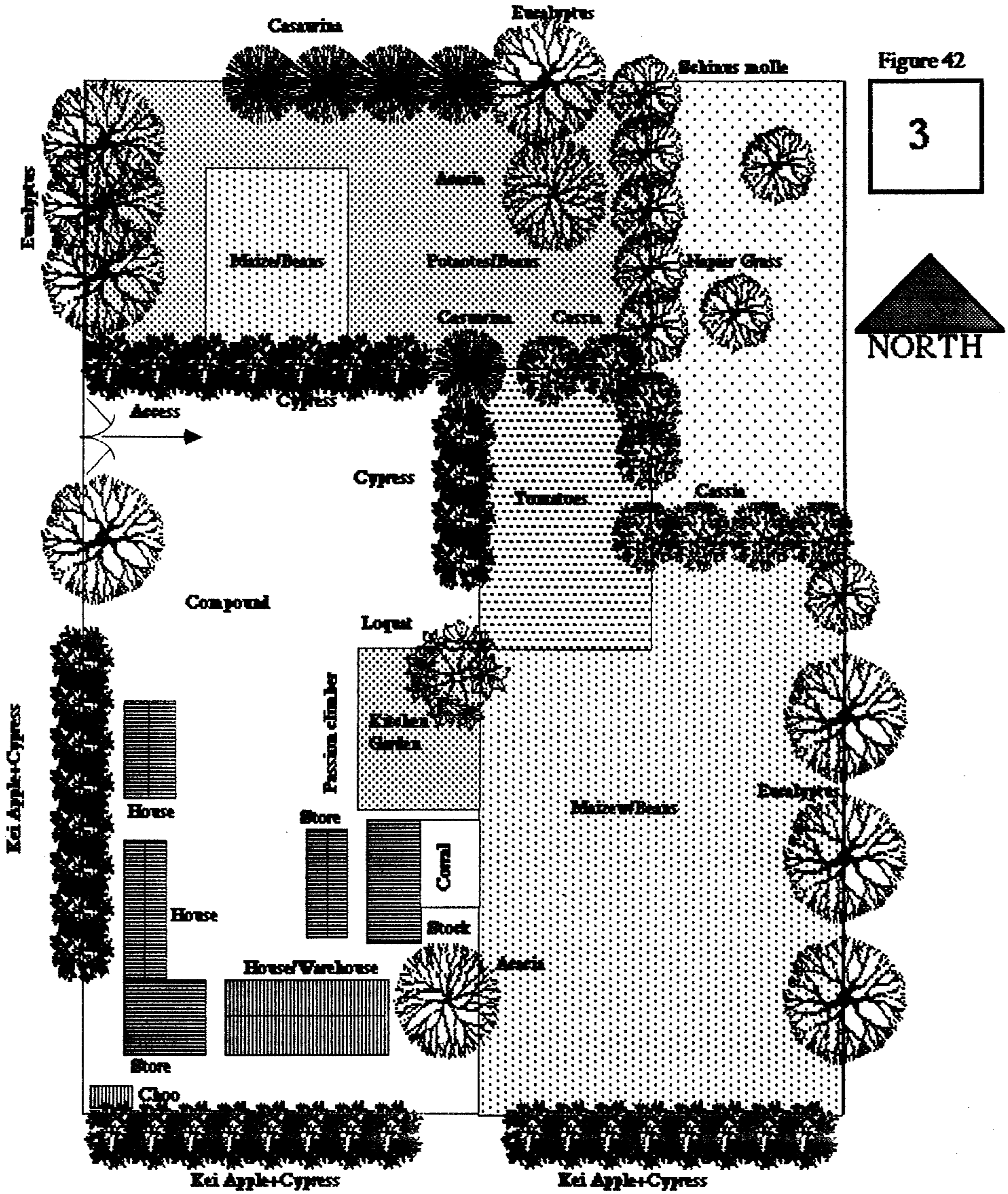
Figure 40, Section of Terraces on Farm #1

Figure 41



2
NORTH
Wind Direction
Windbreak Required
Maize/Beans throughout cropland
Excessive weeds/poor yields
No Terracing – serious erosion
High dessicating winds
Scattered Bananas
Vegetable Seedbed
Eucalyptus
Cypress
Croton
Privy
Store
Store
Stable
Cypress
No Shade in Compound Trees required
Main House
House
Flowers
Access Road
Flowers
Eucalyptus
Crotons
N.T.S.
Main Road

Figure 42



3
NORTH
Casuarina
Eucalyptus
Schinus molle
Eucalyptus
Acacia
Maize/Beans
Potatoes/Beans
Napier Grass
Casuarina
Cassia
Cypress
Access
Cypress
Tomatoes
Cassia
Compound
Loquat
Kitchen Garden
Passion climber
Kei Apple+Cypress
House
Store
Corral
House
Stock
Eucalyptus
House/Warehouse
Acacia
Store
Choo
Kei Apple+Cypress
Kei Apple+Cypress

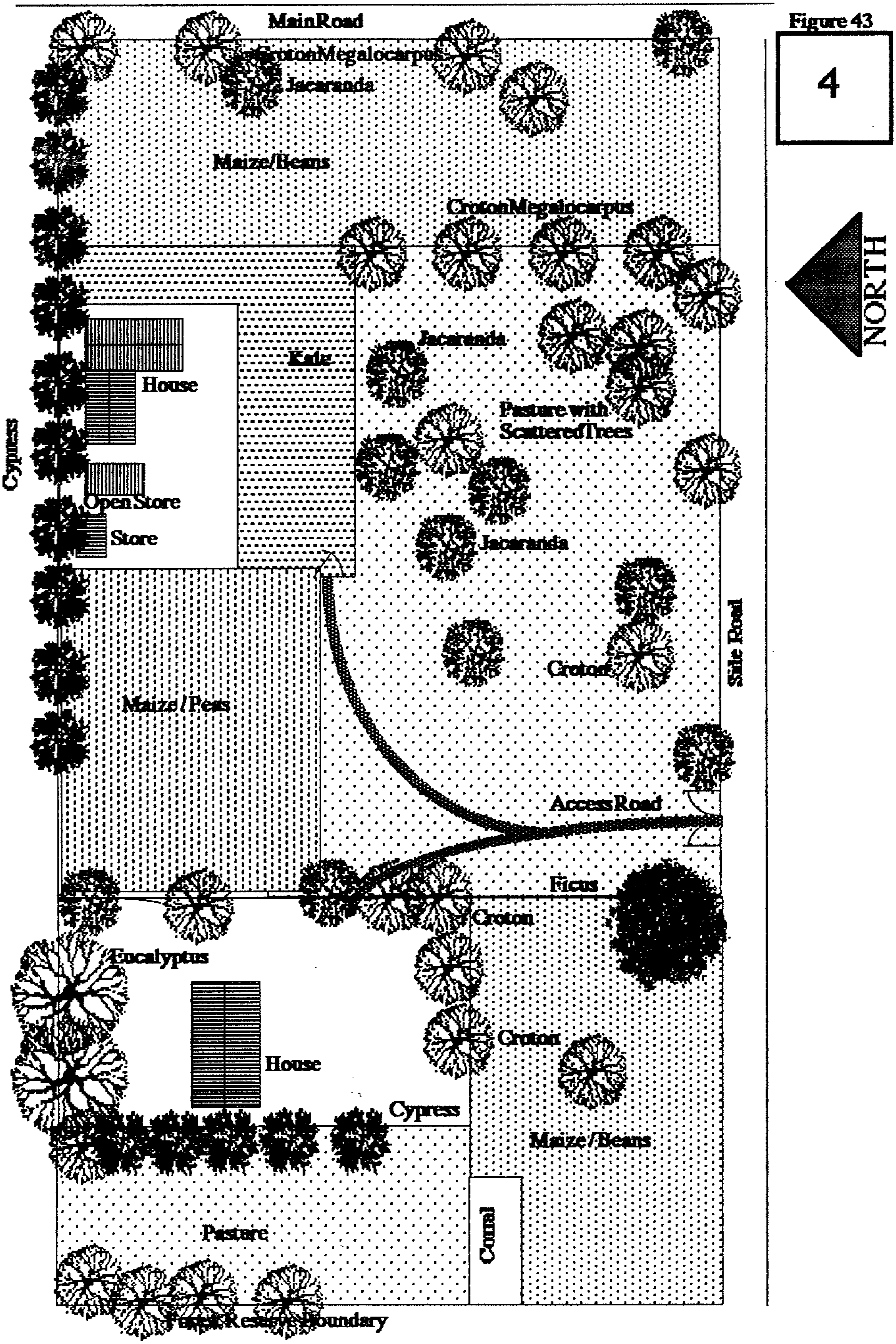
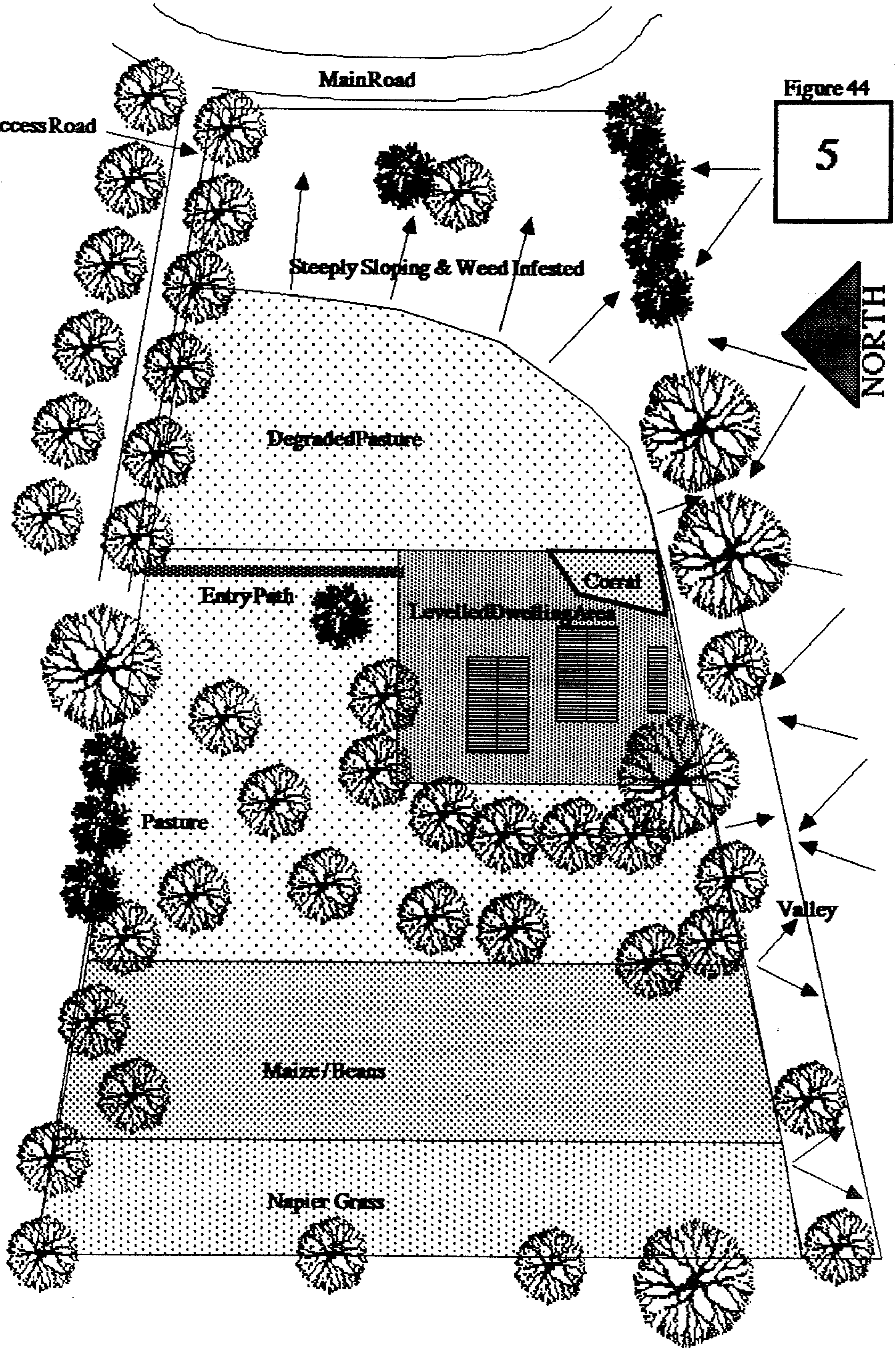


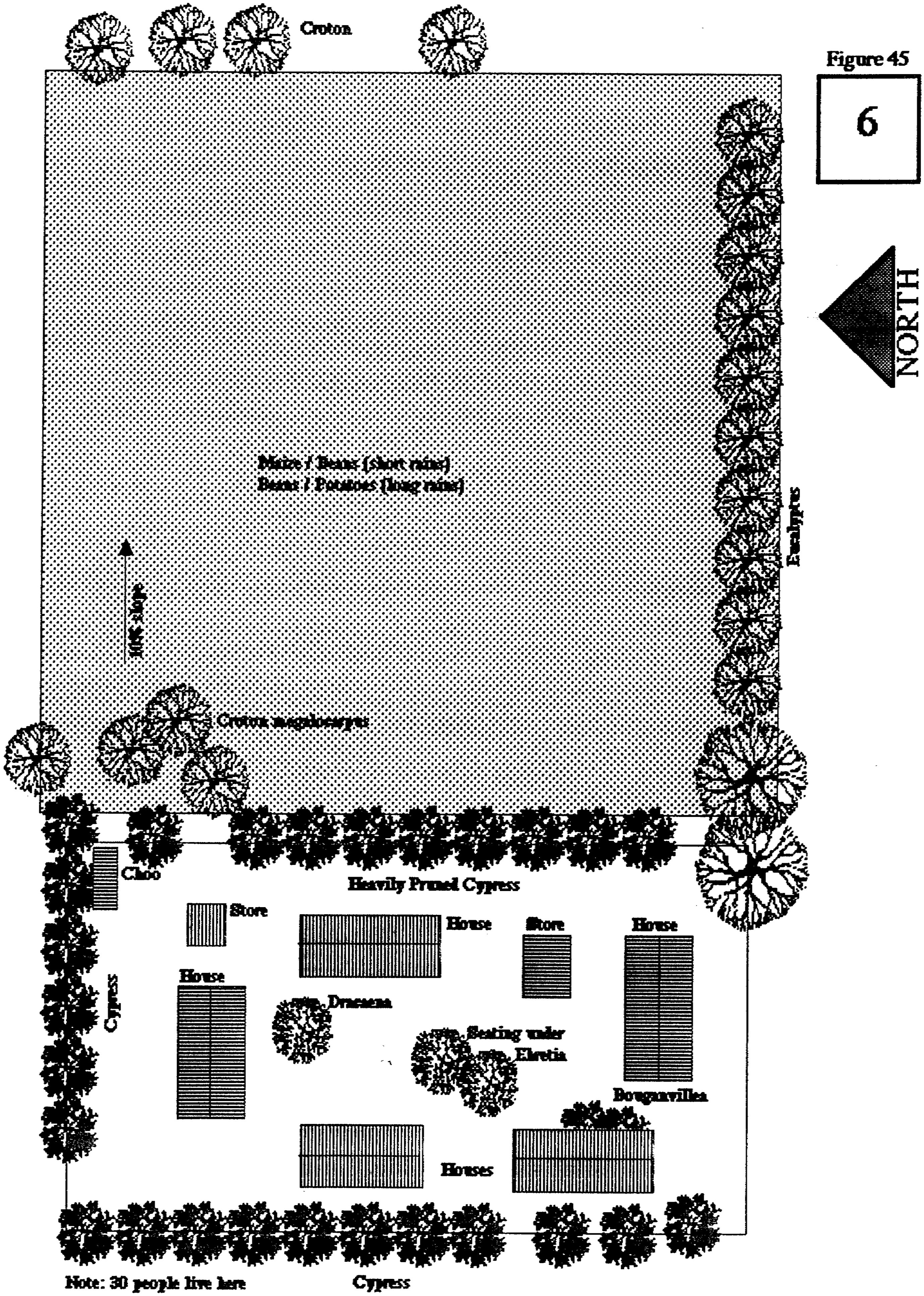
Figure 43
4
NORTH
MainRoad
CrotonMegalocarpus
Jacaranda
Maize/Beans
CrotonMegalocarpus
Jacaranda
Kale
House
Pasture with
ScatteredTrees
Cypress
Open Store
Store
Jacaranda
Side Road
Croton
Maize/Peas
AccessRoad
Ficus
Croton
Eucalyptus
Croton
House
Cypress
Maize/Beans
Pasture
Corral
Forest Reserve Boundary

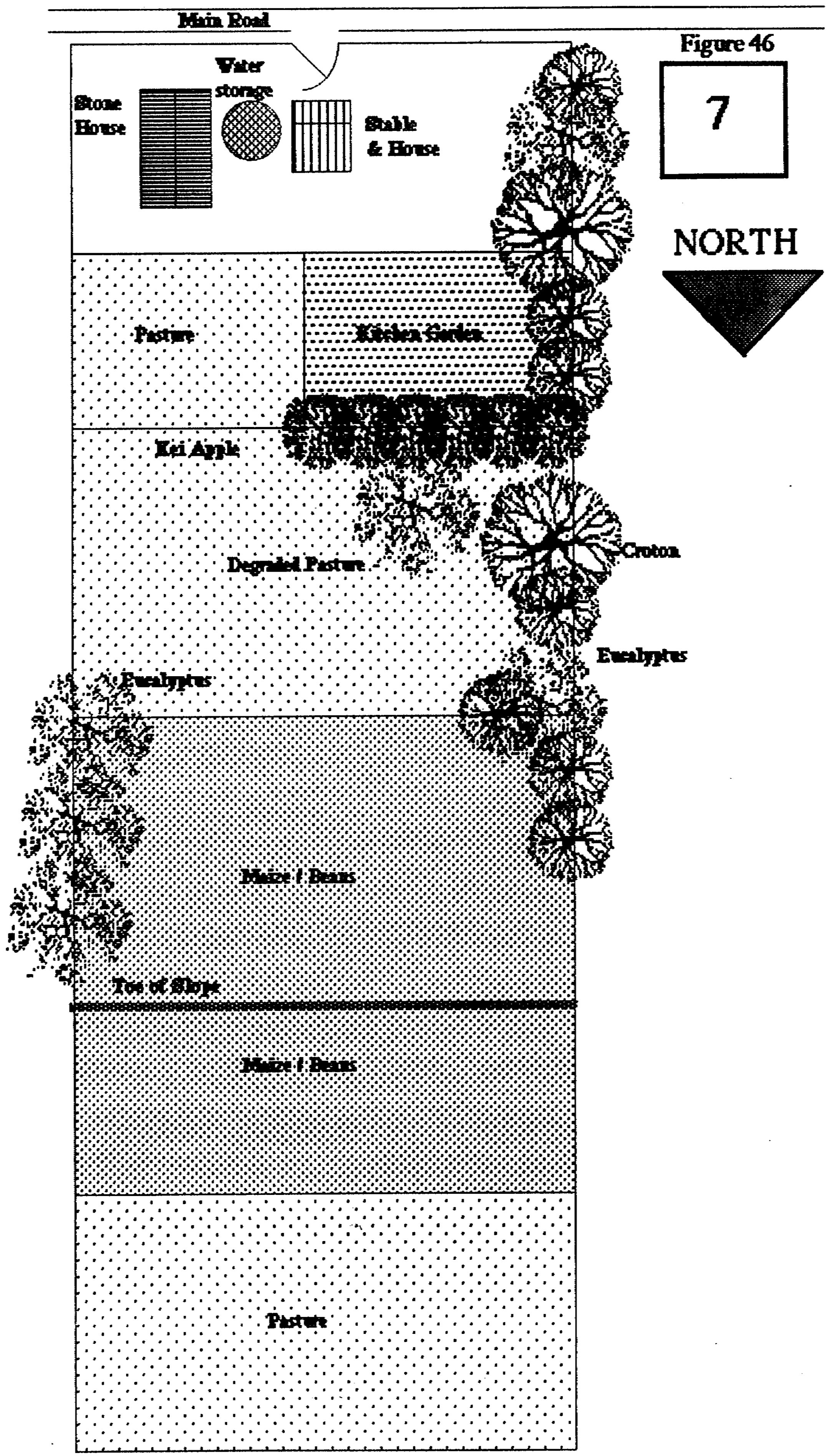
Figure 44



MainRoad
Access Road
5
NORTH
Steeply Sloping & Weed Infested
DegradedPasture
Corral
Entry Path
Pasture
Valley
Maize/Beans
Napier Grass

Figure 45


6
NORTH
Croton
Maize / Beans (short rains)
Beans / Potatoes (long rains)
Hill slope
Eucalyptus
Croton megalocarpus
Choo
Heavily Pruned Cypress
Store
House
Store
House
House
Cypress
Dracaena
Seating under
Ehretia
Bougainvillea
Houses
Note: 30 people live here
Cypress


Main Road
Figure 46
7
NORTH
Water storage
Stone House
Stable & House
Pasture
Kitchen Garden
Kei Apple
Degraded Pasture
Croton
Eucalyptus
Eucalyptus
Maize / Beans
Toe of Slope
Maize / Beans
Pasture

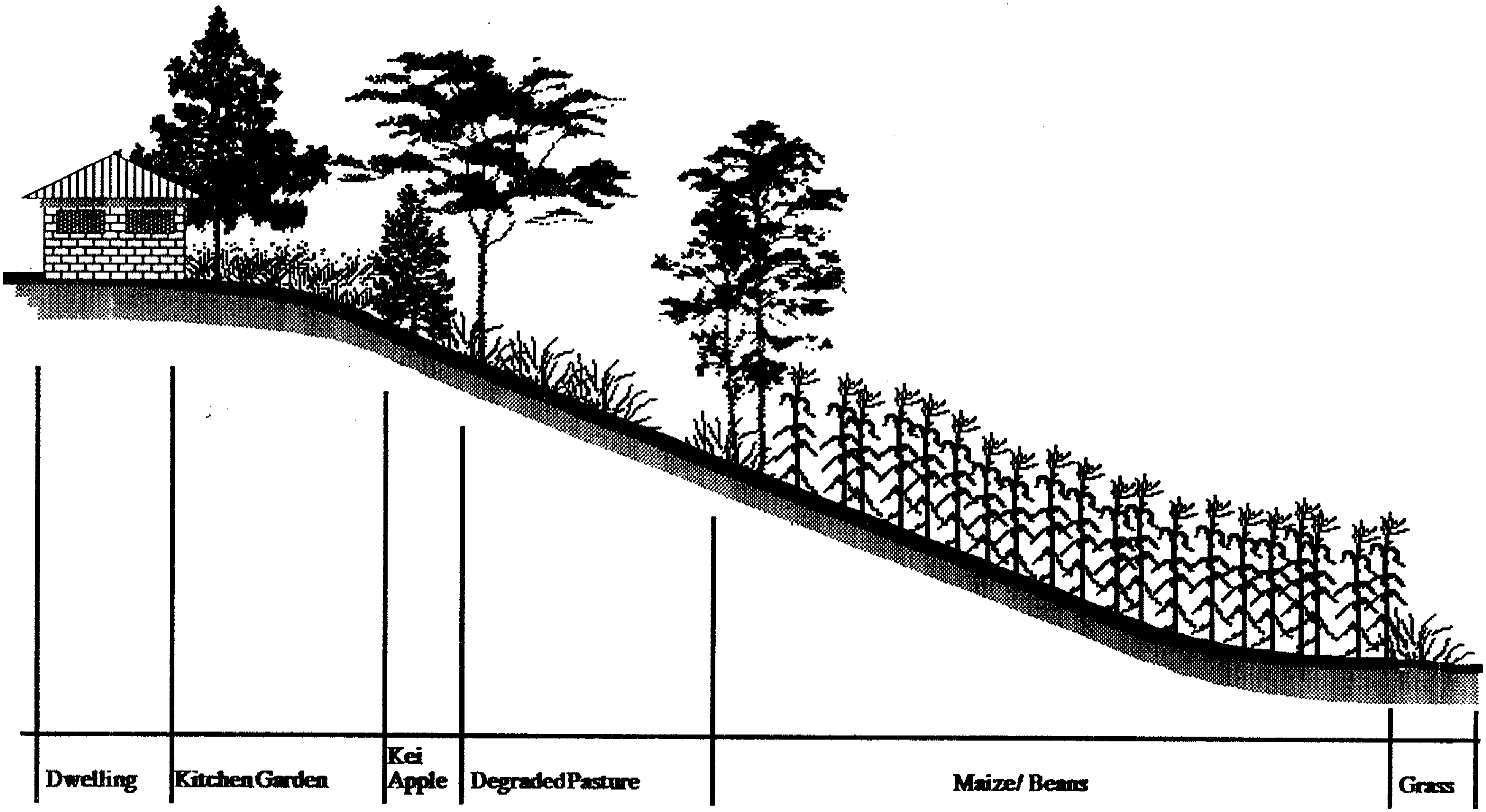


Figure 47, Section of Farm #7

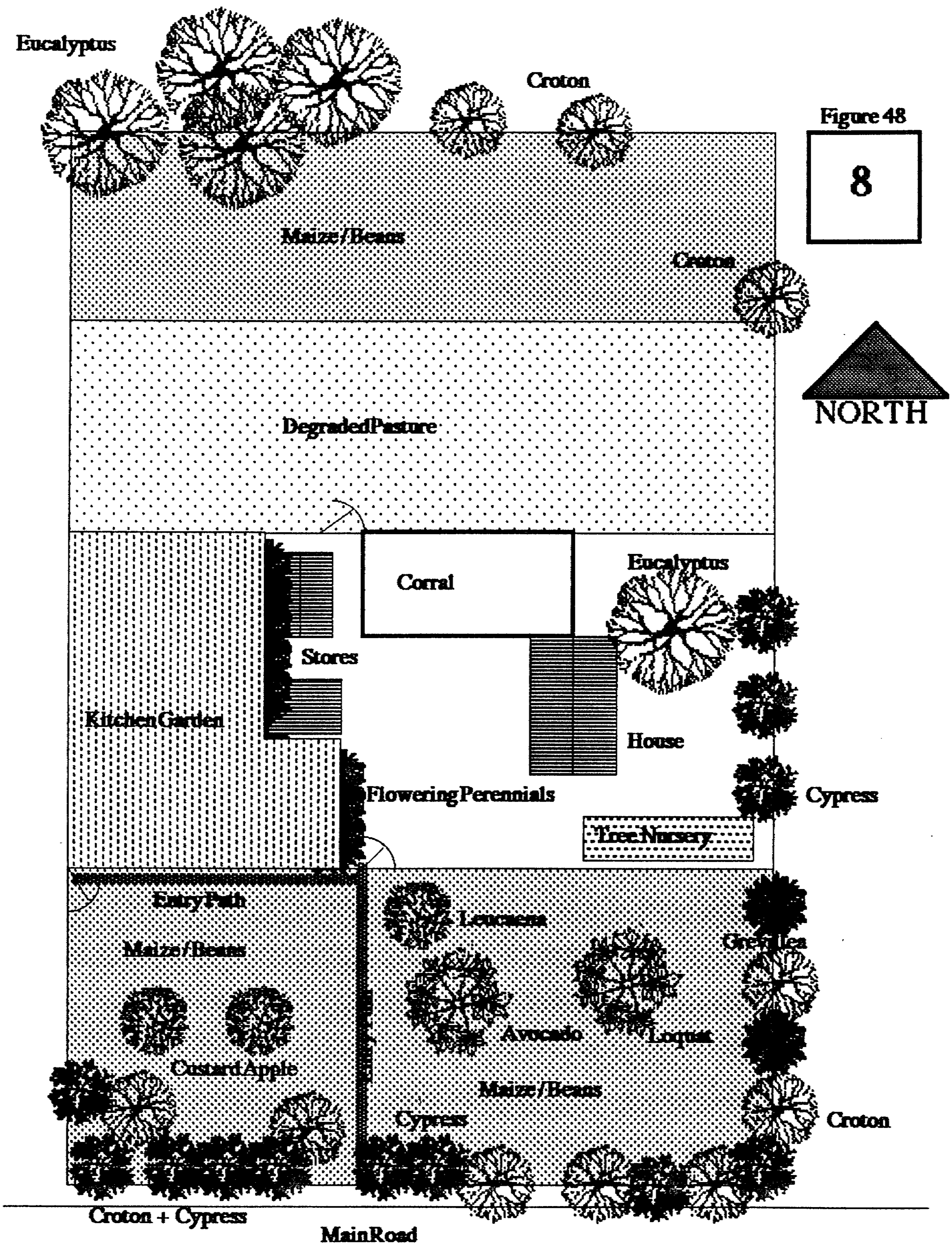


Figure 48
8
NORTH
Eucalyptus
Croton
Maize/Beans
Croton
Degraded Pasture
Corral
Eucalyptus
Stores
Kitchen Garden
House
Flowering Perennials
Cypress
Tree Nursery
Entry Path
Leucaena
Maize/Beans
Avocado
Loquat
Custard Apple
Maize/Beans
Cypress
Croton
Croton + Cypress
Main Road

By far the greatest percentage of farms are held under freehold title. The percentages of farms occupied under the following tenure types are:

Freehold:	81.5 %
Leasehold:	11.5
Squatter:	2.8
Awaitingtitledeed:	4.2

The effect of tenure type on farm management practices can be large. Those leasing land tend to have little incentive to either invest in farm improvements or to consider the long term effects of their agricultural management practices. Formal leases are often nonexistent, or for very short periods, and this lends little security to the tenants. Landlords often prohibit tree planting by tenants as this is seen as a symbol of claim to the land. In addition, lack of title makes access to credit almostimpossible.

Some of the very worst instances of soil erosion in the study area were on leased land. Almost without exception, whenever leasing was encountered, there was serious land degradation. In one instance two leased plots with a total area of 1.6 ha. were cultivated for maize on slopes over 45% with no erosion control whatsoever. The result was rill and sheet erosion so severe that the tenant complained she could feel her house move during a particularly severe storm. In addition, the fence posts in the small valley directly below the farms were completely buried with topsoil removed from the two farms. Incidentally, the soil was a nitosol which has the highest potential for agricultureandgroundwaterinfiltrationinthearea.

Given the shortage of land resources in the area, access to other lands takes on great importance. Unfortunately, access to the forest was not clearly defined in the questionnaire and there was some discrepancy in the results. Although 70% of the farmers interviewed admitted getting much of their fuelwood from the forest, only 38% reported access to other lands. Of those the following percentageswere:

Freeheld by the farmer	60
Leased	24
Publicland	8
Close friend or relative's	8

The use of these other lands is listed below. Public land tends to be used for grazing and fuelwood collection while private lands are most often used for crop production.

Reported uses of other land:		
Not used	10.0%	
Grazing	26.7	
Fuelwood	3.3	**Note**: 71% reported getting fuel from the forest
Annual crops	36.7	
Rented to others	13.3	
Cash crops	6.7	
Residential	3.3	

4.2.1.10. *Production Constraints and Limiting Resources*

Farmers in the area face a number of problems affecting production. The most commonly reported problems were land shortages, climatic conditions, nutrient deficiencies, and pests. The following table lists the percentages of farms reporting various production problems:

Table 12. Production Constraints & Frequency of Reportage - Cropland

Production Problem	Percentage of Farms Reporting
Land shortage	74
Labour shortage	39
Moisture deficiencies	96
Short growing season	96
Unreliable timing of rains	94
Midseason moisture stress	94
Poor infiltration of rain	10
poor rooting conditions	10
poor soil structure/consistency	10
poor drainage/aeration	10
Tillage problems	28
Workability	26
Rocks/stones/roots	6
Soil nutrient deficiencies	57
Waterlogging	16
Weeds	54
Insect Pests	74
Wild Pigs	55
Porcupines	25
Buffalo	28
Theft	20
Inadequate Supply of Inputs	35
Lack of fertilizers	29
Lack of improved seed	14

Table 13. Farmer Rankings of Resources Required to Improve Production

Factor	Rank1	Rank2	Rank3
Water	71.0	21.7	3.1
Land	14.5	17.4	15.9
Inputs(fertilizers, pesticides, seed)	5.8	29.0	38.1
Machinery/implements	4.3	8.7	15.9
Draughtanimals	0	0	3.2
Labour	0	5.7	11.1
Other	4.3	17.4	11.1

The most commonly recognized factor was water deficiency followed by land shortage and a need for inputs.

4.2.2. Livestock

Livestock is an extremely important component of most land use systems in the area. The types and numbers of animals as well as the intensity of management vary from area to area. Small scale intensive animal production is the norm in the eastern slopes while larger scale extensive operations prevail in the west.

4.2.2.1. *The Eastern Slopes*

Livestock of some type is owned by 84% of farmers interviewed. The following table indicates the type and numbers of livestock on the average farm on the eastern slopes.

Table 14. Type & Average Numbers of Livestock on Farms of the Eastern Slopes

Type	Average #(allfarms)	% of farms possessing
Any		84
BeefCattle	0.6	4
DairyCattle	3.5	71
Goats	3	43
Sheep	4	59
Poultry	9	66
Donkeys	0	11
Bee hives	1	20
Totallivestockunits	4.2	

The primary livestock products are meat, milk , hides, eggs and honey. There are very good existing markets for all of these products in Nairobi although transportation and collection problems often limit sales.

Fodder availability is a serious problem in the area and 71% of stock owners experience fodder shortages especially during the dry seasons. The following percentages report their primary source of feed to be: Fresh Grass: 54% Napier Grass: 39% Bought Feed: 7%. The fodder shortage is often so extreme that people will gather fodder as far as the Karen area (10 kilometers away) and haul it on foot.

Fresh grass is gathered on farm, from roadsides, and occasionally from the forest reserve. Improved pasture species are used only by a few farmers. Napier grass is generally produced on farm but it seldom meets demand. The carrying capacity of pastures in similar zones has been estimated at " 1.4 ha./ Livestock Unit (LU) on highland savanna; 1 ha./LU on Nandi setaria between 2 050 and 2 200 meters, or Rhodes grass below that; feeding Rhodes grass, subterr. clover, Lotononis, maize silage and fodder barley down to about 0.25 ha./LU; suited for grade dairy cows and grade cattle" (Ministry of Agriculture, 1983). With averages per farm of 4.2 livestock units, .89 hectares devoted to permanent pasture and .16 hectares to fodder crops, it is clear that the farms are overstocked, given the present intensity of management. The existing pastures are frequently degraded as a result of overutilization. A high percentage of exposed soil and soil creep are common in pasture areas.

89 % of interviewed farmers indicated their willingness to participate in a community cut and carry hayland, while 84% were interested in a community fodder orchard. Although 83% were interested in a community pasture, there were strong concerns voiced about possible disease problems with herds of mixed ownership.

Other livestock production problems noted on farms are listed in the following table.

Table 15. Production Constraints & Frequency of Reportage

Production Problem	Percentage of Farms Reporting
Weight Loss or poor gain	62
Low milk production	59
High mortality	49
Low reproduction rates	12
Water shortage	68
Pasture shortage	46
Browse shortage	26
Fodder shortage	60
Poor quality feed	3
Pasture degradation	16
Inadequate fencing	4
Inadequate shade	3
Inadequate veterinary services	8

The problem of livestock mortality is serious. The cost of grade dairy cattle is very high and represents an enormous investment to the average farmer. If the animal survives, this cost can be recovered in two or three lactations, given proper care and access to markets. However, east coast fever (ECF) is killing many cattle and is no doubt responsible for many of the reported deaths of unknown causes. Animals may be protected against ECF using a serum derived from locally infected but disease resistant wildlife. A research programme towards this end is underway, utilizing the buffalo from the Ngong Hills herd. (Grootenhuis, personal communication) However, the serum is not presently being used by Ngong Hills farmers.

There is significant potential for dairying expansion, but as fodder is still brought from infected areas, protection of valuable grade cattle is fundamental to it's success. Zero grazing of animals with on farm produced fodder, as well as regular tick treatment, is the safest way to avoid ECF. However, given the stocking rates and available land, fodder is often brought from elsewhere and may be tick infested. This is particularly true of grass cut in the forest reserve. In addition, tick infected livestock grazed in the reserve may subsequently be mixed with cattle on the farms.

Beekeeping, although not widespread, has large potential in the hills. There are many suitable species for bee forage and these could be expanded. The price of first grade honey is 50 Ksh./Kg. and producers can sell all they produce. Expected honey yields in the area, given proper management (which is rare), are approximately 50Kg./yr. per hive. This could be a major source of cash as individual farmers could easily manage 10 hives which could gross approximately 20000- 25000 Ksh. per year. This should be considered an area for substantial development by individuals, government and non government organizations alike.

4.2.2.2. *The Rift Valley*

The importance of livestock rises in the western and southern portions of the study area. Larger herds are more common and are grazed over far larger areas. The land in most of this area is suitable only for grazing despite some attempts at arable agriculture. Individual Maasai herds of up 230 cattle and over 200 goats and sheep were reported in the interviews but more commonly there are large (100-200) goat/sheep herds with 10 to 20 cattle per family unit. As land has now been adjudicated and individuals hold title deeds, the traditional Maasai land management is no longer in effect. Ranchers are now leading a sedentary life style and their cattle do not move with the seasons. Lands are often over stocked and, with the concentration of cattle on limited pastures and near water holes, has come associated land degradation.

The western slopes of the forest reserve are moderately to heavily grazed, particularly in the dry seasons. Shortages of both grass and browse were commonly reported. This is leading to serious pasture degradation in some areas and there was great interest in planting browse species and participating in fodder orchards.

The carrying capacity of this zone is estimated at 3 ha./LU. on native grasses and down to 2 ha./LU on Rhodes grass. With supplementary irrigation this can be reduced to 1.2 ha./LU.

4.2.3 Forest Land

The forest reserve is truly a multiple use area. Wildlife in the hills are heavily reliant on available habitat in the reserve (see Wildlife section); the water resources have been tapped (see hydrology section), local people gather both fodder and fuel from the area, local universities and institutions use the area for both education and research, and recreationists enjoy the exceptional visual quality of the area. The area is officially under the management of the forest department although no management plan has been prepared.

4.2.3.1. *Human Influence*

Although there are no formal forestry operations in the reserve, the indigenous vegetation has been heavily impacted by humans and few if any "untouched" areas remain. K.R.E.M.U. (1981) has indicated an average annual loss of 18 ha. of indigenous forest, generally replaced with grassland and/or lower quality bushland. In 1980 only 156 ha. of forest remained in the 3077 ha. forest reserve. This is less than half of what was estimated in 1965. Maasai elders in the area speak of the entire eastern slopes being covered at one time with forest, with the exception of the upper ridge tops and some small meadows.

Perhaps the most profound human influence has been fire (see Ecosystem Stability section) but overgrazing, fuelwood gathering, and charcoal burning are also having an enormous effect. Although illegal, 71% of those surveyed admitted gathering at least some of their fuelwood requirements from the forest. Forest guards allow women to gather dead wood but this is not strictly observed and there are many instances of green wood cutting. If the standard fuelwood requirement approximation (ICRAF, 1983) of 1 m^3 per person per year is used, and assuming that only half of this requirement comes from the forest reserve, it is no surprise that the forest is disappearing. Assuming that the population of 7000 needs wood from the forest, the annual requirements would be 7000M^3. Considering that there is only 440 hectares of forest left (including much degraded areas), this would be 17 M3 per hectare per year, which is well beyond the annual increment of the most productive forests in Kenya.

