ARID LAND AGROFORESTRY PRACTICES: THEIR ROLE IN RESOURCE CONSERVATION AND MANAGEMENT IN THE DAUA VALLEY, MANDERA DISTRICT, KENYA

Ahmed Maalim Mohamed

Dip. (Forestry), Bsc. (Forestry)

A Thesis submitted in partial

fulfilment of the requirements

for the degree of

Master of Philosophy in

Environmental Studies

(Biological Sciences)

School of Environmental Studies,

Moi university,

P.O. Box 3900,

Eldoret, Kenya

February, 1997

DECLARATION BY THE CANDIDATE

This thesis is my original work and has not been presented for a degree in any other university. No part of this thesis may be reproduced without the prior permission of the author and/or Moi University.

AHMED MAALIM MOHAMED — DATE 27-2-97

DECLARATION BY SUPERVISORS

This thesis has been submitted for examination with our approval University supervisors.

E.K. UCAKU-WUN — DATE 3/3/97

D.O. NYAMAI — DATE 27 Feb 1997

Moi University, Eldoret, Kenya

TABLE OF CONTENTS

TITLE PAGE i

DECLARATION ii

TABLE OF CONTENTS iii

LIST OF TABLES vi

LIST OF FIGURES. vii

LIST OF APPENDICES viii

LIST OF PLATES ix

ACKNOWLEDGEMENT x

DEDICATIONS xi

ABSTRACT xii

CHAPTER ONE 1

1. INTRODUCTION 1

CHAPTER TWO 6

2. THE STUDY AREA. 6
- 2.1 Geographical location and size 6
- 2.2 Climate 6
- 2.3 Geology. 8
- 2.4 Relief and drainage 9
- 2.5 Soils. 10
- 2.6 Flora and fauna 10
- 2.7 Socio-economic condition 11
- 2.8 Land use systems 11
  - 2.8.1 Agriculture 11
  - 2.8.2 Livestock 12
  - 2.8.3 Forestry 12

CHAPTER THREE 14

3. LITERATURE REVIEW 14
3.1 ARID LANDS 14
3.1.1 Definition 14
3.1.2 Landforms and soils 15
3.1.3 Flora 16
3.1.4 Agriculture 17
3.2 RELATIONSHIP BETWEEN VEGETATION AND LANDSCAPE CHARACTERISTICS 18
3.3. AGROFORESTRY 20
3.3.1 Definition and scope 20
3.3.2 Agroforestry practices 22
3.3.3 Uses of multipurpose trees and shrubs 24

CHAPTER FOUR 26

4. MATERIALS AND METHODS 26
4.1 PRE-FIELD STAGE 26
4.2 FIELD STAGE 26
4.3 POST FIELD STAGE 31

CHAPTER FIVE 34

5. RESULTS AND DISCUSSIONS 34
5.1 AGROFORESTRY (AF) PRACTICES 34
5.1.1 Horticultural trees on farmlands 50
5.1.2. MPTs for river bank stabilization 52
5.1.3. Border planting with MPTs 57
5.1.4. Silvopastoral practices of MPTs mixed with pastures "Sharmat or Sakar" 58
5.1.5 Shade MPTs on farmlands 65
5.1.6 Live fences and hedges on farmlands 67
5.1.7 Traditional bush fallow 69
5.1.8 Apiculture with MPTs 71
5.1.9 MPTs for herbal medicine 78
5.1.10 MPTs for Ornamental and grave yards 78
5.1.11 MPTs in Rangelands 79
5.1.12 MPTs in soil conservation and on degraded sites 81
5.1.13 Fruit trees and nappier grass mixture 87
5.2: THE DISTRIBUTION OF MPTs BASED ON LANDSCAPE CHARACTERISTICS 88

5.3 USES OF THE MULTIPURPOSE TREES AND SHRUBS OF THE DAUA VALLEY 99

CHAPTER SIX 110

6. CONCLUSIONS AND RECOMMENDATIONS. 110
6.1 CONCLUSIONS 110
6.2 RECOMMENDATIONS 111

REFERENCES 118

LIST OF TABLES

Table 5.1: The main agroforestry practices in the Daua Valley, Mandera District 35

Table 5.2: Distribution of MPTs at sites S1 to S6 in Khalaliyo-Fiqho area, Mandera District. A summary of 90 quadrats. 44

Table 5.3: Distribution of MPTs at sites S1 to S6 in Rhamu-Galicha area, Mandera district. A summary of 90 quadrats. 47

Table 5.4: The main self groups in Central and Rhamu areas, Mandera District that were studied. 83

Table 5.5: The dominant soil and topographic characteristics of the Daua Valley, Khalaliyo-Fiqho area, Mandera District. 89

Table 5.6: The dominant soil ad topographic characteristics of the Daua valley, Rhamu-Galicha area, Mandera District 90

Table 5.7 Duncan's multiple range test comparing slope gradient (%) and EC with respect to the number of species, Rhamu-Galicha area, Mandera District . . . 95

Table 5.8: Duncan's multiple range test comparing slope gradient and EC with respect to the number of trees and shrub species, Khalaliyo-Fihqo area, Mandera District96

LIST OF FIGURES

Figure 2.1: Project study area. 7

Figure 4.1: Sketch of the location of transects and quadrats. 27

Figure 5.1: Schematic representation of the Daua Valley with the main agroforstry and landscape characteristics. 39

Figure 5.2: Sketch of general land use on farmlands along the River Daua, Mandera District. 53

Figure 5.3: The structure of *T. danis* - *I. schimperii* MPTs community along the bank of the River Daua (S1) in Rhamu-Galicha area, Mandera District. . . 55

Figure 5.4: The structure of *H. compressa* - *T. danis* MPTs community along the bank of the River Daua (S1) in Khalaliyo-Fiqho area, Mandera District. . . 56

Figure 5.5: The structure of *A. refeciens* - *T. danis* MPTs community one km from the River Daua (S2) in Rhamu-Galicha area, Mandera District. 59

Figure 5.6: The structure of *A. seyal* - *A. paolii* MPTs community one km from the River Daua (S2) in Khalaliyo-Fiqho area, Mandera District. 60

Figure 5.7: The structure of *A. refeciens* - *C. quercifolia* MPTs community two km from the River Daua (S3) in Rhamu-Galicha area, Mandera District. . 63

Figure 5.8: The structure of *A. refeciens* - *C. quercifolia* MPTs community two km from the River Daua (S3) in Khalaliyo-Fiqho area, Mandera District.. 64

Figure 5.9: The structure of *A. refeciens* - *C. quercifolia* MPTs community three km from the River Daua (S4) in Rhamu-Galicha area, Mandera District. . 72

Figure 5.10: The structure of *B. neglecta* - *A. refeciens* MPTs community four km from the River Daua (S5) in Rhamu-Galicha area, Mandera District 73

Figure 5.11: The structure of *A. horrida* - *C. quercifolia* MPTs community five km from the River Daua (S6) in Rhamu-Galicha area, Mandera District. 74

Figure 5.12: The structure of *I. spinosa* - *E. cuneata* MPTs community three km from the River Daua (S4) in Khalaliyo-Fiqho area, Mandera District.. . . . 75

Figure 5.13: The structure of *I. spinosa* - *C. gracilispina* MPTs community four km from the River Daua (S5) in Khalaliyo-Fiqho area, Mandera District. 76

Figure 5.14: The structure of *I. spinosa* - *C. gracilispina* MPTs community in five km from River Daua (S6) in Khalaliyo-Fiqho area, Mandera District . . . 77

LIST OF APPENDICES

Appendix I: Slope gradient determination 128

Appendix II: Determination of soluble of salts by electrical conductivity 129

Appendix III: Determination of pH of soil suspensions 130

Appendix IX: Measurement of organic matter in soils 131

Appendix V: Particle size analysis (texture) using the mechanical analysis - hydrometer method 132

Appendix VI: Site class terminology for particles larger than 2mm 134

Appendix VII: Soil depth classes 135

Appendix VIII: Soil drainage classes 136

Appendix IX: Useful trees and shrubs of the Daua Valley 137

LIST OF PLATES

Plate 5.1: Cattle grazing in farmland along the River Daua after maize harvest; Central Division, Mandera District.. 38

Plate 5.2: Carrots are some of the many off-season crop species grown through irrigation along the River Daua, Central Division, Mandera District. . 41

Plate 5.3: Mixed fruit MPTs of *Annona cherimoya*, *Mangifera indica* and *Psidium guajava* on farmland along the River Daua, Central Division, Mandera District. 51

Plate 5.4: MPTs deliberately retained by farmers along the Daua River for bank stabilization, Central Division, Mandera District.. 54

Plate 5.5: Camel browsing on *Salvadora persica* in "Sharmat" /pasture, Central Division, Mandera District. 61

Plate 5.6: Shade tree (*Trichilia ementica*) on farmland along the River Daua, Central Division, Mandera District.. 66

Plate 5.7: Naturally growing MPTs for live fence on farmland; Central Division, Mandera District.. 68

Plate 5.8: Traditional bush fallow (grass) on farmland; Central Division, Mandera District. 70

Plate 5.9: Shaded tree nursery (Rural Village Afforestation Group nursery); Central Division, Mandera District.. 84

Plate 5.10: MPTs for soil conservation and on degraded sites; Central Division, Mandera District. The species are *P. juliflora*, *S. siamea* and *M. oleifera*. 86

Plate 5.11: *Tamarix aphylla* with *Echinocloa haploclada* grass for river bank stabilization along the Daua River, Central Division, Mandera District.40

Plate 5.12: *Delonix baccal* in association with *E. cuneata*, *Acacia* spp. and *C. albidus*, Galicha area, Rhamu/Ashabito Division, Mandera District. 145

Plate 5.13a: Preparation of "asal" wood preservative. It is boiled with water and frequently mixed for about 30 minutes. 153

Plate 5.13b: The application of "asal" wood preservative to poles for local houses construction. The broom which is used as a brush is made of Doum Palm. 154

Plate 5.14: Root tubers and reproductive parts of *Hydnora* sp. (Hydnora root parasite) that grows in association with roots of *Acacia* and *Commiphora* spp. 163

ACKNOWLEDGEMENT

Special, sincere and kind thanks goes to my supervisors, Dr. E. K. Ucakuwun and Dr. D.O. Nyamai for their kind and tireless guidance, valuable suggestions and helpful criticism during this study. I will always have an everlasting appreciation.

This study was financed by the Royal Netherlands Government through the School of Environmental Studies for which I am very grateful. Similar thanks goes to KEFRI who accorded me study leave to undertake the M. Phil. studies.

The task for the M. Phil. was not easy to complete without the assistance of my friends, lecturers, relatives, colleagues and well wishers whom I cannot name all here. I thank them for their contribution to this thesis directly or indirectly.

Galaxy of kind appreciation goes to the following for their constant advice, encouragement and comments whenever necessary: Hassan A. Sheikh, Prof. P. Jungerius, Dr. J. Odera, Prof. M. Tole, Dr. W. Yaban, Prof. T. Dietz, Prof. S. Keya, Prof. E. Standa, Prof. F. Sang, Prof. Maleche, Prof. T. Sharma, Prof. Anwar-Ulhaq, Prof. D. Otieno, Prof. C. Okidi, Prof. J. Redhead, Dr. P. Konuche, Dr. B. Kigomo, Dr. S. Dima, Dr. B. Wangila, Dr. L. Wario, Dr. D. Odee, Mr. G. Oba, Dr. H. Kojwang, Dr. M. Kibe, Mr. Hussein O., Mr. K. Orwenyo, Mr C. Nyagot, Mr. P. Juma, Mrs Jacinta N., Mrs. Sikuku C., W. Atie, Mr. Abdirazak A., Mr. Suleiman S., Mr. Lubira and all the staff and students of the school of Environmental studies.