The production and trade of charcoal is also legally controlled. There is little evidence of charcoal production on the eastern slopes but on the west there is a serious problem. On the lower northwest slopes almost every acacia over 7 cm. dbh has been cut recently, and there are many remains of charcoaling piles. The law is obviously not being adequately enforced.

Moss gathering for sale to Nairobi florists is also common and is seriously threatening both the habitat and survival of many orchid species.

4.2.3.2. *Reforestation Efforts*

Reforestation began in 1979 but, until 1982 ,the scale of the operations was small due to a lack of qualified technical staff. In 1982, 60 hectares were replanted. In 1984, 150 hectares were planted at the south east end of the hills by University of Nairobi staff and students. The planted area was declared "University Forest" by President Moi at that time. In 1985, 40 hectares were planted along the 400m boundary strip (originally set aside for those displaced from the forest when the area was gazetted). By 1986 some 500,000 seedlings and 300 hectares had been planted (Ngong Forester, personal communication). Unfortunately, many of these seedlings have failed to become established. Planting stock is obtained from the M.O.E. Ngong Nursery as well as from other ministry nurseries as seedlings become available. The Ngong nursery is presently 2 hectares but could be expanded without much difficulty. Currently the Ngong forester has 50-60 tree planters available on a seasonal basis.

Although the intent of the forest department has been to re-establish an indigenous forest, native germplasm has been difficult to obtain. The following are the species currently in the Ngong nursery that are to be planted out this year (I indicates indigenous species):

Eucalyptus saligna
Luceana sp.
Erythninus sp.
Eucalyptus maculata
Alberia caffra
Cupressus lustanica
Croton megalocarpus (I)
Acrocarpus Fraxinifolia
Casuarina equisetifolia
Shinus molle
Pinus patula

Other species grown at the Ngong nursery which appear promising to the department and may be planted in future, include:

Jacaranda nimisoides
Ekebergia ruepelliana
Sterculia acutifolia
Erythrina tomentosa
Markhamia hildebrandtii (I)
Acacia sp. incl. xanthophloea (I)
Spathodea campanulata
Eleodendron
Marcunia
Cordia abyssinica (I)

As few of the above are indigenous, or have had extensive field trials, the long term survival is uncertain. Indeed, even the short term survival is compromised, both by species/site incompatibility, as well as often inappropriate planting techniques. The establishment rate for the seedlings planted out to date has been low (personal observation) due to the above reasons as well as prolonged drought and damage by mould, termites, mole rats and other pests.

4.2.3.3. *Grazing*

Grazing in the forest reserve has been important to local stockmen for many years. Local herdsmen with permits from the Forest Department graze the area year round (with the exception *technicall* of those areas of recent reforestation). In very dry seasons when fodder reserves outside the forest are depleted, others without approval utilize the area as well. The fences are often cut and prohibited areas are grazed.

There is currently no grazing plan for the area and no attempt has been made to establish carrying capacity or stocking rates. Although, goats are not supposed to graze in the reserve, this is not enforced at all and herds of goats and sheep were observed on every visit to the area.

The level of management has resulted in degradation of both the grazing and forest resources. Invasion of less palatable species is commonly evident and exposed soil on steep, heavily grazed slopes is frequently observed. A comprehensive grazing plan is required if use of the range resource is to be sustained.

4.2.3.4. Recreation

The use of the forest reserve for recreation has a history dating back to the 1920's (Blixen, 1936). The ever decreasing proximity to Nairobi and the local prominence of the area make it very attractive as a day use area for picnicking and hiking. The two motor tracks at the north and south ends of the hills give easy access (for 4x4's) to the main ridge trail which runs the entire length of the hills. There are several game and cattle trails running from the main ridge down the footridges to the reserve boundary but these are infrequently used by recreationists. While some of these trails lead dangerously through buffalo habitat, most skirt the main areas of concentration and some offer safe positions for game viewing eg. across side valleys to buffalo grazing areas.

The local county council has recently established a gate on the north ridge access road and is charging admission to the area. Proper maintenance of the road is required and would encourage visitation. Currently, vehicles may drive where they like in the hills and, although they are limited by topography to some extent, have initiated erosion on parts of the main ridge trail. Although it is not possible to drive the entire ridge trail, many drivers attempt to go as far they can and often are in conflict with hikers on the route. There is no trail maintenance. Parking is informal but most people stop at the last radio antennae.

The lack of security in the Ngong Hills was once a major deterrent for recreationists. The local police have since made a determined effort to improve the situation and now make regular and frequent patrols of the area. Group use of the area is common and these frequently take police escorts on their walks. Regular police patrols are fundamental to any increased use of the area.

4.2.4 Human Settlement

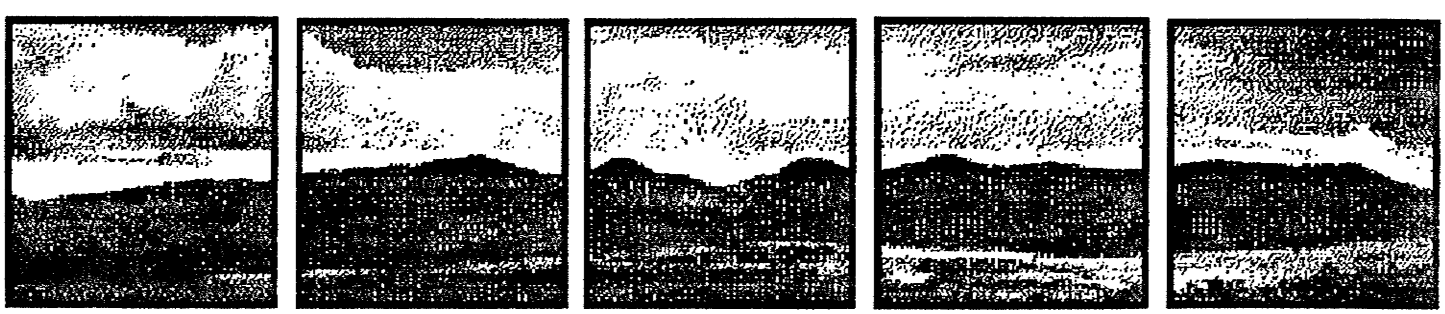
Although the settlement patterns in the Ngong Hills vary with the sector under consideration (see Settlement & Infrastructure Map) , a common feature in all areas is a rapidly increasing human density. The close proximity to Nairobi, which itself has a population growth rate of 10% per annum, has lead to dramatic increases in building, particularly around Ngong Town itself. Many of those living in Ngong commute to Nairobi for work. As Ngong Township lies outside of the Nairobi city limits, it is not subject to Nairobi development controls and this makes the area attractive to developers who may build with few encumbrances. The pattern of development has tended to follow the main roads and linear features although repeated subdivision of plots is very common. The subdivision of land for settlement is causing the loss of valuable agricultural lands. In addition, the increased population has put enormous strain on infrastructure. Sewage treatment facilities are also inadequate and already water rationing is occurring throughout the area.

The major nodes of settlement are Ngong Town and the unplanned Kijiji settlement to the south west of Ngong. Kijiji has many problems of which inadequate shelter, sewage, water, and drainage are the most serious. These two are the only true towns or villages in the study area although Kiserian and Matathia lie near the boundary. The remainder of the eastern and northern portions are densely populated small farms which have also undergone increases in population. The main magnets in the area are government offices, water points, shops, schools, churches and marketplaces.

4.2.5. Other Land Uses

Arable agriculture, grazing, settlement and multiple use forestry are the dominant land uses in the study area but there area other minor uses. Rock quarrying occurs in several locations near or in Ngong Township. Small scale soil mining is also occurring at a few locations including Ngong Town where removals will soon threaten the stability of a major road embankment. Government offices and departmental storage yards are found in the Ngong Township.

Ch. 5 Diagnosis & Design Specifications



5.1. DIAGNOSIS OF MAJOR LAND USE PROBLEMS AND POTENTIALS

An analysis of the detailed farmer surveys and background data yielded the major land use problems and potentials at both the household and ecosystem levels, as well as their contributing causes. The following is summary of the problems and readers are referred to previous sections for specificdetails.

5.1.1. Household Level Diagnosis

As the farm or household unit is the level at which most land management decisions are taken, a diagnosis of problems and potentials at this level is necessary if reasoned proposals are to be made. The following sections examine the various subsystems operating within household.

5.1.1.1. *Food Production Subsystem*

Declining crop yields have been almost universally reported by local farmers. Maize crop failures are frequent in much of the area (the statistical risk is 1 failure in 4 crops). Seasonal shortages of staple foods have been reported by 86% of respondents. Of these 47% report shortages only in bad years, 15% in most years, and 37% experience shortages even in good years. Unsatisfactory yields are also reported in the livestock sector where both gain rates and milk production is seen to be well below optimum. (See land use section for details.)

5.1.1.2. *Cash Subsystem*

As previously mentioned in the socioeconomic section, inadequate cash is a common and serious problem for many households in the study area. Most available cash comes from off farm employment (70% of average total income), with farm income accounting for less than 30% of total income. An examination of expenditure patterns reveals that between 35 and 40% of income is spent on food purchases and about 12% is spent on energy. Staple food shortages occur frequently for many families despite these purchases, indicating either a low level of farm production, cash shortages, or both.

Current alleviation strategies include: working off farm, gathering fuel wood and fodder for sale, and selling surplus foods as available. Although some cash crops are grown in the area, they are not common. Many farmers would like to be growing suitable crops. Other income generating activities such as cottage industries have not been exploited to any great extent. Some efforts have been made to improve farm production but the farmers are faced with many constraints including cash shortages for farm inputs and improvements. The cash flow problems accentuate the downward spiral of decreasing yields, less cash, and a lower quality of life. Clearly, this is an area with potential for improvement.

5.1.1.3. *Energy Supply Subsystem*

Availability of energy, particularly firewood and charcoal is a major issue in the Ngong Hills. The amount of time spent gathering fuel wood greatly reduces the available farm labour. The average amount of time spent securing energy per week is six hours. Many people, particularly those at the lower end of the income spectrum with less available cash to purchase their requirements, spend far more time. Several respondents reported spending every third day gathering firewood. Fully 96% of those interviewed felt that either the supply of, or the amount of time or cash required to obtain their energy, was a problem.

Of the above, the following percentage feel the main problem is :

Time	10.6%
Supply	53.0
Cash	36.4

86% anticipated energy shortages in the future but only 66% were planting trees to alleviate the situation. The following chart indicates the energy type, use and means of supply used by those surveyed:

Table 16. Household Energy Types (Uses + Means of Supply)

Type	**Uses**			**Means of Supply**		
	cooking	heating	lighting	produce	collect	purchase
Firewood	90	41		27	60	37
Charcoal	70					70
Crop Residues*	37			27	19	1
Paraffin	17		77			77
Gas	17		1			17
Electricity	3		6			6

* includes coffee husks, maize stalks etc. (percentages of farms interviewed)

The following percentages reported the location of collected or produced firewood to be:

Forest	71.7%
on farm	24.5
neighbours' land	1.9
other public land	1.9

Many people were unsatisfied with their present energy type and the following percentages reported their preferred energy type to be:

Gas	45.7%
Electricity	14.3
Charcoal	14.3
Paraffin	0
fuel wood	0
Are satisfied with present source	25.7

Considering the response and the possibility of intensive zero grazing systems with manure by-products in the area, low cost bio-gas digesters may be adopted by local people if the initial capital problems can be solved.

Those households in the Kijiji area appeared to have the fewest energy options and many were relying entirely on purchased coffee husks and fuel wood collected from the forest. It is no coincidence that the forest in closest proximity to Kijiji is among the most degraded in the area.

5.1.1.4. ***Shelter Subsystem***

The quality of human habitation in the area is highly variable, ranging from the new large suburban type stone houses of the wealthy, to simple ,traditional, thatched, mud or manure walled homes. The latter, however, is becoming much less common and corrugated metal roofed, wooden or mud and wattle sided buildings are very frequent. Most farms have some form of stock shelter and corral. On the eastern slopes there is commonly a hedge surrounding the farm (see farm diagrams).

For the most part, those living in the western portion of the study area dwell in traditional Maasai homes. Women in this area report difficulty in obtaining desired construction species. Those who have constructed modern, longer lasting designs (in response to a new sedentary life-style) often complain of over heating and fly problems (due to the windows). Several Maasai expressed interest in a design that would combine the traditional house form with much reduced maintenance. Such a dwelling would maintain the basic Maasai form but might use soil cement for plastering. This would have the dual advantage of satisfying local desires in the short run and reducing natural resource material costs in the long run.

The percentages of respondents that felt their needs were **inadequately** met in the following areas were:

Human dwelling	46
Stock shelter	29
Storage	33
Windbreaks	41
Shade for people	33
Shade for stock	23
Shade for crops	46
Fencing - cropland	49
Fencing - grazing land	30
Fencing - corrals, bomas	26
Fencing - security	44
Boundary delineation	9
Drainage protection	1
Building material sources	13

The list includes several elements that may be improved with agroforestry techniques, most notably shade in cropland, building material production, windbreaks and fencing.

5.1.1.5. *Summary of Causal Factors and Constraints*

The following table summarizes the household level problems and causal factors for the smallholder farms in the area.

Table 17. Smallholder Household Diagnostic Summary

Basic Needs Affected	Symptoms	Apparent Causes
Food	Low and declining yields of annual crops	a) Declining soil fertility b) Poor soil structure c) Poor soil workability d) Inadequate inputs e) High cost of fertilizers f) Moisture deficiency g) High evaporation rates h) Desiccating winds i) Weed competition j) Land Shortage k) Insect Pests l) waterlogging (Vertisols) m) lack of manure
	Damage to Crops	a) Wildlife depredation b) Exposure to winds
	Soil Erosion in Annual Fields	a) Inadequate ground cover b) Annual crops on steep slopes c) Inadequate soil conservation structures
	Few Tree Food Crops	a) Inadequate seedlings of desired species b) Insufficient extension c) Insufficient local crop testing

Basic Needs Affected	Symptoms	Apparent Causes
	Low livestock production	a) Inadequate feed sources on farm b) Little access to additional fodder c) Losses to disease (ECF) d) High cost of supplementary feed e) High cost of grade stock f) Inadequate veterinary care g) Small grazing area
Water	Inadequate water for stock and kitchen gardens	a) Water schemes incomplete b) Insufficient on farm storage facilities c) Depletion of soil moisture reserves due to excessive evaporation and moisture competition d) underutilization of channelized water
	Water rationing	a) Water table lowered due to excessive demand and inadequate infiltration due to changes in land use
Cash	Lack of employment opportunities	a) Inadequate development of labour intensive agricultural systems b) Inadequate development of local and cottage industries c) Poor transportation to employment centres
	Difficulty in marketing	a) Lack of coordinated

Basic Needs Affected	Symptoms	Apparent Causes
	products	marketing effort for many products b)Produce transport difficult
	Lack of diversity of cash crops	a) Insufficient trials and extension b) Insufficient seedlings c) Little access to credit
	Poor performance of coffee	a) Insufficient inputs b) Disease
Energy	Shortage of fuel wood over short, medium + long term	a)Overcutting in adjacent forest reserve b) Inadequate on farm production c) Inadequate supply on adjacent public lands d)Inadequate regeneration due to fire, browsing, overgrazing and cutting of seed trees e)Little access to new high production species
Shelter	Shortage of building materials	a) Inadequate on farm and local production b) Insufficient cash
	Inadequate shade and windbreaks	a) Insufficient seedlings and planting b) Low survival rate of seedlings c) Inadequate design

While the largeholder cattlemen of the semi-arid western portion of the study area share many of the concerns of the smallholders to the east, their emphasis is naturally shifted towards livestock production. Very few of those to the west practice arable agriculture although this is changing as agriculturalists (usually with meager success) invade the Rift Valley. The main problems in that area are summarized below.

Table 18. Largeholder (Rift Valley) Household Diagnostic Summary

Basic Needs Affected	Symptoms	Apparent Causes
Food + Cash	Livestock production low	a) Decimation of herds in 1984 drought b) High mortality (disease) c) Inadequate water supply d) Inadequate ranch supply of fodder and browse e) Low productivity of native range f) High cost of grade animals
	Erosion on the range	a) Overstocking b) Poor distribution of stock c) Soil type, slope, climate
Water	Inadequate access to water for both domestic and livestock requirements catchment areas	a) Climate b) Distribution of water c) Deforestation in
Shelter	Insufficient building materials for both traditional and modern structures products	a) New sedentary life-style b) Overgathering c) Destruction of tree growth by fire and over grazing
	Inadequate fencing	a) lack of funds for materials

Basic Needs Affected	Symptoms	Apparent Causes
	Inadequate housing conditions	a) lack of funds for materials
	Lack of appropriate design for modern housing	a) Inadequate user input
Energy	Shortages in the Medium and long terms	a) Overcutting for fuelwood and charcoal both for own consumption and sale b) Inadequate regeneration due to climate, browsing and grazing
Infrastructure	Erosion on roads and paths	a) Poor maintenance b) Inadequate drainage structures c) Inadequate surfacing d) Inappropriate layout

5.1.2. Ecosystem Level Diagnosis

The problems and potentials diagnosed at the household level are nested within the context of the various communities and the ecosystem as a whole. At this level as well, problems related to sustainability and production are found, some of which are the result of the aggregation of household problems, while others are more regionally derived.

Table 19. Ecosystem and Community Level Diagnostic Summary

System	Symptoms / Concerns	Apparent Causes
Climate	High desiccating winds	a) Topography + Orientation b) Lack of windbreaks c) Removal of trees d) Elevation
	High evaporation rates	a) Lack of adequate shade b) Desiccating winds c) High soil temperatures
	Low and unreliable amount of rain	a) Geographic position
Hydrology	Decreased infiltration and Increased spate flows	a) Deforestation and conversion to grassland b) Increased agriculture c) Increased settlement area d) Insufficient tree establishment e) Lack of fire management f) Insufficient water retention and harvesting structures
	High sediment loads in overland flows	a) High speed runoff b) Soil erosion due to poor agricultural and grazing practices ie. tillage in collection and conveyance zones, overstocking etc. c) Lack of adequate ground cover d) Inadequate drainage structures to reduce amount and velocity of flows e) Poor road and path

System	Symptoms / Concerns	Apparent Causes
		construction+maintenance
	Surface and groundwater pollution	a) Increased population densities b) Inadequate sewage treatmenfacilities
Vegetation	Degradation of Indigenous Forest (including reduction in area and species diversity)	a) fuel wood overcollection b) Overgrazing and poor stock distribution c) Browsing by goats d) Fire e) Clearing for agriculture f) Inadequately controlled forest product collection g) Reforestation with exotic species h) Reforestation efforts only marginally successful i) Invasion of undesirable and unpalatable species j) Basic needs of area inhabitants are not being adequately met
Soils	Declining fertility	a) Intensified use of arable land - often over cultivation b) Inadequate fertilizer input due to high costs c) Soil erosion
	Poor Structure + Workability	a) Soil type b) Decreasing organic matter c) Lack of sufficient moisture

System	Symptoms / Concerns	Apparent Causes
Wildlife	Reduction in species diversity and absolute numbers	a) destruction and degradation of habitat by: i) agricultural encroachment ii) competition with stock iii) forest product collection

System	Symptoms / Concerns	Apparent Causes
Settlement + Infrastructure	Increased settlement densities	a) high birth rate b) lowered death rate c) immigration d) urban sprawl of Nairobi e) lack of development guidelines/regulations
	Water supply inadequate	a) inadequate funds b) systems incomplete c) Lowered water table d) increased demand
	Inadequate sewage facilities	a) inadequate funds b) increased demand c) improper facility siting
	Roadways in poor condition	a) inadequate surfacing b) inadequate drainage structures c) inadequate maintenance d) inadequate funds
	Electrification incomplete	a) inadequate funds

The above problems are often interrelated and cannot be viewed in isolation. The following causal diagram indicates the interactions of the major factors as well as identifying possible agroforestry intervention points.

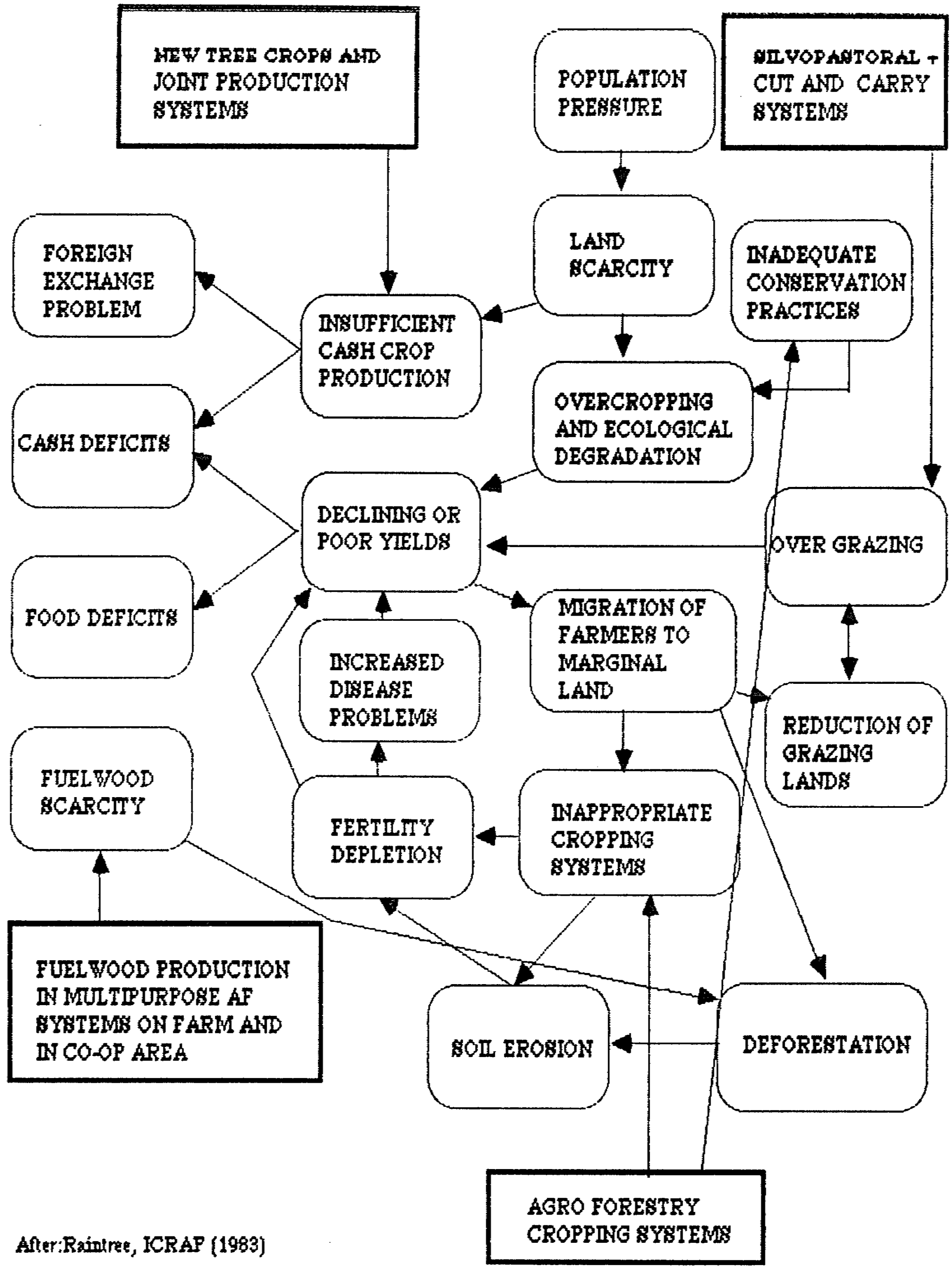


Figure 49. Causal Diagram With Some Possible Agroforestry Interventions

5.2. DESIGN SPECIFICATIONS

Based on the diagnosis of problems and potentials at the household, community and ecosystem levels, it is possible to identify design specifications for both agroforestry and non agroforestry interventions. As the potential list of interventions is long it is necessary to assess the pragmaticism of the various possibilities and to identify priorities for both further research and possible extension.

It must be emphasized that although the results have been derived from both an analysis of the base line data and the detailed farmer interviews, they do **not** represent an ideal specification set, as further review by local farmers and officials would be necessary. This was not possible do to the cancellation of research clearance by the Kenya government. At any rate, the following tables illustrate the process of specification derivation, proceeding from the general to the particular. Table 19 notes the relevance of the general system level specifications. The following list includes various possible agroforestry and non-agroforestry interventions in response to the most important problems and potentials in the area. Priority interventions are then selected based on feasibility and local need. More detailed specifications for the interventions are then listed.

5.2.1. General System Level Specifications

The general system level specifications for potential interventions are listed in the following table. All specifications do not apply to all management types and the table indicates their relevance.

General System Specifications	Relevance to Land Use System			
	Small Farms Eastern Slopes	Largeholdings Western Slopes	Public Lands (off reserve)	Forest Reserve
1. Intensify land use for higher sustained production	●	●	●	●
a) Should increase cash returns to land	●	●		
b) Should offer investment alternatives to decrease goat and non grade cattle herds	●	●		
c) Should maximize use of all farm land including linear elements (boundaries)	●	●		
2. Increase employment opportunities and returns	●	●	●	●
a) Should increase cash returns for labour	●	●		
b) Should increase cash generation for on farm activities of women and men	●	●		
c) Should increase on farm employment opportunities without taxing peak periods	●	●		
d) Increase on-farm processing and other productive on farm employment	●			
3. Rationalize water use	●	●	●	●
a) Improve efficient on farm water use	●	●		
b) Decrease runoff + increase infiltration	●	●	●	●
c) Increase soil and groundwater storage throughout watershed	●	●	●	●

Table 19. Relevance of System Level Specifications

General System Specifications	Relevance to Land Use System			
	Small Farms Eastern Slopes	Largeholdings Western Slopes	Public Lands (off reserve)	Forest Reserve
4. Improve sustainable livestock production	●	●	●	●
a) Maximize on farm fodder sources	●	●		
b) Decrease grazing pressure in forest reserve and common lands			●	●
c) Improve seasonal distribution of fodder on farm and on common lands	●	●	●	●
d) Decrease fodder demands from forest	●	●	●	●
5. Improve wildlife diversity and habitat		●	●	●
a) Decrease stock competition				●
b) Improve wildlife browse & graze			●	●
6. Improve distribution of and access to resources and benefits	●	●	●	●
a) Improve access to public resources			●	●
b) Increase local employment	●	●	●	●
c) Improve management and control of livestock access and forest product collection on public lands			●	●
d) Increase aggregate benefits from public and private lands	●	●	●	●

Table 19 Cont'd. Relevance of System Level Specifications

5.2.2. Summary Overview of Possible Interventions

Diagnosed Problems + Potentials	Non AF Interventions	AF Interventions
1) Food and cash crop shortages		
B) Low and declining crop yields		
i) Low soil fertility	a) Inorganic fertilizers b) Leguminous ground cover	a) High nutrient mulch from woody perennials (WP's) + Multi purpose trees (MPT's) located: i) in hedges ii) intercropped iii) blockplanted iv) pasture areas b) Nitrogen fixing trees and WP's in cropland
ii) Excessive runoff and soil erosion	a) Terracing, cutoff drains, grassed waterways, small check structures, grassed waterways, on farm water impoundment	a) (MPT's) and WP's on terraces + in hedges (following contours) b) Reinforcement of existing soil + water conservation structures with MPT's, WP's + mixed vegetation strips c) Water harvesting with MPT's + WP's in microcatchments
iii) Excessive evaporation and water shortage	a) mulching b) change plant spacing c) divert water from selected drainage channels to cropland and impoundment structures	a) Shade trees in cropland b) Mulch from WP's c) Windbreaks on farm + field boundaries and on common linear landscape elements

Diagnosed Problems + Potentials	Non AF Interventions	AF Interventions
iv) Damage to crops by wildlife and insects	a) Wildlife control b) Insecticides c) Fencing + ditching from MPT's and WP's	a) Live fencing of both farms and forest reserve b) Insecticidal mulch
v) Weed competition	a) Mulch b) Herbicides c) Tillage	a) Mulch from WP's and MPT's.
vi) Lack of cash crop diversity	a) introduce viable new cash crops b) encourage diversity of horticultural production	a) Fruit & Food trees in internal boundary hedges, intercropped, and in pastures
B) Low livestock yields		
i) Fodder shortage due to: a) High labour req'd due to distances to fodder b) Inadequate on farm supply c) Declining supply in forest reserve	a) Plant cut and carry blocks of herbaceous fodder near farms. b) Plant herbaceous fodder on terrace risers + waterways c) Subdivide by fencing grazing areas for better pasture rotation d) Pasture rehabilitation incl. invader suppression by chemical and mechanical methods + reseeding e) Grazing management plan f) Enforcement of plan	a) Fodder orchards of WP's + MPT's in: i) hedgerows ii) terrace risers iii) block planting on farms and adjacent communal lands including forest reserve iv) Live fencing of grazing areas for rotational management v) enrichment planting of browse and herbaceous fodder species in forest reserve commons, and on farm vi) microclimate improvement with windbreaks and shade trees in pastures

Diagnosed Problems + Potentials	Non AF Interventions	AF Interventions
2. Water shortages	a) Diversion to impoundments on and off farms b) Develop impoundment structures for group nurseries c) Reforestation in the forest reserve to improve infiltration d) Maintenance/treatment of existing trees	a) Use MPT's, WP's and grasses to reinforce water structures and drainage channels b) Combine water harvesting with soil conservation techniques using MPT's, WP's etc
3. Energy Shortages	a) Extend electrification b) Promote biogas digesters in zero grazing systems c) Promote fuel conservation ie. modern jiko's etc. d) maintenance of existing trees	a) Plant fuelwood species along external and internal boundaries in combination with live fences and windbreaks b) plant fuelwood in grazing and pasture land c) Plant fuelwood species on common linear landscape elements d) Reforestation with high yielding species in communal fuelwood / fodder lots located on common lands
4. Infrastructural Deficiencies A. Road and pathway erosion	a) Diversion of roadway water to cropland and to on and off farm impoundment structures b) Culverts and ditching	a) Bio-engineering using MPT's, WP's, and grasses to produce fuel, fodder, poles, etc. b) Diversion of water to agroforestry sites

Diagnosed Problems + Potentials	Non AF Interventions	AF Interventions
	c) Grassed or surfaced waterways d) Re-alignment of problem sections e) Rehabilitation of abandoned roads (put to bed)	
B. Waterschemes incomplete	a) Continue construction as funds available b) Divert water to shallow aquifers for local withdrawal c) Encourage farm runoff impoundment	
C. Human comfort	a) Provide additional shade trees on roads, pathways and in public meeting areas	
D. Shelter		
i) Fencing and stock corrals inadequate & expensive		a) Live fencing with of internal and external boundaries with MPT's and WP's
ii) Housing often inadequate		a) grow building materials on and off farm in AF systems
5. Cash Deficiencies		
A. Underemployment	a) develop on farm industries eg. crafts, dairy products processing / milking b) develop tourist related positions ie. guides c) Develop nurseries to support AF interventions	a) Plant MPT & WP cash crops b) Develop bee keeping industry (produce and process) on farms and throughout forest reserve and communal

Diagnosed Problems + Potentials	Non AF Interventions	AF Interventions
		lands. Plant melliferous trees and perennials c) Plant wild indigenous fruit shrubs in forest reserve for picking and sale
B. Suboptimal cash crop production	a) Extension for present and future crops b) Credit for necessary inputs c) Extend present coffee d) Reintroduce pyrethrum e) Improve marketing f) Improve product transport	a) Plant trees and WP's for sale of fuelwood, poles, fruit eg. avocado b) Plant MPT's and WP to support other cash crops
6. Declining availability of raw materials	a) grow thatching material b) develop alternate building technologies	a) Plant charcoaling species in sylvo pastoral system on western slopes b) Plant pole species and integrate into live fences and boundary plantings
7) Climate improvement	a) non vegetative windbreaks b) Protection of existing trees and windbreaks	a) Multi tiered windbreaks incorporating MPT's and WP's b) Provision of shade trees
8) Hydrologic improvement catchments systems on farms	a) Reforestation of upper components within AF	a) Increase % of tree

Diagnosed Problems + Potentials	Non AF Interventions	AF Interventions
	b) Decrease demand through conservation measures ie. mulching, water harvesting etc c) Location of settlements on non porous soils d) Fire control in forest reserve e) Water impoundment schemes f) Grazing management g) Maintenance of ground cover	
Indigenous Vegetation Improvement	a) Control product removal b) Reforestation c) Fire control d) Grazing management	a) Satisfy product demands out of forest with AF systems

Based upon the small farm surveys the following necessary functions and possible landscape niches for trees were identified. Readers are referred to the chart of niche occurrence and current utilization in the land use section.

Planting Sites \ Function	Shelterbelt	Erosion control	Fence	Shade	Fuelwood	Fodder	Browse	Fruits	Mulch	Bee forage	Wildlife	Soil Improvement
Cropland		●		●				●	●			●
Around homes	●		●	●				●		●		
Property boundaries	●		●		●	●	●	●	●	●		
Field boundaries	●	●	●		●	●	●	●	●	●		
Roadsides	●	●		●	●	●	●	●	●	●		
Hedgerows	●	●	●		●	●	●	●	●	●		●
Pastures	●	●	●	●	●	●	●			●		●
Drainagechannels		●			●	●	●			●		
Terraces		●			●	●		●	●			
Perennial orchards		●		●		●		●		●		●
Gullies		●			●	●	●			●	●	●
Woodlots	●				●	●			●	●		
River/stream banks		●		●	●	●		●		●	●	
Rangeland		●	●	●	●	●	●			●	●	●
Unproductive land		●			●	●	●			●	●	●
Forest Reserve		●		●	●	●	●			●	●	
Forest boundary strip			●		●	●		●		●		

Table 20. Location Matrix of Functions and Planting Sites

5.2.3. Short List of Priority Interventions / Candidate Technologies

Based upon a consolidation of problem specific interventions listed in foregoing section the following interventions and/or candidate technologies have been selected for more detailed work and possible extension.

1.) Multi purpose trees and woody perennials alley cropped and in mixtures with annual crops in cropland

2.) Woody perennials for mulch in hedges on rainfed terraces

3.) Woody perennials and grasses on risers of rainfed terraces for cash crops and/or fodder with minimumtillage

4.) Fuelwood, fruit and fodder trees in living fences on farm and internal boundaries

5.) Creation of windbreaks with multi purpose trees and woody perennials

6.) Pasture rehabilitation (grass seeding combined with woody perennials and multipurpose trees)

7.) Planting of fodder and fuelwood in blocks and strips on communal lands and on forest reserve 400 meter boundary strip with improved communal access and management

8.) Planting of melliferous trees and shrubs for bee forage on farms, communal lands and forest reserve

9.) Planting of indigenous trees in upper catchment areas of forest reserve to improve species diversity and wildlife habitat with side products of water, fruit and honey.

10.) Use of living fences for subdivision and rotational management of common lands in Ngong Township

11.) Use of living fences on forest reserve and farm boundaries for wildlife exclusion from fodder orchards on 400m forest strip and from farmlands

12.) Creation of vegetative fireguard on forest reserve boundary

13.) Development of water impoundment structures with adjacent irrigated specialty crop land (on suitable sites on and off farm)

14.) Enrichment planting of browse, fuel + charcoaling wood, construction, melliferous, and soil improving species in grazing lands

15.) Fruit and shade trees in the home compound

16.) Shade trees along public roads and pathways

5.2.4. Technology Specifications for Selected Interventions

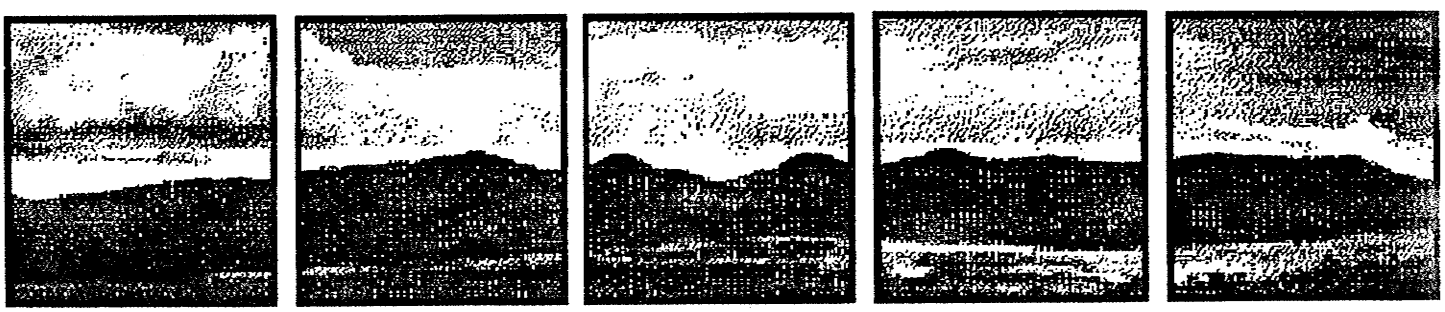
Candidate Technologies	Specifications
1) Multipurpose trees, woody perennials and annual crop combinations (rainfed)	a) Minimum depression of crop yields by effect on: i) light ii) water iii) nutrients (enhancement where possible) b) Optimum component division of environment in both space and time c) Optimum balance of products d) Maximum flexibilty of management including pruning, pollarding and coppicing e) Ecologically appropriate f) High sustainability g) Non-allelopathic relationships h) Crop ground cover % high i) Adaptability j) Availability
2) Woody perennials for mulch in hedges (on and off terraces) with minimum tillage	a) Adequately control weeds b) Provide insecticidal component c) Allow easy sowing and land preparation d) Incorporate easily into soil organic matter e) Improve soil fertility and structure f) Provide erosion cover protection
3) Woody perennials and grasses on terrace risers for cash crops and/or fodder and fuel	a) Ease of propagation b) Fast growth c) Low shade d) Small structure e) Restricted root competition f) Management possibilities include pruning and/or coppicing

Candidate Technologies	Specifications
4) Fuelwood/Fruit and fodder trees in living fences and windbreaks on internal and external farm boundaries (combined with ditching for pigs)	a) Multiple product outputs b) Easy establishment c) Must exclude goats, and wild pigs d) Efficient water utilization e) Should provide animal shade
5) Pasture rehabilitation and enrichment planting	a) Improve quality and quantity of fodder b) Improve seasonal distribution of fodder c) Protect and treat existing tree and desired shrub regeneration d) Must withstand repeated and heavy browsing e) High growth rate f) Non allelopathic g) Highly palatable
6) Fodder and fuelwood blocks and strips on farm and forest strip	a) High yielding species b) Provision of dry season fodder c) Ease of establishment d) Stabilize soil erosion e) Low ignition rate (when green) f) Preference for indigenous species
7) Melliferous trees ands shrubs	a) High nectar flow b) Nectar type must produce high quality honey c) Nectar flow coincides with maximum bee populations d) Indigenous species only in forest reserve e) Should have multiple product outputs
8) Indigenous forest reestablishment (in forest reserve)	a) Endangered or threatened species given priority b) Germplasm from area given priority c) Pure stands to be avoided d) All exotics must be avoided e) Existing exotics to be replaced f) Steep slopes, drainage channels, and other sites of high potential erosion to be given priority attention

Candidate Technologies	Specifications
	g) Melliferous species where possible h) Should improve wildlife habitat (food and cover)
9) Living fences in Ngong Township	a) Must exclude goats and cattle b) Should provide shade for human comfort along existing pathways and roadways c) Ease of establishment d) Drought resistant e) Should contribute positively to the visual quality of the area f) Should provide fuelwood and fruit g) Fence and grazing enclosures should be managed under improved communal access through the local council h) Should utilize melliferous species where possible
10) Living fence on forest reserve boundary	a) Must exclude goats, wild pigs, and buffalo b) Should utilize indigenous species where possible c) Should provide multiple outputs (fuel, fruit etc.) d) Ease of establishment e) Should have low ignition rate f) Should have melliferous components
11) Vegetative fireguard on F.R. boundary (May be combined with above)	a) Low maintenance b) Indigenous species if possible c) Should be evergreen with very low ignition rate d) Low amounts of fine fuels available for ignition in dry seasons
12) Water impoundment with adjacent irrigation of specialty crops	a) must not displace prime agricultural, conservation or wildlife areas b) Must be located on water tight sub base c) Selected crops for irrigation should: i) Have high market value ii) Should be labour intensive

Candidate Technologies	Specifications
	d) Should add to the visual quality of the area
13) Shade and fruit trees in home compound	a) Should have dense canopy for maximum shade b) Should have high growth and/or production rates c) Should contribute to cash and/or nutritional requirements d) Should not displace useable outdoor space with excessive low branching
14) Shade Trees along public pathways and roads	a) Should have dense canopy for maximum shade b) Should add to the visual quality of the area c) Should not be excessively demanding of water d) Should not be overly subject to blow down or disease e) Should be suitable for fuelwood as immature thinning occurs

Ch. 6 Recommendations & Conclusions



6.1. POLICY SET FOR THE NGONG HILLS

The following policy set for the Ngong Hills has been derived from the diagnostic findings, interviews with farmers and local officials, as well as the national and district development plans. The policies are general in nature and are to be used to judge the appropriateness of various land utilization types in the study area. Preference policies are listed which are not exclusionary but, rather, are to be given preference wherever possible. On the other hand, the exclusionary rules included in the policy set, indicate those land uses which are to be definitely excluded from certain areas.

6.1.1. Preference Policies

6.1.1.1. *Policies Related to High Density Settlement*

1. Give preference to high density settlement contiguous to Ngong Town

2. Give preference to high density settlement in areas with high access to employment and commerce

3. Give preference to high density settlement in areas where sewage and water reticulating schemes exist

4. Give preference to high density settlement in areas with high access to public transportation

5. Give preference to high density settlement in areas with high suitability for construction

6. Give preference to high density settlement in areas previously zoned for same

7. Give preference to high density settlement in areas that will not result in downstream and ground waterdegradation

6.1.1.2. *Policies Related to Rural (lower density) Settlement*

8. Give preference to rural settlement in areas with access to reticulated water schemes

9. Give preference to rural settlement in areas that are not in water collection or conveyance zones

10. Give preference to rural settlement in areas that currently support that use

6.1.1.3. *Policies Related to Environmental Quality*

11. Give preference to uses that maintain downstream water quality

12. Give preference to uses that decrease runoff and spate stream flows

13. Give preference to uses that will not cause groundwater contamination

14. Give preference to uses that will increase soil and groundwater storage throughout the watershed

15. Give preference to uses which do not cause significant soil erosion

16. Give preference to uses which maintain or improve soil structure and fertility

17. Give preference to uses which maintain or improve visual quality

18. Give preference to uses which improve the meso and micro climate

19. Give preference to uses which improve human physical comfort

20. Give preference to uses which maintain or improve wildlife habitat

21. Give preference to uses which maintain or improve the vigour and biological diversity of existing biotopes.

6.1.1.4. *Policies Related to Agriculture and Agroforestry*

22. Give preference to Agriculture or Agroforestry on those lands of high suitability

23. Give preference to those Agricultural or Agroforestry systems which improve production

24. Give preference to those uses that improve agricultural resource conservation

25. Give preference to those uses that promote the development of agroforestry

26. Give preference to those uses that improve exports of agricultural products

6.1.1.5. *Policies Related to Horticulture*

27. Give preference to irrigated horticulture on those lands of highest suitability and with high access to suitable water sources

6.1.1.6. *Policies Related to Livestock*

28. Give preference to livestock related uses on lands not of high capability for agriculture, horticulture, high density settlement or conservation.

29. Give preference to intensive zero grazing dairy systems on land holdings less than 20 ha.

30. Give preference to intensive zero grazing dairy systems in areas with road access

31. Give preference to livestock related uses in areas with suitable water and fodder supplies

32. Give preference to those uses which improve the livestock fodder supply

6.1.1.7. *Policies Related to Forestry*

33. Give preference to those uses that promote the conservation and management of forests

34. Give preference to those uses that promote tree planting on private and communal lands

35. Give preference to those uses that promote forestry for public amenities and wildlife

36. Give preference to those uses that promote the development of fuelwood

6.1.1.8. *Policies Related to Conservation*

37. Give preference to conservation in areas of severe potential soil erosion

38. Give preference to conservation in areas of undisturbed natural vegetation and other areas of outstandingbiologicalimportance

39. Give preference to conservation in areas of critical importance to wildlife

40. Give preference to conservation in water catchment areas with high soil and groundwater rechargepotential

41. Give preference to conservation on public forest land

42. Give preference to conservation in stream conveyance zones

43. Give preference to conservation in areas of exceptional cultural/historic importance

6.1.1.9. *Policies Related to Recreation and Tourism*

44. Give preference to extensive recreation/tourism in areas of exceptional visual quality

45. Give preference to intensive recreation in areas with high accessibility to high density settlement

46. Give preference to extensive recreation /tourism on public lands that are not of high conservation value or critical wildlife areas

47. Give preference to those uses that promote tourism

6.1.1.10. *Policies Related to the Provision of Basic Needs*

48. Give preference to those uses that improve the health of the inhabitants

49. Give preference to those uses that provide cash income to local residents

50. Give preference to those uses which improve the provision of water for local residents

51. Give preference to those uses that provide for the energy requirements of local residents

52. Give preference to those uses which provide for the food requirements and improves self sufficiency in basic food stuffs of local residents

53. Give preference to those uses which provide for the shelter requirements of local residents

54. Give preference to those uses that improve local infrastructure

55. Give preference to those uses that promote labour intensive techniques and improve employment opportunities

56. Give preference to those uses that promote " Harambee" or self help

57. Give preference to those uses that promote the " mobilization of domestic resources for equitable development"

58. Give preference to those uses which provide for the basic needs of the most disadvantaged in the area

6.1.2. Exclusion Rules

1. Exclude arable agriculture from the forest reserve

2. Exclude domestic grazing from areas of natural forest, critical wildlife areas, and stream conveyance zones

3. Exclude all settlement including hotel accommodation from the forest reserve

4. Exclude all settlement and arable agriculture from stream conveyance zones

5. Exclude uses other than high density settlement from areas currently used for that purpose

6. Exclude uses that may cause significant groundwater contamination from all areas of high and moderate groundwater recharge potential

7. Exclude uses other than those related to primary production on those lands of highest production suitability

8. Exclude annual crops from climate zones V4 and V5

9. Exclude extensive uses from lands currently under intensive production.

6.2. PRIME SUITABILITY

As described more fully in the methodology section, the land utilization type which had the highest aggregate policy satisfaction, and was not excluded by the exclusionary rules, was determined to have prime suitability for the land unit in question. The land utilization types which were considered are listed below.

6.2.1. Land Utilization Types Under Consideration

Existing Uses

1. Annual Crops (predominantly maizes, beans, peas, and potatoes)*

2. Intensive Grazing of Small Pastures*

3. Extensive Grazing/Browsing of Natural Pastures and Browseland (with fuelwood gathering)

4. High Density Settlement

5. Multiple Use Public Forest Land (with grazing, fuel and fodder gathering)

Potential Uses

6. Multiple Use Protection Forest (emphasis: watershed and wildlife habitat protection, recreation, only light and occasional grazing permitted)

7. Smallholder Agroforestry System (alley cropped annuals and cash crops, windbreaks, internal and external boundary planting complete with zero grazed dairy cattle and fodder crops)*

8. Smallholder Agroforestry System (alley cropped annuals and cash crops, windbreaks, internal and external boundary planting, no cattle)*

9. Extensive Silvopastoral system complete with browse enhancement

10. Communal Cut and Carry Fodder and Fuelwood Orchards∆

11. Conservation

12. Irrigated Horticulture ∆

* includes low density rural settlement
∆ location specific land uses not considered in area wide calculations

As the prime suitability map indicates, few areas have a prime use that corresponds to the current use. While realizing that these changes cannot occur over night, every effort should be made to alter current land use to a more appropriate form in those areas listed as resource consuming (particularly in regards to soil and water resources). In addition, it must be stressed that the methodology of prime suitability selection does not include other possible interventions that have surfaced during the study and which have been summarized earlier.

6.3. SPECIFIC MANAGEMENT RECOMMENDATIONS

The land utilization types designated as prime are general categories and the specific systems and technologies utilized on the various physiographic site types will vary. Management units have been established based on broad similarities of climate, soil, vegetation and current management type. Recommendations are categorized under the four different management types and, within these, under the various management units (see management map). Naturally, these require significant extension and development work to be transformed into reality.

6.3.1. General Recommendations for All Areas

While specific recommendations must address the uniqueness of the various management units, some recommendations are general enough to refer to all units. The following proposals apply to all management units in the study area.

1) Water infiltration and it's efficient utilization must be increased. This is the most important issue in the region. Therefore, land uses which do not incorporate water harvesting and increased infiltration shall be prohibited on all lands designated as extremely important to aquifer recharge. Such uses will be discouraged in all zones other than those designated as of very low importance to aquifer recharge.

2) High density settlement shall be prohibited on Nitosolic and Luvisolic soils.

3) All future settlement shall be prohibited from all intermittent or continuous stream conveyance zones. All present settlement in those zones shall be encouraged to utilize sewage holding tanks or biogas digesters.

4) Agricultural practices that do not incorporate adequate soil conservation practices will be prohibited on all lands of high potential erosion and will be discouraged on lands of medium potential for erosion.

5) Revegetation of all stream conveyance zones will be encouraged.

6) Public awareness and educational programs should be established to inform and educate the public of the critical issues and possible solutions.

7) The University of Nairobi should adopt the area as multi diciplinary research area.

8) Conservation efforts by individuals and groups should be rewarded and provision of economic incentives should made.

6.3.2. Small Holder Mixed Farming

The prime suitability map indicates that agroforestry systems, with and without a zero grazing dairy component, have prime suitability throughout most of the farming areas of the eastern slopes. The selection of the dairy component was based on proximity to roads in order to facilitate milk transport. Undoubtably, many farmers are willing to haul their milk to the road or are producing for themselves or neighbours and would want to adopt the dairy system even though it isn't listed as most suitable.

The major recommendations put forward for the small holder include:

1) Windbreaks as part of a live fencing system of multipurpose trees and shrubs.
2) Alley cropping annuals (maize /beans / potatoes) with fruit/fuel and fodder trees
3) Terrace construction and/or consolidation utilizing fruit/fuel and fodder trees and fodder grass
4) Internal boundary planting with fodder/fuel trees/shrubs and fodder grass
5) Multipurpose shade trees in the compound
6) Treatment of roads and pathways for stability and comfort
7) Water harvesting
8) Zero grazing of dairy cattle
9) Extensive development of apiculture throughout the area.
8) Prohibition of all further land subdivision

The specifications for the design are listed elsewhere, but fundamentally, the systems seeks to produce fuel and food self sufficiency while at the same time contributing significantly to fodder and cash production. Typical plans and sections of systems for a farm on steeply sloping Nitosolic soils with climate type III (Management unit SH1) are presented as are plans for gentle Vertisolic lands on climate type IV (Management unit SH2). Treatment of roadways are also illustrated in following figures (50a, 50b & 51).

Figure 50a Present Problems on Roadways

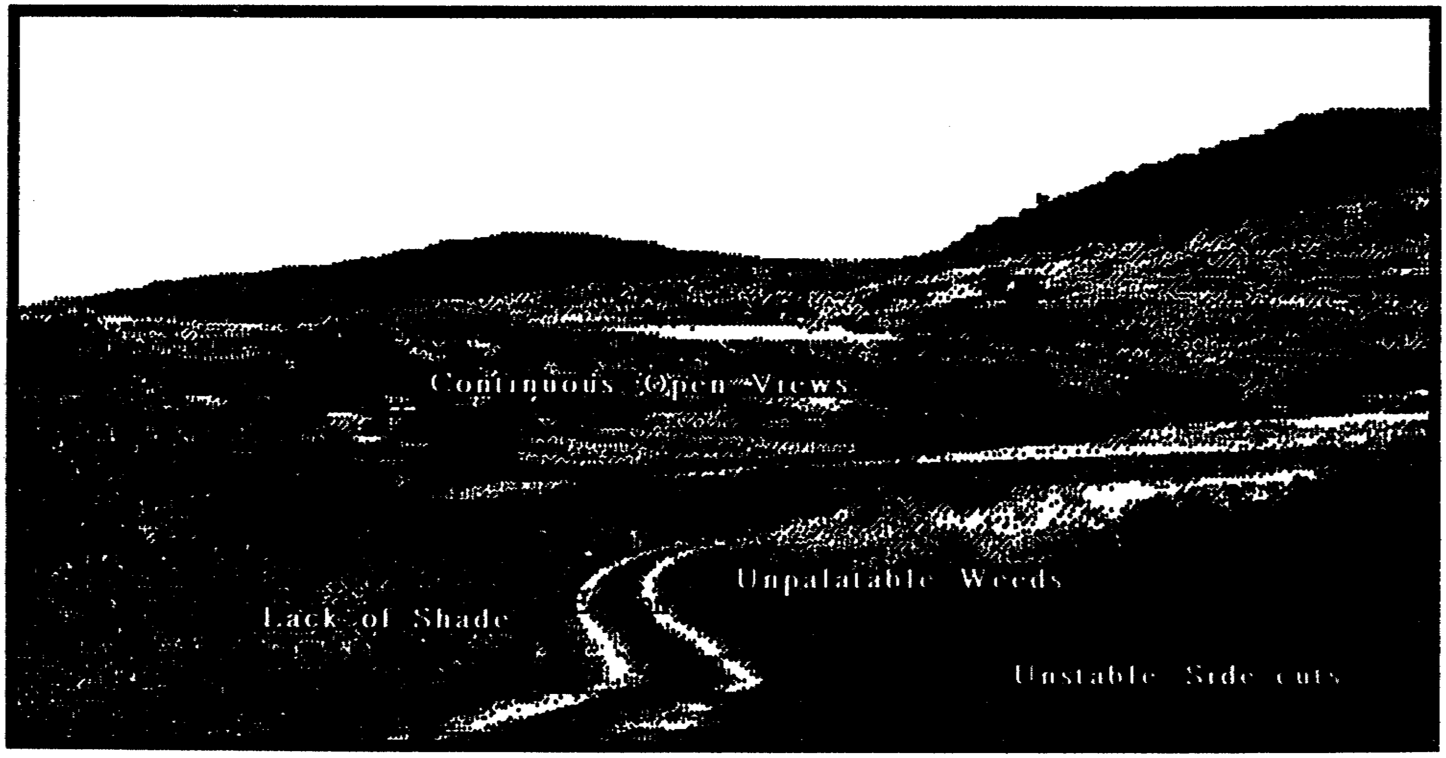
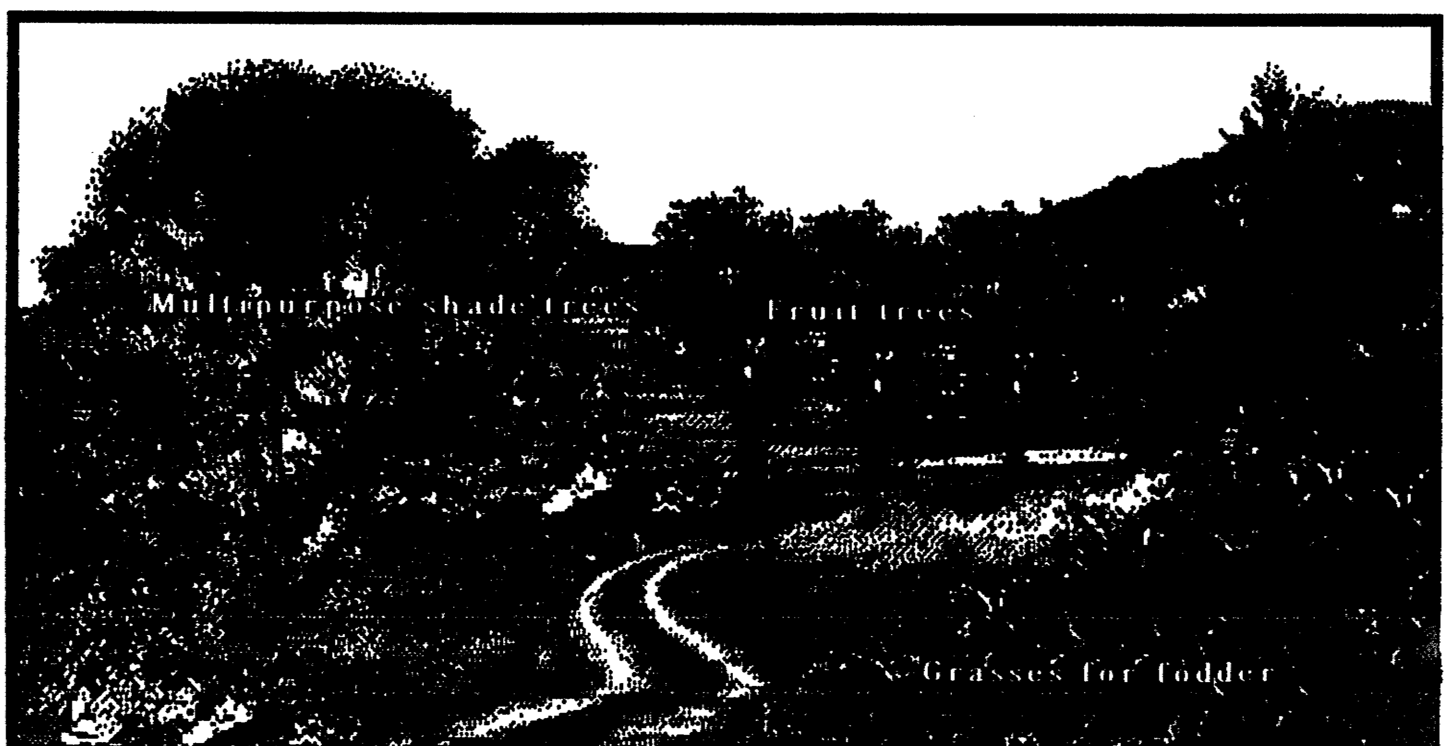


Figure 50b Potential Interventions on Road Allowances



Fuelwood   Fruit & Shade Trees

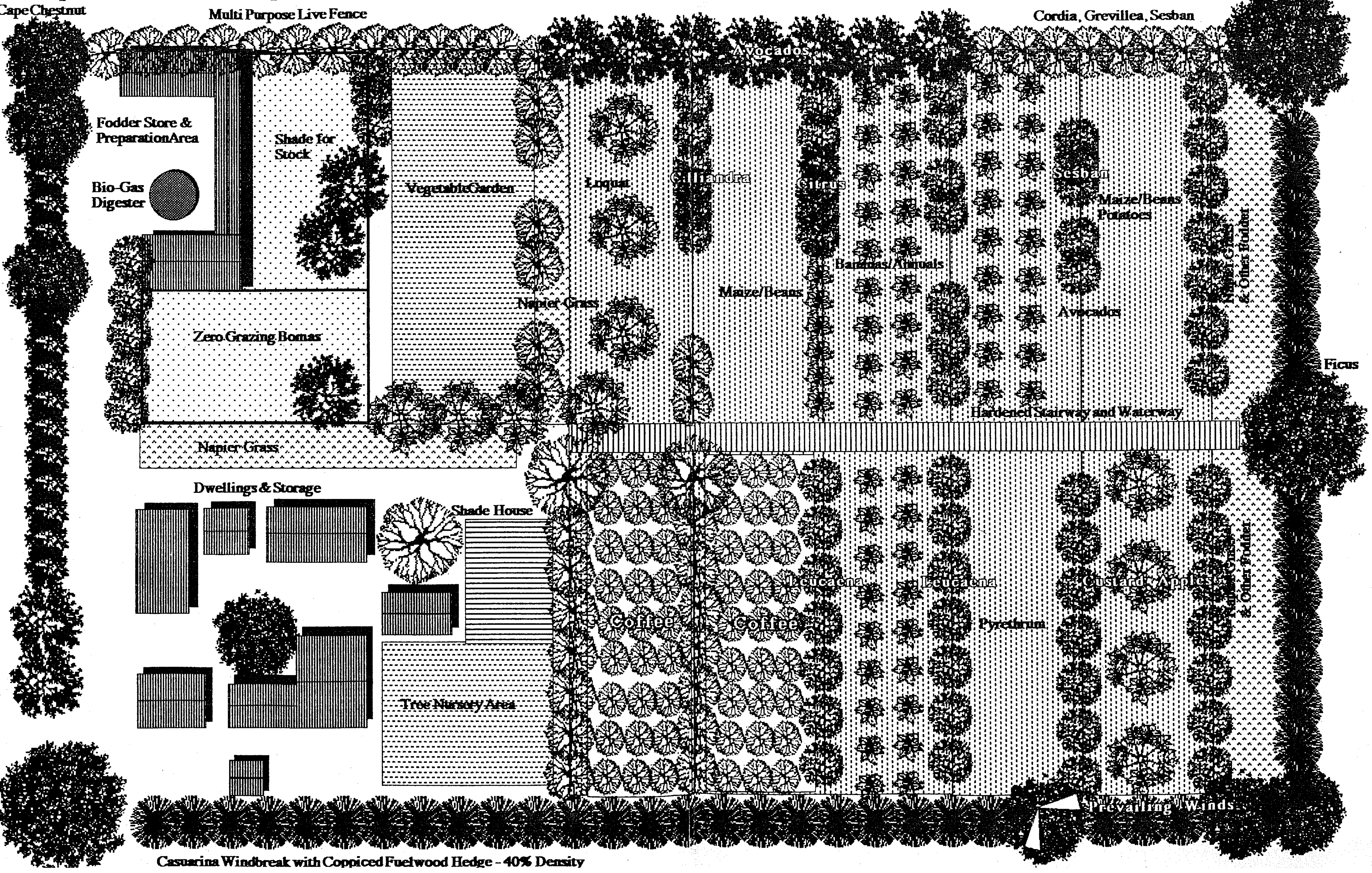
Bank Stabilization with Fodder & Browse Species

Figure 51. Typical Roadway Treatment

Aside from addressing the environmental and production problems, the systems have large potential for cash generation. Both dairy products and honey are in great demand and producers can expect to sell all they produce (if product transportation problems can be solved). The fruit tree component is targeted for both home and market consumption while the staple crops are mainly for home consumption . There has been no attempt to change the staple crop of maize as it so deeply entrenched in the area. Rather, every effort has been made to improve the growing conditions for it as well as to recommend that it is planted only during the long rains.

If the recommendations are carried out, the resulting landscape will be much more compartmentalized. The aggregation of individual farm solutions would help solve more regional problems such as high desiccating winds and runoff.

Figure 52. Possible Design for Small Holder Farm



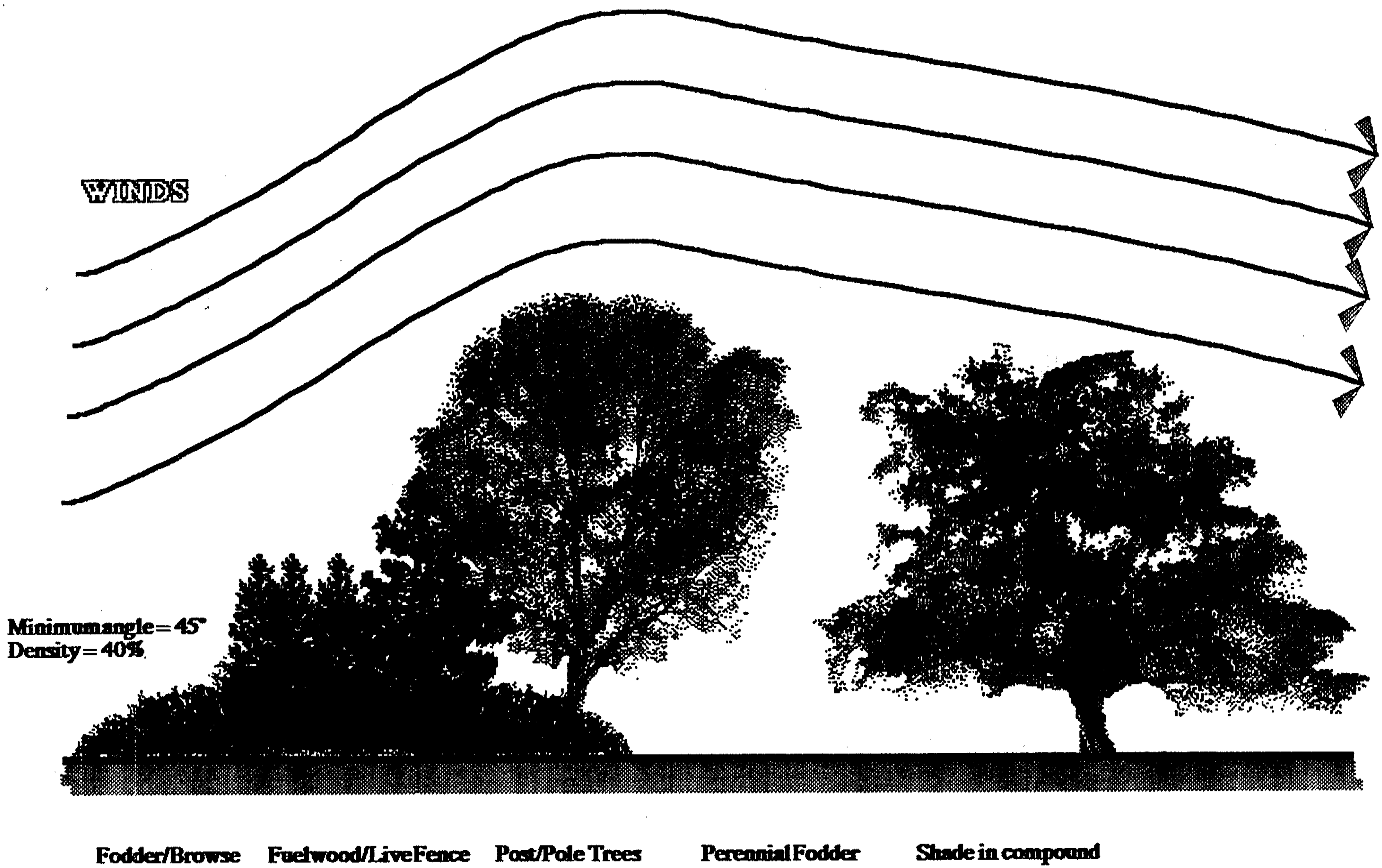


Figure 53. Possible Functions of On Farm Windbreaks

Possible solutions for small holder farms

The plan (figure 52) is one example of what a typical farm could look like. The sections and plans that follow illustrate in greater detail some of the elements of the scheme.

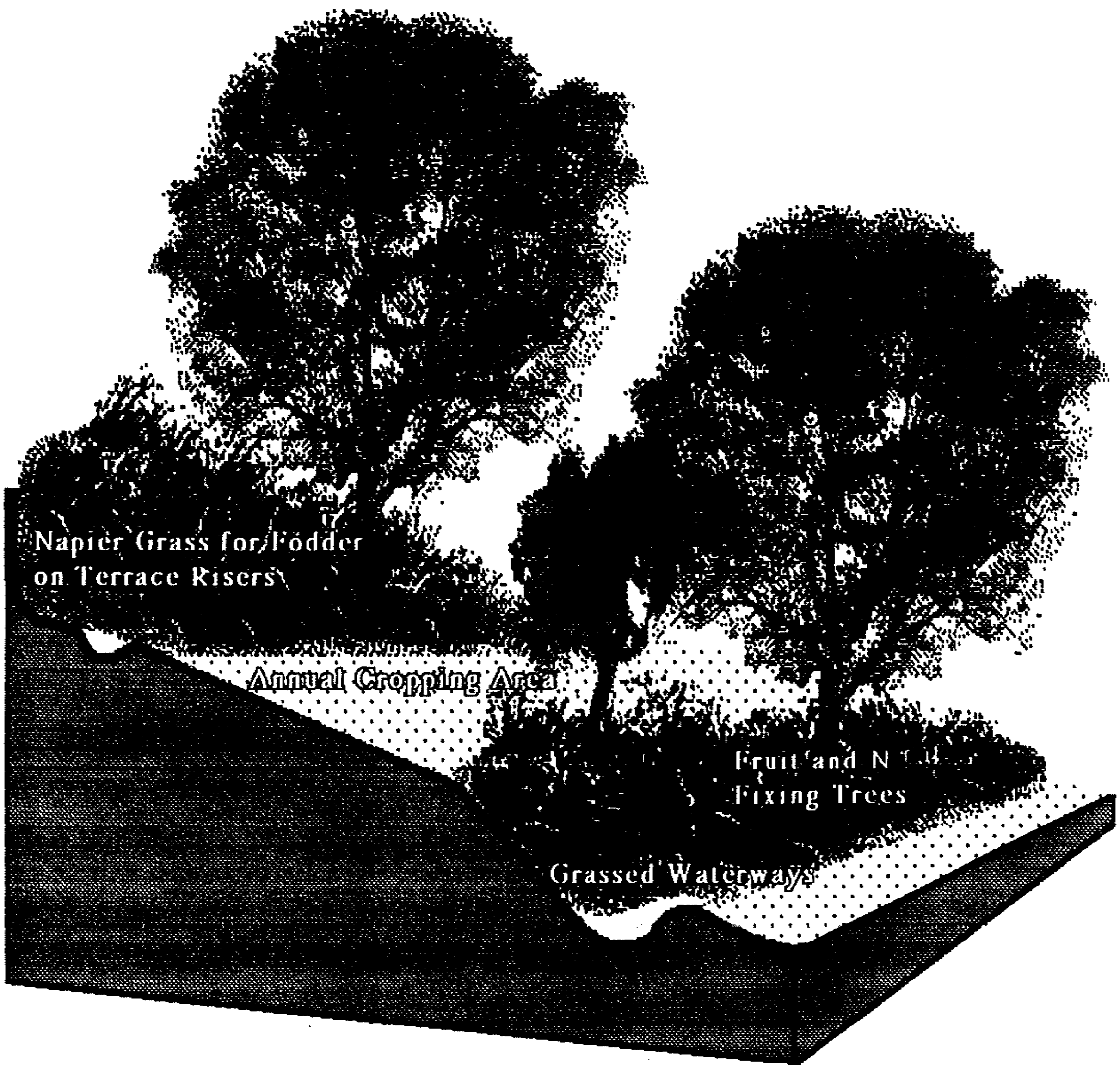


Figure 54. Typical Terrace for Small Holder Farm

Figure 55. Example of Alley Cropping

6.3.3. Extensive Large Holders of the Western Slopes and Rift Valley

The most urgent requirements of those largeholders living in the western portion of the study area are to improve browse and range conditions. Accordingly, the recommendation for this area include:

1) Protection of existing regeneration
2) Planting of browse/fodder/fuel/charcoal (for cash) trees in the range.
3) Fodder production in live fenced orchards

Management unit LH1 currently supports far more trees than the LH2. Protection of existing regeneration is therefore more critical in this unit. Although individual sapling protection with thornbush fencing is possible, it may be far more efficient (in terms of the amount of thorn branches used) to live fence larger sections of the range. Certainly, this is the case for the fodder orchards (see plan below), which will provide fodder in the form of leaves and pods during the dry season. Species selected for charcoal production are less palatable and should require less protection than the fodder species.

Melliferous trees (such as *Acacia spp.*) should be given a high priority in both the large holder units as the potential for apiculture development is very high. Possible melliferous species for this area include:

Acacia asak
Acacia mellifera
Acacia saligna
Acacia seyal
Acacia tortilis
Albizia chinensis
Albizia lebbeck
Cassia siamea
Delonix elata
Eucalyptus camaldulensis
Eucalyptus globulus
Eucalyptus tereticornis
Lespedeza bicolor
Lespedeza leucocephala
Pithecellobium dulce
Prosopis chilensis
Prosopis juliflora
Robinia pseudoacacia
Schinus molle
Sesbania sesban
Tamarix aphylla
Ziziphus spina-christi

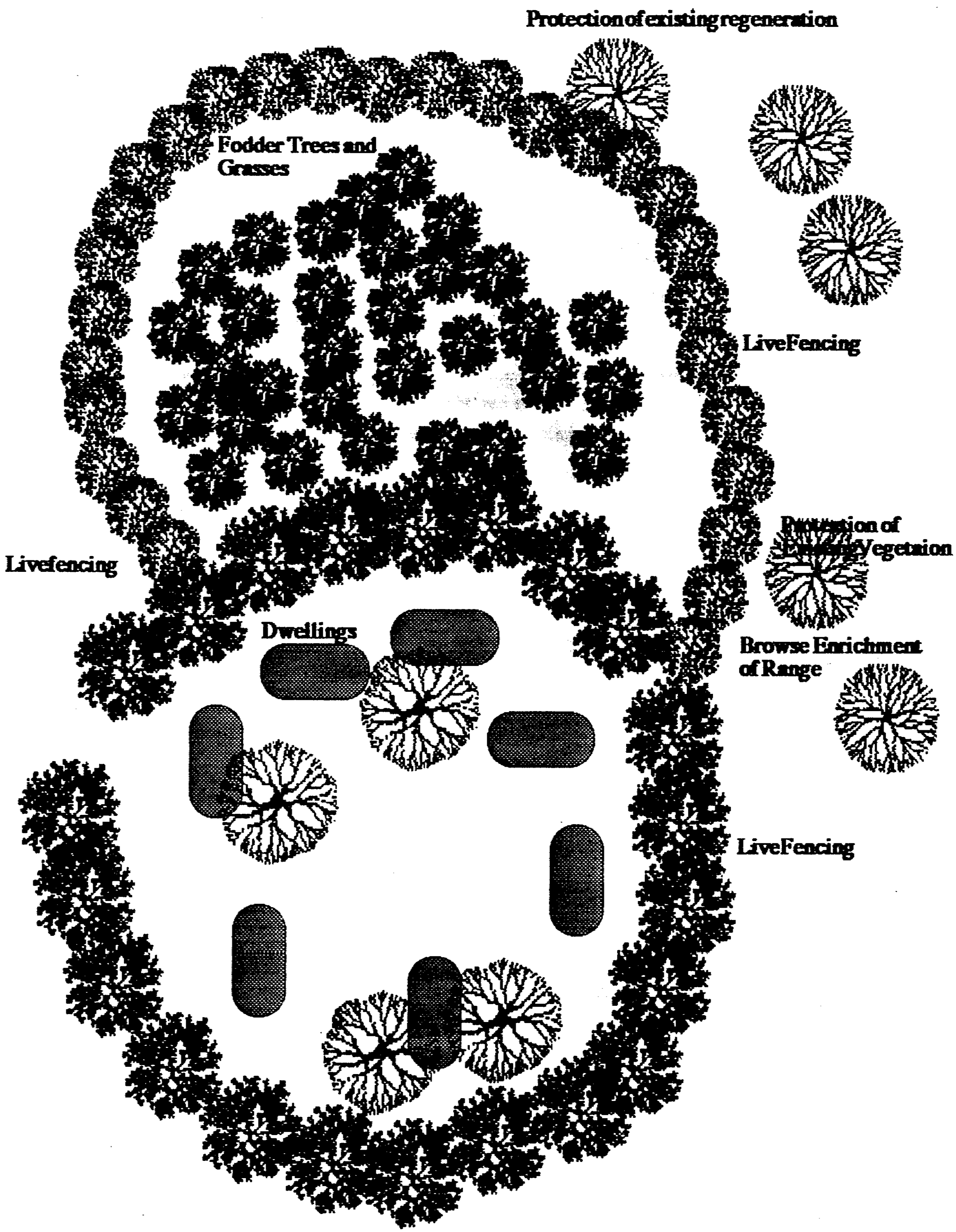


Figure 56. Possible Treatment of Rift Valley Holdings

6.3.4. Ngong Township

Ngong Township lands (Management Unit PL1) are either public or leased from the council and the town therefore has a degree of control over their use. It is suggested that those lands currently under agricultural production on Nitosolic soils remain so or be converted to agroforestry systems. High density settlement should not be allowed to expand onto such land. Rather, settlement should be contained along Ngong Road where densities could be significantly increased and additions to the infrastructure could be minimized . The soil survey indicated several areas in the immediate vicinity of Ngong Town that had bedrock close to the surface, overlain by vertisols. These areas should be further delineated by detailed soil survey and allotted to high density residential use. It is believed that by concentrating settlement in these areas significant increases in population could be accommodated without consuming valuable agricultural lands.

The increases in population that are certain to occur in Ngong Town will have to be accompanied by increases in both construction and maintenance of infrastructure if environmental degradation is to be avoided. The sewage treatment in the area is currently suffering from disrepair and should be rehabilitated. A major effort must be made to connect all new and existing residences in the town to the system. As sewered systems become more viable with higher densities, this further makes the case for high density spinal development along Ngong Road.

A major problem area in Ngong Township is the village of Kijiji, where densities are high and provision of infrastructure is low. High runoff rates into the valley below are causing serious erosion and a very large area requires rehabilitation (see figure below). As sewage treatment in Kijiji is extremely limited, the runoff water is polluted. It is suggested that the runoff gully from Kijiji be hardened to withstand the flow and protect the entry road. The small catchment valley below the town could be flooded by the creation of a dam. (see plan for location). The land removed from production is currently so degraded as to be of limited value. It is well located between two ridges to allow for dam construction at a reasonable cost. The construction could be done entirely by hand, thereby providing some much needed employment.

The reservoir created would store spate flows and the water could be used for drip irrigation of horticultural and specialty crops in the adjacent public lands. As the water is likely to be polluted the edges of the pond should be planted to papyrus to encourage biological purification. The papyrus could subsequently be harvested on a rotational basis and used for local craft and furniture industries. The possibility of aquaculture should be explored but may be of limited potential. The following plan indicates some possibilities for the site. Not only would this plan relieve a serious erosion and pollution problem but the resulting pond and associated cropping could add to the employment potential of the area. The plans and section below conceptually illustrate the scheme.