I am grateful to the following who made my field work easy: My research assistant Mohamed Aden; my brothers Yussuf, Hussein and Jinow; Hussein Abdullahi, Abdirashid Ali and A.M. Abdille of Khalaliyo primary; Ibrahim Mohamed of Bur Abor primary and Muktar Daud of Yabicho Primary schools. Thanks to the D.C, D.Os, Chiefs and Assistant chiefs in the study area.

Kind thanks to the collaborative and educative farmers, pastoralists, members of the various afforestation groups and the parataxonomists. Thanks to the nomadic camel caravan who assisted in transporting my soil samples from Galicha to Rhamu. Grateful thanks goes to all the staff of the Departments of agriculture, Meteorology, Forestry, Agriculture, livestock and Emergency Drought Recovery programme. The NDVI data was provided by the noble DRSRS with the courtesy of Nicholas Ganzin. Kind thanks to him and D. Githinji. I am very grateful to the East African Herbarium staff especially Mr. Magogo and Mr. Muasya and to Mr. Mumiukha of Egerton University who helped identify some of the unknown species. I am greatly indebted to KEFRI for giving me access to the soil laboratory to analyse more than 50 Kg of soil. Thanks to Dr. Nyamai and D. Kamau who facilitated the laboratory work. To the staff of the laboratory, sincere thanks especially to Mbuthia, Omolo, Jack, Kamau and Arek among the many.

I wish to thank ICRAF, KEFRI, Moi University, SES, KSS-NAL, Nairobi University and the British Council for giving me access to their libraries. Thanks to all who took their time to read this thesis and to those I referred.

kind words goes to my parents, mother Medina Sheikh (who educated me with firewood); father Maalim Mohamed; uncles Mohamed Ibrahim, Mohamed Yerrow, Adan Haji, Ali Ibrahim and Cousins Abdullahi, Abass, Kalthuma, Issack, Kassim, Adan Zulu and Adan Bare for their constant encouragement. Last but not the least, I am most gratefully indebted to my wife Ramla Maalim and son Muhammad for their love, endurance and patience throughout my studies.

The thesis is a product of many noble brains and hands but the ultimate decision has always been mine and any errors or omissions are my own.

DEDICATIONS

To all Environmental Scientists of the Royal Netherlands and East Africa, not forgetting all those who are in the front line championing the adoption of agroforestry technologies in Africa south of Sahara.

ABSTRACT

Agroforestry is a traditional practice in the Daua Valley, Mandera District and yet very little effort has been made to document it. This problem has contributed to a significant gap in knowledge resulting in retarded development of improved agroforestry technologies for the area. Consequently, little is known of the useful woody components of the Valley and their habitats which is of crucial importance as increase in livestock and human population combined with change in the way of life is causing their erosion. Furthermore, the indigenous knowledge of the farmers and pastoralists have recieved little attention in the planning process and development of land use strategies by development agencies. The implication of the above constraints is that the use of this valley's land and vegetation resources without adequate knowledge may subject their continued use to abuse by the indigenous population, refugees as well as development agencies. One of the strategies for vegetation conservation in the area lies with the documentation of the knowledge of the user groups in retaining or/and planting useful trees and shrubs in farms and pastures. The study was conducted to understand the relationship between the existing agroforestry practices and vegetation conservation and how the resources vary with landscape characteristics in order to develop resource data base for the Daua Valley.

The study was undertaken by carrying out reconnaissance and farm surveys and line transects (5 km each in a 75 km^2 area) in Rhamu/Ashabito and Central/Khalaliyo Divisions, respectively. The bio-physical and socio-economic parameters (soil, gradient, vegetation species and their distribution and land use practices) were taken in the field. Soil samples were collected for further analysis for physical and chemical properties. The distribution of woody vegetation was compared to landscape characteristics (using multiple regression) and the agroforestry practices. The study also examined the general condition of the vegetation using normalized difference vegetation index and the method of important value index was employed to determine the dominant indigenous species. Further details regarding the utilization of the local species were obtained from parataxonomists (local experts), farmers and pastoralists.

The vegetation distribution trend is strongly influenced by topography. The uplands, midlands and lowlands were mainly covered by deciduous vegetation except for evergreen riparian woodlands along the river. The study further noted that 13 agroforestry practices were dominant in the valley. Generally silvopastoral practices of agroforestry were common. However in the area immediately bordering the river, multipurpose trees and shrubs for river bank stabilization and horticultural trees in farmlands were popular.

The study also established that traditional agroforestry practices had more species diversity and better vegetation cover than the introduced ones. The over 100 species identified provided productive and protective uses and their distribution within the valley was affected the combined factors of human influence and landscape characteristics of slope gradient and soil physical and chemical properties. The ecologically and economically important species within the valley were mainly *Thespesia danis*, *Hyphaene compressa*, *Lawsonia inermis*, *Mangifera indica*, *Psidium guajava* and *Acacia seyal* in the lowlands; *Acacia refeciens*, *Cordia quercifolia* and *Boswellia neglecta* in the midlands and uplands.

Finally, this study would like to emphasize the importance of involving the local people and utilizing their knowledge particularly in the process of developing improved land use practices through the use of agroforestry technologies for soil, water and vegetation conservation.

CHAPTER ONE

1. INTRODUCTION

Aridity is a term which is easy to understand but difficult to define in precise terms. The backbone of the present internationally accepted definition of arid lands was developed by Meigs (1953). He used Thorthwaite's (1948) concept to develop an aridity index to divide arid regions into hyper-arid, arid and semi-arid. The aridity index (AI) is calculated as the ratio of precipitation (P) and potential evapotranspiration (PET). AI values modified by UNEP (1992) of < 1.0 indicates annual moisture deficiency. Hyper-arid areas (desert) have an AI of < 0.05, arid ranges from 0.05 to 0.2, and semi arid of 0.2 to 0.5. Global coverage of arid lands is 37.3%. For Africa this is 56.96% (UNEP, 1992). Even in sub-Saharan Africa, large parts are arid. One of the most important natural resources in arid areas is vegetation.

Flora of arid lands are dominated by sparse and specialized plants of thorny and succulent xerophytic trees, shrubs and grasses. The vegetation resource is fragile due to the extreme variability of the climate that has low rain fall and high temperatures. This means that if the vegetation is not rationally utilized, the area will become a desert (Amuyunzu, 1988). The natural resources of the arid lands support 281.23 million people in the world, out of which arid lands of Africa accommodates 108 million (UNEP, 1992). Since the mid 1970s, population growth rate has exceeded 3% per annum in half of the 34 predominantly dry countries (Kenya being one of them). This increase in population causes land degradation (Grainger, 1990) and reduces land available for nomadic pastoralism, hence encourages sedentarization and degradation of the environment. At the same time increase

in population especially in the limited humid areas of Kenya is forcing people to settle in the fragile arid areas.

Kenya's arid and semi arid environment covers 83% of the total land surface (Muchena and Pouw, 1981). It supports approximately 50% of the livestock population and 20% of the Kenyan population. Mandera is one of these districts. The fragile environment of Mandera is being degraded by inappropriate agricultural activities and an ever increasing population of human and livestock in the last two decades.

Land use in arid lands for agriculture is limited by shortage of water. Rain-fed agriculture with drought resistant crops is possible by run-off harvesting. The dominant land use in Mandera is silvopastoral in nature which covers about 98% of the land, and is supplemented by agriculture in the remaining 2% of the land, especially along the River Daua. The main crops are maize, bananas, goose necked sorghum and cowpea. The farms have multipurpose trees and shrubs (MPTs) which have been planted or left deliberately, hence the existence of agroforestry practices in the district. In arid environment, trees and shrubs are important economically. They are exploited for fodder, fuelwood, building material, food for human, handicraft material and medicine for man and livestock (Amuyunzu and Oba, 1991). In recent times agroforestry practices have been diversified especially along the River Daua, mainly in Central and Rhamu Divisions.

Rhamu and Central Divisions are settled by pastoral Somalis. Nomadism has been adopted as a survival strategy to ensure optimum utilization of the available resources. Traditionally they move about with their mobile houses and only require fencing material for their livestock enclosures against wildlife predators. Before the 1960s fuelwood use was restricted to dry parts and it was a taboo to cut living MPTs for firewood. Fire is

needed to roast and boil meat, give warmth, reading Quranic tablets and roasting beverages like coffee beans and those made of milk plus twigs and barks of trees like *Boswellia microphylla* and *Commiphora pseudopaolii*. During the dry seasons some of the nomads used to clear a small portion of land with clayey soils so as to grow sorghum after which the site is abandoned (a restricted type of shifting cultivation).

The arrival of the Colonial Government did not affect the way of life of the Somalis. Their constant movement combined with rare use of living trees and shrubs, meant that pressure on woody plants was minimal. However, series of man made and natural disasters have changed this environmentally conscious resource management practice. These are:

(a) The civil "Shifta" wars and the droughts of the 1960s forced people to settle in central places especially in a zone of 1 to 5 Km width along the River Daua.

(b) The settled part of the community concentrated on the clearing of the natural vegetation along the river for farming, planting mainly maize and sorghum which requires wood for cooking. The clearing has exposed large tracts of the river bank to erosion, threatening its existence in the long run.

(c) The district's human population increased between 1969 and 1993 from 95,000 to 131,757; and livestock population (estimate) increased from about 360,000 to nearly 900,000 from 1978 to 1993 (GoK, 1994). The increase of human and livestock populations around the remaining indigenous vegetation in Mandera is threatening its existence. This process leads to a more serious problem of species erosion and desertification. The conflicting demands of agriculture on one hand and the pastoral land use on the other are threatening the survival of the Daua ecosystem which if otherwise is properly managed has

vast potential for sustainable multipurpose uses.

(d) The subsequent droughts of 1970s and 1980s have made the provision of food relief an almost permanent feature in Rhamu and Mandera. The former settlements in the meantime have grown to large permanent towns, for example Rhamu and Mandera.

(e) Influx of refugees from Somalia and Ethiopia in the late 1980s and early 1990s further accelerated clearing of MPTs to provide the urgently required fuelwood, shelter and generation of income.

These demographic changes in the district have lead to reduction in MPTs layers especially around settlements. From Mandera town, it will now take 5-7 days for donkey cart to fetch firewood. Since these changes are still taking place in Rhamu and Central Divisions, there is urgent need to conduct studies on vegetation resource assessment and relate them to human influence and land scape characteristics.

Little effort has been made to document the existing agroforestry practices because research institutions have often justified their absence by citing inaccessibility and insecurity in northern Kenya (Nunow, 1994); yet the practices are economically and ecologically useful to the people, livestock and the environment of Mandera, forming a unique land use system comparable to that of the River Tana. Indeed the Daua River is the bloodline of the district's human, livestock and wildlife population. This problem has contributed to the retarded development of appropriate agroforestry technologies for the area. Consequently, the exploitation of the MPTs of the Daua Valley and its surroundings by the indigenous population, refugees and development agencies without adequate knowledge of the type of species, their requirements, uses and management by farmers and pastoralists may subject their continued use to abuse. The selection of potential species for

possible improvement and development within a particular ecological and economic niche can only be carried out successfully when based on adequate information (FAO, 1988a).