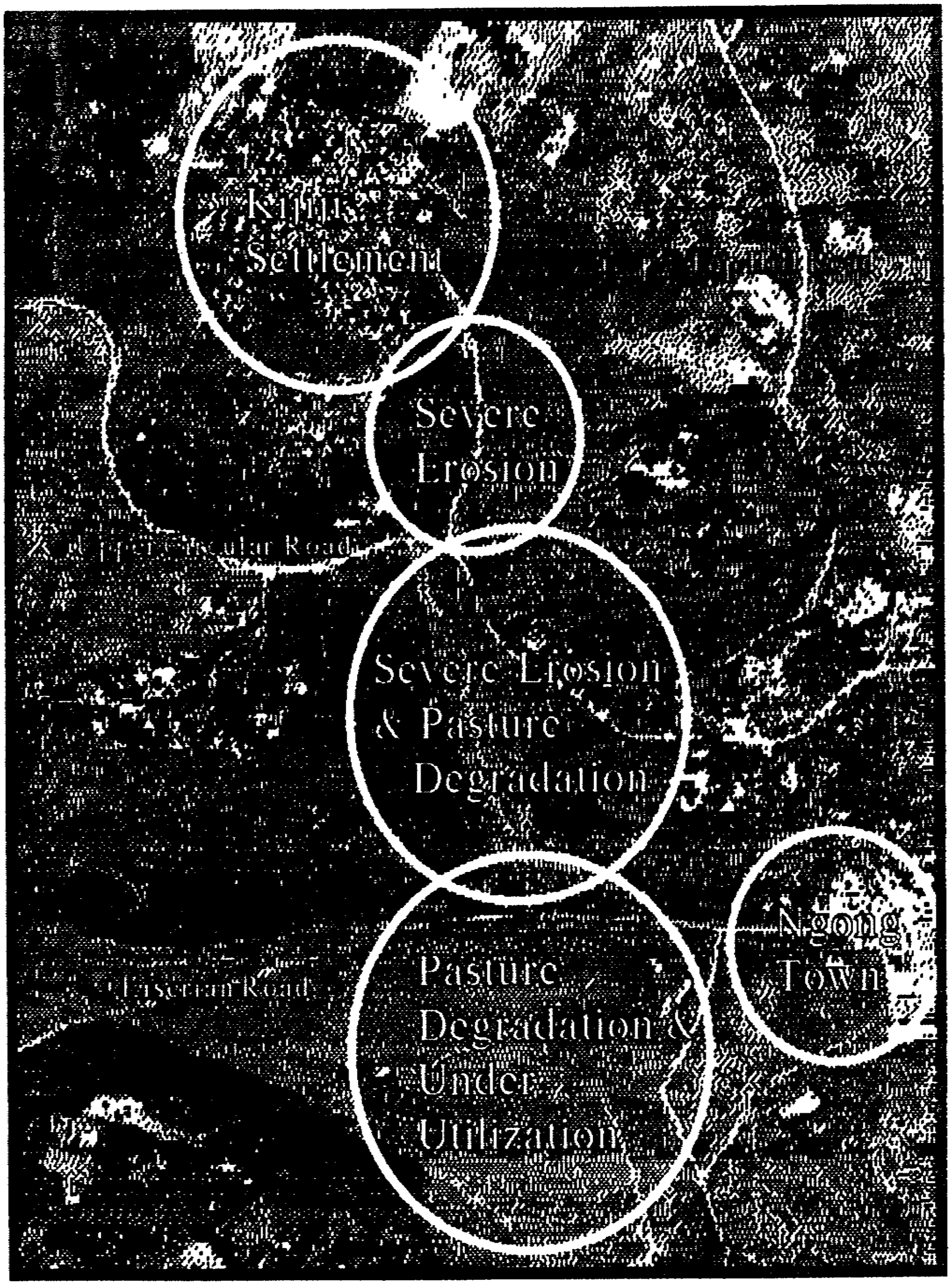


Figure 57. General Context of Proposed Reservoir

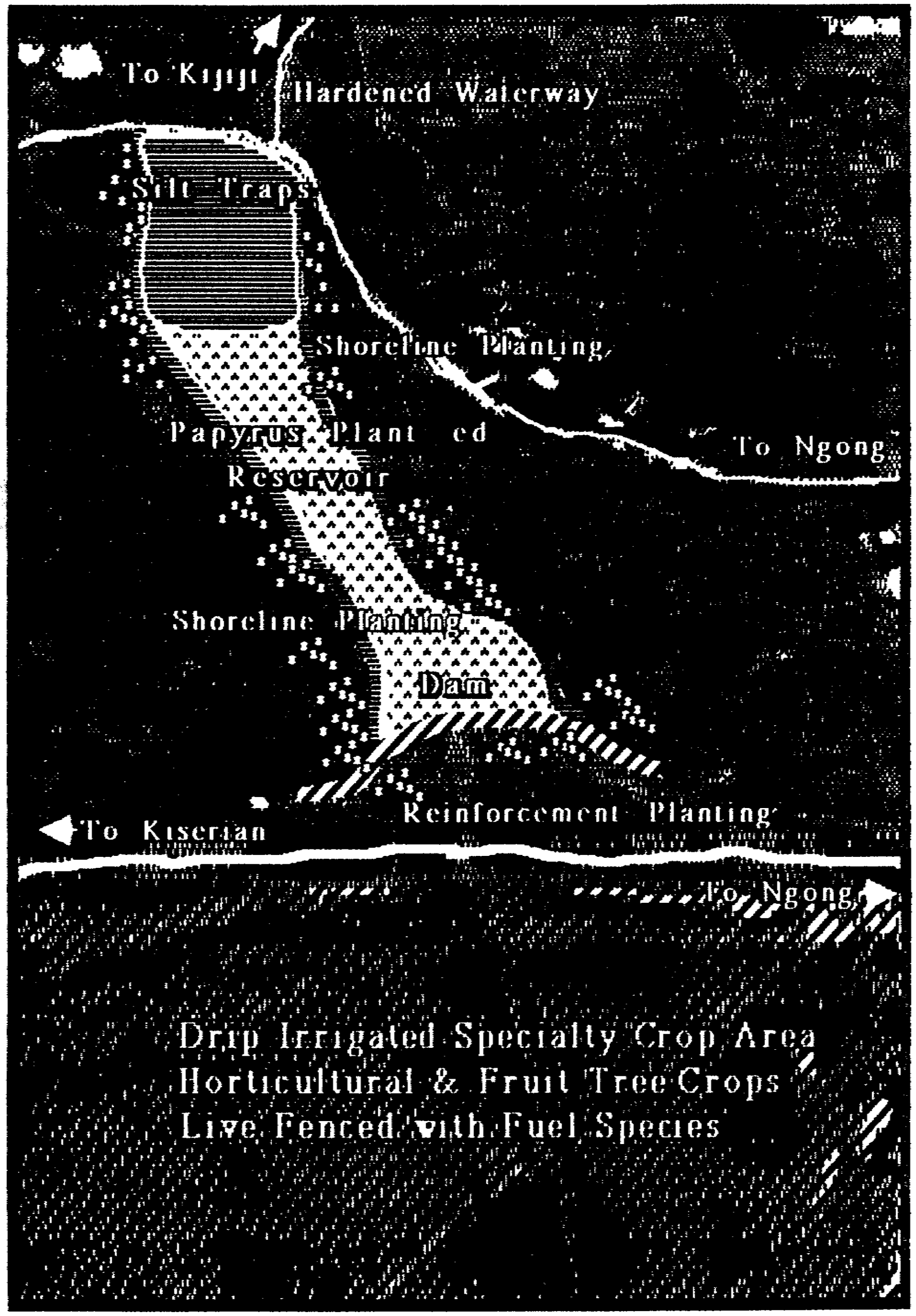


Figure 58. Conceptual Plan of Proposed Kijiji Reservoir

Figure 59. View of Proposed Kijiji Reservoir

6.3.5. Public Forest Land

Interventions in the forest reserve have long been recognized as necessary. They have, however, met with limited success. In addition some of the interventions have been misguided. Although it is commonly agreed that the hills must be reforested, such agreement does not apply to the method. The forest department is attempting reforestation with predominantly exotic species. This is being done despite calls by others, including the President, for indigenous plantations. Recognizing the difficulty in obtaining native germplasm, future efforts must be directed towards the establishment of a native forest on the Ngong Hills. There are only 3077 hectares of forest reserve. The prime function of this land is water catchment protection (above **all** other uses).

In order to maximize the utilization of the land while at the same time protecting it's primary function, compatible land uses should be encouraged. Unfortunately for some, this does not include heavy grazing of steep slopes or browsing of regeneration. It also does not include unsupervised firewood collection. Recognizing that the forest reserve is currently providing many people with resources (eg. 71% of the sample population admitted getting at least some of their fuel requirements from the reserve) any future plan must provide for those requirements in some way if it is to succeed. Those collecting fuel and fodder in the reserve must have their needs met or they will attempt to meet anyway. Assuredly, these attempts will not be in the way the land manger might wish.

6.3.5.1. *Management Units*

Although the prime suitability map indicates the prime use for all of the forest reserve to be protection forest, the form of the forest will of course vary with site conditions. Recognizing this, the different management units have been proposed. The following are the broad recommendations for each unit.

Unit FR1

1) Enhancement and conservation of existing forest stands by:

   a) Protection of regeneration

   b) Rehabilitation of thickets

   c) Total domestic grazing exclusion

   d) Replanting to Afromontagne and Transitional Montagne species

2) Wildlife habitat enhancement by:

   a) Browse and pasture manipulation

   b) Creation of small enclosed meadows and increased "edge effect" during replanting

Unit FR2 a,b

1) As above but replanting with Dry Montagne species

Unit FR3a,b

1) Enhancement and conservation of indigenous vegetation by:

a) Protection of indigenous regeneration

b) Harvesting of invader thickets for fuelwood (closely supervised by forestry staff)

c) Replanting to Afromontagne and Transitional Montagne species

2) Planting of melliferous trees

3) Emergency (drought) grazing only

FR4a

1) Conversion to extensive silvopastoral system utilizing indigenous species only by:

a) Protection of indigenous vegetation and regeneration

b) Planting of all stream conveyance zones to transitional montagne species

c) All other planting to transitional and dry montagne species (emphasis melliferous and charcoalingspecies)

FR4b,c

1) Protection of indigenous vegetation and regeneration

2) Planting of all stream conveyance zones to dry montagne species

3) Browse and Wildlife habitat improvement utilizing indigenous species only

4) Melliferous trees for apiculture

5) Domestic grazing strictly excluded

FR5

1) Protection of indigenous vegetation and regeneration

2) Browse and Wildlife habitat improvement utilizing indigenous species only

3) Melliferous trees for apiculture

4) Emergency domestic grazing strictly excluded

Unit FR6, Fuel and Fodder Boundary Strip

In keeping with a desire to protect and enhance the natural resources of the hills, while at the same time meeting the requirements of local people, it is suggested that a two hundred meter strip be established on the *inside* of the eastern forest boundary running from the Magadi Road to the road leading to the top of the hill. This represents approximately 168 hectares or 5% of the total gazetted land. It is proposed that the strip be managed as a communal fuel and fodder orchard. It would have live fencing on either side to exclude both cattle and goats from the forest reserve and wildlife from the farming area. At no time would arable agriculture be allowed in this strip and continuous vegetative ground cover would be maintained at all times. Any residual forest remnants should be identified and are to be maintained in their natural state. Perennial shrub, tree and grass crops would be planted. Sections of the strip would be allotted by water drainage basin to groups of residents from that drainage downstream. (see section below) These people would be responsible for all work on the plot and would reap the benefits. Technical backstopping would be provided by the forestry department. (including provision of seedlings at cost)

A further benefit of the strip would as a vegetative fireguard. Harvesting would occur just prior grass curing thus reducing the risk of fine fuel ignition. The selection of species for the live fencing also has accounted for low ignition rates.

It should be recalled that the government had offered, but then subsequently withdrawn, to allow the squatters in the forest to resettle on a 400 meter strip inside the reserve. There should be the political will to establish the new strip, understanding that, although the intensively managed area consumes a portion of gazetted forest land, it may indeed save the remaining area from further degradation. Once the strip is established, then all incursions into the forest by gathers must stop and this **must be enforced.**

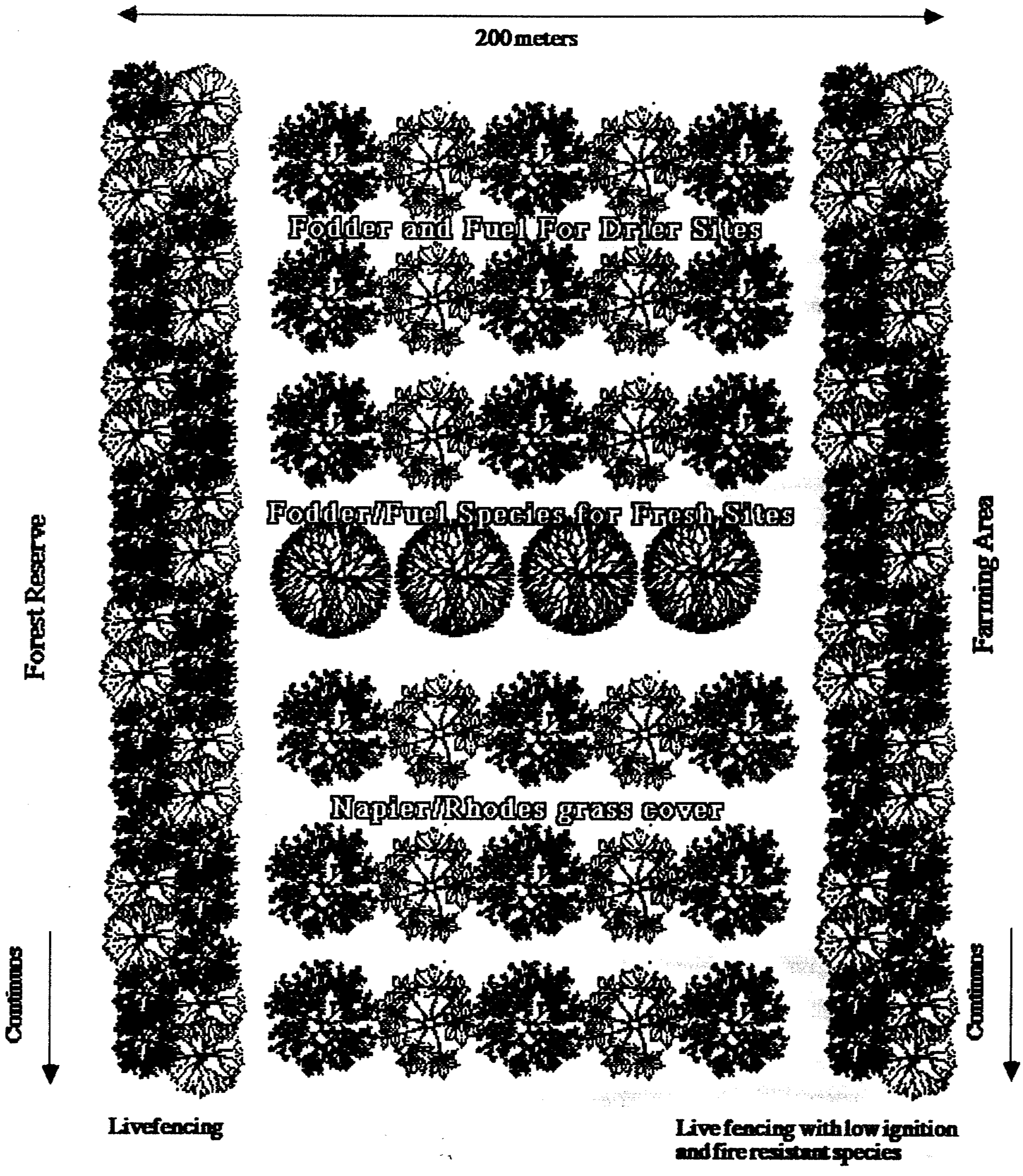
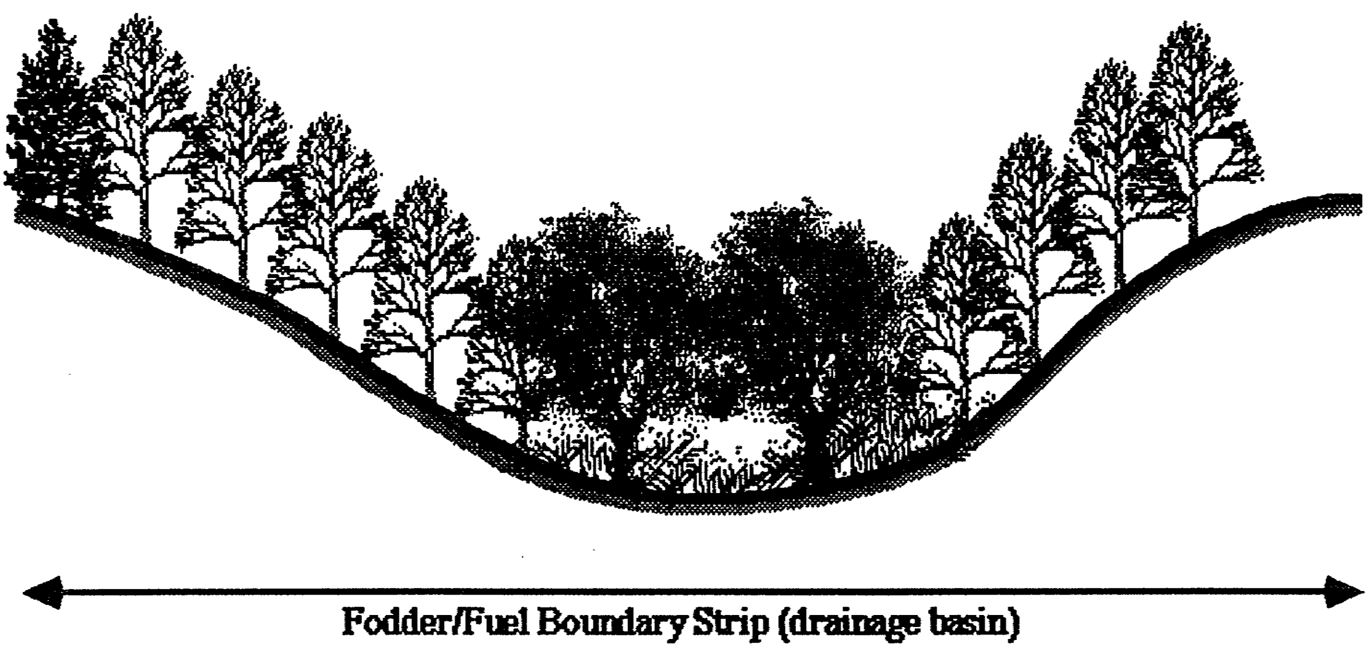


Figure 60. Proposed Forest Boundary Fuel/ Fodder Strip

Figure 61. Section of Proposed Forest Boundary Fuel/ Fodder Strip



6.3.5.2. General Planting Recommendations

The efforts of the forest department to establish plantations have often been thwarted by the difficult conditions. It is suggested that all planting follow the general approach of planting the indigenous species that are occurring on similar sites in the forest. A strict policy of indigenous planting only should be followed in the forest reserve.

The southern and western ends of the reserve are dry and will not support a dense forest. (management Unit FR4a) As they are currently utilized for extensive grazing, it is suggested that any planting in these areas be directed towards the establishment of a light canopy cover that allows for continued grassland. The suggested species and spacing for planting are shown below.

The main canopy species for planting should be:

Below 2200 meters on the Eastern Slopes:
Dombeya goetsenii (this is a particularly melliferous tree and should receive priority)
Albizia gummifera
Croton megalocarpus
Calodendron capense
Markhamia hildebrantii

Above 2200 meters, on the eastern slopes:
Dracaena afromontana
Ekebergia capensis
Cassiapourea malosana
Cussonia holstii
Schefflera volkensii
Teclea nobilis
Akokanthra sp.

Above 2300 meters on the western slopes:
Olea africana
Cussonia holstii
Euphorbia candelabrum

Below 2300, on the western slopes:
Acacia mellifera

Acacia tortillis
Tarchoanthus camphoratus
Acacia drepanolbium

It is suggested that the department concentrate on these few species and get them established. As the eastern slopes receive the most rainfall and stand to benefit most from reforestation, they should be replanted first. Planting efforts should concentrate on those areas that offer the greatest potential for success, namely, well watered valley bottoms with deep soils. After these areas are established, efforts can turn to more problematic sites. The established areas will start to modify their immediate environment and will, with time, reestablish themselves. Species diversity will increase as the stands develop more niches by natural succession.

Germplasm should be obtained from local indigenous stock to ensure proper provenance. Planting stock should be containerized with a well developed root structure in order to deal with possible drought conditions. The planting site should not be pre-dug, as is the case now, for this only tends to further desiccate the site. Rather, it should be prepared just prior to planting and should incorporate small scale water harvesting to direct overland flow towards the planting site.

The success of the foregoing efforts is dependent on proper site protection from fire and destruction of seedlings by domestic stock. Such protection is fundamental to the entire reforestation program and should receive serious attention. A fire control plan for the area should be drawn up and regular fire control training of the planting crews and should be undertaken.

6.3.5.3. *Tourism and Recreation*

The benefits to both the local and national economies of tourism could be substantial. Currently the potential is not realized. The following efforts should be made in order to increase the attractiveness of the area to both local users and tourists alike.

1.) The road to the antennae on the ridge should be repaired and receive regular maintenance. Diversion ditches and grassed waterways are required as current erosion on the road is serious.

2.) The old road parallel to the present one should be cross ditched and seeded where necessary.

3.) The standing old power poles should be removed.

4.) The antennae and radio station fences should be covered in vines grow. If possible, tall he buildings should be painted a very light, neutral brown.

5.) Parking should be designated at the last and second last radio stations.

6.) Interpretive signage should be erected near the trail head describing the geology of the area (surely among the most interesting in the world)

7.) All vehicular traffic should be banned from the hills with the exception of the main road to the antennae station. Traffic barriers should be established at both ends of the ridge. This will eliminate user conflicts as well as reducing the damage by 4x4's currently occurring on the tracks.

8.) The walking track along the ridge should be extended and marked to run from the Magadi Road to the Kibiko Road.

9.) A track should be developed to run from the main ridge to the Finch-Hatton Memorial taking advantage of game viewing to buffalo commonly across the valley. (see map)

10.) Ensure that no hotels are constructed in the reserve as this would significantly diminish the attraction of the hills. (a possible site for a hotel is on the ridge, south of the Magadi Road about 3/4 Km.)

6.4. IMPLEMENTATION

The responsibility for implementing the majority of the suggestions in this plan rests with the local people. While some seedlings and technical advice may come from the Departments of Forestry and Agriculture, there is certainly no possibility of those departments doing any of the actual planting on private lands. The local farmers have clearly shown a willingness and ability to plant trees, as the private lands now have far more trees and hedgerows than were shown on the 1978 photography. Indeed, some of the areas are barely recognizable. Additionally, many farmers in the area have a highly developed knowledge of agroforestry techniques. The willingness and ability to plant is a great resource but requires direction if land use in the area is to be optimized. The development of a series of model farms and demonstration plots will help in this direction.

6.4.1. Model Farms and Demonstration Projects

Although, the Department of Agriculture does have some "model farms" in the area, many of the finest farms we visited were not among them. Several exemplary farms within each drainage basin, should be identified and provided with seedlings free of charge complete with detailed technical advice. Once the proposed systems are established on the model farms the individual farmer can act as a local extension officer. Department officials (of which there are plenty in the area) can identify problem farms within the drainage basins and direct them to the model farms for instruction. The model farmer must be paid a stipend for his efforts in order to allow him to hire extra labour. It is felt that by transferring the extension work to a local farmer who has actually applied the advice on his own farm, the credibility and success of the program will be enhanced. It must be stressed that the model farms, if they are to succeed, must not be anomalies in the area. They must represent a situation, in terms of economic and other resources, that many farmers in the area have, or would have, a reasonable chance of achieving.

Other demonstration plots should be established at schools, but should adopt a different strategy than has previously been employed. Most of the projects at schools in the area have met with very little success due in most part to management problems. A local farmer should be employed to manage the small demonstration plots. If they do not succeed for reasons of management, he is simply replaced. The plots can be used for instruction at the schools as well as for the general population. Other possible agroforestry demonstrations could be at shops such as those on the upper circular road, churches etc. In all cases it is suggested that one individual be ***hired*** and ***held*** *responsible* for it's success.

The proposed forest fuel and fodder strip can also be used for demonstration purposes but arable cropping will not be allowed in that area and therefore it's usefulness as an example will be limited to live fencing, fuelwood production and fodder orchards.

6.4.2 Nurseries and Seedling Production

As production of viable seedlings of the desired species is fundamental to the success of the program, the following suggestions should be implemented.

1.) The existing government nursery at Ngong should be expanded and it's production doubled. A doubling in production should not be a great problem as most of the necessary resources are already on site. This should not merely be a doubling of production of the species currently employed, but should be of those recommended earlier for planting. There are frequent complaints that farmers cannot get the species they desire and this problem must be addressed.

2.) Seedlings should be grown on a contract basis for the government by local producers and/or organizations. Specifications for planting stock should be set and bids taken for their production. The stock is then provided to farmers at cost or used in government reforestation efforts on the hill. In this way local nursery expertise is nurtured and taken advantage of. It is expected that this method will be more cost effective than government nurseries. Transportation problems and costs should be reduced.

3.) Germplasm must be found for the seedling production. This is commonly seen as a bottleneck in agroforestry production and serious efforts must be made to overcome the problem. Seed sources should be identified and purchased well in advance of the production (while maintaining proper seed storage to ensure viability). Indigenous germplasm should be collected by qualified technical forestry staff only.

4.) Selected individuals and / or organizations should be selected for nursery training through the Nursery Training Centres (Japanese Project), or the Fuelwood Afforestation and Extension Project.

6.4.3. Planting

Local people must plant their own trees. As mentioned earlier the farmers must pay for the cost of the seedlings used on their own farms and ranches. This is to ensure that care is taken with the investment. Additionally, it is suggested that rebates (of the cost of the seedlings) be paid to farmers/ranchers if they successfully establish the trees. After all, the benefits of additional tree planting accrue to those residing off farm as well and this fact should be recognized.

In the public areas outside of the forest reserve eg. roadways, local residents would be paid a small fee to establish roadside trees and shrubs provided to them at no cost. Prunings from these trees would be available to those who established them. Selective fellings would occur in time and the resulting wood would be sold by the sub-location to help finance the scheme. The trees would then be replanted on the same basis.

Planting in the forest reserve should be carried out by both government employees and contract planters and the results compared. The latter are used more and more frequently in other countries with good success. The contract is let based upon a 100% survival rate of seedlings. Planting checks are conducted by forestry staff and deductions made for poor planting. Not only may private planting contracts prove to be more cost effective than government planting, but larger areas may be planted (assuming available seedlings).

6.4.4. Major Projects

The major projects mentioned, namely, the forest boundary strip and the Kijiji reservoir and accompanying irrigated specialty crops have special organizational and funding requirements. The following sections briefly examine these issues but is by no means comprehensive and requires further study.

6.4.4.1. *The Forest Boundary Strip*

Perhaps the largest problem to overcome on this project is that of access to the land; who should have it and who should coordinate the efforts. As group organizations in the area appear to be weak, it is suggested that farmers be organized by Department of Agriculture staff on a drainage basin basis. The forest strip assigned to them will be from height of land to height of land and will include bottom lands and side slopes. As the size of the strip will be limited, it is important that the number of people with access to the area does not exceed it's ability to produce a reasonable amount for each farmer. As this area is seen as a supplementary area to their own farms, it does not have to provide all their fuel and fodder requirements. Access must definitely be limited to those living in the hills themselves. It is not necessary that the participants be land owners. In the case of the Kijiji residents, none are land owners. The specific requirements of the group will have to be reassessed as they will vary from drainage to drainage. Kijiji residents for example have greater need for fuelwood and less need for fodder than many other residents in the hills.

In this project, the lead agency must be the Forest Department.

6.4.4.3. *The Kijiji Reservoir and Irrigated Specialty Crops*

This project again is problematic organizationally. As the entire project is within Ngong Township, it is suggested that the Town council coordinate all activities. After a detailed project design is completed it could be submitted to a number of organizations for funding. The project could employ many people and these should be hired from within the township only.

Management of this public project could become burdensome to the town and it is suggested that the overall manger be on private contract and accountable for project success and continued viability after initial installation.

6.4.4.4. *Extensive Silvopastoral Systems of the Rift Valley*

Given the harsh climatic conditions of the Rift Valley seedlings should be produced on the eastern slopes and shipped for planting. Organization must be by individual cattleman. Orders for numbers of trees/shrubs should be taken a year in advance and staggered delivery dates selected taking into account the possible planting amounts per day.

6.4.5. **Partial List of Organizations Offering Advise and/or Funding**

The following organizations are active in the field of agroforestry, community forestry or fuelwood development. Individuals, groups and organizations in the study area are urged to contact them for advice and, in some cases, possible funding for projects.

Partial List of Organizations Offering Advise and/or Funding

Major National Organizations

1) Environment Liaison Centre

2) Kenyan Agricultural Research Institute

3) The Green Belt Movement

4) Kenya Energy Non-Governmental Organizations Association

5) Kenya Renewable Energy Development Project

6) Kenya Woodfuel Development Project

7) Ministry of Agriculture - Soil Conservation Project

8) The Forest Department

9) Permanent Presidential Commission on Soil Conservation and Afforestation

10) Rural Afforestation Extension Scheme

11) Special Energy Programme - GTZ

Other Organizations

12) CARE -Kenya

13) Appropriate Technology Centre - Kenyatta University

14) Energy Initiatives for Africa

15) Action Aid - Kenya

16) Establishment Project of Nursery Training Centre for Social Forestry

17) Fuelwood Afforestation and Extension Project

18) German Agricultural Team in Kenya

19) German Forestry Team - GTZ

20) Mazingira Institute

21) Maendeleo ya Wanawake's Women and Energy Project

22) Salvation Army

23) Mennonite Central Committee

24) United Nations Environmental Program

25) OXFAM

26) Renewable Energy and Environmental Conservation Association in Developing Countries

27) International Council for Research in Agroforestry

6.5. Future Research

This project has sought to adopt an integrated approach to the investigation and planning of the Ngong Hills landscape. It has been, necessarily, multi-disciplinary in nature. Ideally, such a study would employ experts in the various fields and the landscape architect would coordinate the work. In this study, however, the author has been a one man multi-disciplinary team and the accuracy of the work in a number of areas of study has no doubt suffered. In addition the withdrawal of research clearance limited field work. However, as the prime objective of the study has been to test the planning methodolgy, these inaccuracies must be considered secondary. It is hoped that future work in the area will address these short comings. The following work is recommended for future study:

1) A detailed cruise of the vegetation of the forest reserve and correlation of the results with SPOT satellite imagery.

2) Study of the vegetative ecology of the area with particular emphasis on succession and community behavior in response to grazing and fire.

3) Preparation of a detailed management plan for the forest

4) Preparation of a fire control plan for the forest and adjacent areas.

5) A detailed soil survey in the area of Ngong Town in order to identify sites for high density development

6) A complete survey of all wildlife in the reserve and preparation of a detailed wildlife management plan for the area

7) Study of soil degradation (both erosion and fertility depletion) under various cropping and agroforestry systems)

8) Testing and evaluation of suitable cash crops (including tree crops) and their incorporation into agroforestry systems.

9) Testing of hydrologic response to various land uses

10) Testing of the planning methodolgy with more local peoples input (as was originally planned, but impossible due to government restrictions)

11) Testing of the methodolgy with more detailed land utilization types

12) Testing of the planning methodolgy at different scales (over both larger areas and smaller areas; in Kenya, at the district and locational and sub-locational scales)

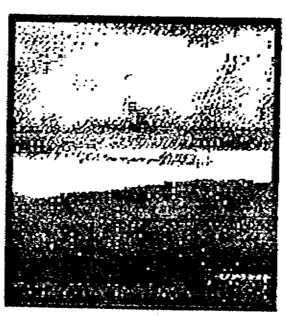
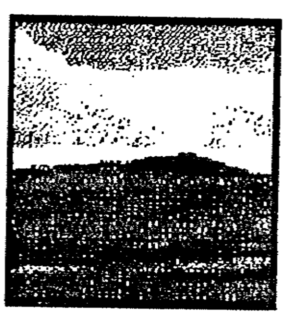
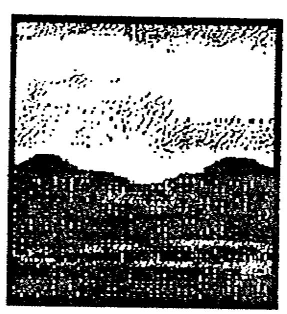
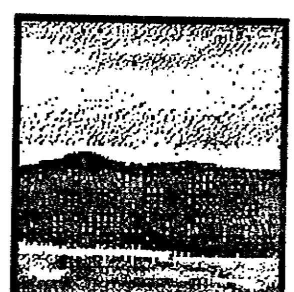
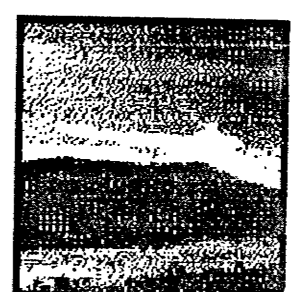
13) Testing of the planning methodolgy in combination with satellite imagery and a geographic information system (GIS)

6.6. CONCLUSION

This research project has been an attempt to examine, in a holistic manner, the issues and concerns facing the Ngong Hills, and to develop a reasoned plan of action based upon that examination. The study has looked at both the bio-physical and socio-economic environments as well as the national and historical context of the study area, in as detailed a manner as time and resources permitted. To be sure, there are short comings in the particulars of the plan that require further refinement, but the development and testing of the planning process has been completed. The process put forward is one in which land uses are matched to land in such a way as to maximize the satisfaction of the bio-physical and socio-economic requirements of the area. It is the opinion of the author that the process tested is viable and deserving of further study.

If sustainable agricultural production, together with environmental stability, is to be achieved in the face of enormous human pressures, comprehensive development proposals must be put forward that consider the harmony and balance of the overall system. Stability can only be achieved if the landscape evolves to serve the community in such a way that it integrates both the economic and the ecological processes that support it.

Bibliography



R E F E R E N C E S

Alexander, Christopher (1962) The Use of Diagrams in Highway Route Location: An Experiment, Publication No.161, Dept. of Civil Engineering, Massachusetts Institute of Technology, Cambridge.

Appleyard, D.S. (1963) The View From the Road, M.I.T. Press, Cambridge.

Auweck, F.; Schaller J.; Sittard, M.(1979) "Planning and the Agricultural Landscape" in *Gartei undLandschaft,* 7/1979

Barry, Roger C.,1981, MountainWeatherandClimate, Methuen and Co., London , New York

Battiscombe, E. (1936) Trees and Shrubs of Kenya Colony, Government Printer, Nairobi

Berger, J. (1978). "Towards an Applied Human Ecology for Landscape Architecture and Regional Planning" in *Human Ecology* 6:179-199

Blundell, Michael, (1982), The Wild Flowers of Kenya, William CollinsSons and Co. Ltd. , London

Bowen N.L.,1937, *Nepheline Contrasts,* in American Minerology , No.21.

Brown, L.H. ; Cochene, J., 1973, A Study of the Agroclimatology of the Highlands of East Africa WMO No. 125, Geneva.

Buck, L; Alitsi, E.M. (1984) Agroforestry Plots for Rural Kenya Project - Progress Report-1983, MazingiraInstitute,Nairobi.

Campbell, David J., (1984)" Response To Drought Among Farmers and Herders in Southern Kajiado District,Kenya",in *HumanEcology,* Vol.12, No 1,1984.

Chadwick, G. (1971) A Systems View of Planning, Pergamon, Oxford.

Chambers, Robert 1983 , Rural Development , Putting the Last First, Longman, London

Chavangi, Noel A.; Engelhard, R.J.; Jones, Valerie (1985) Culture As The Basis For Implementing SelfSustaining WoodfuelDevelopmentProgrammes, Kenya Woodfuel Develoment Programme, The BeijerInstitute, Nairobi.

Collie, G.L., 1912, *Plateau of British East Africa* in Bulletin of Geological Society of America No.23 pp. 297-316.

Crowe, Sylvia (1966) Forestry in the Landscape Forestry Commision Booklet no.18, H.M. StationaryOffice, London.

Darnhofer,T., 1983 , *Additional Climatic Information* in Resources for Agroforestry Diagnosis and Design, I.C.R.A.F. ,Nairobi

Dent, David; Young, Anthony (1971) Soil Survey and Land Evaluation, George, Allen, and Unwin, London.

Duffy, P.J. (1979) "The Application of Ecological Land Classification to Environmental Impact Assesment" in Applications of Ecological (Biophysical) Land Classification in Canada ELC Series #7, Environment Canada, Ottawa.

Eckbo, G (1973) *Open space and Land Use* in Land Use and Landscape Planning, first edition edited by D. Lovejoy, Barnes and Noble, New York.

Edwards, K.A., 1973, *The Water Balance of Catchments in the Highlands of Kenya,* in Agroclimatology of the Highlands of Eastern Africa, WMO No. 339, Geneva.

Elliot, Charles (1902) Charles Elliot, Landscape Architect, Houghton Mifflin, Boston.

Elsner, Gary H.; Smardon, R.C., editors (1979) Proceedings, Our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource. U.S.D.A. Forest Service, Berkeley.

F.A.O. - UNESCO, 1974; Soil Map of the World, Vol.1 Legend, UNESCO, Paris

F.A.O., Guidelines for Soil Profile Description, FAO, Rome

F.A.O. (1976) A Framework For Land Evaluation, Soils Bulletin No.32, Rome.

F.A.O. (1979) Forestry For Local Community Development, Misc./77/22, Rome

F.A.O. (1981) Agriculture: Towards 2000, F.A.O., Rome

Findlater, J., 1973, *Some Notes on the General Circulation of the Atmosphere and Seasona Weather Patterns of Eastern Africa* in Agroclimatology of the Highlands of Eastern Africa, WMO No. 339, Geneva.

Fortmann, L.; Rocheleau D.; "Women and Agroforestry: Four Myths and Three Case Studies" in *Agroforestry Systems* 2(4); 253-272.

Friend, A. (1979) "Ecological Mapping and Socio-Economic Statistics" in Applications of Ecological (Biophysical) Land Classification in Canada ELC Series #7, Environment Canada, Ottawa.

Geiger, Rudolph, 1961, The Climate Near the Ground, Vieweg and Sohn, Brunswick, Germany.

German Agricultural Team (GTZ), 1983, Farm Management Handbook of Kenya, Vol. II Published by the Kenyan Ministry of Agriculture, Nairobi.

Getahun, Amare (1984) "Stability and Instability of Mountain Ecosystems in Ethiopia" in *Mountai Research and Development* Vol.4, No.1, pp.39-44.

Gevaerts E.A.L., 1970, *Hydrogeology of the Nairobi Area, Second Edition* Government of Kenya, Ministry of Agriculture Technical Report No. 1

Gigon, Andreas (1983) "Typology and Principles of Ecological Stability and Instability" in *Mountain Research and Development* Vol.3, No.2, pp.95-102.

Gimbarzevsky, P. (1979) "Structuring of Land Systems With the Aid of the System 2000" in Applications of Ecological (Biophysical) Land Classification in Canada ELC Series #7, Environment Canada, Ottawa.

Glaser, Gisbert; Celecia, John (1981) "Guidelines for Integrated Ecological Research in the

Andean Region" in *MountainResearchandDevelopment* Vol.1 No.2, pp.171-186.

Government of Kenya (1984) Kajiado District Development Plan 1984/1988, Ministry of Finance, Rural Planning Division, Nairobi.

Gregory J.W. , 1920, *TheAfricanRift Valleys*, in Geographic Journal, vol.56.

Hackett, Brian (1971) Landscape Planning An Introduction to Theory and Practice, Oriel Press, Newcastle upon Tyne.

Hagerstraand,T. (1970) "What About People in Regional Science" in Papers and Proceedings of the Regional Science Association No.24 p. 7-21

Hall, Peter (1979) *Planning: A geographer's View*, in Resources and Planning, edited by B. Goodall and A. Kirby, Pergamon, Oxford.

Heston Jr., Randolph (1975), DesignRespondsibility, Halstead Press, Stroudsbusy, Pa.

Hills, G. Angus (1974) "A Philisophical Approach to Landscape Planning", in *Landscap. Planning* 1:(1974) 339-371.

Hills, G. Angus; Love, D.V.; Lacate, D.S.;(1970) Developing A Better Environment, Econ. Council of Ontario, Toronto.

Hills, G. Angus; (1961) The Ecological Basis for Land Use Planning, Res. Report 46, Ontario Dept. of Lands and Forests, Toronto, Ontario

Hizuchi, Tadahiko (1983) The Visual and Spatial Structure of Landscapes, M.I.T. Press , Cambridge.

Hoek, Annet van den; Rocheleau, Dianne (1984) The Application of Ecosystems and Landscape Analysis in Agroforestry Diagnosis and Design: A Case Study From Kathama Sub-Location, Machakos District, Kenya, I.C.R.A.F., Nairobi.

Hough, John (1984) "An Approach to an Integrated Land Use System on Michiru Mountain, Malawi" in *Parks*, Vol.9 , No.3/4.pp1-3.

Hurni, Hans (1983) "Soil Erosion and Soil Formation in Agricultural Ecosystems: Ethiopia and Northern Thailand" in *MountainResearchandDevelopment* Vol.3, No.2, pp.131-142.

Huxley, P.A.(editor), (1983) Plant Research and Agroforestry, I.C.R.A.F., Nairobi.

Huxley, P.A.; Wood P.J. (1984) Technology and Research Considerations in ICRAF's "Diagnosis and Design" Procedures , I.C.R.A.F., Nairobi.

Hyden, Goran (1983) No Shortcuts to Progress, University of California Press, Berkeley

I.C.R.A.F. (1983) Guidelines for Agroforestry Diagnosos and Design, Working Paper 6, I.C.R.A.F., Nairobi.

I.C.R.A.F. (1983) Resources for Agroforestry Diagnosis and Design - a Handbook of Useful Tools and Materials ,Working Paper 7, I.C.R.A.F., Nairobi

I.F.L.A. (1982), IFLA Yearbook 1982/83, International Federation of Landscape Architects, Versailles

Ives, Jack; Messerli, Bruno (1984) "Stability and Instability of Mountain Ecosystems: Lessons Learned and Recomendations for the Future" in *Mountain Research and Development* Vol.4, No.1,pp.63-71.

Jackson, J.B. (1984) Discoveringthe VernacularLandscape., Yale University Press, New Haven and London.

Joubert P., *Building Materials of Nairobi*, unpublished report.

Kenya Horticultural Society (1950) Gardening in East Africa. A Practical Handbook, 3rd Edition; Longmans, Green and Company, London

Kenyan Meteorological Department, 1980, Collected Climatological Statistics for Kenyan Stations. unpublished.

Kenya Rangeland Ecological Monitoring Unit (Ochanda, Epp, Doute), 1981, Monitoring Forest Cover Changes of Selected Natural Forests in Kenya Using Remote Sensing Techniques, KREMU Technical Report #46.

Krenkel, E., 1925, GeologieAfrikas.

Krinner, Claudia (1985) "The Wasted Chance" in *Garten und Landschaft*, March, 1985.

Leigh, R. (1978) "The Role of the Microbehavioral Approach to Regional Analysis" in Theory and Method in Urban and Regional Analysis, ed. by P.W. J. Bately, Pion Ltd., London

Leo, Christopher, (1984), Land and Class in Kenya, University of Toronto Press, Toronto

Lewis, P. (1963) Recreation in Wisconsin, Dept. of Resource Development, State of Wisconsin, Madison.

Litton, R. Burton Jr. (1971) Landscape Control Points: A procedure for Predicting and Monitoring Visual Impacts. U.S.D.A. Forest Service Research Paper PSW-91 Pacific Southwest Forest Research Station, Berkeley.

Litton, R. Burton Jr. (1968) Forest Landscape Description and Inventories: A basis for Land Planning and Design. U.S.D.A. Forest Service Research Paper PSW-49. Pacific Southwest Forest Research Station, Berkeley.

Low, Setha M. (1981) "Social Science Methods in Landscape Architecture Design" in *Landscape Planning* 8(1981) 137-148

Luff, D.O.; Ojamaa, P.M. (1979) "The Value of Ecological (Biophysical) Land Classification in Land Use Planning" in Applications of Ecological (Biophysical) Land Classification in Canada ELC Series #7, Environment Canada, Ottawa.

Lynch, Kevin (1980) Managing the Sense of a Region, M.I.T. Press, Cambridge.

Marsh, William M. (1983) Landscape Planning -Environmental Applications Addison-Wesley Publishing, Reading, Mass.

Matheson F.J., 1966, *Geology of the Kajiado Area, Kenya Geological Survey Report No. 70*

McDonald, G.T.; Brown, A.L. (1984) "The Land Suitability Approach To Strategic Land-Use Planning in Urban Fringe Areas" in *Landscape Planning* Vol. 11, No. 2, July.

McHarg, I. (1969) Design With Nature, Doubleday/Natural History Press, New York.

McLoughlin, J.B. (1969) Urban and Regional Planning: A Systems Approach, Faber, London.

Messerli, Bruno (1983) "Stability and Instability of Mountain Ecosystems: Introduction to the Workshop" in *MountainResearchandDevelopment* Vol.3, No.2, pp.81-94

Messerli, Paul (1983) "The Concept of Stability and Instability of Mountain Ecosystems Derived from the Swiss MAB-6 Studies of the Aletsch Area" in *Mountain Research and Developmen* Vol.3, No.3, pp. 281-190.

Messerschmidt, D.A. (1985) "Commentary on "Agricultural Land Evaluation For National Land-use Planning in Nepal" "in *MountainResearch andDevelopment,*Vol.5, No.2 ,pp 147-150

Mitchell, Colin (1973) Terrain Evaluation, Longman Group, London.

Moithe, H.T., 1973, *Summary of Discussions on Rainfall*, in Agroclimatology of the Highlands of Eastern Africa, WMO No. 339, Geneva.

Moore, Gary T.; Golledge, Reginald G. (1976) Environmental Knowing, Dowden, Hutchison and Ross, Stroudsburg, Pennsylvania.

Muller, Maria S.; " Traditional Cultural Identity in New Dwellings of Urban Africa" in *Ekistic* 307, July/August 1984.

Nieuwolt, S., 1973, *The Influence of Aspect and Elevation on Daily Rainfalls: Some Examples from Tanzania in* Agroclimatology of the Highlands of Eastern Africa, WMO No. 339, Geneva.

Newton, N.T. (1971) Design on the Land, the Development of Landscape Architecture, Harvard University Press, Cambridge.

Ngugi, D.N.; Karau, P.K.; Nguyo, W.; EastAfricanAgriculture, MacmillanPublishers, Nairobi

Nyamweru, Celia, 1983, Rifts and Volcanoes, A Study of the East African Rift System, Thomas Nelson (Nigeria) Ltd.

Ondingo, R.S., 1971, The Kenyan Highlands, Land Use and Agricultural Development, East African Publishing House, Nairobi.

Oliver, Paul (Ed), 1971, Shelter in Africa, Barrie and Jenkins, London

Periera, H.C., 1973, Land Use and Water Resources in Temperate and Tropical Climates, Cambridge University Press, London

Pettman, Ralph (1981) Biopolitics and International Values- Investigating Liberal Norms, Pergamon, Oxford.

Pulfrey, William, 1948, *Stone Deposits of Ngong*, unpublished report

Quin, A.L. (1979) " The Use of Ecological Information in Settlement Planning" in Applications of Ecological (Biophysical) Land Classification in Canada ELC Series #7, Environment Canada, Ottawa.

Rocheleau, Dianne (1984) "Development of A Methodology For Agroforestry Diagnosis and Design (D&D) at Varying Scales (In-House Discussion Paper), Mimeo, I.C.R.A.F., Nairobi.

Rocheleau, Dianne (1984) "Criteria for Re-Appraisal and Re-design: Intra-Household and Between-Household Aspects of FSRE in Three Kenyan Agroforestry Projects " in Proceedings of the Annual Farming Systems Research and Extension Symposium, Kansas State University, Oct.7-10, 1984 Manhattan, Kansas.

Rowe, J.S. (1979) "Revised Working Paper on Methodology/Philosophy of Ecological Land Classification in Canada" in Applications of Ecological (Biophysical) Land Classification in Canada ELC Series #7, Environment Canada, Ottawa.

Saggerson E.P., 1971, *Geology of the Nairobi Area, Kenya Geological Survey Report No. 98*, Unpublished notes

Sikes H.L., 1926, *The Structure of the Eastern Flank of the Rift Valley Near Nairobi*, Geological Journal LXVIII, pp. 385-402.

Steinert, Wolf (1985) " Landscape Planning and Agriculture I - The Landscape Architect's Problems " in *Garten und Landschaft*, March, 1985.

Steinitz, Carl; Parker, P.; Jordan, L. (1976) *Hand Drawn Overlays: Their History and Prospective Uses* in "Landscape Architecture", Vol. 66, No.5

Suess, E., 1892, Die Bruke des Ost-Afrika.

Teel, W., (1985), A Pocket Directory of Trees and Seeds in Kenya, KENGO, Nairobi

United States Department of Agriculture, Forest Service (1973) National Forest Landscape Management, Vol. 1, USDA Handbook no. 434. U.S. Government Printing Office, Washington.

United States Department of Agriculture, Forest Service (1974) National Forest Landscape Management, Vol. 2, Chapter 1, The Visual Management System USDA Handbook no. 462. U.S. Government Printing Office, Washington.

__________ (1975) Number 462. Vol. 2, Chapter 2: Utilities.

__________ (1976) Number 478 Vol. 2 Chapter 3: Range

__________ (1976) Number 484 Vol. 2 Chapter 5: Timber

U.S. Bureau of Land Management (1975) Bureau of Land Management Manual Section 6300: Visual Resource Management, B.L.M., Washington.

Vroom, Meto J. (1973) *Volthe De Lutte: A Systematic Approach to Land Planning in Scenic Rural Areas - The Netherlands*, in Land Use and Landscape Planning, 1st edition, edited by D. Lovejoy, Barnes and Noble, New York.

Walker, E.E., 1903, *Report on the Geology of the East Africa Protectorate* in Africa. No. 11 (cd. 1769).

Weddle, A.E. (1978) *Applied Analysis and Evaluation Techniques* in Land Use and Landscape Planning 2nd edition, edited by D. Lovejoy, Barnes and Noble, New York.

Werkmeister, Hans Friedrich, (1984) " Planning by One Consultant" in *Garten und Landschaft*, March, 1984.

Werkmeister, H. F. (1973) *The Oelbach Valley Landscape Plan* - in Land Use and Landscape Planning first edition, edited by D. Lovejoy, Barnes and Noble, New York.

Whittle, J. (1950) "The Preparation of Planning Maps", in Town and Country Planning Textbook ed. by APRR, the Architectural Press, London.

Wiken, E.B. (1979) "Ecologically Based Planning: A Report on the CCELC Urban Workshop" in Applications of Ecological (Biophysical) Land Classification in Canada ELC Series #7, Environment Canada, Ottawa.

Willis, Bailey, 1936, Studies in Comparative Seismology: East African Plateaus and Rift Valleys,

Wilson, A. (1972) Papers in Urban and Regional Analysis, Pion, London.

Winiger, Matthias (1983) "Stability and Instability of Mountain Ecosystems: Definitions for Evaluation of Human Systems" in *Mountain Research and Development* Vol.3, No.2, pp.103-111.

Young, Anthony (1985) An Environmental Data Base For Agroforestry, Working Paper 5, I.C.R.A.F., Nairobi.

Young, Anthony (1984) Site Selection For Multipurpose Trees, I.C.R.A.F., Nairobi.

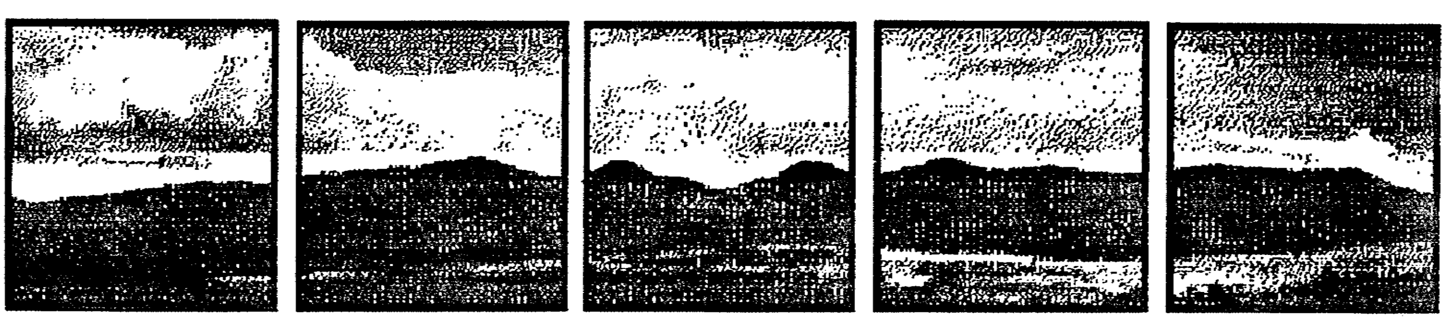
Young, Anthony (1984) Evaluation of Agroforestry Potential in Sloping Areas, Paper presented to the International Workshop on Land Evaluation for Land Use Planning and Conservation in Sloping Areas, ITC, the Netherlands, I.C.R.A.F., Nairobi.

Young, Anthony (1984) Land Evaluation For Agroforestry: The Tasks Ahead, I.C.R.A.F., Nairobi.

Vonk, Remko (1984) Report on the Siaya Agroforestry Project. ,Care- Kenya Nairobi.

Zube, Ervin H.; Brush, R.; Fabos, J. eds. (1975) Landscape Assessment: Values, Perception, and Resources. Dowden, Hutchison, and Ross, Stroudsburg, PA.

Appendices



Appendix 1. Laboratory Results of Representative Soil Samples

PROFILE # 1

General Information:

Mapping Unit:	VB2
Soil Classification:	pellic VERTISOL
Agro-ClimatolgicalZone:	IV-5
Elevation:	1860 m
ObservationDate:	1986/09/02
Location(UTM):	372509
GeologicalFormation:	Ngong Volcanics
Local Petrography:	Undifferentiatedbasanites,tephrites,atlantites,ankaratrites
Physiography:	DepositionalPlain
Slope Gradient:	0 - 2%
Land Use:	Grazing, arable agriculture, recreation (school yard)
Vegetation:	Grassland: *Themeda*, *Cynodon* Some scattered *Acacia* sp.
Overwash:	None
Surface runoff:	Moderate
Surfacesealing/cracks:	Slight sealing (4mm), cracking (45 mm wide x 500mm deep)
Drainage Class:	Poorly drained
Human Influence :	Heavy
Erosion:	Severe in drainage channels, otherwise slight
Effective Soil Depth:	150 cm. +

ProfileDescription:

A1	0 - 25cm.	Very dark grey (10YR 3/1) when dry and black (10YR 2/1) when moist. Clay; Strong and coarse, angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; frequent and evenly distributed fine roots. Many cracks (5 cm) throughout horizon. Smooth and gradual transition to:
AC	25 - 95cm.	Black (10YR 2/1) when moist; Clay; Moderate and coarse, angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; Cracking evident to 45 cm.; common fine to medium roots. Abundant slickensides; Smooth and gradual transitionto:
C	95 - 150cm.	Very dark grey (10YR 3/1) when moist. Clay; Strong and coarse, angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; Few carbon nodules (1 -2 mm) evenly distributed. Few fine and medium roots.

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 1 pellicVERTISOL

Mapping Unit	VB2			
Laboratory No.	1.1	1.2	1.3	
Horizon	A1	AC	C	
Depth (cm)	0 - 25	25 - 95	95 - 150	
pH- KCl_2	3.83	5.06	5.16	
pH- H_2O	5.66	7.06	7.26	
% C	1.26	0.80	0.10	
% N	0.045	0.066	0.029	
P (ppm)	3.0	3.1	19.0	
Texture	Clay	Clay	Clay	
% Sand	27.12	24.20	25.74	
% Clay	55.82	54.14	56.05	
% Silt	17.06	21.66	18.21	
CEC (me/100g)	52.0	50.0	49.9	

PROFILE # 2

General Information:

Mapping Unit:	FR2
Soil Classification:	orthic LUVISOL
Agro-Climatolgical Zone:	IV-5
Elevation:	1940 m
Observation Date:	1986/09/02
Location (UTM):	367501
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	Footridge
Slope Gradient:	5 -10%
Land Use:	Grazing, arable agriculture
Vegetation:	Grassland adjacent to continuous cropland
Overwash:	None
Surface runoff:	Moderate
Surface sealing/cracks:	none observed
Drainage Class:	Moderately well drained
Human Influence :	Heavy: cultivation, terracing, overgrazing
Erosion:	Moderate to heavy where unterraced, otherwise slight
Effective Soil Depth:	55 cm.

Profile Description:

A	0 - 20	Very dark greyish brown (10YR 3/2) when moist; Clay; strong, medium, sub-angular blocky structure; very hard when dry, very firm when moist, sticky and plastic when wet; few to common very fine pores. Common fine and medium roots; Surface very stony (class 3); Smooth and gradual transition to:
B	20 - 55	Very dark grey (10YR 3/1) when moist; Clay; strong, medium, sub-angular blocky structure; very hard when dry, very firm when moist, sticky and plastic when wet; few fine pores. Abrupt transition to:
C (R)	55+	Mottled greyish brown (10YR 5/2) and yellowish brown (10YR 5/8) decomposing saprolite. Easily broken with spade but with no root penetration. Sample 2.3 is of crushed saprolite.

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 2 Orthic LUVISOL

Mapping Unit	FR2			
Laboratory No.	2.1	2.2	2.3	
Horizon	A	B	C (R)	
Depth (cm)	0- 20	20 - 55	55 +	
pH- KCl_2	6.74	5.97	5.94	
pH- H_2O	7.82	7.42	7.50	
% C	1.99	2.64	.60	
% N	0.29	0.28	0.18	
P (ppm)	32.5	16.6	35.1	
Texture	Clay	Clay	Sandy clay loam	
% Sand	27.78	28.32	54.96	
% Clay	42.46	44.36	30.38	
% Silt	30.06	27.33	14.66	
CEC (me/100g)	45.7	49.3	37.0	

PROFILE # 3

General Information:

Mapping Unit:	RS1, RS2, RS3
Soil Classification:	LITHOSOL
Agro-Climatolgical Zone:	IV-6
Elevation:	2000 m
Observation Date:	1986/09/02
Location (UTM):	361481
Geological Formation:	Ngong Volcanics
Local Petrography:	tephrites
Physiography:	Scarp
Slope Gradient:	40%
Land Use:	Grazing, Wildlife
Vegetation:	*Themeda* Grassland, scattered *Acacia* and *Euphorbia*
Overwash:	None
Surface runoff:	excessive
Surface sealing/cracks:	none observed
Drainage Class:	Excessively drained
Human Influence :	Moderate: heavy grazing pressure, burning, wood cutting.
Erosion:	Moderate to heavy on cattle/game tracks; potential: severe.
Effective Soil Depth:	10 -20 cm.

Profile Description:

A	0 - 10 cm.	Dark brown (7.5 YR 3/2) moist; Clay loam; moderate, medium, granular structure; Slightly hard when dry, Friable when moist, slightly sticky and slightly plastic when wet; Abundant very fine and fine pores; Common fine to medium roots. Abrupt transition to:
R	20 + cm.	Grey (10YR 5/1) mottled with strong brown (7.5 YR 5/8) and dark reddish brown (5YR 3/2) stone. Can be broken easily with spade and is infrequently penetrated by medium and fine roots.

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 3 LITHOSOL

Mapping Unit	RS1,2,3			
Laboratory No.	3.1	3.2		
Horizon	A	R		
Depth (cm)	0 - 20	20+		
pH- KCl_2	5.57	5.22		
pH- H_2O	6.94	7.11		
% C	1.92	0.32		
% N	.07	.03		
P (ppm)	102.0	110.0		
Texture	Clay Loam	Rock		
% Sand	39.61	NA		
% Clay	31.60	NA		
% Silt	28.79	NA		
CEC (me/100g)	30.6	33.4		

PROFILE # 4

General Information:

Mapping Unit:	FS1
Soil Classification:	dystric NITOSOL
Agro-Climatolgical Zone:	III-5
Elevation:	2080 m
Observation Date:	1986/09/05
Location (UTM):	372492
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	Footridge
Slope Gradient:	15%
Land Use:	Grazing, Arable cropland
Vegetation:	*Euphorbia, Cypress,* maize, beans, citrus, other arable crops
Overwash:	None
Surface runoff:	moderate at site, accellerated on adjacent steep slopes
Surface sealing/cracks:	none observed
Drainage Class:	Well drained
Human Influence :	Heavy: forest clearing, cultivation, terracing
Erosion:	Light on terraced lands, severe on unterraced steep lands;
Effective Soil Depth:	150 + cm.

Profile Description:

A	0 - 30 cm.	Dark reddish brown (5YR 3/4) when dry, Dark reddish brown (5YR 3/2) when moist; Clay; moderate, medium, subangular blocky structure; slightly hard when dry, friable when moist, slighly sticky and plastic when wet; many fine and medium pores; abundant fine and common medium roots; Gradual and smooth transition to:
A2	30 - 60 cm.	Dark reddish brown (5YR 3/3) when dry, Dark reddish brown (5YR 2.5/2) when moist; Clay loam; moderate, medium, subangular blocky structure; slightly hard when dry, friable when moist, slighly sticky and plastic when wet; common very fine, fine and medium roots; Diffuse and smooth transition to:
B	60 - 150 cm.	Yellowish red (5YR 4/6) when dry, Dark reddish brown (5YR 3/4) when moist; Clay; moderate, medium, subangular blocky structure; slightly hard when dry, friable when moist, slighly sticky and plastic when wet; few very fine roots.

Soil Chemical Analysis Results — **Soil Classification**

PROFILE # 4 — dystric NITOSOL

Mapping Unit	FS1			
Laboratory No.	4.1	4.2	4.3	
Horizon	A1	A2	B	
Depth (cm)	0 - 30	30 - 60	60 - 150	
pH- KCl_2	5.25	5.82	5.37	
pH- H_2O	6.56	7.22	6.92	
% C	1.48	2.05	0.64	
% N	0.14	0.31	0.08	
P (ppm)	0.98	8.0	1.30	
Texture	Clay	Clay Loam	Clay	
% Sand	23.80	24.00	14.14	
% Clay	56.36	37.32	75.08	
% Silt	19.84	38.62	10.78	
CEC (me/100g)	28.3	35.0	28.5	

PROFILE # 5

General Information:

Mapping Unit:	RS1
Soil Classification:	(humic) orthic LUVISOL
Agro-Climatolgical Zone:	III-6
Elevation:	2300 m
Observation Date:	1986 / 09 / 03
Location (UTM):	370469
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	Convex Ridgetop
Slope Gradient:	0-5%
Land Use:	Grazing, Wildlife
Vegetation:	*Themeda* grassland
Overwash:	None
Surface runoff:	moderate
Surface sealing/cracks:	none observed
Drainage Class:	Well drained
Human Influence :	Heavy: some forest clearing, road building, burrow pit
Erosion:	Light
Effective Soil Depth:	50 cm.

Profile Description:

A	0 - 15cm.	Dark brown (7.5YR 3/4) dry, dark brown (7.5YR 3/2) moist; Sandy loam; Slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; Strong, medium to coarse, granular structure; abundant very fine to fine pores; abundant fine and medium roots; Clear transition to:
B	15 - 50cm.	Dark reddish brown (5YR 3/4) dry, Dark reddish brown (5YR 3/3) moist; Sandy clay loam; moderate, medium, subangular blocky structure; slightly hard when dry, slightly firm when moist, slightly sticky and slightly plastic when wet; common very fine and micro pores; abundant fine and medium roots; abrupt transition to:
R	50 +	Grey (10YR 5/1) and yellowish brown (10YR 5/6) mottled rock (saprolite).

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 5 orthic LUVISOL

Mapping Unit	RS1			
Laboratory No.	5.1	Not analysed	5.2	Not analysed
Horizon	A	B1	B2	R
Depth (cm)	0 - 15	15 - 30	30 - 50	50+
pH- KCl_2	4.04		3.84	
pH- H_2O	5.92		5.27	
% C	3.36		3.46	
% N	0.50		0.32	
P (ppm)	0.8		0.2	
Texture	Sandy Loam		Sandy Clay Loam	
% Sand	61.80		61.73	
% Clay	14.98		24.25	
% Silt	23.22		14.02	
CEC (me/100g)	29.6		28.8	

PROFILE # 7

General Information:

Mapping Unit:	FR2
Soil Classification:	orthic LUVISOL
Agro-Climatolgical Zone:	III-5
Elevation:	1940 m
Observation Date:	1986/09/03
Location (UTM):	405410
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	Convex Ridgetop
Slope Gradient:	0-10%
Land Use:	Mixed farming
Vegetation:	*Eucalptus, Croton megalocarpus,* maize, beans etc.
Overwash:	None
Surface runoff:	moderate
Surface sealing/cracks:	none observed
Drainage Class:	Moderately well drained
Human Influence :	Heavy: cultivation, terracing, dwellings
Erosion:	Light
Effective Soil Depth:	85 cm.

Profile Description:

A1	0 - 10 cm.	Dark yellowish brown (10YR 3/4) dry and very dark grey (10YR 3/1) moist; Clay; Moderate, medium, subangular blocky structure; very hard when dry, very firm when moist, slightly sticky and slightly plastic when wet; common fine pores and common very fine - medium, few coarse cracks (2cm.); gradual smooth transition to:
A2	10 - 30 cm.	Very dark grey (10YR 3/1) dry and very dark greyish brown (10YR 3/2) moist: Clay loam; Moderate, medium, subangular blocky (slightly prismatic) structure; very hard when dry, very firm when moist, slightly sticky and slightly plastic when wet; few fine pores, few coarse cracks (2cm.); common very fine-medium roots, few coarse roots; gradual and smooth transition to:
B	30 - 45 cm.	Dark reddish brown (5YR 3/4) mottled with black (5YR2.5/1) and very dark greyish brown (10YR 3/2) (all when dry); Clay; Moderate, medium, subangular blocky structure; very hard when dry, very firm when moist, slightly sticky and slightly plastic when wet; few fine pores; very few fine roots; few manganese shot like (2mm) concretions. Clear transition to:
C	45 - 85 cm.	Light brownish grey (2.5YR 6/2) mottled with light yellowish brown (10YR 6/2) and dark yellowish brown (10YR 4/4) when dry and dark grey (10YR 4/1) and brown (10YR 5/3) when moist: Moderate, medium, subangular

blocky structure also common gravel 15-25mm throughout horizon; very hard when dry, very firm when moist, slightly sticky and slightly plastic when wet; very few fine roots; common very fine pores; Abrupt transition to:

R 85 + cm. Massive rock layer. No root penetration.

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 7 **orthic LUVISOL**

Mapping Unit	**FR2**			
Laboratory No.	**7.1**	**7.2**	**7.3**	**7.4**
Horizon	**A1**	**A2**	**B**	**C**
Depth (cm)	**0 - 10**	**10 - 30**	**30 - 45**	**45 - 85**
pH- KCl_2	**4.90**	**4.84**	**5.18**	**5.38**
pH- H_2O	**6.84**	**6.60**	**7.02**	**7.05**
% C	**2.33**	**1.22**	**0.28**	**2.05**
% N	**0.23**	**0.17**	**0.09**	**0.07**
P (ppm)	**5.0**	**0.7**	**0.2**	**0.3**
Texture	**Clay**	**Clay loam**	**Clay**	**Clay**
% Sand	**39.50**	**39.58**	**40.66**	**41.01**
% Clay	**40.15**	**37.72**	**41.82**	**40.83**
% Silt	**20.35**	**22.70**	**17.52**	**18.16**
CEC (me/100g)	**27.5**	**23.3**	**29.7**	**26.4**

PROFILE # 9

General Information:

Mapping Unit:	FS1, FS3, FR1
Soil Classification:	dystric NITOSOL
Agro-Climatolgical Zone:	III-5
Elevation:	2000 m
Observation Date:	1986/09/04
Location (UTM):	384483
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	footridge side slope
Slope Gradient:	35%
Land Use:	Mixed farming
Vegetation:	*Eucalptus, Cypress, Croton* maize, beans etc.
Overwash:	None
Surface runoff:	Excessive
Surface sealing/cracks:	None observed
Drainage Class:	Well drained
Human Influence :	Heavy: cultivation, terracing, dwellings
Erosion:	Moderate to severe
Effective Soil Depth:	150 + cm.

Profile Description:

A	0 - 25 cm.	Dark reddish brown (5YR 3/4) dry and Dark reddish brown (5YR 3/3) moist; Clay; moderate, medium, sub angular blocky structure; hard when dry, friable when moist, sticky and slightly plastic when wet; common fine and medium pores; abundant fine to very fine roots; smooth and gradual transition to:
B1	25 - 60 cm.	Dark reddish brown (5YR 3/3) dry and moist; Clay; moderate, medium, sub angular blocky structure; hard when dry, friable when moist, sticky and slightly plastic when wet; common medium pores; common fine to very fine roots; smooth and gradual transition to:
B2	60 - 90 cm.	Dark reddish brown (5YR 3/4) dry and Dark reddish brown (5YR 3/3) moist; Clay; moderate, fine, sub angular blocky structure; hard when dry, friable when moist, sticky and slightly plastic when wet; common very fine pores; few fine to very fine and medium roots; diffuse transition to:
B3	90 - 150 cm.	Yellowish red (5YR 4/6) dry and reddish brown (5YR 4/4) moist; Clay; weak, very fine to fine, sub angular blocky structure; hard when dry, friable when moist, sticky and slightly plastic when wet; common micro to very fine pores; very few fine to medium roots.

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 9 **dystric NITOSOL**

Mapping Unit	FS1,3, FR1			
Laboratory No.	9.1	9.2	9.3	9.4
Horizon	A1	B1	B2	B3
Depth (cm)	0 - 25	25 - 60	60 - 90	90 -150
pH- KCl_2	3.71	4.79	4.93	5.04
pH- H_2O	5.23	6.38	6.82	6.40
% C	1.08	1.12	0.98	0.39
% N	0.14	0.24	0.18	0.10
P (ppm)	1.8	0.3	0.3	0.9
Texture	Clay	Clay	Clay	Clay
% Sand	19.18	18.54	17.48	17.40
% Clay	50.70	51.86	49.39	50.74
% Silt	31.12	29.60	34.13	31.86
CEC (me/100g)	19.2	24.5	21.1	18.7

PROFILE # 11

General Information:

Mapping Unit:	FS2
Soil Classification:	vertic LUVISOL
Agro-Climatolgical Zone:	III-5
Elevation:	1940 m
Observation Date:	1986/09/02
Location (UTM):	403421
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	Footridge
Slope Gradient:	15 - 20%
Land Use:	Pasture, arable agriculture
Vegetation:	Grassland adjacent to continuous cropland
Overwash:	None
Surface runoff:	Moderate
Surface sealing/cracks:	slight sealing 3 - 4mm. minor cracking
Drainage Class:	Moderately well drained
Human Influence :	Heavy: cultivation, terracing, overgrazing
Erosion:	Moderate to heavy where unterraced, otherwise slight
Effective Soil Depth:	110 cm.

Profile Description:

A	0 - 20 cm.	Dark reddish brown (5YR 2.5/2) both dry and moist; Clay; Strong, medium, subangular blocky structure; common fine pores; very hard when dry, very firm when moist, very sticky and very plastic when wet; common medium and fine roots; common fine pores; smooth transition to:
B	20 - 50 cm.	Dark reddish brown (5YR 3/3) when dry and Dark reddish brown (5YR 3/2) when moist; Clay; Strong, medium to coarse, subangular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; slightly shiny ped faces; Few fine pores; Smooth transition to:
C	500 - 110 cm.	Dark reddish brown (5YR 3/2) when dry and moist; Clay; Strong, medium to coarse, subangular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; Few fine pores; slightly shiny ped faces; Abrupt transition to:
R	110 + cm.	Mottled grey (5YR 5/1), yellowish red (5YR 5/6), (5YR 5/8); Rock (Saprolite).

Soil Chemical Analysis Results — **Soil Classification**

PROFILE # 11 — orthic LUVISOL

Mapping Unit	FS2			
Laboratory No.	11.1	11.2	11.3	not analysed
Horizon	A	B	C	R
Depth (cm)	0 - 20	20 - 50	50 - 110	110+
pH- KCl_2	5.14	4.94	5.27	
pH- H_2O	6.78	7.00	7.30	
% C	1.71	0.20	0.14	
% N	0.28	0.33	0.15	
P (ppm)	1.7	0.25	0.3	
Texture	Clay	Clay	Clay	
% Sand	22.10	20.76	18.38	
% Clay	59.36	60.00	59.90	
% Silt	18.54	19.24	21.72	
CEC (me/100g)	36.8	41.0	39.6	

PROFILE # 13

GeneralInformation:

Mapping Unit:	VB1
SoilClassification:	pellicVERTISOL
Agro-ClimatolgicalZone:	V-4
Elevation:	1820 m
ObservationDate:	1986/09/06
Location(UTM):	362384
GeologicalFormation:	Ngong Volcanics
LocalPetrography:	Limurutrachytes andquartztrachytes
Physiography:	Valley floor (near edge of western slopes)
Slope Gradient:	0 - 5%
Land Use:	Grazing,wildlife
Vegetation:	Grassland, scattered *Acaciasp.*
Overwash:	None
Surface runoff:	Moderate
Surfacesealing/cracks:	heavy cracking 50mm. wide, 65 cm. deep, slight sealing
DrainageClass:	Imperfectlydrained
Human Influence :	Moderate: overgrazing, wood cutting
Erosion:	slight
Effective Soil Depth:	150 + cm.

ProfileDescription:

A	0 - 15 cm.	Black (10YR 2/1) dry and moist; Clay; strong coarse sub angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; abundant coarse pores, abundant fine and medium roots; extreme swelling characteristic; stony surface (class 3); smooth and gradual transition to:
AC	15 - 150 cm.	Black (2.5Y 2/0) dry and moist; Clay; strong coarse sub angular blocky structure; extremely hard when dry, extremely firm when moist, very sticky and very plastic when wet; common slickensides; common medium pores in upper portion only; few medium roots to 60 cm.;

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 13 VERTISOL

Mapping Unit	VB1			
Laboratory No.	13.1	13.2		
Horizon	A	AC		
Depth (cm)	0 - 15	15 - 150		
pH- KCl_2	6.3	6.14		
pH- H_2O	7.74	7.44		
% C	1.72	1.27		
% N	0.16	0.12		
P (ppm)	2.0	0.2		
Texture	Clay	Clay		
% Sand	19.18	20.78		
% Clay	63.50	58.20		
% Silt	17.32	21.02		
CEC (me/100g)	49.1	51.8		

PROFILE # 14

GeneralInformation:

Mapping Unit:	FS2
SoilClassification:	luvicPHAEOZEM
Agro-ClimatolgicalZone:	IV-5
Elevation:	2020 m
ObservationDate:	1986/09/06
Location(UTM):	387390
GeologicalFormation:	Ngong Volcanics
LocalPetrography:	Undifferentiatedbasanites,tephrites,atlantites,ankaratrites
Physiography:	Footridge(midslope)
Slope Gradient:	15%
Land Use:	Grazing, wildlife, occassionalagriculture
Vegetation:	Grassland, scattered *Acaciasp.*
Overwash:	None
Surface runoff:	Moderate
Surfacesealing/cracks:	slight sealing (2mm)
DrainageClass:	Moderatelywelldrained
Human Influence :	Moderate: overgrazing, small soil quarry, wood cutting, fire
Erosion:	slight
Effective Soil Depth:	150 + cm.

ProfileDescription:

A	0 - 25 cm.	Dark reddish brown (5YR 3/2) dry and moist; Silty clay loam; hard when dry, friable when moist, sticky and plastic when wet, common medium and fine pores; abundant fine roots; few worm casts; smooth and gradual transition to:
B1	25 - 65 cm.	Dark reddish brown (5YR 3/3) dry and moist; Clay; hard when dry, friable when moist, sticky and plastic when wet, few medium and fine pores; common fine roots; smooth and gradual transition to:
B2	65 - 150 cm.	Dark reddish brown (2.5YR 3/4) dry and dark red (2.5YR3/6) moist; Clay; hard when dry, friable when moist, sticky and plastic when wet, few medium and fine pores; very few fine roots.

Soil Chemical Analysis Results — **Soil Classification**

PROFILE # 14 — orthic LUVISOL

Mapping Unit	FS2			
Laboratory No.	14.1	14.2	14.3	
Horizon	A	B1	B3	
Depth (cm)	0 - 25	25 - 65	65 +	
pH- KCl_2	5.13	4.93	3.64	
pH- H_2O	6.60	6.64	6.62	
% C	1.52	0.64	0.15	
% N	0.22	0.20	0.12	
P (ppm)	0.55	0.15	0.1	
Texture	silty clay loam	clay	clay	
% Sand	18.4	17.61	15.46	
% Clay	38.76	58.56	73.16	
% Silt	42.84	23.83	11.38	
CEC (me/100g)	30.8	24.3	32.5	

PROFILE # 15

GeneralInformation:

Mapping Unit:	RS2, RS4
SoilClassification:	eutricREGOSOL
Agro-ClimatolgicalZone:	IV-5
Elevation:	2020 m
ObservationDate:	1986/09/08
Location(UTM):	376391
GeologicalFormation:	Ngong Volcanics
LocalPetrography:	Undifferentiatedbasanites,tephrites,atlantites,ankaratrites
Physiography:	midslope of western scarp
Slope Gradient:	20%
Land Use:	Grazing,wildlife
Vegetation:	Grassland, scattered *Acaciasp. Euphorbia*
Overwash:	none
Surface runoff:	moderatetoaccellerated
Surfacesealing/cracks:	slight sealing (2mm)
DrainageClass:	welldrained
Human Influence :	moderate: overgrazing, wood cutting, fire
Erosion:	slight
Effective Soil Depth:	45 cm.