This study was conducted from August 1994 to May 1995 in Central and Rhamu Divisions, Mandera District focusing on the development of a resource data base for future agroforestry research. The divisions are the most deforested part of the Daua Valley and with one of the most diverse agricultural practices. In addition to the reconnaissance and farm surveys conducted on the area's farmlands, an area of 75 Km^2 in each of the two divisions were studied to understand the influence of the landscape characteristics on the distribution of the indigenous MPTs. The specific objectives of the study were:

1. To determine the agroforestry practices in the River Daua Valley and its surroundings
2. To study the relationship between the different agroforestry practices and their role in resource conservation and management
3. To study the distribution of the MPTs as affected by landscape characteristics
4. To study the uses of the MPTs in the Daua Valley.

CHAPTER TWO

2. THE STUDY AREA

2.1 Geographical location and size

Mandera is one of the three districts in North Eastern Province, the others being Garissa and Wajir. It lies between latitude 2° 11' to 4° 17' North and longitude 39° 41' to 41° 57' East and shares international boundaries with Ethiopia to the North and Somalia to the West and South west. Mandera lies about 1200 Km north east of Nairobi (Fig.2.1).

The district covers an area of 26,470 Km^2. It has six administrative divisions: Rhamu/Ashabito, Central/Khalaliyo, Takaba, Fino, Banissa and Elwak. The research was conducted in Rhamu/Ashabito and Central/Khalaliyo.

Communication in the area is by road, air, telephone and foot. The roads are earth with few murrum parts. There is a daily air flight that connects the area with Nairobi. Transport within the district is limited to lorries, public vehicles and animals (camels and donkeys).

2.2 Climate

Mandera is one of the hottest districts in the country with a mean annual temperature of 28.3° C. The mean annual maximum temperature is 34.5° C. The highest temperatures are experienced during the months of January to April and in the months of August to December. The hottest month is March with an average temperature of 37° C. The coldest month is July with an average maximum temperature of 32.8° C and an average minimum temperature of 23.0° C.

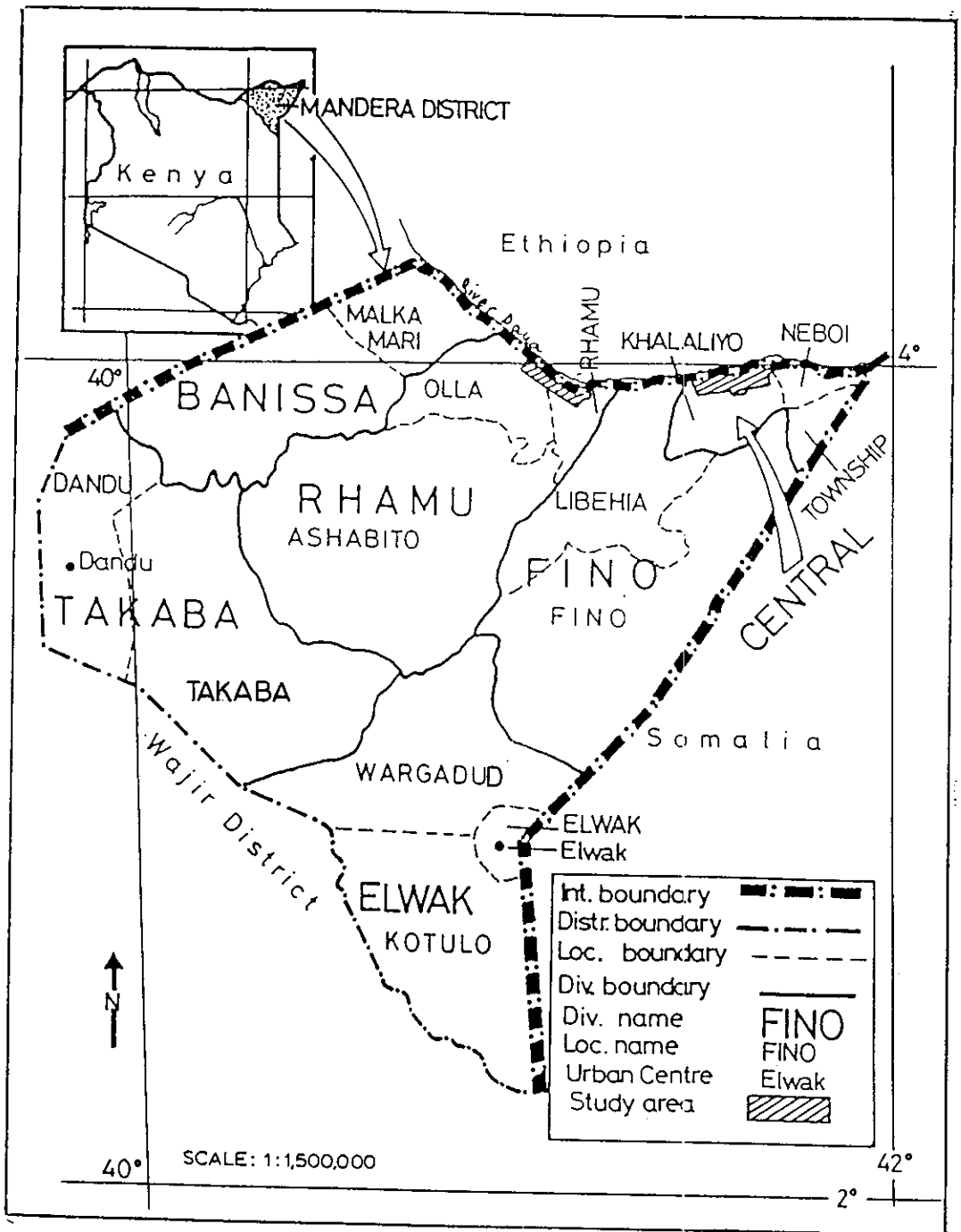


FIG. 2.1 PROJECT STUDY AREA

The highest temperature ever recorded since 1977 is 40.2° C, whereas the minimum day temperature ever recorded is 21.4° C.

The mean annual precipitation of Mandera is 255 mm covering two seasons: March - May and October - November, respectively. The mean monthly rainfall for Rhamu (1988 - 1992) is 19.01 mm while for Mandera (1935 - 1980) it is 21.25 mm. The highest total annual rainfall ever recorded in the district in the last 22 years is 486.4 mm (1993) and the lowest ever recorded in the same period is 87.5 mm (1975). The mean rate of evaporation per month ranges from 221 mm in May to 312 mm in March. In December to February the wind blows mostly from north east to east and general wind direction is from south to south west between May to September. The wind speeds are generally weak from October to May with an average of 5 - 7 knots and high from June to September with an average of 8 - 10 knots. Afternoons have higher wind speed than mornings. Cloud cover is dense during the months of March to September with 3.1 to 6.0 oktas. The relative humidity is high in the rainy seasons with 41% in the afternoon and 81% in the mornings. The mean monthly atmospheric pressure is in the range of 980.4 to 980 7 mb.

2.3 Geology

Mandera District lies south of the Ethiopian Highlands. It is covered by sedimentary rocks that range in age from Mesozoic to Recent, and the Precambrian basement system (Mozambique belt).

The basement rocks are metamorphosed sediments, comprising rock types such as schist, gneiss, marble and quartzite. It covers mainly Takaba Division (Ojany and Ogendo, 1973). The Mesozoic sediments are of Jurassic and Cretaceous age (Joubert, 1957).

The Jurassic beds consists of two divisions:

1. the Daua limestone series comprise limestones, argillaceous and calcareous shales. the sediment beds have been disturbed by folding and faulting in some parts of the district.
2. the Mandera series comprise of a gypsiferous series shales and mudstones, sandstones and limestones.

The cretaceous rocks are made up of the Danissa and Marehan series. The Danissa beds are massive sandstones with minor siltstones in the upper part. The Marehan series uncomformably overlie the Jurassic system and consists of siltstones, sandstones, shales and limestones. The study sites are covered by Daua limestones and Marehan series in Rhamu and Central Divisions respectively.

The Quaternary (Cenozoic) sediments consist of Elwak beds, Banissa and Rhamu sediments. The River Daua alluvium residual soils are of recent origin.

2.4 Relief and drainage

Mandera is characterized by low inselbergs in the central and western areas, located on sedimentary plains that rise gradually from Kutulo and Mandera towards Malka Mari areas about 200 m, 300 m and 1000 m above sea level (A.S.L), respectively. The Daua River which marks half of the district's boundary with Ethiopia, originates from the southern hills of the Ethiopian Highlands and flows eastward through Malka Mari, Rhamu, and Mandera into Somalia. The plains are further dissected by numerous ephemerals "lagas" that form a dichotomous pattern which drain off into the river. The southern end of the district is a lowland which is part of the Wajir low belt (Ojany and Ogendo, 1973).

The Daua valley has an average width of about 5 km but decreases towards the

source, hence uplands and midlands sometimes merge while the width of the lowlands are reduced. The valley has concave - convex (S-shaped) cross section.

2.5 Soils

There are no detailed soil map of Mandera available (GoK, 1993; GoK, 1994). Kenya Soil Survey have identified 18 major soils of arid and semi-arid lands on the Exploratory map of the country at scale of 1:500,000 (Muchena and Pouw, 1981). From this classification, Ferralsols, Gleysols, Lithosols, Fluvisols, Arenosols, Solonetz, Vertisols, Xerosols and Solonchaks are the likely soils that exist in the district.

2.6 Flora and fauna

The vegetation of the district has been broadly classified as thorn bushland, thicket and scrub, dominated by *Acacia* and *Commiphora* species (Pratt *et al*, 1966) and riparian woodlands along the river (Shabaani *et al*, 1992). Rocky sites are dominated by lithophytic species of *Acacia*, *Boswellia*, *Commiphora* and *Euphorbia* species. Dry river beds are dominated by *Acacia tortilis* with insignifant number of *Terminalia polycarpa*, *Gardenia volkensii* and *Delonix baccal* (in very hilly western areas of the district). The grass species are dominated by *Aristida kelleri*, *Tetrapogon* sp and *Chloris virgata* on rocky sites; *Urochloa trichopus* along seasonal water courses; *Cyperus* sp (sedges) and *Sporobolus* sp. in loamy-clay soils along the River Daua.

Large varieties of birds and mammals are common within plains and the Daua Valley but their population is decreasing with increase in human and livestock population and the destruction of their habitat mainly for agriculture.

2.7 Socio-economic condition

The district has a local population estimate of about 131,757 (1993) with a male:female ratio of 1:1.09 which is higher than the average (1:1.02) for Sub-Saharan Africa. The division with the highest population is Elwak with 29,085 (GoK, 1993), but Central/Khalaliyo Division has the highest population density of 23 person per km^2 (GoK, 1993), followed by Takaba and Rhamu/Ashabito Divisions with 6 and 4 persons per km^2, respectively. Most of the population is rural based.