ProfileDescription:

A	0 -15 cm.	Dark grey (10YR 4/1) mottled with dark greyish brown (10YR 4/2) and very dark grey (10YR 3/1) when dry; Clay (very stony and gravelly); Very hard when dry, firm when moist, plastic and sticky when wet; Moderate, medium, sub angular blocky, structure; common fine and medium pores; common fine and medium roots; smooth and gradual transitionto:
B	15 - 45 cm.	Very dark greyish brown (10YR 3/2) mottled with yellowish brown (10YR 5/6); Clay with progressively more gravel; Moderate, medium, sub angular blocky, structure; Very hard when dry, firm when moist, plastic and sticky when wet;few fine and medium roots; common fine to medium pores; Diffuse boundaryto:
R	45 + cm.	Yellowish brown (10YR 5/8), light yellowish brown (10 YR 6/4), and black (2.5Y 2/0); Rock (including pyroclasts (5cm.) and gravel with minor inclusions of clay in coarse pores; common coarse pores; little root penetration.

Soil Chemical Analysis Results | **Soil Classification**

PROFILE # 15 | **eutricREGOSOL**

Mapping Unit	RS2, RS4			
Laboratory No.	15.1	15.2	not analysed	
Horizon	A	B	R	
Depth (cm)	0 - 15	15 - 45	45 +	
pH- KCl_2	4.94	4.97		
pH- H_2O	5.30	5.85		
% C	1.80	0.88		
% N	0.12	0.11		
P (ppm)	8.45	8.45		
Texture	Clay	Clay		
% Sand	20.36	19.04		
% Clay	51.24	59.36		
% Silt	28.4	21.60		
CEC (me/100g)	38.5	44.6		

PROFILE # 17

GeneralInformation:

Mapping Unit:	VB3
SoilClassification:	luvicPHAEOZEM
Agro-ClimatolgicalZone:	V-5
Elevation:	1740 m
ObservationDate:	1986/09/08
Location(UTM):	356397
GeologicalFormation:	Ol Esayeti and Limuru Volcanics
LocalPetrography:	Phonolites
Physiography:	valley floor at toe of faulted ridge
Slope Gradient:	10%
Land Use:	grazing, wildlife
Vegetation:	grassland, scattered *Acacia sp.*
Overwash:	none
Surface runoff:	moderate
Surfacesealing/cracks:	none observed
Drainage Class:	moderatelywelldrained
Human Influence :	moderate: overgrazing, woodcutting, fire
Erosion:	slight
Effective Soil Depth:	100 cm.

ProfileDescription:

A	0 - 20 cm.	Very dark greyish brown (10YR 3/2) dry, very dark grey (10YR3/1) moist; Clay loam; very hard when dry, very firm when moist, and sticky and plastic when wet; Moderate , medium, subangular blocky structure; common scorpions, beetles in horizon, termite mound nearby; Abundant fine pores; few fine roots; smooth and gradual transition to:
AB	20 - 30	Dark brown (10YR 3/3) dry, Very dark greyish brown (10YR 3/2) moist; Clay; very hard when dry, very firm when moist, and sticky and plastic when wet; Moderate, medium, subangular blocky structure; few fine roots; common fine pores; Smooth and gradual transition to:
B	30 - 100	Very dark greyish brown (10YR 3/2) dry and moist; Clay; very hard when dry, very firm when moist, and sticky and plastic when wet; Moderate, medium to coarse, sub angular blocky; few fine roots; common fine pores; abrupt transitionto:
R	100 +	Rock

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 17 **luvicPHAEOZEM**

Mapping Unit	**VB3**			
Laboratory No.	**17.1**	**17.2**	**17.3**	**not analysed**
Horizon	**A**	**AB**	**B**	**R**
Depth (cm)	**0 - 20**	**20 - 30**	**30 - 100**	**100 +**
pH- KCl_2	**5.36**	**5.30**	**5.55**	
pH- H_2O	**6.8**	**6.35**	**6.45**	
% C	**1.76**	**0.68**	**0.83**	
% N	**0.19**	**0.15**	**0.37**	
P (ppm)	**9.2**	**0.1**	**6.4**	
Texture	**Clay loam**	**Clay**	**Clay**	
% Sand	**35.66**	**36.91**	**34.17**	
% Clay	**38.48**	**44.52**	**46.19**	
% Silt	**25.86**	**18.57**	**19.64**	
CEC (me/100g)	**24.3**	**28.8**	**27.8**	

PROFILE # 18

General Information:

Mapping Unit:	FS3
Soil Classification:	orthic LUVISOL
Agro-Climatolgical Zone:	III-6
Elevation:	2140 m
Observation Date:	1986/09/08
Location (UTM):	378460
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	footridge
Slope Gradient:	30%
Land Use:	grazing, wildlife
Vegetation:	*Albizia, Dombeya*
Overwash:	none
Surface runoff:	accellerated if vegetation removed otherwise slow.
Surface sealing/cracks:	none observed
Drainage Class:	well drained
Human Influence :	moderate: wood cutting, fire
Erosion:	slight
Effective Soil Depth:	40 cm.

Profile Description:

A	0 - 25 cm.	Dark reddish brown (5YR 2.5/2) moist; sandy clay loam; moderate, medium, subangular blocky structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; abundant very fine and fine pores; Abundant medium and fine roots (forming mat); Smooth and gradual transition to:
B	25 - 40 cm.	Dark reddish brown (5YR 2.5/2) moist; sandy clay loam; strong, medium, subangular blocky structure; very hard when dry, friable when moist, sticky and plastic when wet; Common medium and fine roots (much less than A); abrupt transition to:
R	40 + cm.	Yellowish red (5YR 4/6) mottled with very dark grey (5YR 3/1); Saprolite

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 18 **orthic LUVISOL**

Mapping Unit	FS3			
Laboratory No.	18.1	18.2	not analysed	
Horizon	A	B	R	
Depth (cm)	0 - 25	25 - 40	40 +	
pH- KCl_2	5.28	5.25		
pH- H_2O	6.01	6.59		
% C	3.90	2.64		
% N	0.33	0.36		
P (ppm)	2.7	2.0		
Texture	sandy clay loam	sandy clay loam		
% Sand	58.0	58.16		
% Clay	22.3	21.2		
% Silt	19.7	20.64		
CEC (me/100g)	34.8	33.6		

PROFILE # 20

General Information:

Mapping Unit:	FR1
Soil Classification:	orthic LUVISOL
Agro-Climatolgical Zone:	III-6
Elevation:	2240 m
Observation Date:	1986/09/08
Location (UTM):	376452
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	footridge crest
Slope Gradient:	20%
Land Use:	grazing, wildlife
Vegetation:	*Albizia*, *Dombeya* and *Themeda/Pennisetum* grassland
Overwash:	none
Surface runoff:	accellerated if vegetation removed otherwise slow.
Surface sealing/cracks:	none observed
Drainage Class:	well drained
Human Influence :	slight to moderate: wood cutting, some overgrazing, fire
Erosion:	slight
Effective Soil Depth:	110 cm.

Profile Description:

A	0 - 25 cm.	Very dark greyish brown (10YR 3/2) dry and moist; Clay; Strong, medium, subangular blocky structure; very hard when dry, slightly friable when moist, sticky and plastic when wet; few very fine pores; abundant fine roots; smooth and gradual transition to:
B	25 - 45cm.	Brown to Dark brown (10YR 4/3) dry and dark yellowish brown (10YR 3/4) moist; Clay; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few fine to micro pores; few fine roots; Clear transition to:
C	45 - 110 cm.	Dark brown (10YR 4/3) moist; Clay loam; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; few fine to micro pores; few fine roots; Abrupt transition to:
R	110 + cm.	Saprolite

Soil Chemical Analysis Results **Soil Classification**

PROFILE # 20 orthic LUVISOL

Mapping Unit	**FR1**			
Laboratory No.	**20.1**	**20.2**	**20.3**	
Horizon	**A**	**B**	**C**	
Depth (cm)	**0 - 25**	**25 - 45**	**45 +**	
pH- KCl_2	**5.30**	**5.10**	**3.77**	
pH- H_2O	**5.60**	**6.58**	**6.72**	
% C	**4.15**	**1.51**	**1.27**	
% N	**0.35**	**0.33**	**0.24**	
P (ppm)	**1.55**	**0.2**	**3.4**	
Texture	**clay**	**clay**	**clayloam**	
% Sand	**37.93**	**38.14**	**38.86**	
% Clay	**45.28**	**42.32**	**38.22**	
% Silt	**16.79**	**19.54**	**22.92**	
CEC (me/100g)	**35.5**	**31.7**	**30.0**	

PROFILE # 23

General Information:

Mapping Unit:	RS2
Soil Classification:	vitric ANDOSOL
Agro-Climatolgical Zone:	IV-6
Elevation:	2340 m
Observation Date:	1986/09/08
Location (UTM):	370456
Geological Formation:	Ngong Volcanics
Local Petrography:	Undifferentiated basanites, tephrites, atlantites, ankaratrites
Physiography:	small valley on western scarp
Slope Gradient:	60%
Land Use:	grazing, wildlife
Vegetation:	scattered *Euphorbia sp.*, *Themeda/Hyparrhenia* grassland
Overwash:	none
Surface runoff:	excessive
Surface sealing/cracks:	none observed
Drainage Class:	excessively drained
Human Influence :	slight to moderate: fire
Erosion:	slight but potential severe
Effective Soil Depth:	100 cm. but highly variable

Profile Description:

A	0 - 20 cm.	Black (10YR 2/1) moist; Loam; slightly hard when dry, very friable when moist, non sticky and non plastic when wet; abundant fine pores; abundant fine and medium roots; smooth and gradual transition to:
B	20 - 100 cm.	Very dark grey (10YR 3/1) moist; Clay loam; hard when dry, friable when moist, slighlty sticky and slightly plastic when wet; abundant fine pores; common fine and medium roots; abrupt transition to:
R	110 + cm.	Rock

Soil Chemical Analysis Results | **Soil Classification**

PROFILE # 23 | vitricANDOSOL

Mapping Unit	RS2			
Laboratory No.	23.1	23.2	not analysed	
Horizon	A	B	R	
Depth (cm)	0 - 20	20 - 100	100 +	
pH- KCl_2	5.91	5.95		
pH- H_2O	6.97	7.36		
% C	4.24	2.0		
% N	0.66	0.62		
P (ppm)	8.8	3.7		
Texture	Loam	Clay loam		
% Sand	43.60	37.75		
% Clay	11.40	38.60		
% Silt	45.0	23.65		
CEC (me/100g)	46.1	49.5		

Appendix 2. Farm Survey Questionnaire

Appendix 2. Farm Survey Questionnaire

FARM QUESTIONNAIRE

Sample# ________________

Date: Yr. ____ Mo. ____ Day ____

Grid Location ________________

Interviewer: ________________ **Respondent name (optional)** ________________

General landuse pattern ____________________ **Landuse system#** __________

Soil Type ________________________ **Slope%** ________________________

DEMOGRAPHY

Respondent **Age** _____ **Sex** _____ **Education** ____________________

Others	M	F		M	F
0-4			40-44		
5-9			45-49		
10-14			50-54		
15-19			55-59		
20-24			60-64		
25-29			65-69		
30-34			>69		
35-39			Total		

Grand Total (both sexes) ______________

HISTORY

Length of time respondent has:
a) lived in area ____________ **Worked this land** ____________

What form of land use was practiced at beginning of that period?

____

What was the vegetative cover type at the time of occupation? (specify species)

____

What Changes have occurred in land use and condition (incl. weather) since that time?____

____

____

____

____

RESOURCES and USE

Land

Land Size Category: 1) landless; 2) 0-2 ha 3) 2.1-5 ha 4) 5.1-10 ha 6) over 10 ha

Land Use Type	Area/ha. (main farm/outfields) or number	Yields	Observations
Rainfed cropland			
list crops (indicate long (L) or short (S) rains			
a)			
b)			
c)			
d)			
e)			
f)			
g)			
Note: Rank Cash crops1,2,3...etc in terms of cash generation			
Irrigated cropland			
Fallow			
Permanent Pasture			
Trees + Shrubs (Fruit, coffee etc) Human food			
Other Trees+Shrubs (Woodlot,Forest,fodder)			
Fodder Crops			
Dwelling Space (incl. all out Bldgs.)			
Water			
Kitchen Garden			
Nursery			
TOTAL			

TENURE **(Freehold, Lease** (Note length and type),**Public)**

Shared lands

Access to other lands? Y/N

Owner	Use	Location:(grid location)	Distance/Journey time

LABOUR

Type	Number	Farm Respondsibilities	Non-farm Activities
Family			
Adult Male			
Adult Female			
Children			

Hired or Exchange (specify rate or commodity)

Type	Number	Farm Responsibilities
Adult Male		
Adult Female		
Children		

LIVESTOCK

Type	Number	Use	Yearly Yield	Feed (see below)
Beef Cattle				
Dairy Cattle				
Sheep				
Goats				
Poultry				
Donkeys				
Other (eg. bees)				

FEED CODE: fresh grass (G); stored hay (H); maize cobs (M); tree fodder (T) cassava chips (C); other (specify).

Is fodder availabilty a problem? ______________________

When?(at what times of the year) ______________________

____

OTHER RESOURCES

Tools and Equipment (type and number): ______________________

____

____

Other (specify): ______________________

____

____

What major improvements have you made to your land?______________________

____

____

What improvements would you most like to make? ______________________

____

____

____

LIMITING RESOURCES

If you wanted to improve the production of your farm, which of the following would you most need? Rank and give purpose.

RANK	FACTOR	PURPOSE
	land	
	labour	
	Draught animals	
	Inputs (Fertilzers,Seedlings,Pesticides)	
	Machinery/Implements	
	Water	
	Other	

PROBLEM IDENTIFICATION IN HOUSEHOLD PRODUCTION SUBSYSTEMS

Food Production Subsystem

Production Objectives (indicate primary or secondary objective P/S)

Production
Staple food self sufficiency ____
Supplementary production of staples____
Purchase
Purchase of most staples____
Supplementary purchase of staples ____
Sale
Sale of food cash crops____
Sale of surplus food crops____

Supply Problems
Do Seasonal Shortages of Staples Occur? Y/N____
In what season?____
They occur:
____ only in bad years ____ in most years ____ even in good years

	Main Times Of				
Main Crops	Planting	Weeding	Harvest	Consumption	Purchase

Causal Factors Respondsible for Supply Problems

CROP PRODUCTION

Causal Factors	Explanatory Notes (incl.alleviation methods)
___ Land shortage	
___ Labour Shortage	
___ Draught power shortage	
___ Moisture deficiencies	
___ short growing season	
___ unreliable timing of rains	
___ midseason moisture stress	
___ poor infiltration of rain	
___ low water holding capacity	
___ Poor rooting conditions	
___ shallow soils	
___ poor structure/consistency	
___ poor drainage/aeration	
___ Tillage problems	
___ workability	
___ rocks / stones / roots	
___ Soil nutrient deficiencies	
specify and note evidence	
___ Soil erosion	
___ Other hazards	
___ flooding/waterlogging	
___ salinization	
___ soil toxicities	
___ weeds	
___ crop diseases	
___ insect pests	
___ other pests	
___ theft	
___ Inadequate supply of inputs	
___ fertilizers	
___ seeds	
___ Other factors:	

LIVESTOCK PRODUCTION

Problems/Causal Factors	Season	Notes
___ Weight loss or poor gain		
___ Low milk production		
___ High mortality		
___ unweaned animals		
___ adult animals		
___ Low reproduction rates		
___ Land shortage		
___ Labour shortage		
___ Water shortage		
___ Pasture shortage		

___ Browse shortage ______________________
___ Fodder shortage ______________________
___ Poor quality of feeds (specify) ______________________
___ Pasture degradation ______________________
___ Bush encroachment ______________________
___ Soil erosion (Type) ______________________
___ Fire hazard ______________________
___ Inadequate fencing ______________________
___ Inadequate shade ______________________
___ Inadequate veterinary services ______________________
___ Other factors ______________________

What % of your farm is subject to the following:

Erosion	Gully	Rill	Sheet	Wind
Slight				
Moderate				
Severe				

What have you done to alleviate above and is it adequate?______________________

Water Supply Subsystem

Use	Source	Adequate(Y/N)	Distance	Dist. Change I/D/U *
Drinking				
Washing				
Stock				
Irrigation				

* Change in last five years I=increase; D=decrease; U=unchanged

Who draws the water? ______________________

Do you have any water storage facilities? ______________________

Are you using any water conservation measures? Y/N __________
What measures are you using? (eg. mulch, windbreaks, etc.)
____

Energy Supply Subsystem

Circle and check appropriate areas

	Uses			Means of Supply			Amount
Type	Cooking	Heating	Industry	Produce	Collect	Purchase	(I or A)*
firewood							
charcoal							
crop residues							
dung							
paraffin							
gas							
electricity							
other							

* State amount and adequacy. I = Inadequate; A = Adequate

What type of stove are you using? ____________

Location of woodfuel (firewood and charcoal) ____________

Time spent securing energy? ____________

Is this more than it was five years ago? ____________

Would the household prefer to be using other energy sources? If so specify type and species desired. ____________

Is supply, time or cash expenditures considered a problem? ____________

Are energy shortages anticipated in the future? ____________

What are you doing to improve the situation? ____________

Shelter Subsystem

Shelter Resource	Status	Needs
Human dwelling		
Stock shelter		
Storage		
Windbreaks		
Shade for people		
Shade for stock		
Shade for crops		
Fencing - cropland		
Fencing - grazing land		
Fencing - corrals, bomas		

Fencing - security

Delineation of boundary

Delineation of tracks

Protection of catchment areas

Protection of drainage/irr.

Building posts,poles,sawlogs

Roofing materials

Raw Materials Subsystem

Cottage Industry	Raw Material	Produced/Purchased	Problems/Causes

Cash Supply Subsystem

Expenditures — **Amount and/or % of total Expenses** — **Problems**

- ____ Food
- ____ Clothing
- ____ Energy
- ____ Shelter
- ____ Raw Materials
- ____ Social Expenses
- ____ School Expenses
- ____ Crop Inputs
- ____ Hired Labour
- ____ Equipment Purchase/rental
- ____ Livestock Purchase
- ____ Veterinary Expenses
- ____ Other (specify)

Income Sources — **Amount and/or % of total income**

- ____ Sale of cash crops
- ____ Sale of surplus foods
- ____ Sale of livestock
- ____ Sale of cottage Ind. Products
- ____ Sale of tree products
- ____ Off farm employment
- ____ Gifts and remmittances
- ____ Other (specify)

Total income per family group?____

Are savings possible?____

What times of year is cash a bottleneck?____

Social Production Subsystem

Social Production/Expediture	Problems/causes
eg. weddings,dowry,subdivision,funerals,inheritance	

Management Practices

1) a.Do you fallow any of your land? (Y/N) ______
b.If so what is the length of fallow? ______

2) a.Do you use manure, fertilizer, or mulch? ______
b. If so how much? ______

3) Do you plant any trees on your land? ______
If so , complete below.

SPECIES	No.	LOCATION *	REASON **	% SURVIVAL

*Location Code: 1)Trees in rows along path 2)Trees around the compound 3)Scattered trees in the fields 4)Riverine trees 5)Hedges 6)Plantation/woodlot 7)Natural woodlot/shrubs/bushes 8)Pasture 9) Terraces

**Reason code: 1)Fuelwood 2)Charcoal 3)Beam Posts 4)Building Poles 5)Posts 6)Roundwood 7)Honey 8)Animal fodder 9)Green manure 9)Food and fruit 10)Medicinal 11)other (specify)

4) What is the main reasons for seedling mortality? ______

______

5) Where do you get your seedlings? ______
1) Community nursery 2) Government nursery
3) Private nursery 4) Transplants from own land
5)Transplants from other lands (specify where)
6)Natural regeneration 7) On farm nursery

6) a.Is this nursery well located? ______
b.Can you suggest a better place? ______

7) Can you obtain the species you desire? ______

8) If you were going to plant trees next year, what species would you plant, where and for what reasons? ______

______

____

____

9) a. Do you ever plant trees outside the farm boundary?__________
   b. If so , for what reason?__________
   c. What species?__________
   d. Do others plant?__________

10) Would you participate in the following and what problems might arise? Can you suggest possible locations?

Undertaking	Participate (Y/N)	Potential Problems	Location(grid)
Community Woodlot			
Community Pasture			
Community Fodder Orchard			
Cut and Carry Hayland			
Community Nursery			

11)Should existing pasture lands be turned into forest plantations? (Y/N)______

12)Have the number of trees in the area increased or decreased in the last five years?__________

1) increased
2) decreased
3) remained the same
4) Don't know

13) If answer to 12 is 1) , How has this occurred?__________

1) Protected by local people
2) Protected by government
3) Population not increased
4) New plantations established
5) More than one answer

14) If answer to 12 is 2) , How has this occurred?__________

1) Population increased
2) Cultivation increased
3) Uncontrolled cutting
4) Too much grazing
5) Fire
6) More than one answer

15)Do you prune or pollard your trees?

____

16) Do you belong to any agricultural organizations or self help groups? If so please specify?__________

17) What activities are involved in above?__________

____

____

18) How many man/hours per week is worked on your land during the following periods? Sowing Season ________ Growing Season ________ Harvest________

Possible Niches for Trees and Shrubs

Mark for each potential niche whether it is/has:

A.
1. Major or Primary niche
2. Secondary niche
3. Niche uncommon or doesn't exist

B.
1. Few or no trees now in niche
2. Some growing there now
3. Planted trees there now

A	B		Access ..Private, Public, Shared (lease, exchange, etc)
___	___	1 Hegerows	___
___	___	2 Fallow Land(short term)	___
___	___	3 Fallow land (long term)	___
___	___	4 Woodlots	___
___	___	5 Rangeland	___
___	___	6 Pastures	___
___	___	7 Perennial plantations or orchards	___
___	___	8 Cropland	___
___	___	9 Around Home	___
___	___	10 Property boundaries	___
___	___	11 Field boundaries	___
___	___	12 Roads, trails, public places	___
___	___	13 Riverbanks	___
___	___	14 Gullies	___
___	___	15 Terraces	___
___	___	16 Drainage channels	___
___	___	17 Waterholes	___
___	___	18 Other(specify)	___

General Comments/ Major Concerns of Respondent

____

____

____

____

____

____

____

____

____

____

Personal Observations

Attitude to questioning 1) Reluctant 2) Deceptive 3) Open and obliging ________

____

Attitude to Agriculture 1) Carefree 2) Mediocre 3) Keen ________

Other: ____

____

____

____

____

Appendix 3. Map Reductions

Soils Mosaic 1

Legend to the Soil Mapping Units

Soils of the Ridges and Scarps

RS1 - Complex of moderately deep to shallow orthic LUVISOLS and LITHOSOLS

RS2 - LITHOSOLS with inclusions of shallow eutric REGOSOLS & moderately deep vitric ANDOSOLS

RS3 - LITHOSOLS

RS4 - Shallow eutric REGOSOLS with inclusions of Lithosols and shallow vitric ANDOSOLS

Soils of the Footridges and Footslopes

FS1 - very deep dystric NITOSOLS

FS2 - moderately deep orthic LUVISOLS with very occasional inclusions of dystric NITOSOLS

FS3 - Shallow orthic LUVISOLS with occasional inclusions of dystric NITOSOLS

FR1 - Complex of deep dystric NITOSOLS and moderately deep orthic LUVISOLS

FR2 - Moderately deep to shallow LUVISOLS

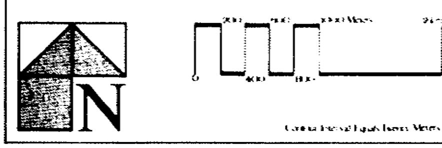
Soils of the Valley Bottoms and Volcanic Plains

VB1 - Deep pellic VERTISOLS (extreme swelling characteristics)

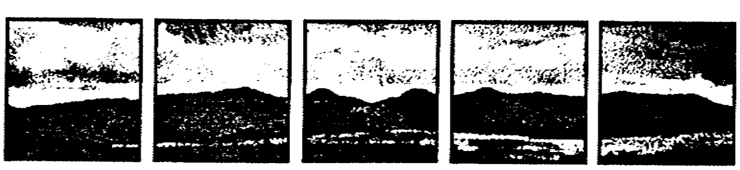
VB2 - Deep pellic VERTISOLS (moderate swelling characteristics)

VB3 - Moderately deep to deep luvic PHAEOZEMS

Note: For descriptions of representative profiles see Appendix



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



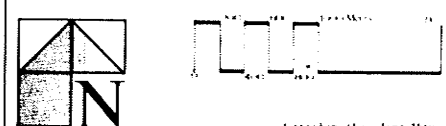
NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA

Vegetation Mosaic 2

Legend to the Vegetation Classes

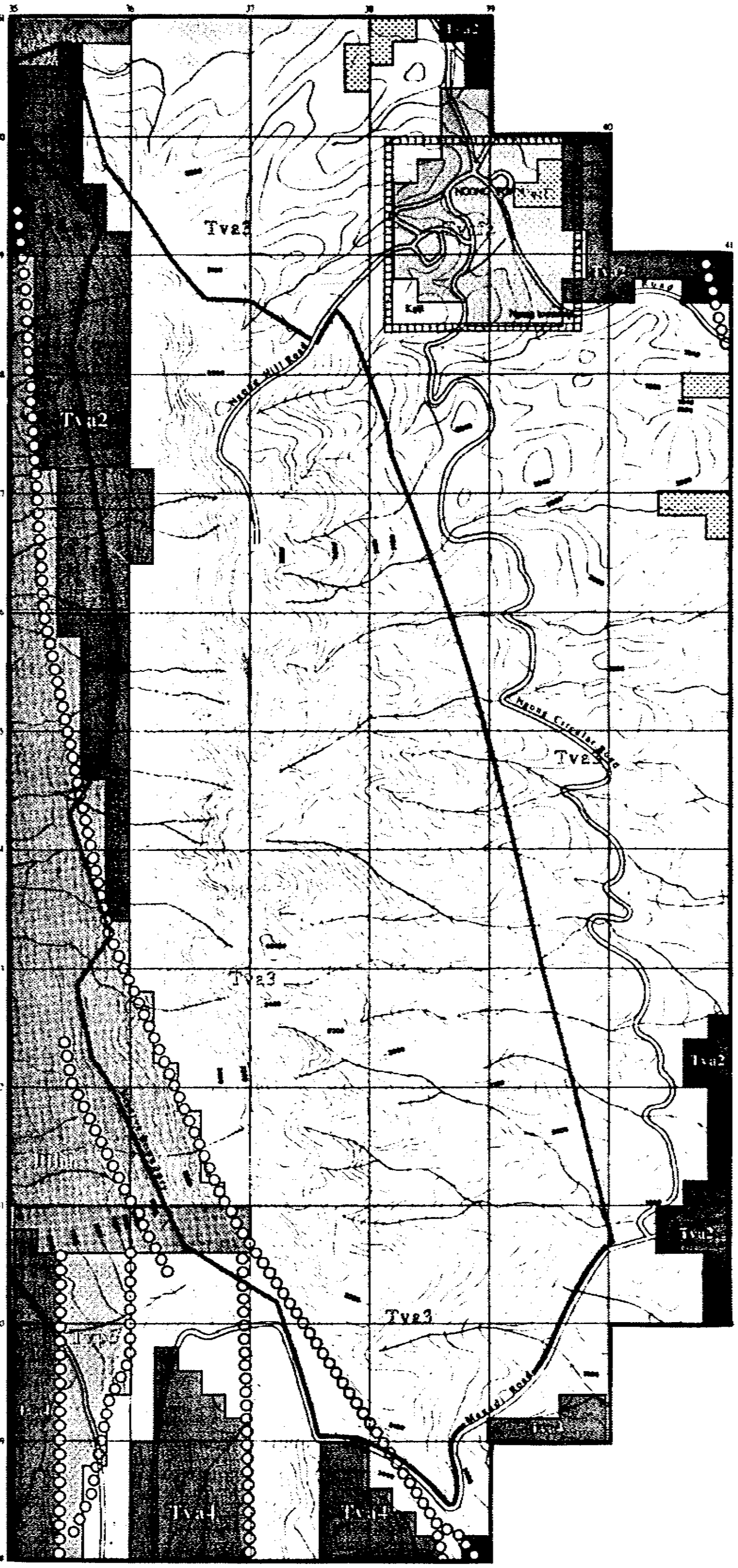
A	Annual Crops (w=woody overstory)
B	Pasture (w= wooded pasture)
C	Undifferentiated Afromontagne Forest
D	Transitional Montagne Forest
E	Dry Montagne Forest
F	Thickets (interspersed with grassland)
G	Grassland
H	Grassland with occassional forest remnants and thickets
I	Thornbush Grassland
J	Dry Thornbushland
K	High Density Settlement Areas

Note: See report for diagrams and details of the classes



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA

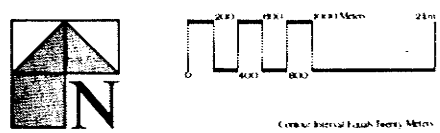


Geology Map 1

Legend

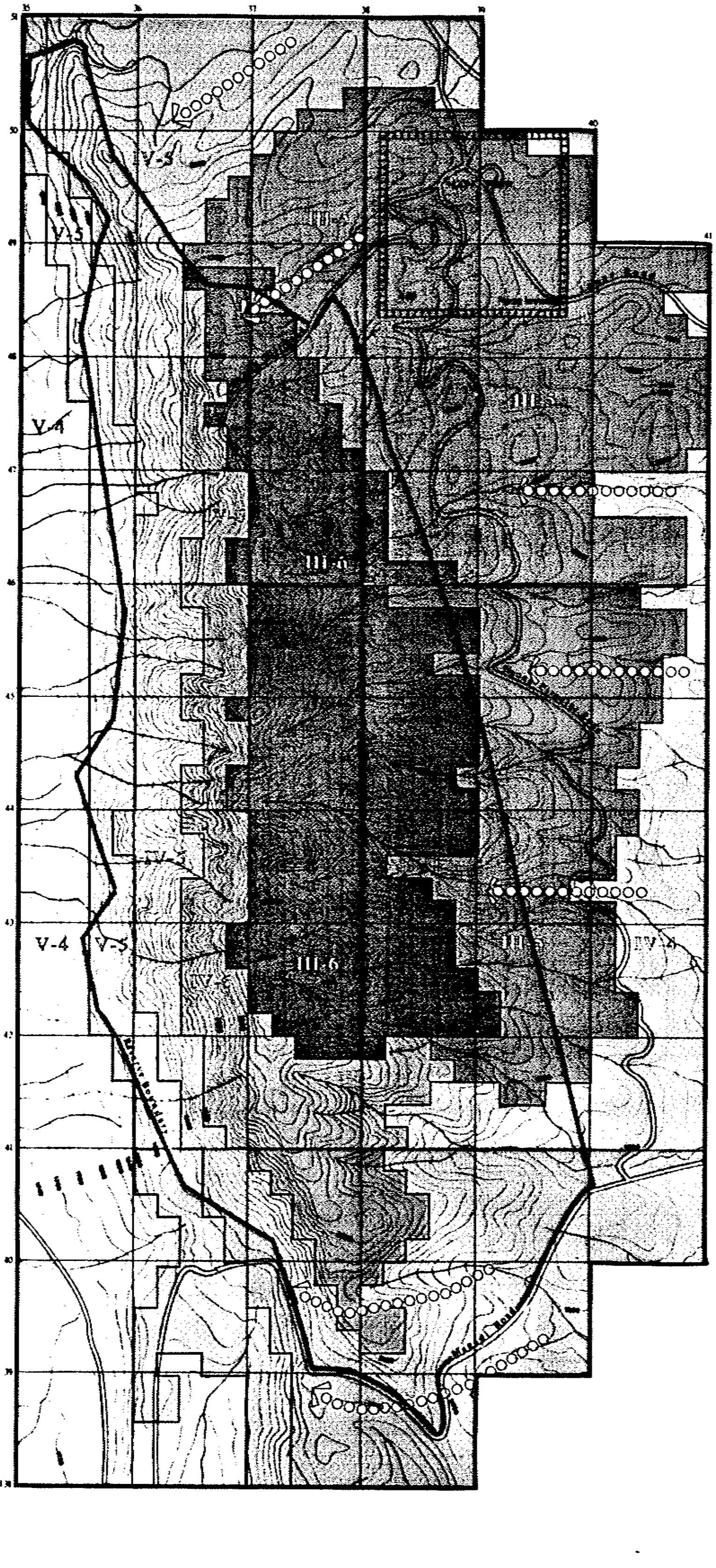
- Tephrites, Tva2
- Alluvium, Clays, Swamp Soils
- Middle & Upper Kerichwa Valley Tuffs, Tvtf2
- Lower Kerichwa Valley Tuffs, Tvtf1
- Ol Esayeti Oligoclase Tephrites, Tva4
- Phonolites, Tvp6
- Limuru Trachytes & Quartz Trachytes, Plh1
- Basanites, Tephrites, Atlantites, Ankaratrites (undifferentiated), Tva3
- OOO Faults

Source: Saggerson (1971)



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



Climate Map 2

Legend to the Bio-Climatological Classes

- III-6, subhumid
- III-5, subhumid
- IV-6, subhumid to semi-arid
- IV-5, subhumid to semi-arid
- V-5, semi-arid
- V-4, semi-arid

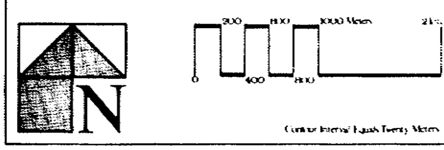
Climate Classes

Zone	R/Eo%	Class	Av. Ann Rainfall	Av. Ann Pot.Evap (Eo)	Vegetation	Potential for agriculture	Risk of failure of adapted Maize crop
III	50 - 65	sub-humid	800-1400	1450-2200	Dry forest and Moist Woodland	High to Medium	Fairly Low 5 - 10%
IV	40 - 50	sub humid to semi-arid	600-1100	1550-2200	Dry Woodland and Bushland	Medium	Low 10 - 25%
V	25 - 40	semi-arid	450-900	1650-2300	Bushland	Medium to Low	High 25 - 75%

Temperature Classes

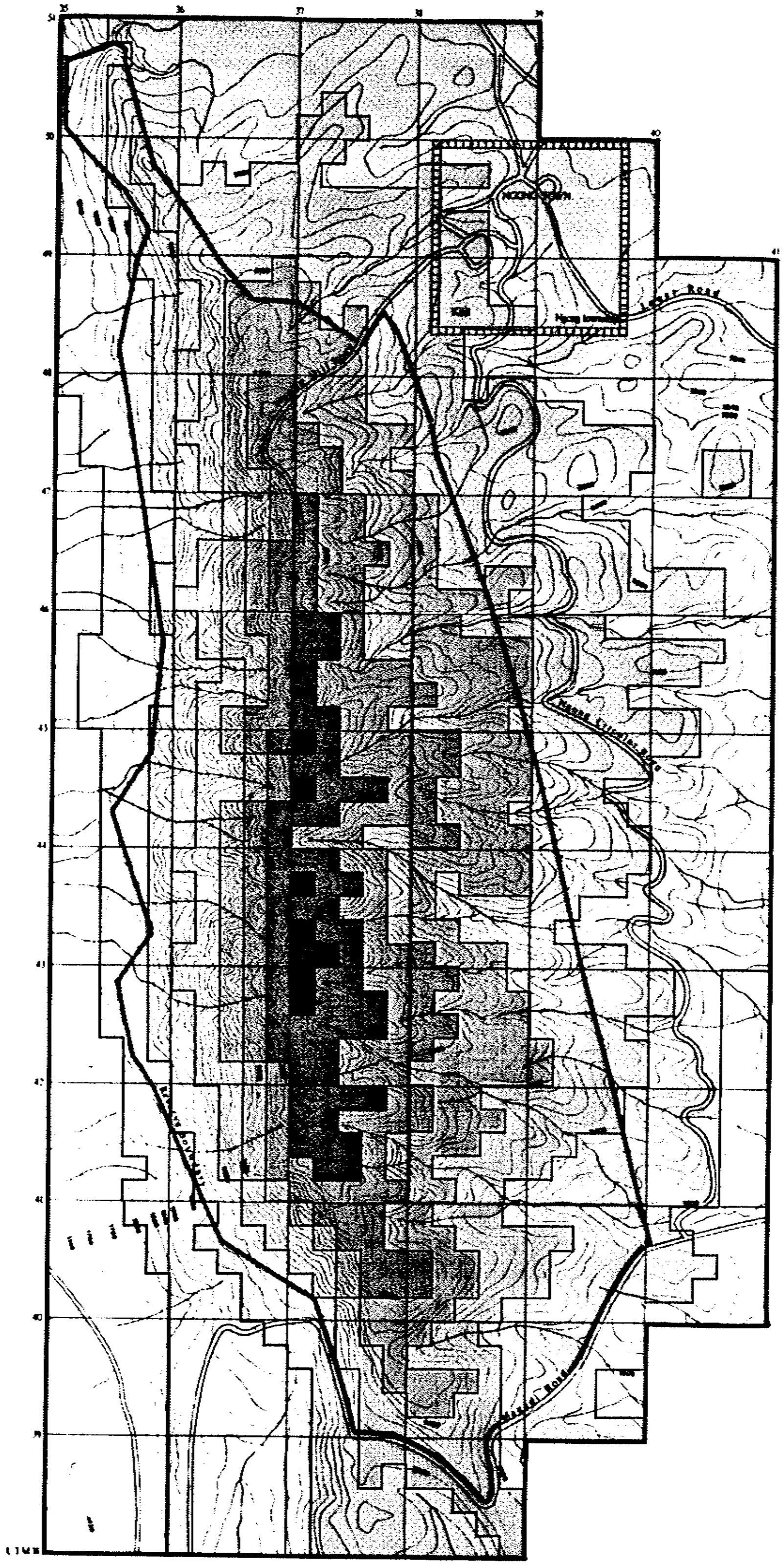
Temp. Class	Mean ann. Temp.°C	Class	Mean Maximum Temp	Mean Minimum Temp.	Absolute Minimum	Night Frost	Altitude	Description
6	14 - 16	fairly cool	20 - 22	8 - 10	0 - 2	rare	2150-2450	Upper Highlands
5	16 - 18	cool temp	22 - 24	10 - 12	2 - 4	very rare	1850-2150	Lower Highlands
4	18 - 20	warm temp	24 - 26	12 - 14	4 - 6	none	1500-1850	Lower Highlands

General Wind Direction (see also Wind Rose)



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

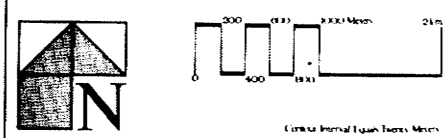
NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