Apart from the pastoralists movements, the only significant migration noted was that of a huge influx of 140,000 refugees from Somalia and Ethiopia in early 1992. These refugees settled in Mandera, Elwak, Rhamu and Banissa towns.

The district gets its water supply from the River Daua, boreholes or from earth dams which are unevenly distributed throughout the district.

2.8 Land use systems

The potential and utilized land for various land use systems can be summarized as follows: agriculture covers about 20,000 ha that is partly or fully utilized mostly along the River Daua and a few isolated pockets in the hinterland which are rain-fed. the rest of the 26,740 km^2 is utilized by nomadic pastoralists.

2.8.1 Agriculture

Most of the agricultural land is irrigated, especially along the River Daua but this is supplemented by rain-fed agriculture mainly in Banissa, Takaba and Mandera. Major crops are maize (*Zea mays*), goose necked sorghum (*Sorghum bicolor*), cow pea (*Vigna*

sinensis) and green grams (*Phaseolus aurens*) and they are supplemented by off-season vegetables and crops like kales , tomatoes (*Lycopersicon esculentum*), onions (*Allium cepa*), capsicum (*Capsicum frutescens*), pumpkins (*Curcubita pepo*), water melons (*Citrullus lunatus*), simsim (*Sesmum indicum*) and ground nuts (*Arachis hypogea*). The crops are grown with fruit trees of banana (*Musa serpentium*), mangoes (*Mangifera indica*), paw paw (*Carica papaya*) and guava (*Psidium guajava*).

2.8.2 Livestock

Livestock production in the district was estimated at 885,823 consisting of 299,123 camels, 123,000 cattle, 3,700 donkeys and 460,000 sheep and goats (District livestock office Mandera, 1995). Nomadic pastoralism is the dominant type of land use in the district covering almost 98% of the land. During the rainy seasons, livestock grazing shifts towards the plains. After the start of the dry seasons, the livestock (mainly cattle, sheep and goats) are grazed in individually owned pastures called "Sharmat or Sakar" along the River Daua and "lagas". This applies to the pastoralists with individual farms. In the very dry seasons, livestock grazing is concentrated along the river and hills found in central and western parts of the district.

2.8.3 Forestry

Forest Department is concentrating on extension, afforestation and agroforestry activities in demonstration plots and on degraded lands. The Department is promoting tree planting through communal groups. The main species used for afforestation and agroforestry are *Azadirachta indica*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Canocarpus*

lancifolius, *Senna siamea*, *Melia azadirach*, *Moringa oleifera*, *Mangifera indica*, *Psidium guajava* and *Leucaena leucocephala*.

A number of agroforestry practices exist in the district which may be classified as agrisilviculture (combination of trees and crops on the same land management unit, for example farms) or agrosilvopastoral (combination of trees, crops and livestock/pasture) and silvopastoral (combination of trees and livestock/pasture) (Nair, 1985). In these practices, MPTs have been deliberately retained on farms and rangelands.

CHAPTER THREE

3. LITERATURE REVIEW

3.1 ARID LANDS

3.1.1 Definition

Many definitions of aridity have been put forward based on the classical, index and water balance approaches. The classical approach relates climatic elements with vegetation and soil (Walter, 1964 and Muller-Samman and Kostchi, 1994). The index approach involves the use of a standard formula; an example is that of Muller - Samman and Kotschi (1994) in which aridity is determined from a nomogram. The water balance concept explores the relationship between evapotranspiration and precipitation (Beaumont, 1989). This approach which was developed by Thornthwaite (1948) forms the backbone of the most commonly used definition of arid lands. It was further modified by Meigs (1953) and UNEP (1992) to develop aridity index (AI) which is calculated as a ratio of P/PET; where P is precipitation and PET is potential evapotranspiration. AI < 1.0 indicates annual moisture deficits.

Aridity represents a lack of moisture in average climatic conditions, caused by one of the four climatic situations which may interact in the case of individual arid land areas: Continentality, topography, anti-cyclonic subsidence and ocean currents (FAO, 1988c).

In Kenya, the Kenya Soil Survey (KSS) have used the water concept approach in land evaluation of reconnaissance survey to make agro-ecological zones and delineate zones of aridity (Braun and Mungai, 1981). The identified zones of aridity are sub-humid, semi arid, arid and very arid.

Arid land precipitation is generally low and variable through out the year. Torrential rains can occur locally causing high flush floods. Temperature varies with latitude, longitude, distance from the sea and time of the day but wind velocity is high (Beaumont, 1989).

3.1.2 Landforms and soils

Types of landforms in arid lands vary but a generalized model was mentioned by Beaumont (1989) composed of uplands, alluvial fan, plains and lowlands with salt desert in the depressions.

More than three-quarter of the world's arid lands consists of just two main types of soils of sandy Entisols (sandy) and aridisols (Grainger, 1990). Other common soils of arid lands are Alfisols, Mollisols and Vertisols.

Arid land soils are susceptible to both water and wind erosion accelerated by agriculture and overgrazing (Grainger, 1990). Poor management of irrigated cropping and water supplies causes salinization, alkalinization and water logging (Muller-Samann and Kotschi, 1994). Arid lands soil texture especially the top soil is composed of silt and fine sand (Sanchez, 1976). Soils of upland are shallow and coarser and flood plains with fine texture and deep profiles and if well drained they provide fertile agricultural soils (Beaumont, 1989).

The soils of Kenya's arid lands are described as problem soils as a result of their physical and chemical properties which limit their use particularly for agriculture (Muchena, 1985). Muchena and Pouw (1981) indicated that Kenya's arid land soils are composed of Acrisols, Cambisols, Chernozems, Ferralsols, Gleysols, Phaeozems,

Lithosols, Fluvisols, Luvisols, Nitosols, Arenosols, Regosols, Solonetz, Andisols, Vertisols, Planosols, Xerosols and Solonchak. But the most common orders are Solonetz, Solonchaks and Arenosols (Gicheru and Wanjogu, 1990). Sombroek *et al* (1976) generalized the soils of Mandera as Yermosols and Arenosols.

3.1.3 Flora

As aridity increases, woodland becomes discontinuous and is eventually reduced to individual or small clumps of trees. Then grassland takes over as the dominant vegetation type and eventually gives way to scrub that is preceded by no vegetation under extreme aridity except along ephemerals where plant with deep rooting systems are able to tap ground water (Beaumont, 1989).

In arid and semi-arid zones, plant are of hydrophytes (grows along streams and marshlands), mesophytes (found in aerated and soils with moisture of above wilting point) and xerophytes that survives on soils moisture below wilting point (below 5% moisture) are common (Beaumont, 1989). Muller - Samann and Kotschi (1994) divided the flora of arid lands into dry savanna, semi-desert and desert while Grainger (1990) categorized the flora as desert, thorn woodlands and savannas. He also noted arid lands flora to be specialized plants of escapers (ephemerals), drought evaders (use water economically), drought resistants (succulents) and drought endurers (become dormant during dry seasons).

In Kenya, arid land's vegetation have been described as bushland, woodlands, grassland, bushed grassland, wooded grassland and dwarf shrub grassland (Pratt *et al*, 1966). The physiography of the vegetation in North Eastern Kenya, may be bushland and shrub thicket, bushland, wooded and /or bushed grassland (Sombroek *et al*, 1976). Pratt

et al (1966) generally classified the vegetation of Mandera District as thorn bushland and thicket and desert thorn scrub. Extensive survey of Mandera District's soils, landform and vegetation resources by Ministry of Livestock Development and GTZ (German Technical Cooperation) described the vegetation as mainly bushland with evergreen woodland along the River Daua and the landform as almost flat to undulating (Shaabani *et al*, 1992).

3.1.4 Agriculture

Agricultural use of dry lands is limited by shortage of water (Muller- Samman and Kotschi, 1994). Rain-fed agriculture is possible with special water-harvesting technique and it is limited to drought resistant crops such as millet, sorghum, simsim and groundnuts. Livestock keeping is dominant. The production of the region can be improved through the integration of drought resistant MPTs into farmlands.

Semi-arid areas (zone V) of Kenya have marginal arable agriculture; arid areas (zone VI) have low potential for arable farming; and very arid (zone VII) has very low potential for arable farming (Braun and Mungai, 1981). Rain-fed arable farming is not possible in North Eastern Kenya in view of the prevailing climatic conditions but the land is used for nomadic grazing and near sources of permanent surface water, some irrigation schemes are in execution or under consideration (Braun and Mungai, 1981). Preliminary studies on the suitability of the Daua Valley for irrigation was studied by Sombroek *et al* (1973) who noted the start of recent irrigation but described the dominant agricultural practice as extensive grazing. They indicated the importance of conducting a full-scale feasibility study and semi-detailed soil survey.

3.2 RELATIONSHIP BETWEEN VEGETATION AND LANDSCAPE CHARACTERISTICS

The distribution of plants varies in most landscapes. The variations are often tied to environmental conditions, mainly the soils, topography (slope) and past events of land use. The relationship between vegetation, soil and topography are so intricate that, in an ecological perspective, they are hardly to be considered as separate entities (Goodall and Perry, 1981).

Topography is a factor that modifies the effect of other factors of soil formation such as time, climate, organisms and parent material (Fanning and Fanning, 1989). The greatest role of slopes in dry areas is through their control of the amount of moisture received or lost by run off. The upper positions of the steep slopes would retain the least, and the lower positions of the gentle slopes retain the highest the amount of moisture (Goodall and Perry, 1981). In a study of the effect of gradients on species composition of desert vegetation near El-Paso, Texas, Williams (1969) found that, there are complex of species in sites with deeper soils where water is trapped than those of xeric sites.

There is no doubt that soils affect plants hence soils are life-support systems. In arid regions, the soils in low places in the landscapes tend to be more saline and support associated salt tolerant plant (halophytes) or have no vegetation at all. Conversely, soils in higher places in the landscape tend to have sparse grasses and shrubs that do not need to be salt tolerant (Fanning and Fanning, 1989).

Box (1961) in South Texas recognized different plant communities on different soil textures; Ayyad and Ammar (1974) in the Egyptian Desert recognized species distribution in relation to soil characteristics that affect soil moisture. In addition Thomas (1941) in

Sese Island, Uganda; and Lang-Brown and Harrop (1962) in Kabale, Uganda, found that species distribution are also related to soil pH and texture. Cabido *et al* (1987) in a high plateau of the Cordolea Mountains, Central Argentina reported that soil moisture, soil depth, soil texture and hydrological position in the landscape are the major factors affecting vegetation distribution. Lehmann and D'anzer (1987) in their evaluation of the toposequence of western slopes of Jebbel Marra, Darfur, Sudan concluded that the main factors limiting plant distribution to be the availability of water, which is affected by depth, texture, organic matter and stone content. Species distribution in the Avedat Desert, Israel and that of the Egyptian Deserts are also affected by the presence of stones and gravels on slopes (Noy-Meir *et al*, 1970; Kassas and Iman, 1954). Oslon and Hupp (1986) in their studies on the variability of the vegetation of Mill run Water shed, Virginia, USA in relation to geology, soils and geomorphology recognized that vegetation was closely related to soils and therefore also to the bedrock types. Catena of the vegetation of semi arid Australia and different environmental factors (Noy-Meir, 1973) indicates that the vegetational variation is produced by an interaction between rainfall and texture. The position of rills and runnels, their depth and the presence of gravels and the slope gradient on the landscape is known to affect the distribution of different plant communities in the Negev Desert of Israel and Egyptian Deserts (Kassas and Girgis, 1964; Tadmor *et al*, 1962). The effect of salinity on the distribution of plant species was studied by Shreve (1942) and Flowers and Evans (1966) in the Great Salt Lake region, USA; Kassas (1957) in the Western Coast of the Red Sea; Tadros (1953) and Tadros and Atta (1958) in the Mediterranean Coast of Egypt and found that salinity causes species zonation with more tolerant species occupying areas with high salinity. In addition, alkalinity, slope and

texture are known to affect vegetation zonation in the Shadscale zone of South Eastern Utah, USA (West and Ibrahim, 1968).