Relief Map 3

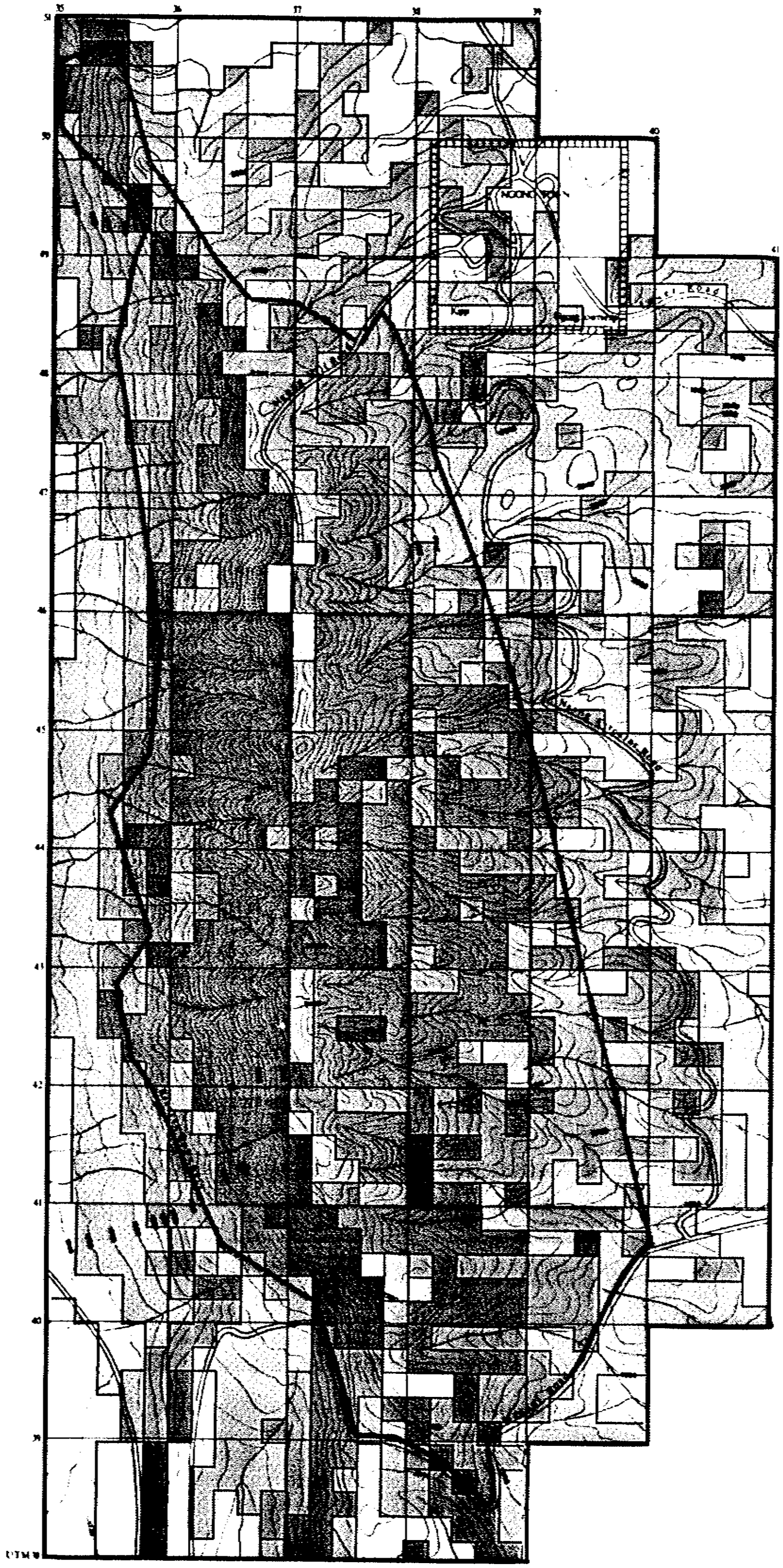
Legend to the Elevation Classes

- 2400 - 2500 meters (A.S.L.)
- 2300 - 2400
- 2200 - 2300
- 2100 - 2200
- 2000 - 2100
- 1900 - 2000
- 1800 - 1900
- 1700 - 1800



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



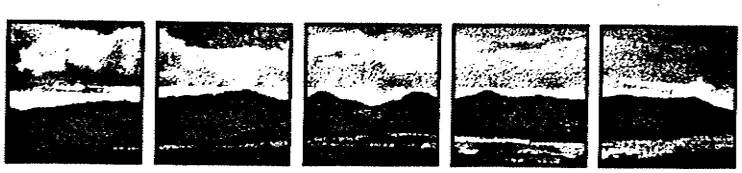
Slopes Map 4

Legend to the Slope Classes

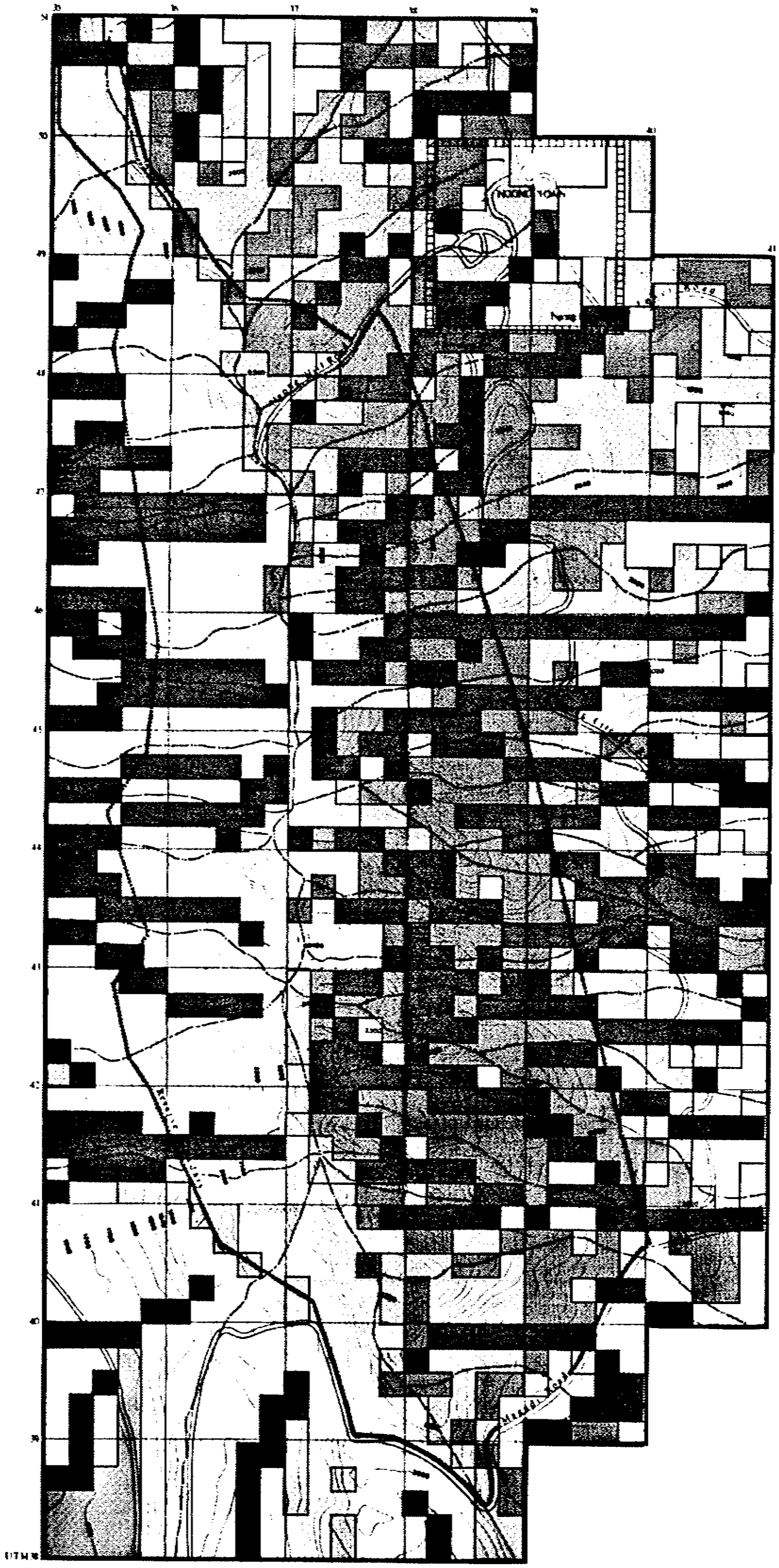
> 45%	Very Steep	
30 - 45%	Steep	
18 - 30%	Moderately Steep	
8 - 18%	Moderate	
3 - 8%	Gentle	
0 - 3%	Very Gentle	

N

J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



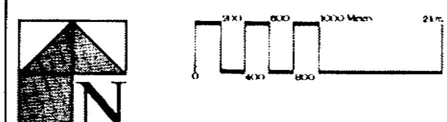
Hydrology Map 5

Legend to the Aquifer Recharge Classes*

- Extremely High Aquifer Recharge Value
- High Aquifer Recharge Value
- Moderate Aquifer Recharge Value
- Low Aquifer Recharge Value
- Very Low Aquifer Recharge Value

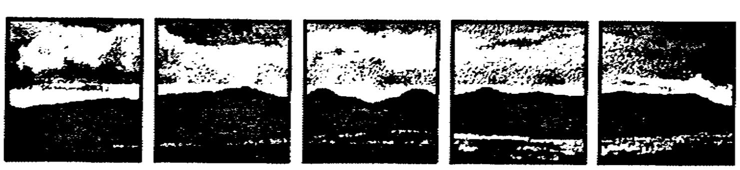
Stream (Seasonal)
Drainage Basin Divide
1,2... Drainage Basin Identification Number

* Based on climate, soil permeability, slope, vegetation and current land use

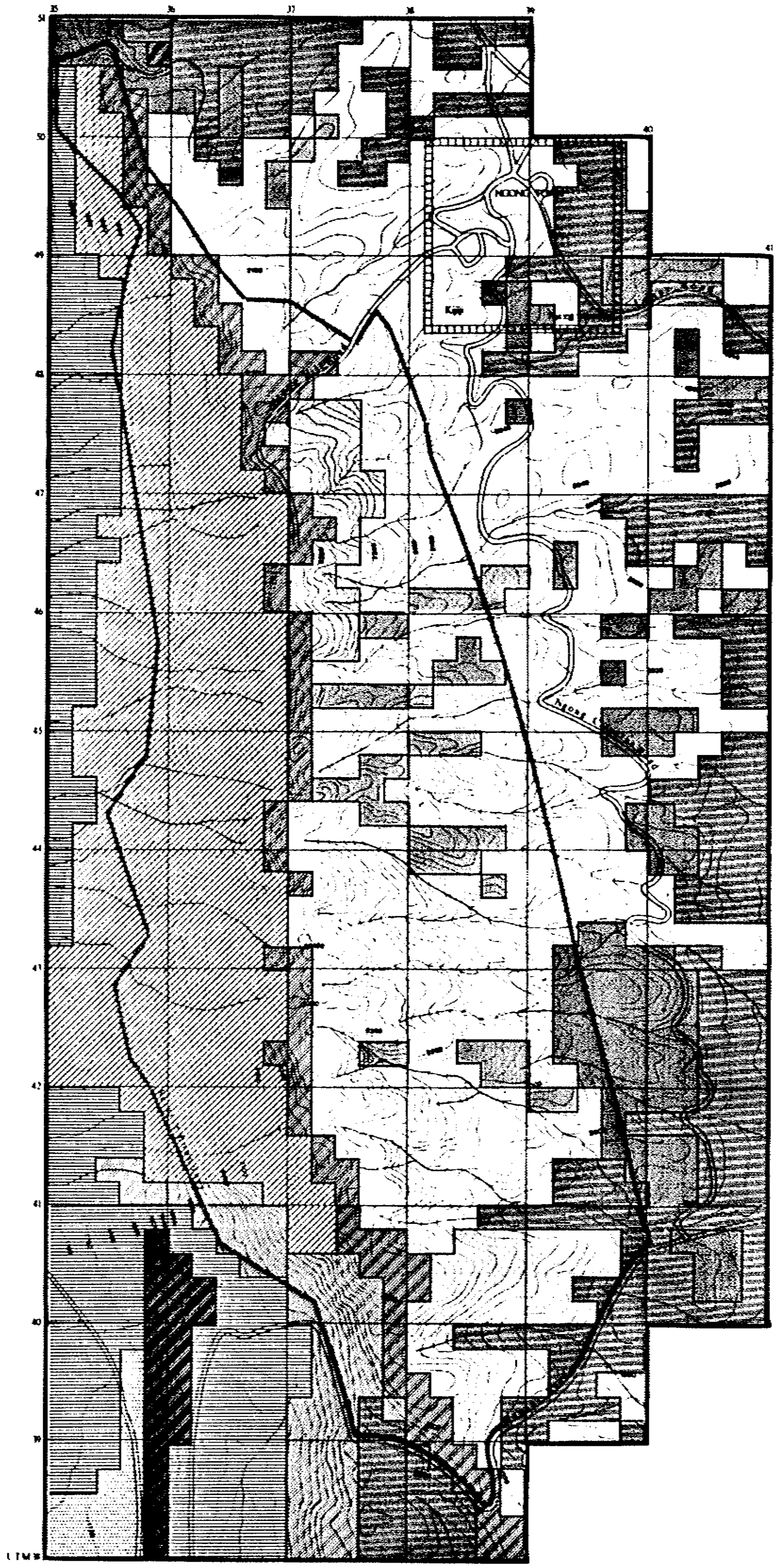


Contour Interval Equals Twenty Meters

J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



Soils Map 6

Legend to the Soil Mapping Units

Soils of the Ridges and Scarps

RS1 - Complex of moderately deep to shallow orthic LUVISOLS and LITHOSOLS

RS2 - LITHOSOLS with inclusions of shallow eutric REGOSOLS & moderately deep vitric ANDOSOLS

RS3 - LITHOSOLS

RS4 - Shallow eutric REGOSOLS with inclusions of Lithosols and shallow vitric ANDOSOLS

Soils of the Footridges and Footslopes

FS1 - very deep dystric NITOSOLS

FS2 - moderately deep orthic LUVISOLS with very occasional inclusions of dystric NITOSOLS

FS3 - shallow orthic LUVISOLS with occassional inclusions of dystric NITOSOLS

FR1 - Complex of deep dystric NITOSOLS and moderately deep orthic LUVISOLS

FR2 - Moderately deep to shallow LUVISOLS

Soils of the Valley Bottoms and Volcanic Plains

VB1 - Deep pellic VERTISOLS (extreme swelling characteristics)

VB2 - Deep pellic VERTISOLS (moderate swelling characteristics)

VB3 - Moderately deep to deep luvic PHAEOZEMS

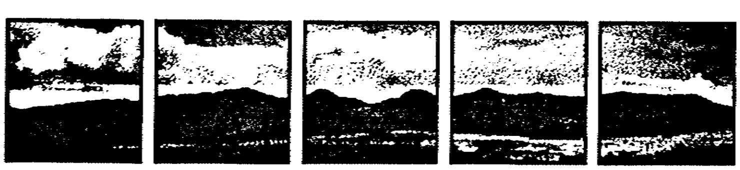
Note: For descriptions of representative profiles see Appendix

N

0 200 400 800 1000 Meters 2km

Contour Interval Equals Twenty Meters

J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



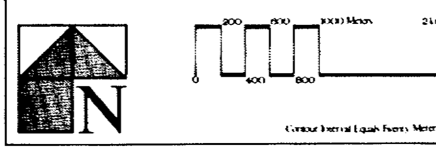
NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA

Erosion (Potential) Map 7

Legend to the Potential Erosion* Classes

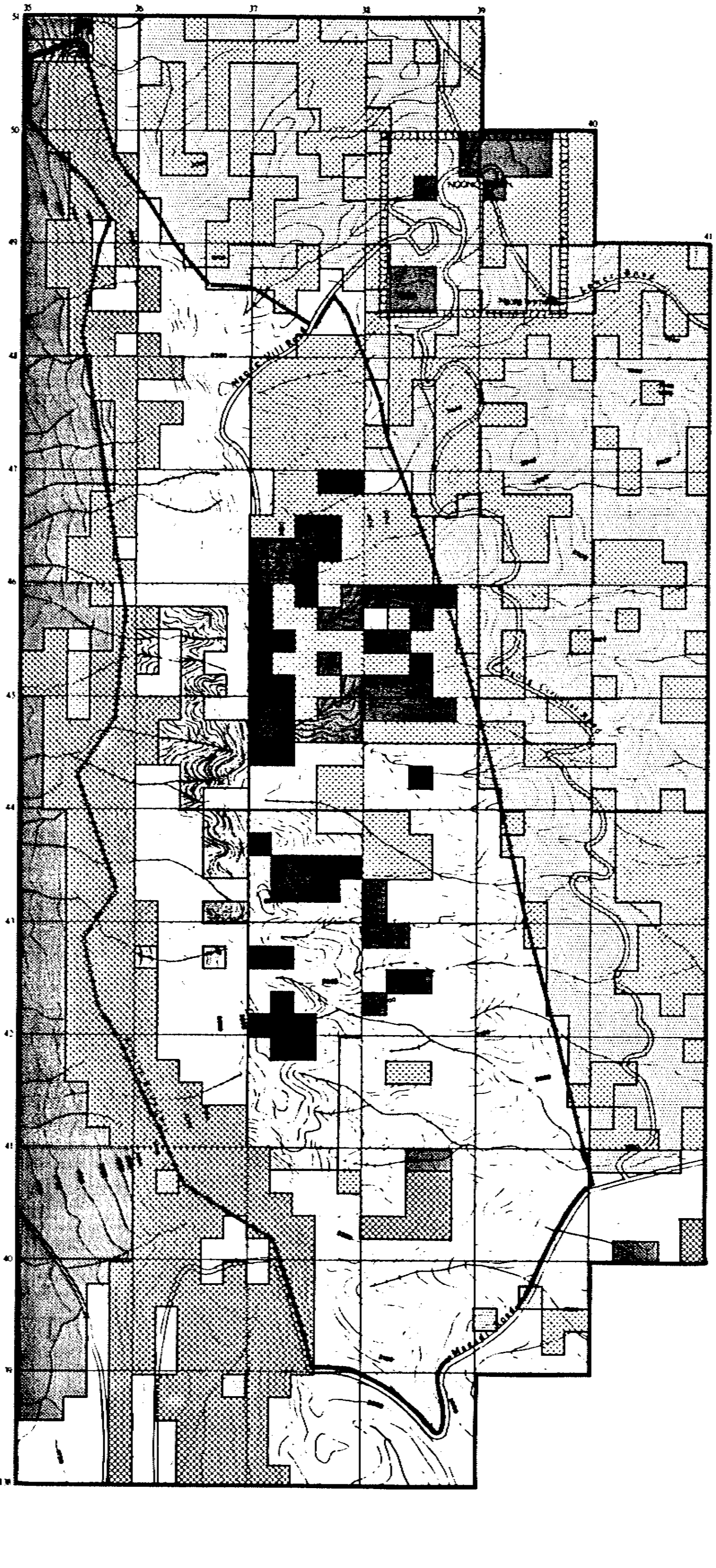
- High Potential for Erosion
- Moderate Potential for Erosion
- Low Potential for Erosion

* Potential for erosion in the event of vegetative cover removal



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA

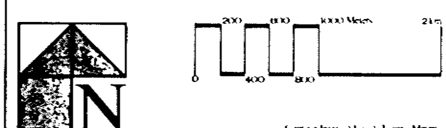


Vegetation Map 8

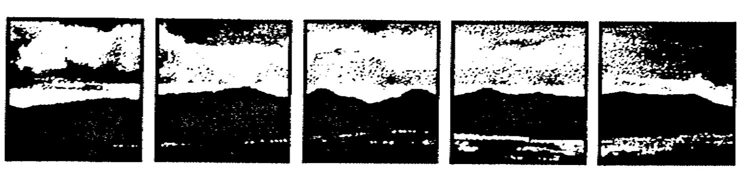
Legend to the Vegetation Classes

- Annual Crops (w=woody overstory)
- Pasture (w= wooded pasture)
- Undifferentiated Afromontagne Forest
- Transitional Montagne Forest
- Dry Montagne Forest
- Thickets (interspersed with grassland)
- Grassland
- Grassland with occassional forest remnants and thickets
- Thornbush Grassland
- Dry Thornbushland
- High Density Settlement Areas

Note: See report for diagrams and details of the classes

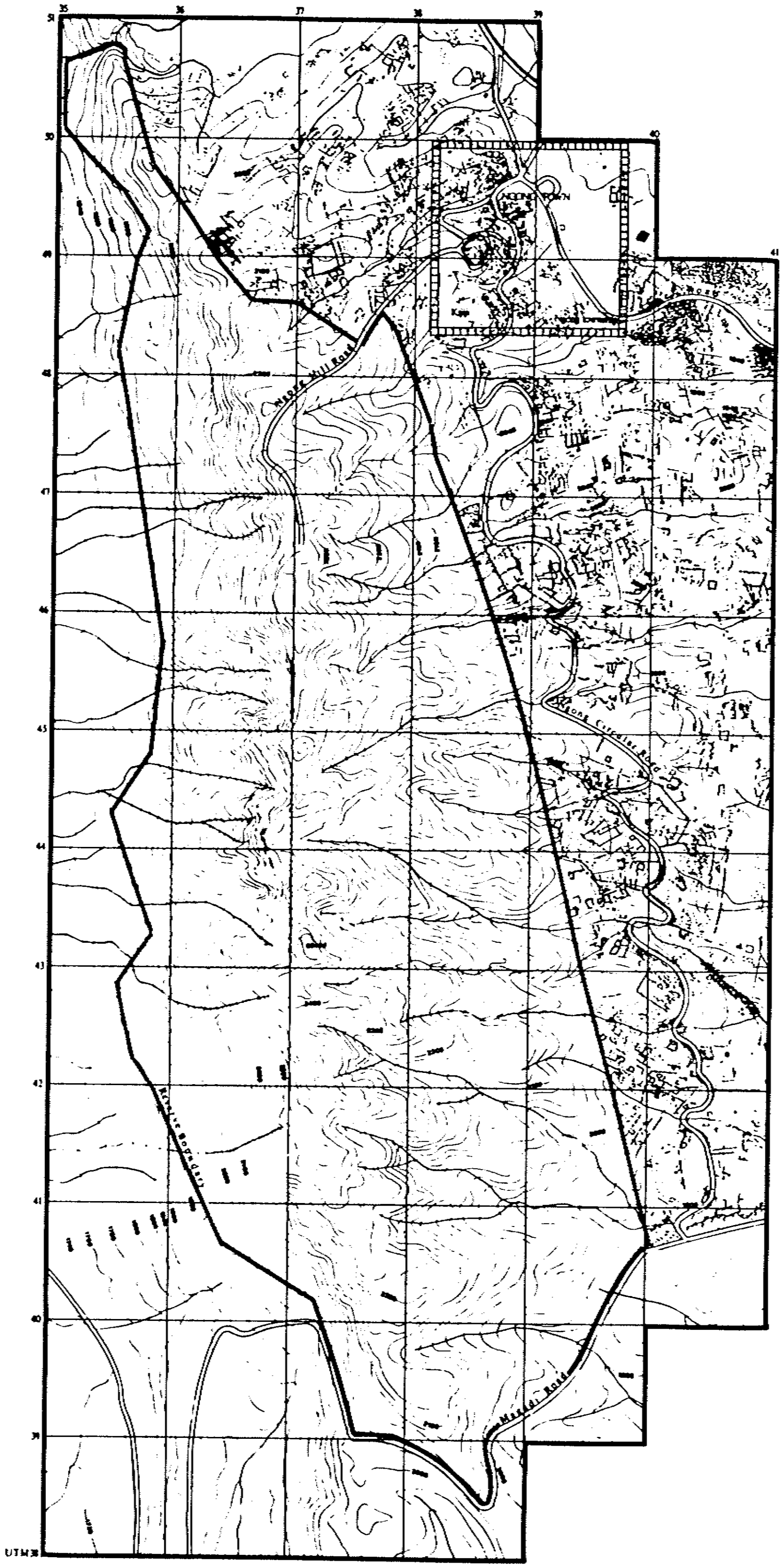


J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study

RIFT VALLEY PROVINCE KENYA



Trees Map 9

Trees and Hedges on Smallholder Lands

N

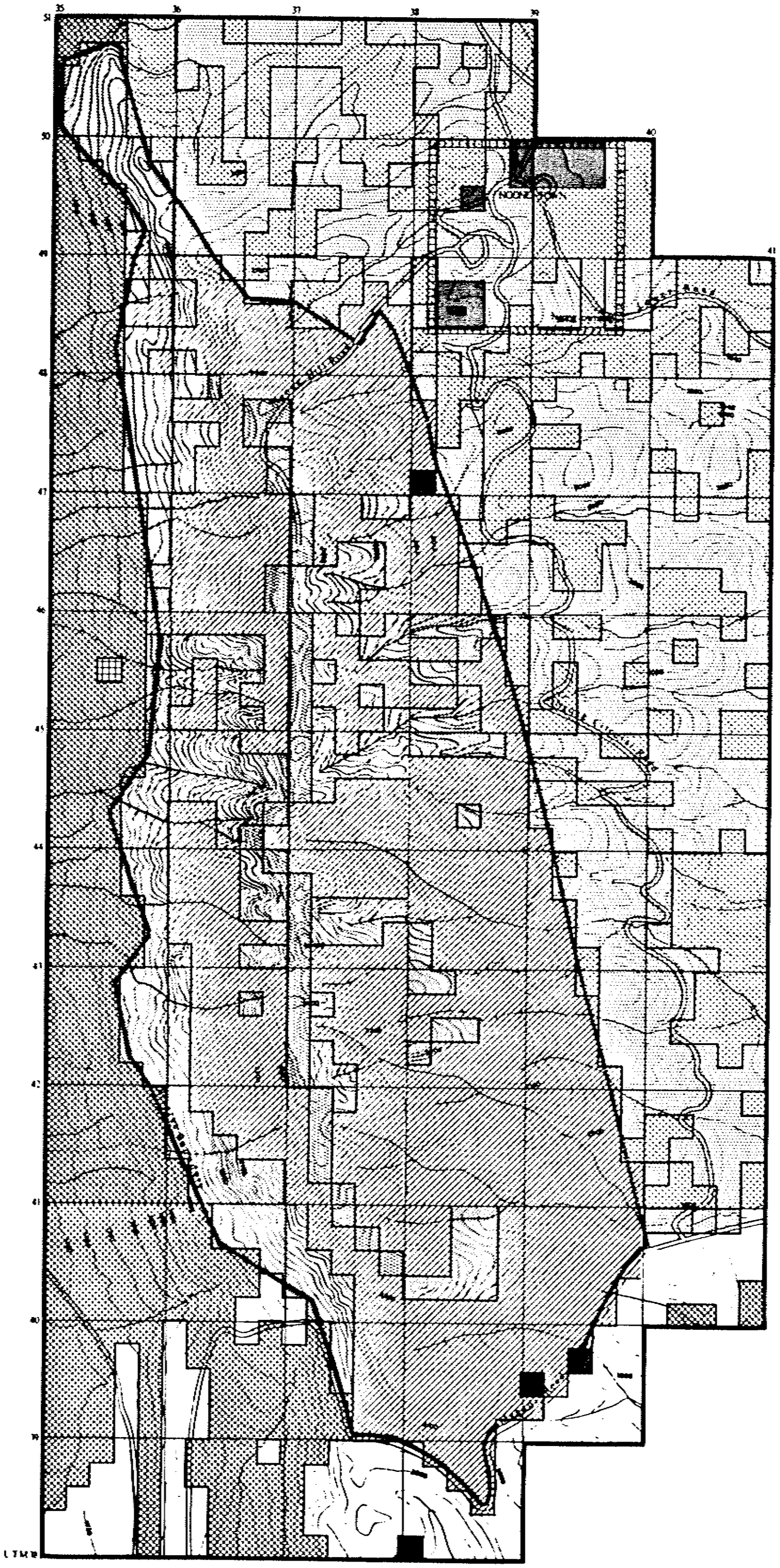
0 200 400 600 800 1000 Meters 2 km

Contour Interval Equals Twenty Meters

J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study

RIFT VALLEY PROVINCE KENYA



Land Use Map 10

Legend to the Land Use Classes

Smallholder Private Lands (holdings < 20 ha.)

- Mixed farming >50% annual crops
- Mixed farming >50% perennial crops
- Mixed farming >50% grazing of small or improved pastures
- Irrigated agriculture
- Tree and shrub crops

Largeholder Private Lands (holdings > 20 ha.)

- Grazing / browsing of natural pastures by cattle, sheep, goats and wildlife, fuelwood gathering
- Annual crops

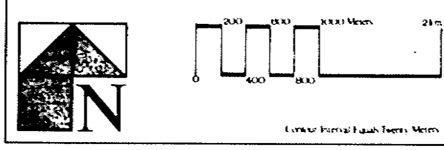
Common Lands (Public holdings)

- Water catchment, wildlife habitat, extensive grazing
- Water catchment, wildlife habitat, extensive grazing, fuelwood gathering, natural forest
- Tourism and Recreation
- Mixed farming

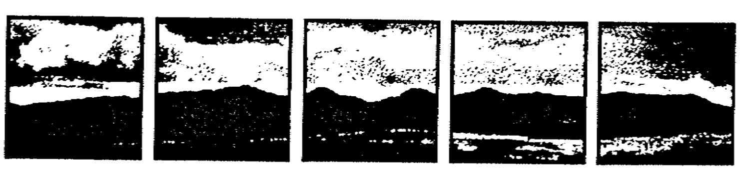
All Lands (public & private holdings)

- High density settlement
- Extractive industries (murram and soil)

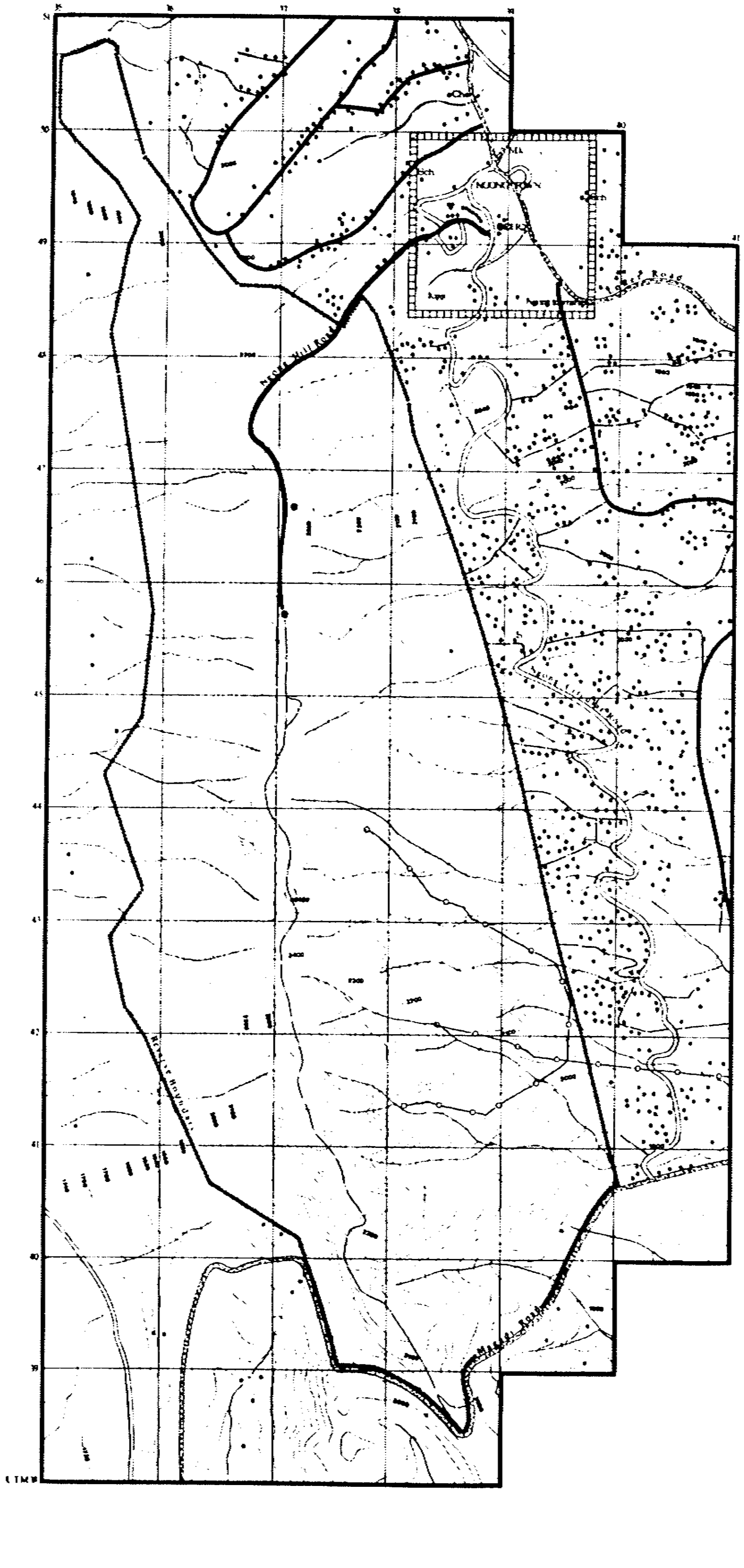
Note: Legend reflects predominant land use. Lesser uses may be present in grid cell. See computer data base for details



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



Settlement Map 11

Legend to the Infrastructure

- Building or cluster of buildings
- Antennae installation
- Developed spring
- Surface water impoundment
- All weather road (bound surface)
- Improved loose surface road (occassionally impassable to saloon car)
- Motorable track (double width)
- Motorable track (single width, saloon cars not recommended)
- Foot path or minor 4x4 track
- Powerline
- Water Pipeline (in place or soon to be constructed)

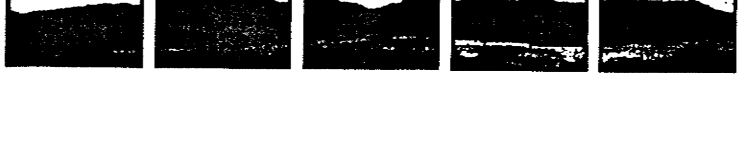
Sch........School	DHQ........District Head Quarters
Ch.........Church	Nur.........Nursery
Sh..........Shops	Mk..........Market

N

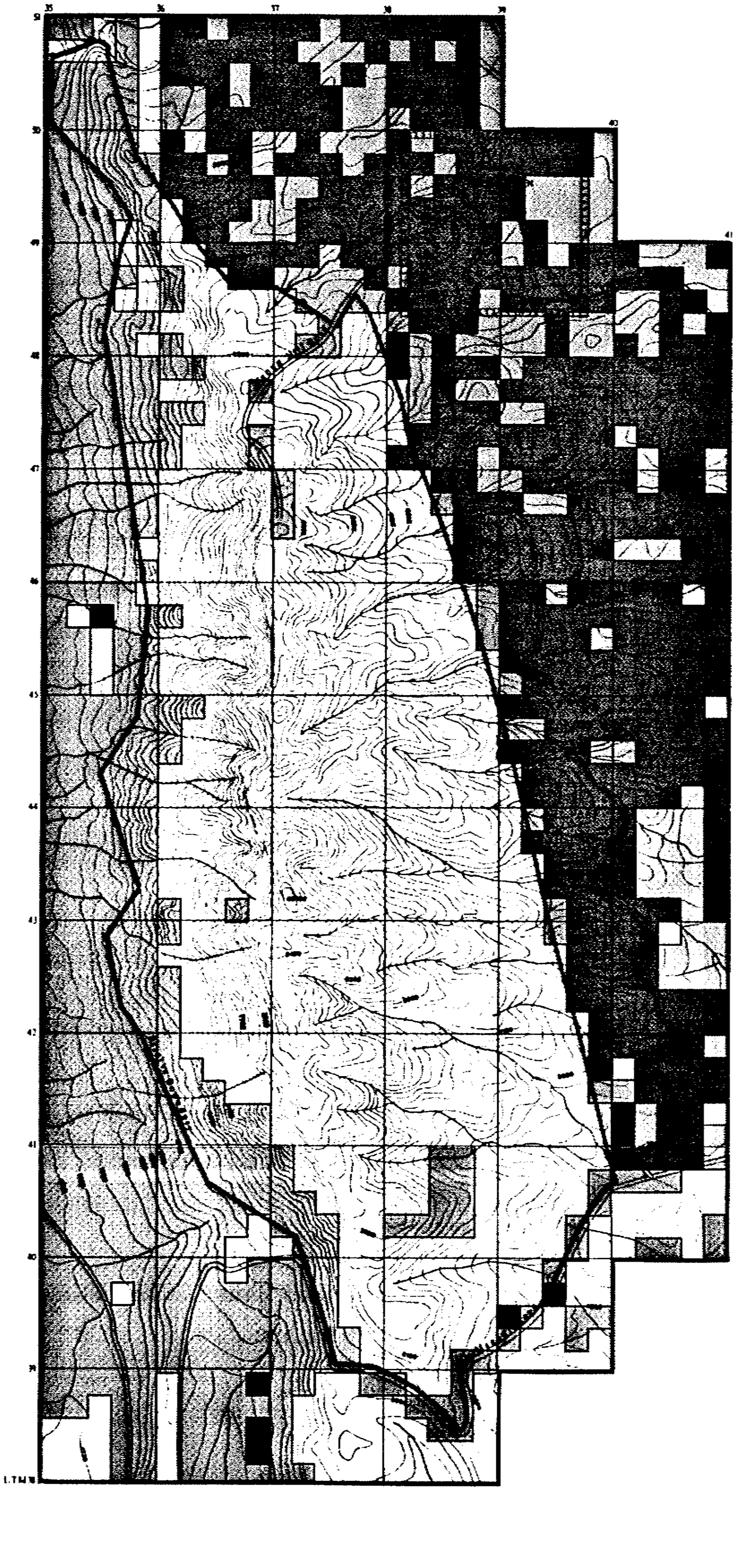
0 200 400 600 800 1000 Meters 2km

Contour Interval Equals Twenty Meters

J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



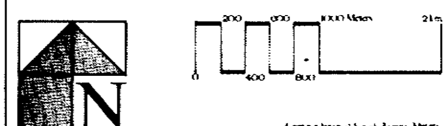
Stability Map 12

Impact on Erosion*

Legend to the Stability Classes

- Resource Consuming
- In Equilibrium - Compromise Area
- Resource Safeguarding

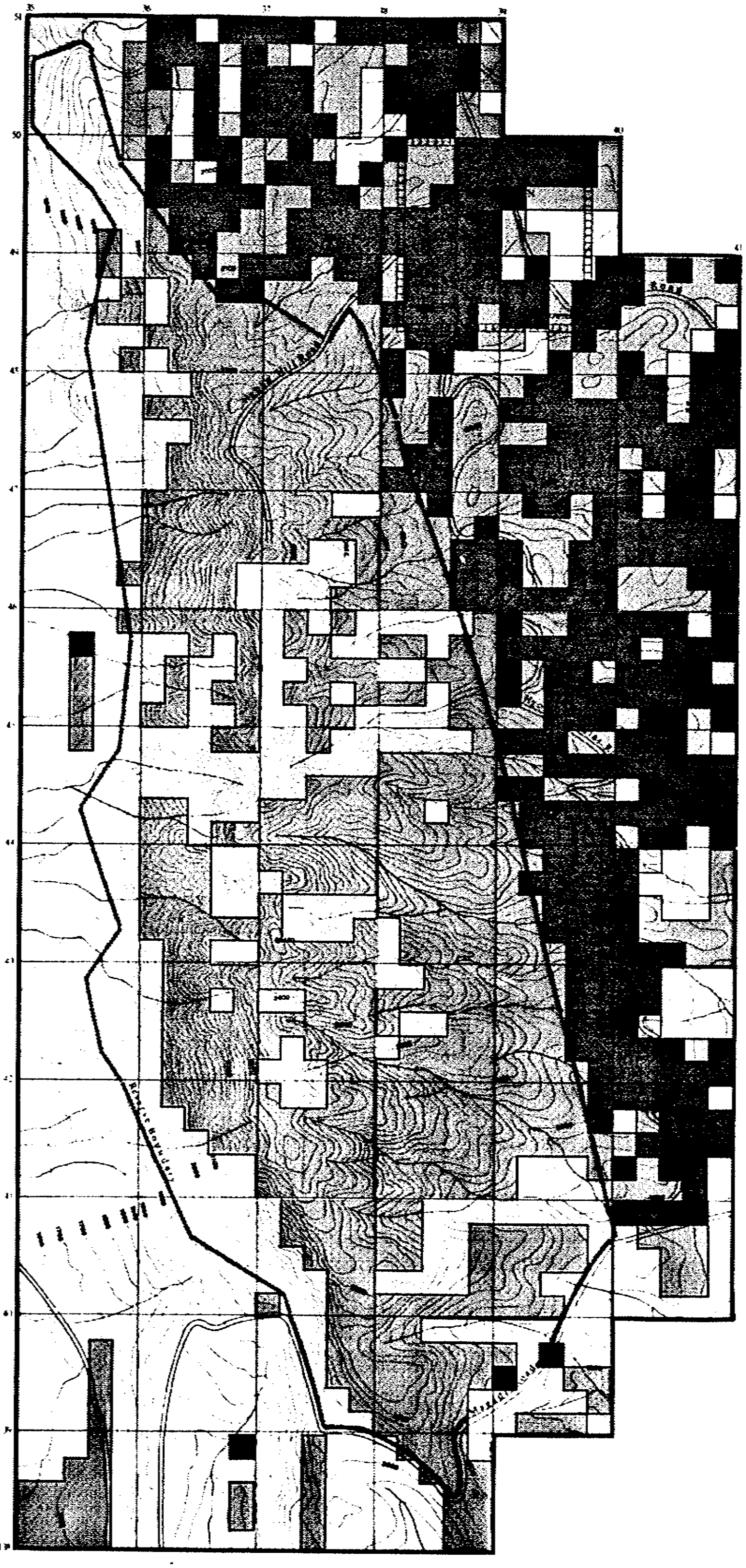
* Integration of Habitat and Land Use to yield impact on erosion