The distribution of vegetation in the Lake Manyara National Park, Tanzania are determined by salinity, pH, texture, flood occurrence, drainage, moisture availability, slope gradient and the occurrence of stones and rocks (Loth and Prins, 1986). Oba (1991) in his studies on the common floodplain woodland types and species of the lower River Turkwell, Turkana District, Kenya recognized that texture, nearness to the river levees and drainage affect their distribution.

3.3. AGROFORESTRY

3.3.1 Definition and scope

Agroforestry is a collective name for all land use systems and technologies in which woody perennials are deliberately combined in the same land management unit with herbaceous crops/or animals, in either some form of spatial arrangement or temporal sequence. In these systems, there are both ecological and economic interactions among the many components (Lundgren, 1982; Lundgren and Raintree, 1983; Nair, 1989a; Punam and Kholsa, 1990). A part from ecological and economic benefits agroforestry in addition, results in social contributions from the components (Fahlstrom, 1992/93). The management unit can be small or as large as range land pastures (Rocheleau *et al*, 1988). Agroforestry is a new interdisciplinary science and concept dealing with an age old practice. It has recently come into international prominence as a potential source of solutions to many inter related problems of production and conservation troubling land use systems in the tropical and subtropical regions of the world today (Lundgren and Raintree,

1983). Woody components have traditionally been included in small-holder management systems in the tropical regions of Africa, America and Asia as a source of fuelwood or food and to restore soil fertility. The traditional use of land by the small-holder of the tropics has been particularly affected by demographic pressure, leading to an increase in the proportion dedicated to cropping, with corresponding shortening of the fallow period necessary to restore fertility (Torres, 1989). Agroforestry is a sustainable multipurpose system whose output can be adjusted to the local needs (Beets, 1989).

An agroforestry practice denotes a specific land management operation of an agroforestry nature on a farm or other management unit, and consists usually of the arrangements of components in space and time vis-a-vis the major function of the tree component. An agroforestry practice can exist even in a non-agroforestry land-use system (Nair, 1989a).

The term agroforestry in arid lands implies the integration of trees into or as part of agriculture mainly animal husbandry and the value of trees and shrubs lies in the fodder they provide to supplement grass in particular, during dry season or drought periods (Van Doorne, 1989; Kinyua, 1989). Increasing human and livestock populations have tremendous pressure on arid lands of Kenya resulting in ecological degradation through over exploitation turning it into wasteland, which in turn causes degradation of the quality of life of the people, posing a threat to survival (Kinyua, 1989).

The Government of Kenya has developed major policy interventions that have direct and positive impact on agroforestry development in Kenya, for example Forestry policy for Kenya-Sessional paper number one of 1968 and the establishment of KEFRI (Kenya Forestry research institute) in 1986 (Getahun, 1989). Line ministries/departments

like Agriculture and Forestry are also active in agroforestry promotion.

Agroforestry in arid lands is special as a result of it being carried out in an environmentally difficult conditions (Fahlstrom, 1992/93). As a result of population increase and change of the life style of the people, MPTs in arid area are under threat hence the need for research. Agroforestry can be used to change degraded landscape to productive stage not by a single farmer but by total community mobilization and involvement (Ngumy, 1992).

3.3.2 Agroforestry practices

Rocheleau *et al* (1988) divided agroforestry practices broadly into practices in cropland, those with structural conservation measures, practices in between places and those in pastures and rangelands. Nair (1989) used species component, their arrangements and interactions, the functions of woody components and ecological adaptability of the species to classify agroforestry practices.

Punam and Khosla (1990) classified the traditional agroforestry systems of the Himachal Himalaya of India using important value index and identified the most ecologically successful species as *Prunus domestica*, *P. armenicicia*, *P. amygdalus* and *Pyrus communis*. Zou and Sanford (1990) conducted survey and classification of agroforestry practices in China using component combinations and identified 10 practices of agrosilvicultural system, 3 practices of silvopastoral system; 2 practices of agrosilvomedical system; 4 practices of agrosilvofishery system and 6 practices of agrosilvopastoral system. Jambulingam and Fernandes (1989) studied agroforestry systems and practices of Tamil Nadu, India and identified 2 systems and 6 agroforestry practices.

Mellink *et al* (1991) summarized 22 agroforestry practices of Sri-Lanka using component characteristics.

In Costa Rica, Budowski (1987) conducted research on living fence as a wide spread agroforestry practice. Padoch and Jong (1987), conducted research on the traditional agroforestry practices of the native and Ribereno farmers in lowland Peruvian Amazon and identified diverse agroforestry practices, with Swedden fallow type of shifting cultivation dominating.

Lesile (1987) conducted agroforestry survey of Somalia using component arrangements and identified the practices of life fencing and hedges, shelter belts, boundary planting, bush fallow, shifting cultivation, intercropping of crops with widely scattered trees, temporary intercropping with fruit trees and trees for stabilization of soil and canals. Fernandes *et-al* (1989) studied and described the agroforestry practices of Mount Kilimanjaro, Northern Tanzania using the existing farm components as multistorey Chagga homegardens. Traditional agroforestry practices in Zimbabwe have been studied by Campbell *et al* (1991) who recognized that MPTs for fruits, shade, social meetings, fuelwood and for ash production are deliberately left in fields, while less useful species are removed. Adelgbehin and Igboanugo (1990) studied agroforestry practices in Nigeria and divided the practices according to ecological vegetation zones of those in the Rain forest and derived Savanna zones, those in Southern Guinea and those in Sudan and Sahel Savannas.

The main agroforestry practices common in Kenya have been described by Getahun (1989) as wind break/boundary planting, mixed intercropping and enriched fallows, trees with crops, homegardens and fruit orchards, shamba or taungya system, wattle plantations,

plantation crops with shade trees and woodlots. Three arid land agroforestry systems/practices were briefly described by Fahlstrom (1992/93) as shifting cultivation with trees left in the field in Tharaka-Nithi District, multipurpose trees and shrubs in cropland and homestead in Solo, Marsabit District and multistorey fruit trees with agricultural crops in a farm not named in Central Division, Mandera District.

3.3.3 Uses of multipurpose trees and shrubs

Studies on the identification and uses of MPTs have been conducted in many parts of the world. Nair (1989) divided the uses of MPTs into productive and protective uses.

Forezen and Oberholzer (1984) researched on the MPTs in hill farming systems of West Nepal and found the deliberate retention or the incorporation of trees and shrubs on farms for their uses especially fodder, fuelwood and control of soil erosion. MPTs on farmlands of Tamil Nadu, India have been studied by Jambulingam and Fernandes (1989) for use as food reserve, fuelwood, fruits and fodder.

Von Maydell (1990) worked on the uses and characteristics of trees and shrubs of the sahel. He indicated the part of the species used and its level of importance. FAO (1988b) documented 110 multipurpose plant species which are mainly used for food in Africa giving brief taxonomic characteristics, the edible parts, food value (nutritional content) and other uses and their ecological distributions. Bekele-Tesema *et al* (1993) compiled useful trees and shrubs of Ethiopia using information from the rural people.

ICRAF (1992) prepared a selection of useful trees and shrubs of Kenya with special reference to the humid areas using extensive consultations and local visits.

Traditional use of arid areas is livestock raising. During the dry seasons, when

grazing is in short supply, the animals browse. Camels exploit the taller trees and bushes, cattle the average to lower bushes, and goats mostly on lower levels (Pratt and Gwynne, 1977). Browse plays an important role in livestock nutrition in these areas through the provision of protein, vitamins and mineral elements which lack in grasses during the dry seasons. Some of the most common families of arid land's MPTs are Capparaceae, Tiliaceae and Mimosaceae (Kinyua, 1989). In addition to the indigenous families mentioned above, other MPTs recommended for use in arid lands are (Getahun and Reshid, 1989): *Cajanus cajan*, *Cassia siamea*, *Casuarina equisitifolia*, *Erythrena abyssinica*, *Leuceana leucocephala*, *Prosopis cineraria*, *P. pallida* and *Sesbania sesban*. Ndiang'ui (1989) made a list of potential and less known MPTs; some of which could be important in Mandera area are: *Acacia* spp, *Albizia* spp, *Erythrina* spp. *Delonix* spp, *Cassia* spp, *Parkinsonia* spp, *Tamarindus indica*, *Lannea* spp, *Cordia* spp, *Boswellia* spp, *Boscia* spp, *Lawsonia* spp, *Dobera glabra* and *Grewia* spp. Barrow (1991) noted the importance of trees and shrubs in arid lands especially in Turkana as:

- Dry timber for fuelwood and charcoal
- Building timber for houses, fencing and thatching
- Food for livestock particularly in dry season
- Wild fruits and food for people
- Veterinary medicine for variety of livestock diseases
- Human medicine for a variety of diseases
- Amenity for shade to act as a meeting place
- Variety of cultural values, water purification ceremonial.

their specimen were taken to the East African Herbarium, Nairobi for identification. Kenya trees and shrubs (Dale and Greenway, 1961) and Kenya trees, shrubs and lianas (Beentje, 1994) and Collin Guide to the Wild Flowers of East Africa (Blundell, 1987) were used to identify species. Based on the general botanical data the structure of the multipurpose trees and shrubs were described in the field. Species that were considered unique at the site were noted.

Parataxonomists views on the species identified was an important part of the field work. Local uses and vernacular names (where possible) were enquired from the local experts on MPTs. Over refreshment of roasted coffee beans (a respected traditional practice in Mandera), interviews were held with parataxonomists. Branches with leaves, flowers or fruits of the encountered species were shown to them and the experts were given the freedom to put their views on the local name, uses and other special attribute of the species. The experts were composed of nomads, local herbalists (both men and women) and experienced people. In one of the interviews, I could include the experience of a Somali expert from Somalia.

Quadrat study paid more attention to the natural vegetation. In case the point of sampling had been cleared (which was common along the river), the nearest 10 to 30 m natural vegetation was sampled. Special human disturbances in the area were noted. The general conditions of the areas vegetation was studied using NDVI (Normalized Difference Vegetation Index) which was derived from NOAA-AVHRR (National Oceanic and Atmospheric Administration-Advanced Very High Resolution Radiometer) images. The data (1993 -1994) was obtained from the Department of Resource Surveys and Remote Sensing (DRSRS) for the rainy periods.

The NDVI is produced routinely and is calculated by:

$$NDVI = \frac{DN\ (Channel\ 2)i - DN\ (Channel\ 1)i}{DN\ (Channel\ 2)i + DN\ (Channel\ 1)i}$$

where DN is the digital number representing the reflectance from the channel N for the i^{th} pixel. The NDVI reflects vegetation conditions of the area.

Other sources of data were Meteorological Department, Livestock, Agriculture and Forest Departments.

4.3 POST FIELD STAGE

The NDVI maps were processed at DRSRS (by courtesy of Nicholas Ganzin) for the short and long rain 1993 and for the long rains of 1994. The woody vegetation data was summarized for each of the treatments (distance from the river bank - S1 to S6 and the site characteristics). Density, relative density, cover, relative cover, frequency, relative frequency and Important value Index (IVI) were calculated for all the MPTs species using the method of Misra (1968):

Density = the number of individuals in a unit area,

Frequency = the chance of finding a given species within a sample,

Cover = the proportion of the ground occupied by vertical projection to the ground from the aerial parts of the plant estimated according to Braun-blanquet (1951).

$$\text{Relative Density (RD)} = \frac{\text{Density of a given species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a given species}}{\text{Total frequency of all species}} \times 100$$

$$\text{Relative Cover (RC)} = \frac{\text{Cover of a given species}}{\text{Total cover of all species}} \times 100$$

Important value index (IVI) = RD + RF + RC.

The field data values for cover, frequency and density were expressed in values per hectare for standardization purposes. IVI data was used to identify the dominant species in the valley so as to be used in general vegetation description

The relationship between soil, slope gradient and vegetation were analyzed using Multiple regression of the SAS scientific package and the treatments that were significantly different were compared using Duncan's multiple range test.

The site descriptions were summarized for all the quadrats. For ease of planning purpose, the edaphic and the slope gradient data were grouped into class ranges mostly as recommended by Kenya Soil Survey (1987) with modifications where necessary (Appendix I to VIII). The class range that has the highest frequency was taken to represent the site. If the most frequent range represents >70% then it is used to describe the site. If the range is <70%, the most frequent and second most frequent classes were chosen to describe the site. Textural triangle was used to classify soil texture.

The agroforestry practices were analyzed by the classification scheme proposed by

Nair (1985). On farmlands, the arrangements of trees, shrubs and crops were classified according to Huxley (1979). Brief ecological and taxonomical descriptions and the economic uses of each species were indicated.

CHAPTER FIVE

5. RESULTS AND DISCUSSIONS

5.1 AGROFORESTRY (AF) PRACTICES

The agroforestry practices in the study area are summarized in table 5.1. Generally all the farms accommodate more than one practice but the most common along the river bank is the growing of horticultural (fruit) trees with crops. Trees mixed with pastures "Sharmat" or "Sakar" is the most common practice at 1 km from the river and trees in range lands dominate 2 km to 5 km from the river. All practices except for soil stabilization and conservation had, apart from the woody component, the animal component. This shows that the community which was once a pure nomadic is changing towards diverse agroforestry practices. The common livestock components within the valley and its surroundings are cattle, sheep, goats, camels and donkeys. The camels are more common in farms in dry seasons when fodder is less in upland pastures. After the crops have been harvested, the animals are allowed to feed freely on crop residues in the fields (plate 5.1) but the MPTs especially fruit trees are protected from direct livestock browse or damage.

The farmers do not necessarily settle on their farms, a tradition common in high potential areas of the country. Instead they are in farm villages about one and half to three km away from the river (Fig. 5.1). When crops are in the field, a member of the farmer's family has to spend the night in the farm to guard against wildlife pests. During the dry season when mosquito population has reduced, the farmer may move his homestead to the farm or within half to one km range.

Table 5.1 : The main agroforestry practices in the Daua Valley, Mandera District

AGROFORESTRY PRACTICES	DESCRIPTION (ARRANGEMENT OF COMPONENTS)	MAJOR GROUPS OF COMPONENTS (w= woody f= fodder a= animals)	MAIN TYPES OF AGROFORESTRY INTERACTIONS IN space(s)/ time(t)	FUNCTIONS OF WOODY COMPONENTS prt=protective prd=productive	ECOLOGICAL ADAPTABILITY (Edaphic and slope gradient
1. MPTs for river bank stabilization [3]	MPTs along the river in spaced or dense stands	w: naturally occurring MPTs or planted h: common crops in early establishment period f: dry fodder available	s: zonal or scattered t: concomitant	prt: river and environmental stabilization along the river prd: various tree products	Edaphic: mod. to strongly saline, clayey to loamy, orange to brown, deep to v.deep, SWED to MWD soils. Slope: gently undulating to undulating
2. Border planting [1]	MPTs along the within and without farm boundaries	w: naturally occurring MPTs or planted h: common crops within the fields surrounded by MPTs	s: zonal (dense or scattered along the borders) t: interpolated	prt: windbreak, shade prd: various tree products	Edaphic: mod. to strongly saline, clayey to loamy, orange to brown, deep to v.deep, SWED to MWD soils. Few isolated farms with mod. alkaline, silty to loamy, orange, mod. deep to deep and WD soils.Slope: gently undulating
3. MPTs on pastures "sharmat" [1]	MPTs are scattered irregularly sparsely or with few dense stands	w: MPTs usually of fodder values f: present a: present	s: mixed sparse t: coincident	prd: MPTs as fodder and various products prt: shade, windbreak and environmental protection	Similar to sites with AF practice one above but some sites have gravelly soils and rolling slopes

4. Horticultural trees on farmlands [2]	MPTs are scattered haphazardly or in linear patterns with a species or many species combined	w: fruit trees h: common agricultural crops	s: mixed dense t: concomitant	prd: MPTs for fruits and various other products prt: shade and river bank stabilization	Similar to sites with that of AF practice one above
5. Shade MPTs on farmlands [1]	MPTs are dotted haphazardly	w: MPTs usually for shade value h: common agricultural crops a: present especially in dry seasons	s: mixed sparse t: interpolated	prd: various products Prt: MPTs for shade and other environmental protection	Similar to sites with AF practice two above
6. Live fences and hedges on farmlands and grave yards [3]	MPTs around farmlands	w: pure stands of *Euphorbia tirucalli* and other naturally occurring MPTs h: crops within the farmlands a: present	s: zonal along farm borders t: interpolated	prd: various products prt: MPTs for fencing and other environmental protection	Similar to sites with AF practice two above
7. MPTs and Nappier grass mixture [2]	Nappier grass between fruit trees	w: fruit trees f: present	s: zonal t: coincident	prd: fruit and fodder production prt: soil conservation	Similar to sites with AF practice two above
8. Bush fallow [1]	Natural regeneration of MPTs are left to grow during the "fallow period"	w: fast growing naturally occurring MPTs and grasses h: common agricultural crops	t: separate (in rotational cycles)	prd: wood and thatch products	Similar to sites with AF practice one above
9. Apiculture with MPTs [3]	MPTs for honey production scattered in farms	w: MPTs for bee forage h: common agricultural crops	s: mixed sparse t: intermittent	prd: honey and other products Prt: shade, soil and river bank stabilization	Similar to sites with AF practice one above

10. MPTs for herbal medicine [1]	MPTs along the river or scattered	w: medicinal MPTs h: common agricultural crops	s: mixed sparse t: intermittent	prd: medicine especially against malaria plus other products prt: soil conservation	similar to sites with AF practice one above
11. MPTs for ornamental [3]	MPTs around homestead	w: MPTs for aesthetic a: present	s: mixed sparse or variable	prt: shade, meetings and aesthetic prd: fuelwood and other products	soil: mod. alkaline, mod. to strongly saline, gravelly sandy to loamy, bright brown to orange, shallow to mod. deep, excessivelly well drained slope: gently to rolling
12. MPTs in soil conservation and reclamation [2]	MPTs for soil reclamation	w: MPTs for soil stabilization h: common agricultural crops	s: zonal (strip) t: intermittent	prt: soil conservation prd: various tree products	On degraded site (former refugee camps) Soil: sandy-loamy Slope: gently undulating
13. MPTs on rangelands [1]	MPTs scattered	w: MPTs for fodder and other uses h: herbs and grasses a: present f: present	s: mixed sparse t: coincident	prd: MPTs for fodder, fuelwood, fruits, building and various other uses	Soil: mod. alkaline and alkaline, stony and gravelly silty to loamy, orange to bright brown, shallow to v. shallow, excessively well drained Slope: gently undulating to rolling

AF = agroforestry SWED = some what excessively drained MWD = Moderately well drained

WD = Well drained

1 = Traditional practices 2 = Exotic (introduced) practices 3 = Hybrid of traditional and exotic practices

Plate 5.1: Cattle grazing in farmland along the River Daua after maize harvest; Central Division, Mandera District. In the fore ground are onions (an off-season crop) and fruit plantations in the back ground.

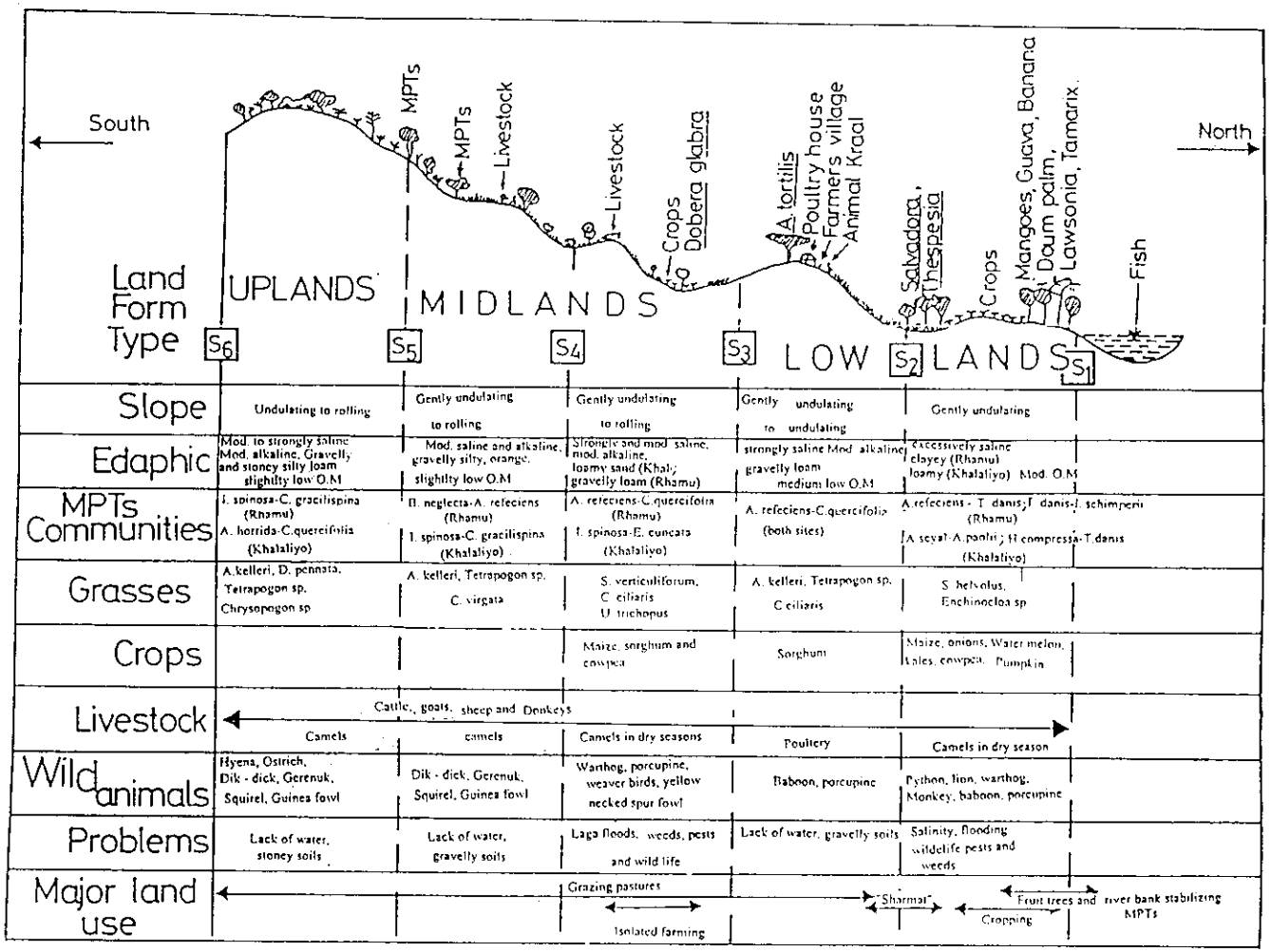


Fig.5.1: Schematic representation of the Daua Valley with the main Agroforestry and Landscape characteristics

A farmer may own one or more pieces of land along the river or "lagas".The farm size ranges from 0.5 to 40 acres, depending on farmer's wealth, the amount of land inherited or acquired when the land was cleared in the 1960s and 1970s.