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study

RIFT VALLEY PROVINCE KENYA



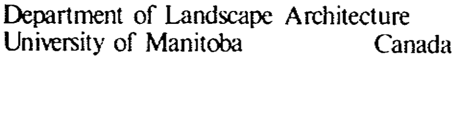
Stability Map 13

Impact on Soil Fertility *

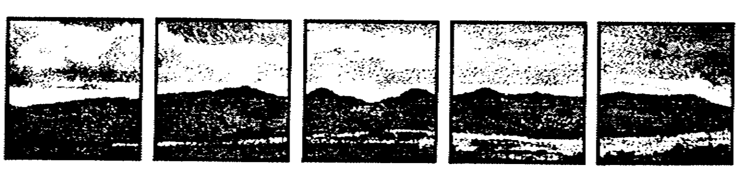
Legend to the Stability Classes

- Resource Consuming
- In Equilibrium - Compromise Area
- Resource Safeguarding

* Integration of Habitat and Land Use to yield impact on soil fertility

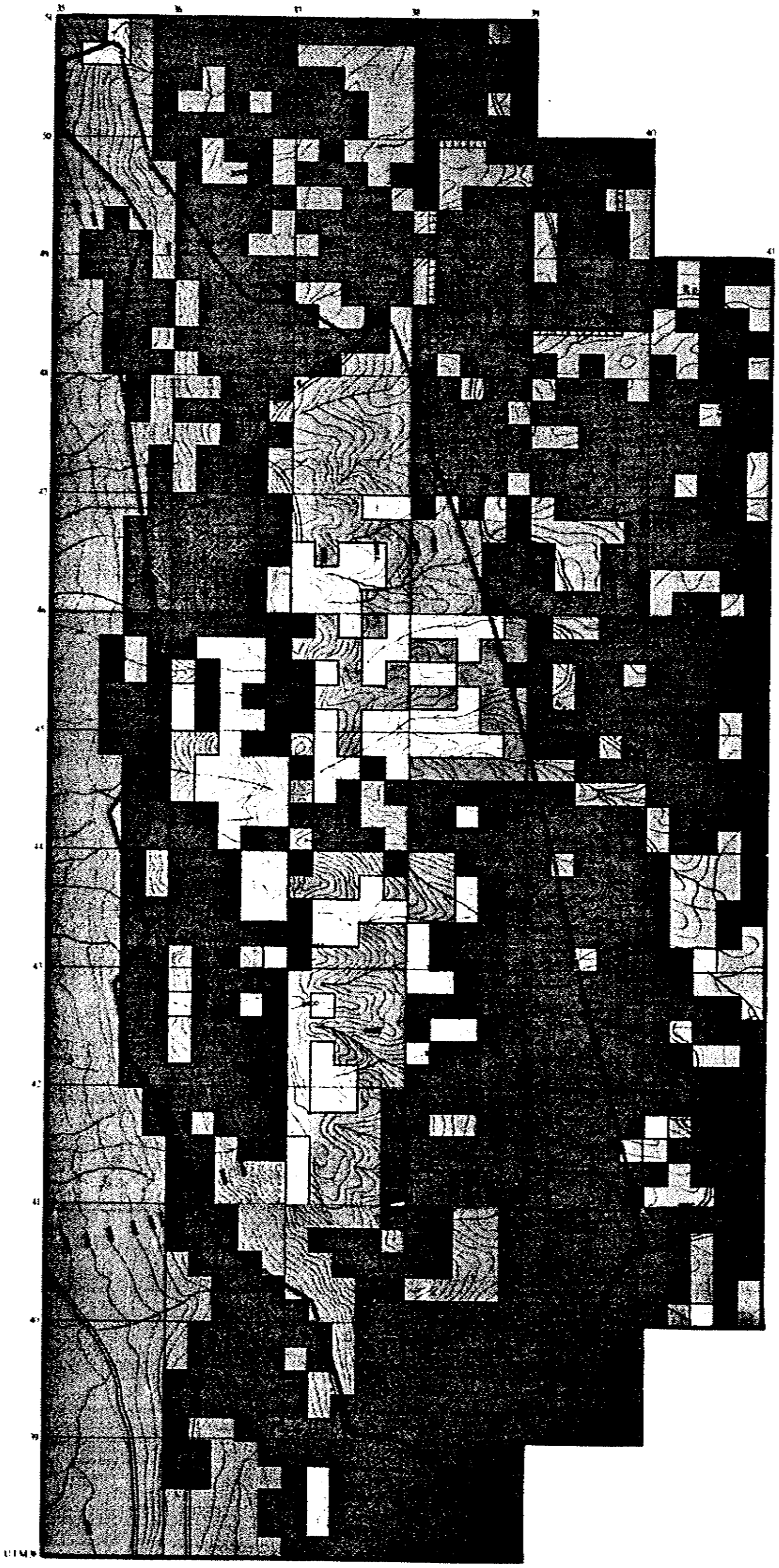


J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study

RIFT VALLEY PROVINCE KENYA



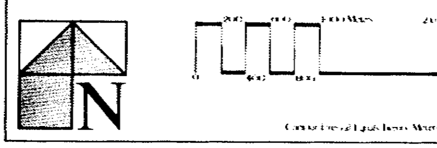
Stability Map 14

Impact on Microclimate *

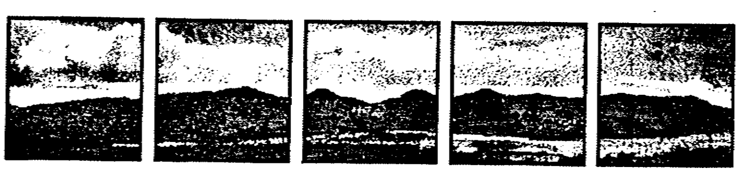
Legend to the Stability Classes

- Resource Consuming
- In Equilibrium - Compromise Area
- Resource Safeguarding

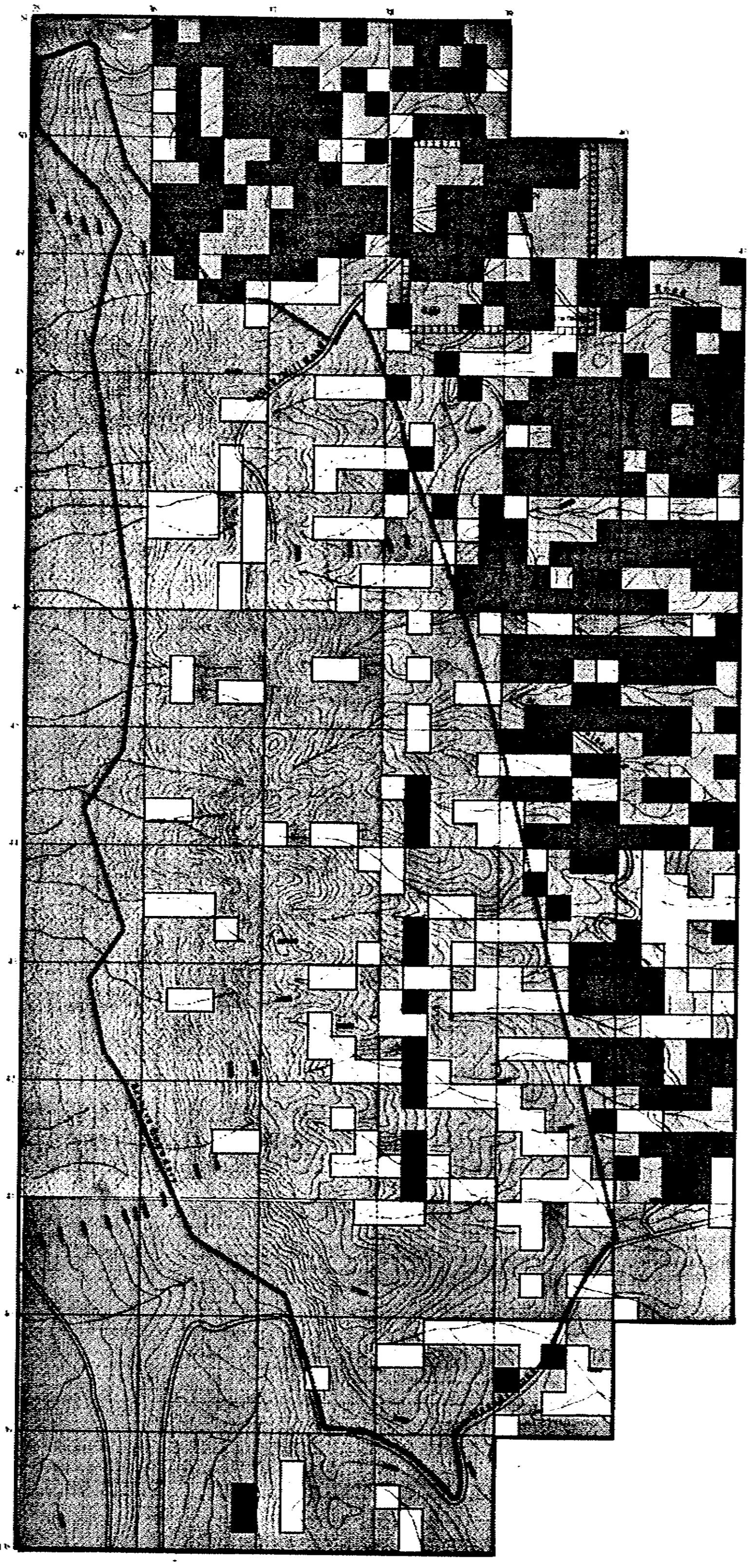
* Integration of Habitat and Land Use to yield impact on microclimate



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



Stability Map 15

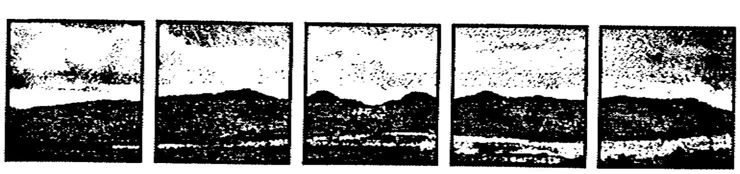
Impact on Water Availability*

Legend to the Stability Classes

- Resource Consuming
- In Equilibrium - Compromise Area
- Resource Safeguarding

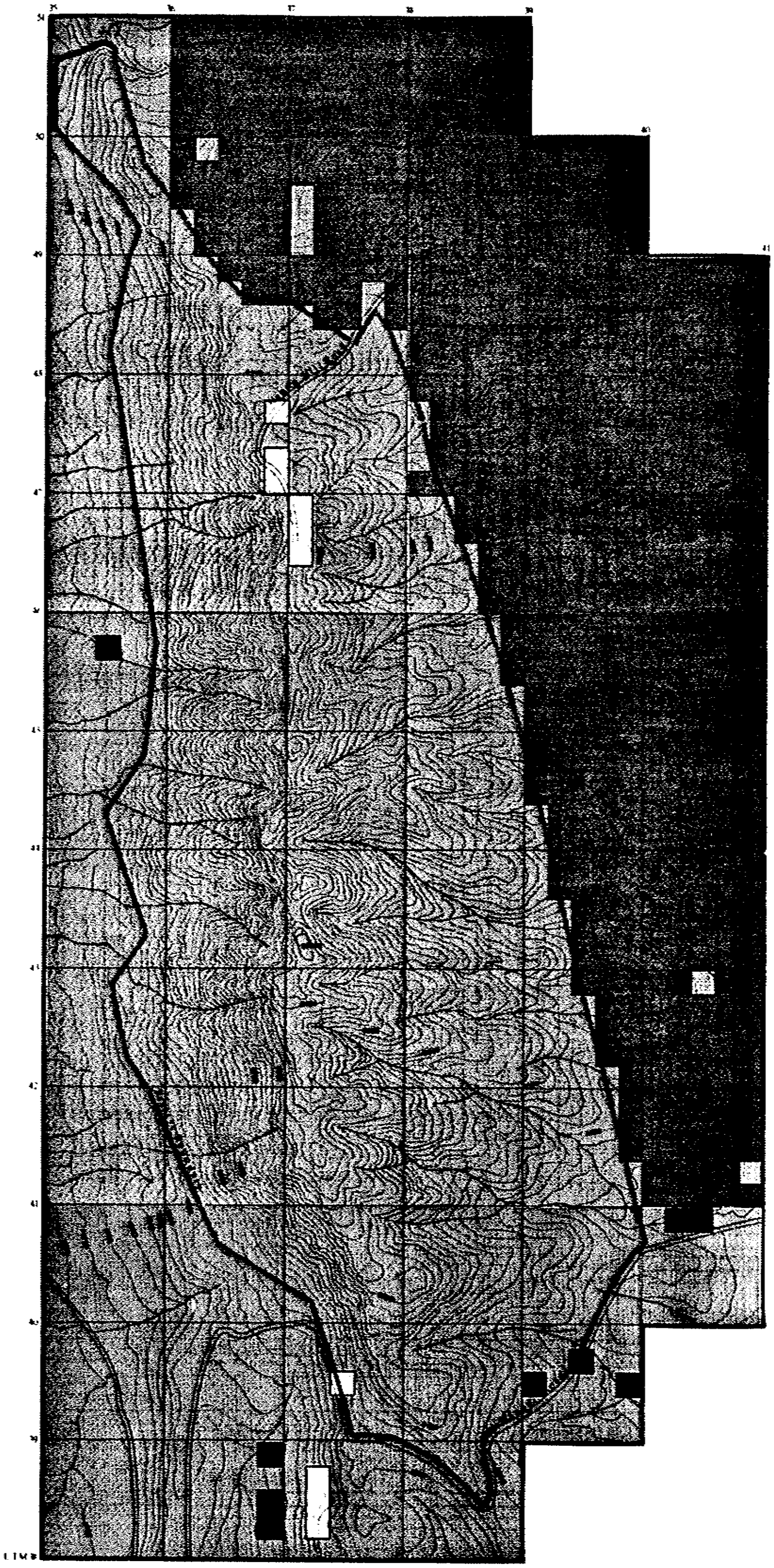
* Integration of Habitat and Land Use to yield impact on water availability

J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study

RIFT VALLEY PROVINCE KENYA



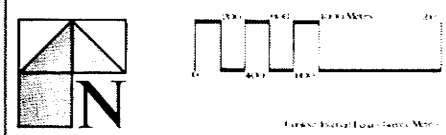
Stability Map 16

Impact on Species Diversity *

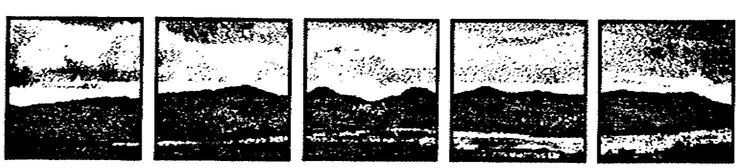
Legend to the Stability Classes

- Resource Consuming
- In Equilibrium - Compromise Area
- Resource Safeguarding

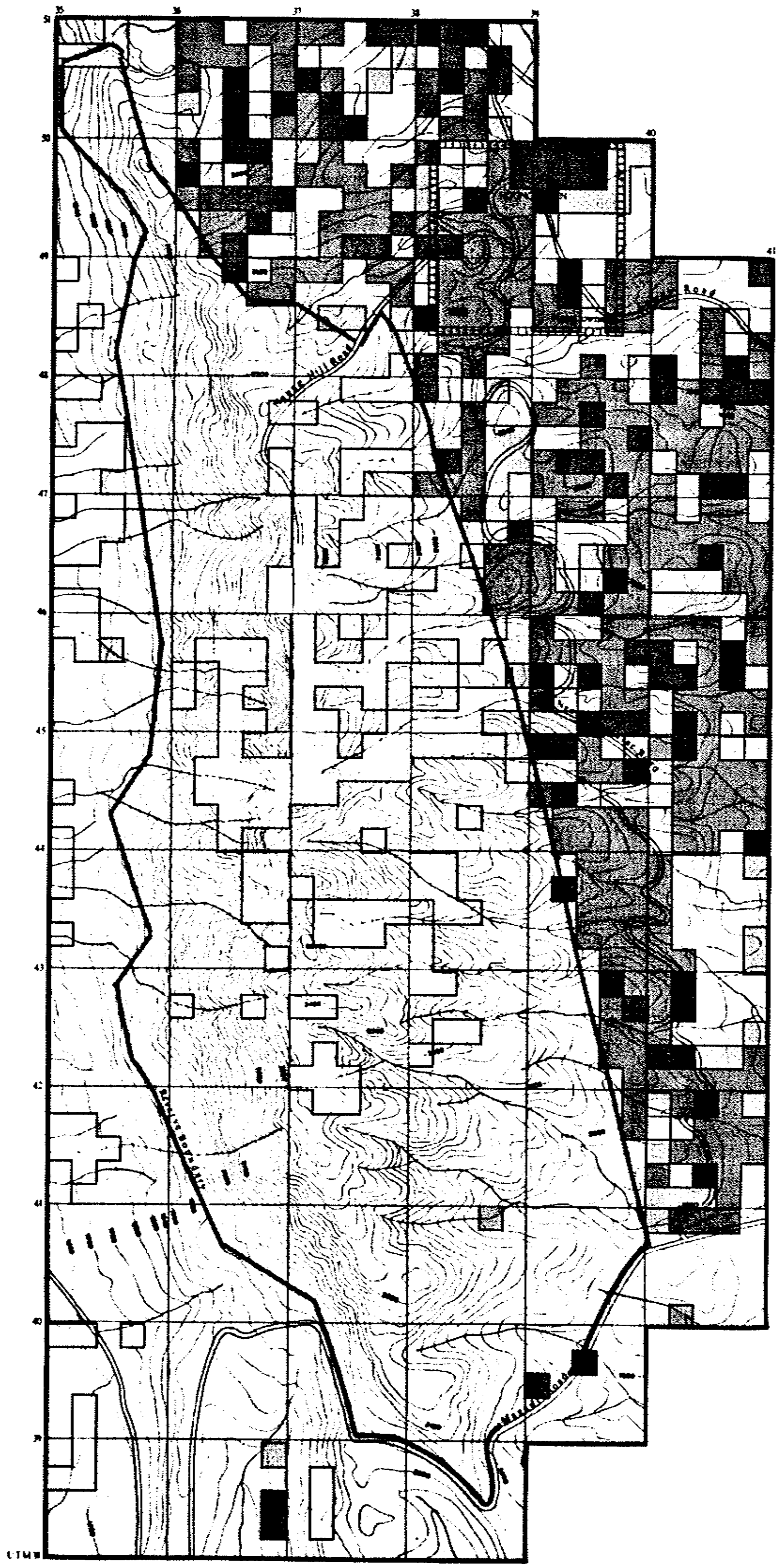
* Integration of Habitat and Land Use to yield impact on species diversity



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada



NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



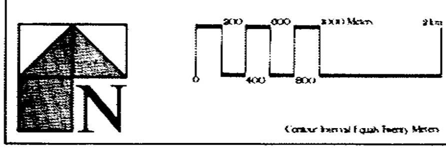
Stability Map 17

Total Impact on Primary Production

Legend to the Relative Impact Classes*

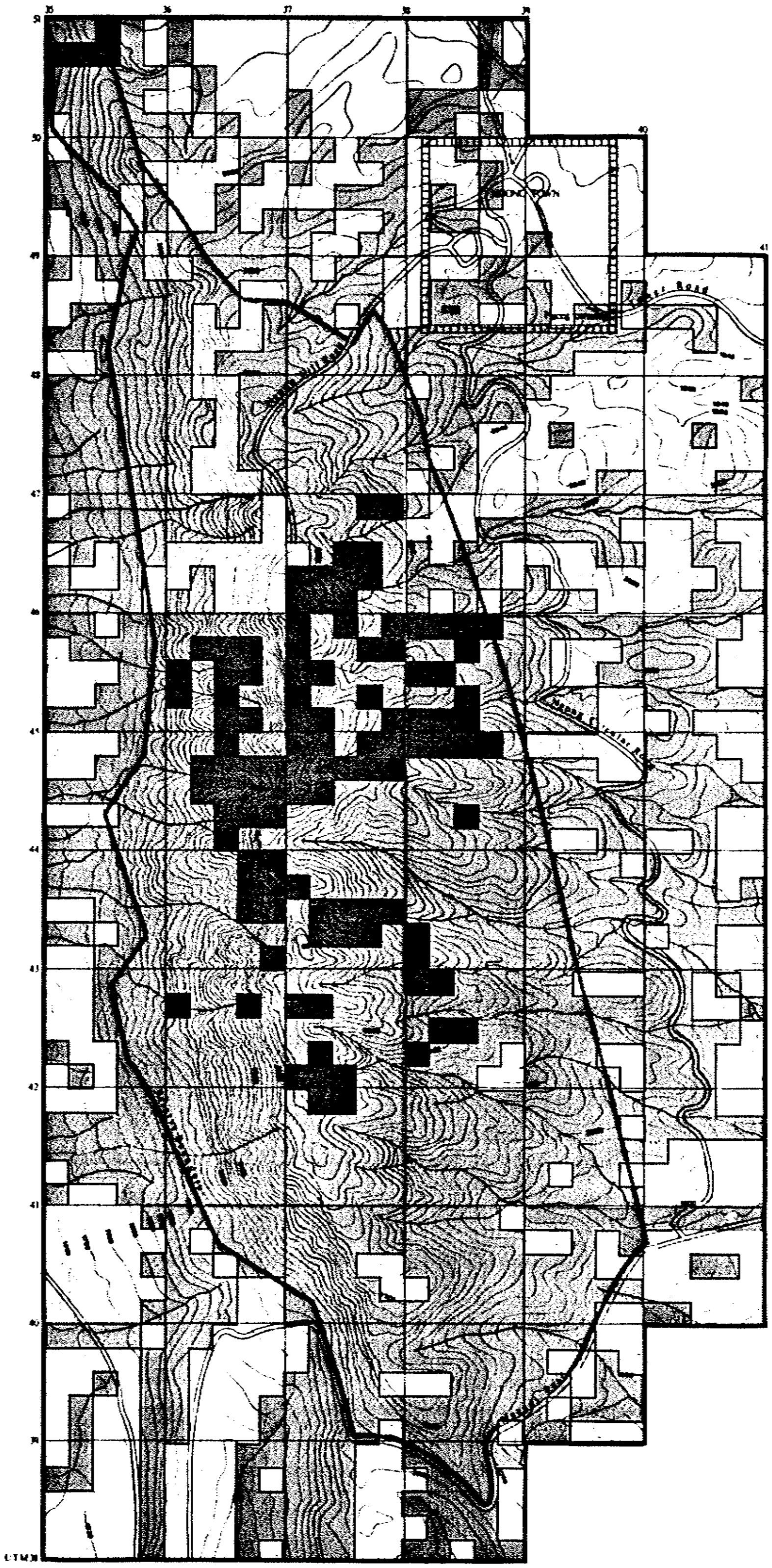
- Highest Impact
- Higher Impact
- Medium Impact
- Lower Impact
- Lowest Impact

* Refers to the impact of current land uses on the factors affecting primary production



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA



Conservation Map 18

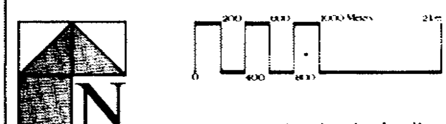
Legend to the Conservation Classes

Priority 1 - Unique or Endangered Habitats

Priority 2 - Habitats Requiring Special Management (eg. to avert soil erosion or maintain aquifer recharge)

Priority 3 - Common or Large Scale Habitats

* Integration of Habitat and Land Use to yield impact on erosion



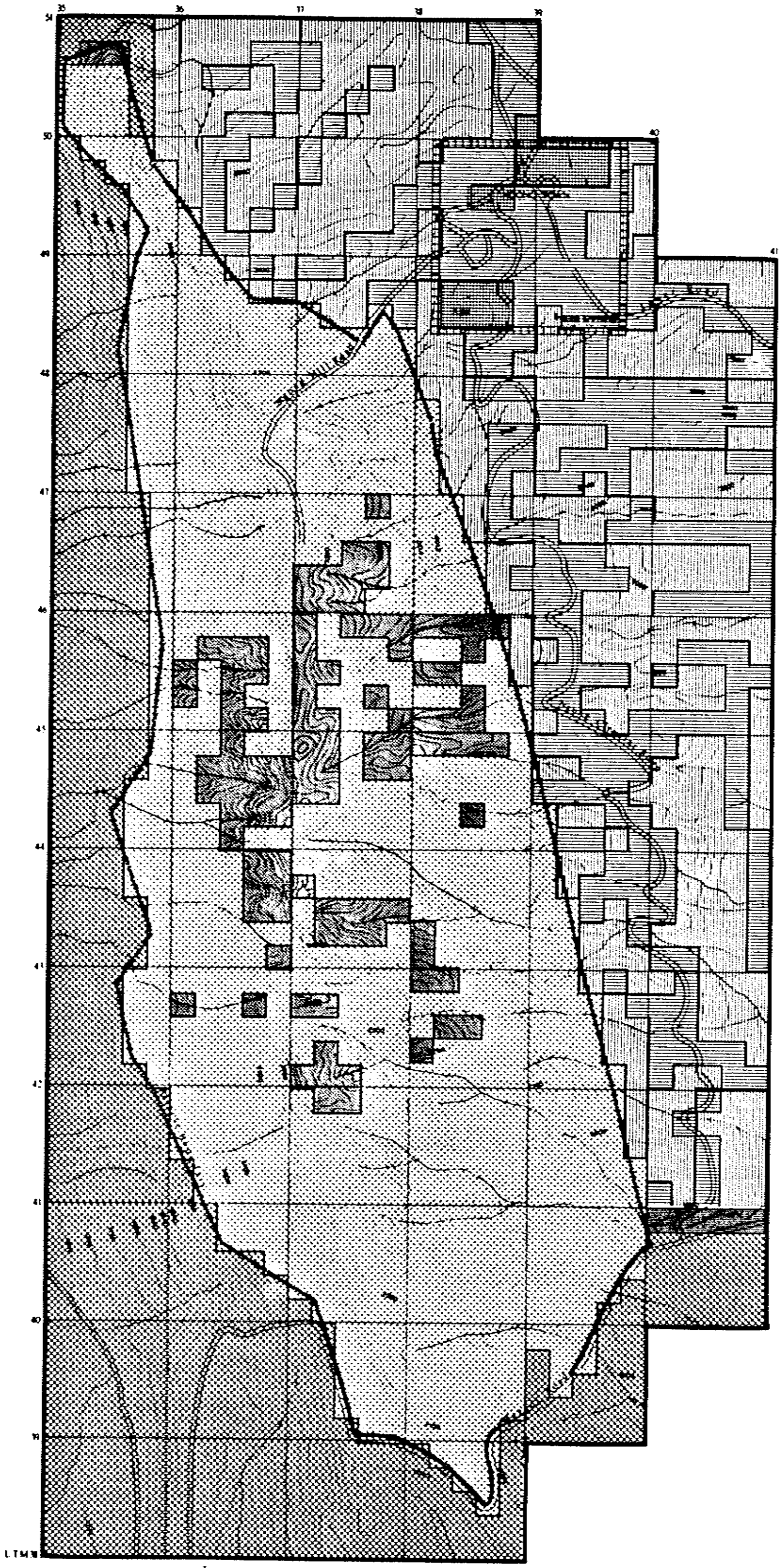
J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada





NGONG HILLS
a landscape study

RIFT VALLEY PROVINCE KENYA



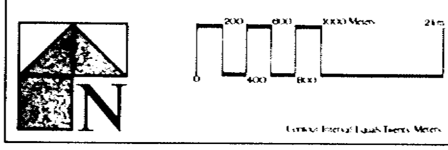
Suitability* Map 19

Prime Land Use Suitability

Legend to the Land Use Classes

- High Density Settlement
- Small Holder Agroforestry System (alley cropped annuals & cash crops, windbreaks, internal & external boundary planting, zero grazed dairy cattle)
- Small Holder Agroforestry System (as above but without zero grazing)
- Extensive Silvopastoral System
- Multiple Use Protection Forest Emphasis: Watershed & Wildlife Protection Tourism & Recreation, Light & Occassional Grazing
- Conservation

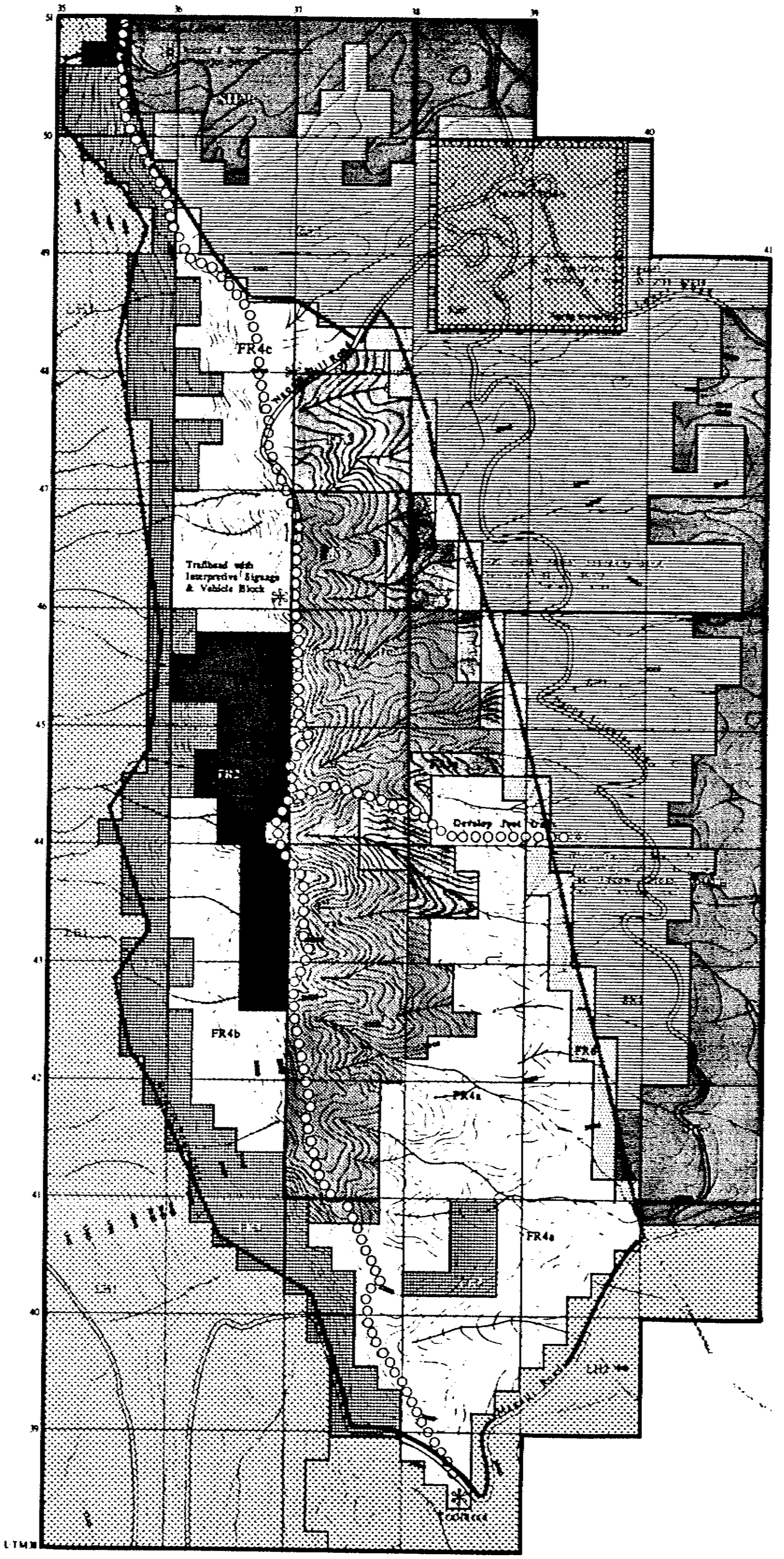
* Based on Aggregate Policy Satisfaction



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study

RIFT VALLEY PROVINCE KENYA



Management Map 20

Units of the Public Forest Reserve

FR1 — Enhancement and conservation of existing forest stands; Protection of regeneration; Rehabilitation of thickets; Total domestic grazing exclusion; Browse and wildlife habitat enhancement; Replanting to Afromontagne and Transitional Montagne species

FR2 a,b — Enhancement and conservation of existing forest stands; Protection of existing regeneration; Rehabilitation of thickets; Total domestic grazing exclusion; Browse and wildlife habitat enhancement; Replanting to Dry Montagne species

Protection of existing indigenous regeneration; harvesting of invader thickets; Replanting to Afromontagne and Transitional Montagne species; Melliferous trees forApiculture; Emergency grazing only

FR4a — Protection of indigenous vegetation and regeneration; Conversion to extensive silvopastoral system utilizing indigenous species only, All stream conveyance zones to be reforested with transitional montagne species; Melliferous trees forApiculture; Controlled grazing permitted

FR4 a,b — Protection of indigenous vegetation and regeneration; Browse and wildlife habitat enhancement utilizing indigenous species; Melliferous trees forApiculture; Domestic grazing strictly excluded

FR5 — Protection of indigenous vegetation and regeneration; Browse and wildlife habitat enhancement utilizing indigenous species, Melliferous trees forApiculture; Emergency domestic grazing only

FR6 — Communal fuel and fodder orchard; 200 meter strip on the inside of the forest boundary

Units of the Small Holder Farming Areas

Conversion to Agroforestry cropping systems; Water harvesting. Melliferous trees forApiculture; Extensive shelterbelt planting. Roadway drainage rehabilitation and planting as indicated. Further subdivision of land prohibited

Conversion to Agroforestry cropping systems; Water harvesting. Melliferous trees forApiculture; Extensive shelterbelt planting. Roadway planting as indicated; Further subdivision of land prohibited

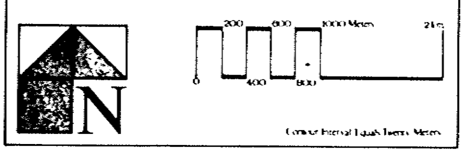
Units of the Large Holder Ranching Areas

Enhancement of silvopastoral system with browse / pasture rehabilitation, fuel and charcoaling tree species. Melliferous trees for Apiculture; Enclosed fodder orchards;Indigenous species where possible, Water harvesting; Annual cropping discouraged

Establishment of silvopastoral system using indigenous species where possible; Water harvesting

Units of Public Leasehold Land

Settlement development prohibited on Nitosolic or Luvisolic Soils; High density linear development on Ngong Road; special projects



J. Douglas Olson 1987
Department of Landscape Architecture
University of Manitoba Canada

NGONG HILLS
a landscape study
RIFT VALLEY PROVINCE KENYA

Appendix 4 Sample Data Base Print Out

RID LOCATION:386490

OIL TYPE: 15
LOPE: 19-25%
LIMATE: III-5
RAINAGE CLASS: well
HYSIOGRAPHIC SITE TYPE:1541
AND UTILIZATION TYPE: 111700

ANAGEMENT TYPE:smallholder		AQUIFER RECHARGE:	Moderate
XISTING VEGETATION:11		POTENTIAL EROSION:	Low
AND USE SYSTEM:15411117001		CONSERVATION VALUE:	Moderate
ABITAT:	1541110300	WATER ELEMENT:	Not present

ABITAT TYPE: 1541110300
AFEGUARDING EFFECT ON:

EROSION	1	WATER AVAILABILITY	1
SOIL IMPROVEMENT	1	SPECIES DIVERSITY	1
MICRO CLIMATE	3	AVERAGE VALUE	1
		TOTAL SAFEGUARD	7

AND USE SYSTEM: 15411117001

MPACT ON:EROSION	5	WATER AVAILABILITY	5
SOIL IMPROVEMENT	5	SPECIES DIVERSITY	5
MICRO CLIMATE	[illegible]	AVERAGE VALUE	[illegible]
		TOTAL IMPACT	25

NTEGRATION MODEL

EROSION	-4	WATER AVAILABILITY	-4
SOIL IMPROVEMENT	-4	SPECIES DIVERSITY	-4
MICRO CLIMATE	-2	AVERAGE VALUE	-4
		TOTAL IMPACT	-18