Two or more practices may be found simultaneously in a farm. The main components of the AF practices are field crops, animals and MPTs. The deliberate retention of MPTs on farmlands and range lands and the planting of MPTs on farms and in homesteads, helps in the conservation of the species of multiple output and ultimately that of soil and water conservation. But the cutting of species that is not of economic use today could lead to the erosion of species that could be of value in future and the disruption of the food chain and food web of the unique ecosystem.

Silvopastoral practices of "Sharmt" and MPTs in range lands are the dominant land use in the valley. It does not add extra cost to preserve the MPTs in such practices (Niamir, 1990), hence silvopastoral practices supports biodiversity but vulnerable because of its reliance on natural regeneration and the lack of replacement of MPTs for fodder. The leaves and pods from fodder species are gathered from existing MPTs and this leads to increased degradation of these phytogenetic resources (ICRAF, 1995).

1. Crops components

The major crops are maize, water melons, pumpkins, groundnuts, hot chilli peper, onions, tomatoes, sorghum, sweet potatoes (*Ipomea batata*), cow peas, banana (*Musa serpentium*) and sugarcane (*Saccharum afficinarium*). The crops especially off-season crops that take three months to mature are grown through irrigation (plate 5.2) using river water. The crops products are marketed in nearby centres, the neighbouring districts and in the nearby towns of Somalia and Ethiopia.

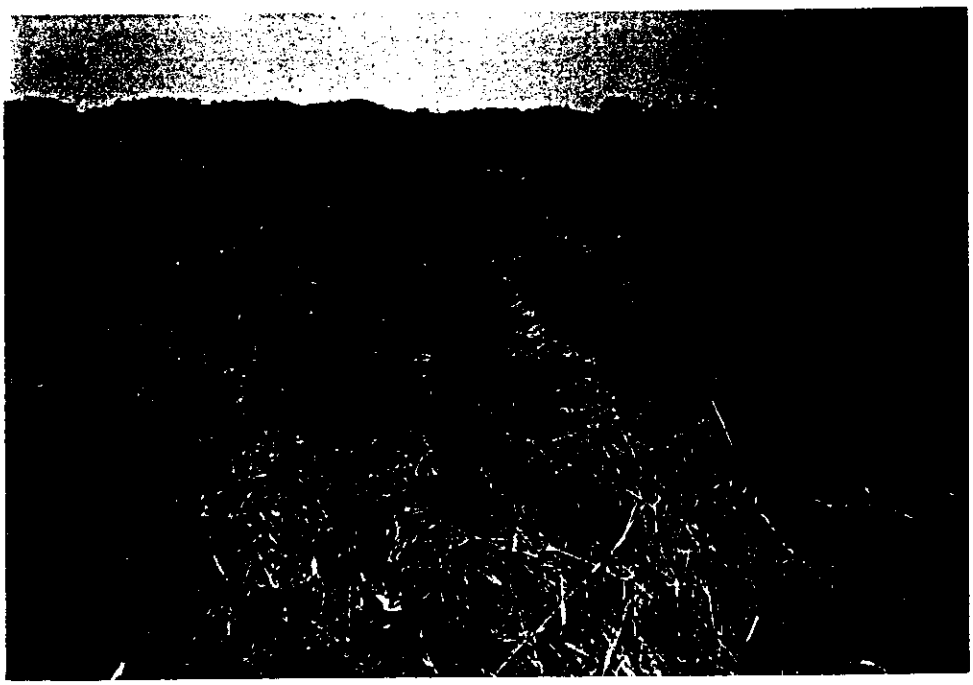


Plate 5.2: Carrots are some of the many off-season crop species grown through irrigation along the River Daua, Central Division, Mandera District.

2. Livestock components

Livestock graze in individually owned pastures "sharmat" or in crop land after harvest, but they mainly graze/browse in vast areas of natural pastureland. Maize and sorghum stovers are generally stored on tree tops to fed the animals in very dry seasons. Availability of fodder in dry seasons, trypanosomiasis and tick borne diseases are the major problem to livestock rearing in the valley. The main livestock types are camels, cattle/oxen, sheep, goats, donkeys and poultry.

Animals	**Uses**
Cattle	Milk, meat, sale, skin mats, wet skin believed to treat ulcer/gastric patients, manure, horn used to remove "bad blood" from the body, social status and investment bank
Oxen	Draught, sale, manure, income by hiring
Sheep	Milk, meat, sale, manure, fat/soup believed to treat complex diseases and as investment bank
Donkeys	Transport and for sale
Camels	Transport, meat, milk, sale, manure, skin mat, skin thread for making local container holders and traditional poles for house construction. Skin for local shoe making
Poultry	Eggs, chicken, sale, time keeping and for economic utilization of farm products.

3. Trees/shrubs components

Several MPTs were found on farmlands and rangelands and they are the prominent feature of the agroforestry practices. Most of these species were not planted but deliberately preserved/retained. The common naturally occurring species are listed in tables 5.2 and 5.3. These are the species that were preferred by the farmers/pastoralists for their multiple outputs (productive and protective uses). The farmers and pastoralists have over the years learned to conserve useful phytogenetic resources.

The main agroforestry (AF) practices and their implications in resource conservation and management

AF practices along the river bank were found to be intensive but becomes more extensive in nature towards the uplands. Thirteen AF practices were identified of which six were traditional, three were introduced and four were hybrid of traditional and introduced practices. Traditional practices are farmer/pastoralist based and there is very little input from research and development. All the practices were positive to soil, water and species conservation but the diversity of the species was more with traditional practices.

There are few MPTs in the lowlands than the uplands. This can be contributed to man's activities of clearing for farming and sprawl of settlements (Marsh, 1991). Apart from human influence in the distribution of MPTs in the valley, landscape characteristics also plays a leading role.

Table 5.2: Distribution of MPTs at sites S1 to S6 in Khalaliyo-Fiqho area, Mandera District. A summary of 90 quadrats.

	Sites number from the bank of the River Daua at one km interval							Sites number from the bank of the River Daua at one km interval					
MPTs species	S1	S2	S3	S4	S5	S6	MPTs species	S1	S2	S3	S4	S5	S6
Acacia tortilis	-	+	+	+	+	+	*Adenium obesum*	-	+	+	+	+	+
A. seyal	+	+	+	-	+	+	*Boscia minimifolia*	-	-	+	+	+	+
A. senegal	+	+	+	+	+	+	*B. tomentella*	-	-	+	-	+	+
A. paolii	-	+	+	+	+	-	*B. anguisitifolia*	-	+	+	-	-	-
A. refeciens	-	+	+	+	+	+	*Boswellia neglecta*	-	-	+	+	+	+
A. edgeworthii	-	-	+	+	+	+	*B. rivae*	-	+	-	+	+	+
A. nubica	-	-	+	-	+	-	*B. microphylla*	-	-	-	+	+	+
A. mellifera	-	-	+	-	-	-	*Bleripherisperm lanceolatum*	-	-	+	+	+	-
A. horrida	-	-	+	+	+	+	*B. pubscens*	-	-	-	-	+	+
Anistotes tanensis	-	+	+	+	+	+	*Boscia coriacea*	-	-	-	-	-	+
Asparagus sp.	-	-	+	-	+	-	*Balaria maxima**	-	-	-	+	-	-
*Abutilon mauritianum**	-	-	-	-	+	-	*Balanitis rotundifolia*	-	+	+	+	+	+
*Aerva javanica**	-	-	+	+	+	-	*Cadaba glandulosa*	-	+	+	+	+	+
Albizia anthelmentica	-	+	-	-	-	-	*Cordia senensis*	+	-	-	-	-	-

Commiphora myrrha	-	+	+	+	+	+	*C. quercifolia*	-	+	+	+	+	+
C. ogandensis	-	+	+	+	+	+	*C. gracilispina*	-	+	+	+	+	+
C. danduensis	-	+	-	-	+	+	*C. rostara*	-	-	-	-	-	+
C. habessinica	-	+	+	+	+	+	*Ipomea donaldsonii*	-	+	+	+	+	+
C. velutina	-	-	!	!	!	!	*Jatropa dichtar*	-	-	-	!	!	!
C. campetris	-	+	+	+	+	-	*Lawsonia inermis*	+	+	-	-	-	+
Carica papaya	-	+	+	+	+	-	*Lycium europeaum*	-	+	+	+	+	+
Cassia sp.	-	-	_	-	+	-	*Moringa borziana*	-	-	-	-	-	+
Citrus lemon	+	-	-	-	-	-	*M. longituba*	-	-	-	-	-	+
Dobera glabra	-	+	+	+	+	+	*Mangifera indica*	+	+	-	-	-	-
Delonix elator	-	-	+	-	-	+	*Parkinsonia sciona*	-	-	-	+	+	+
Euphorbia breviarticulata	-	-	+	-	-	-	*Psidium guajava*	+	-	-	-	-	-
E. cuneata	-	+	+	+	+	+	*P. diosciorides*	-	-	-	-	+	-
E. gossypina	-	-	-	-	-	+	*Phoenix reclinata*	+	-	-	-	-	-
Ficus sur	+	-	-	-	-	-	*Satanocrater paradoxa*	-	-	-	+	-	-
Gardenia volkensii	-	-	-	-	+	+	*Salvadora persica*	-	+	+	+	-	-
Grewia tenax	+	+	+	+	+	+	*Seracocomopsis pallida*	-	-	+	-	-	-
G. lilacina	-	-	+	-	+	+	*Sesamothamnus busseanus*	-	+	+	+	+	+

G. tembensis	-	-	-	-	+	+	*Solanum jubae*	-	+	+	+	+	+
Hyphaene compressa	+	+	-	-	+	-	*Tamarix aphylla*	+	-	-	-	-	-
Hibiscus calyphylus	-	-	-	-	+	+	*Terminalia parvula*	-	+	+	+	+	+
Indigofera schimperii	+	-	-	-	-	-	*T. orbicularis*	-	-	-	+	+	+
I. trita	-	-	-	+	-	-	*T. polycarpa*	-	-	-	-	-	+
I. spinosa	-	-	+	+	+	+	*Ziziphus hamur*	-	+	+	+	+	+
Solanum sp	-	+	-	-	-	+	*Z. mauritiana*	+	+	+	-	+	-

* These plants are herbs but I find them useful to mention because of their uses or uniqueness.

+ = present - = absent

Table 5.3: Distribution of MPTs at site S1 to S6 in Rhamu-Galicha area, Mandera district. A summary of 90 quadrats.

	Site number from the bank of the River Daua at one km interval							Site number from the bank of the River Daua at one km interval					
MPTs species	S1	S2	S3	S4	S5	S6	MPTs species	S1	S2	S3	S4	S5	S6
Acacia tortilis	+	+	+	+	+	+	*B. rivae*	-	-	+	+	+	+
A. seyal	+	+	+	+	+	-	*B. neglecta*	-	+	+	+	+	+
A. senegal	-	+	+	+	+	+	*B. rotundifolia*	-	+	+	+	-	+
A. paolii	+	+	+	+	+	+	*B. anguisitifolia*	-	+	-	+	+	-
A. refeciens	-	+	+	+	+	+	*B. salicifolia*	-	-	+	+	-	-
A. egdeworthii	-	+	+	-	+	:	*B. pubescens*	-	-	-	+	+	-
A. mellifera	-	-	-	-	-	+	*B. minimifolia*	-	+	+	+	+	+
A. horrida	-	+	+	+	+	+	*B. maxima**	-	-	-	+	-	+
A. nilotica	-	+	-	-	-	-	*C. ogandensis*	-	-	+	+	-	+
A. condyloclada	-	-	-	+	+	+	*C. myrrha*	-	+	+	+	+	+
*A. mauritianum**	-	+	-	+	-	-	*C. habessinica*	-	-	-	+	-	+
A. anthelmentica	+	+	+	+	-	-	*C. danduensis*	-	-	-	-	+	+
Adenium obesum	-	-	+	+	-	-	*C. rostara*	-	-	+	+	-	+
Asparagus sp.	-	-	-	+	-	+	*C. gracilispina*	-	+	+	-	-	-

A. tanensis	-	+	+	+	+	+	*C. pseudopaolii*	-	-	-	-	-	+
Azadirachta indica	+	-	-	-	-	-	*C. velutina*	-	+	+	+	+	+
Aspilia mossambicensis	-	+	+	+	-	-	*Cleome handuryana*	-	-	-	-	-	+
*A. javanica**	-	+	+	+	+	+	*Callotropis procera*	-	+	+	+	-	-
Carica papaya	+	-	-	-	-	-	*Citrus lemon*	+	-	-	-	-	-
C. quercifolia	+	+	+	+	+	+	*G. hababensis*	-	-	+	-	-	+
C. senensis	+	-	-	-	-	-	*H. compresa*	+	+	+	-	-	-
Combretum hereroense	-	+	+	+	+	+	*Helitropium steudneri**	-	-	-	-	+	+
C. aculeatum	-	-	+	+	-	-	*H. calyphyllus*	-	+	-	+	-	-
Caucanthus albidus	-	+	+	+	+	+	*I. spinosa*	-	+	-	+	+	+
Clandostigma hildebrandtoides	-	+	+	+	+	+	*I. schimperi*	+	+	+	-	-	-
C. glaucascens	-	+	+	-	+	+	*I. donaldsonii*	-	+	+	+	+	+
Croton somalensis	-	+	+	+	-	-	*Justicia* sp.	-	+	-	+	+	+
Cassia sp.	-	-	-	-	+	+	*Kigelia africana*	-	+	-	-	-	-
D. glabra	-	+	+	+	+	+	*Kirkia tenuifolia*	-	-	+	+	-	+
Delonix baccal	-	+	+	+	-	+	*L. inermis*	+	+	+	+	-	-
E. cuneata	-	+	+	+	+	+	*L. europaeum*	-	+	+	-	+	+
Erythrochlamys spectabilis	-	-	+	+	+	+	*Lannea malifolia*	-	-	-	+	-	-

Ficus sp.	+	-	-	-	-	-	*L. shweinfurthii*	-	-	-	+	-	-
F. sur	+	+	-	-	-	-	*Lantana* sp.	-	+	-	-	+	+
G. volkensii	-	+	+	+	+	+	*M. borziana*	-	-	+	-	+	-
Psidium guajava	+	-	-	-	-	-	*Mangifera indica*	+	+	-	-	-	-
Grewia bicolor	-	-	-	-	-	+	*M. longituba*	-	+	+	-	-	-
G. tembensis	-	+	+	+	+	+	*Occimum suave*	-	-	-	-	+	+
G. tenax	-	+	+	+	+	+	*P. reclinata*	+	-	-	-	-	-
Grewia villosa	-	-	+	-	+	+	*P. scioana*	-	-	-	+	+	+
G. lilacina	-	+	+	+	+	+	*Prosopis juliflora*	+	+	+	-	-	-
*Glorisia minor**	-	-	-	+	-	-	*S. jubae*	-	+	-	+	+	+
S. busseanus	-	+	+	+	+	+	*S. persica*	-	+	+	-	-	-
S. pallida	-	-	+	+	+	+	*T. danis*	+	+	+	+	-	-
T. polycarpa	-	+	+	+	+	+	*T. parvula*	-	-	+	-	-	-
T. orbicularis	-	-	-	+	-	+	*T. aphylla*	+	-	-	-	-	-
Wrightia demartiniana	-	-	+	+	+	+	*Z. hamur*	-	-	-	-	+	+
Z. mauritiana	+	+	+	+	-	-							

* These plants are herbs but I find them useful to mention because of their important uses or their uniqueness.

+ = present - = absent

5.1.1 Horticultural trees on farmlands

It involves fruit tree husbandry, a practice where farmers include fruit trees on their farms either for economic production or to improve famliy's diet (SWCB, 1992). The practice was present in all the surveyed farms along the river bank. Orchards of fruit trees are established close to the river sometimes acting as river bank stabilizers. The MPTs were planted 4-5 m apart usually in linear arrangements, sometimes mixed (plate 5.3) and at times in pure stands. Crops are planted between the trees when they are still tender until they close their canopies. Seedlings are raised in the farmers nurseries and the planted tender seedlings are watered in the dry seasons. Crops are also planted behind the trees away from the river. The main economically useful MPTs species are Mangoes (*Mangifera indica*), Guava (*Psidium guajava*), Paw paw (*Carica papaya*), Custard apple (*Annona cherimoya*), Lemons (*Citrus lemon*) and Desert banana (*Musa serpentium*) but farmers are still diversifying the species with the trials of other fruit trees, for example Ovacado (*Persia americana*) at Haji Kerrow's farm. The replacement of indigenous species by economically important species in farms along arid land river courses was also reported by Niamir (1990), SWCB (1992) and Nair (1989). Pruning is conducted to increase crown size, hence fruit productivity.

The major crops grown with the MPTs are goose necked sorghum, maize and cowpea. The MPTs apart from the provision of fruits, provide bee forage, shade for tree nursery (plate 5.3) and farmers, firewood, poles, income and river bank stabilization. The planting of fruit trees is ideal for river bank stabilization (Simute, 1992).

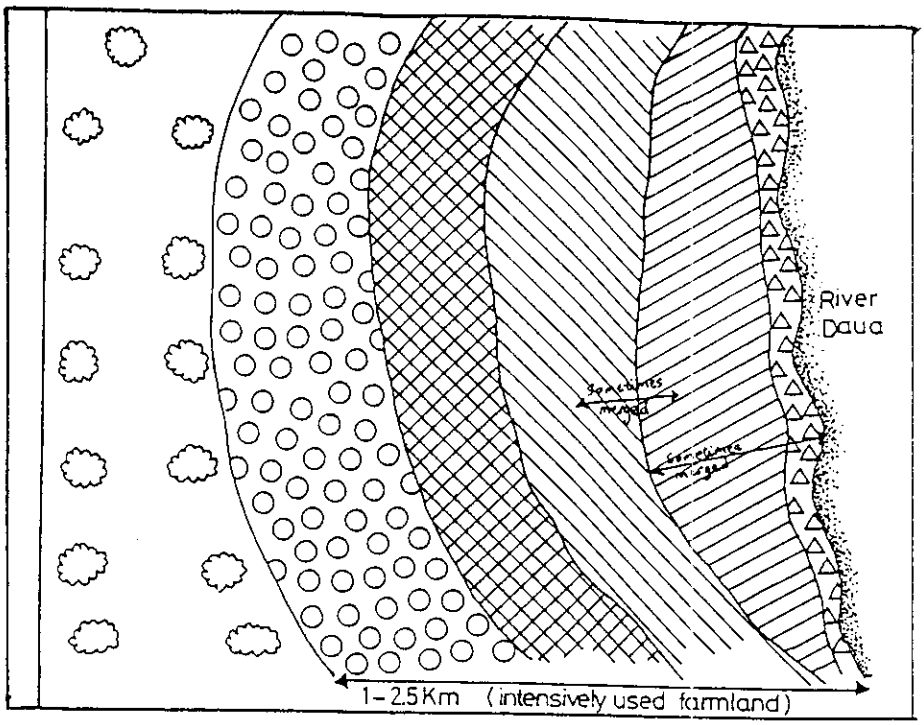
Plate 5.3: Mixed fruit MPTs of *Annona cherimoya*, *Mangifera indica* and *Psidium guajava* on farmland along the River Daua, Central Division, Mandera District.

Problems associated with fruit farming in the area are theft, lack of species diversity, prolonged floods (paw paw perishes), birds and mammal (mainly baboons and monkeys) pests, insect pests, diseases and strong wind that causes immature fruit fall.

The planting of horticultural trees along the river is as a result of farmers initiative combined with extension work. The Government through the Agricultural Department discourages clearing of river bank and if cleared encourages fruit tree planting. It is important to note the generalized model of land use of farms along the river (Fig.5.2). The planting of the fruit trees near the bank of the river could also be related to soil texture which is more sandy than further away from the river. It could also be related to the tolerance of fruit trees to floods than crops and the fact that fruit species like banana requires frequent irrigation, hence the nearer the source of water the more it is economical in the use of water.

5.1.2. MPTs for river bank stabilization

In arid areas such Mandera, river course is important for natural riparian forests and wild life, livestock and cropping. Land use changed towards cropping but in most of the farms, the naturally occurring MPTs have been deliberately retained along the river bank (plate 5.4). Examples of the species are *H. compressa*, *T. danis*, *L. inermis*, *A. seyal*, *P. reclinata*, *I. schimperii*, *F. sur*, *T. aphylla* and *T. indica*. Indigenous MPTs with high IVI (Fig.5.3 and 5.4) on the river bank were noted to have been favoured for river bank stabilization.



LEGEND

MPTs in Range Land (Communal pastures)

Sharmat (Pasture zone) with natural MPTs

Crops, vegetables (grazed when there are no crops by camels, goats, sheep and cattle)

Long duration perennial fruit trees (mangoes, guava lemons) sometimes mixed with sugarcane

Short duration perennial fruit plants (pawpaw and banana) sometimes mixed with cowpea

Natural MPTs for river bank stabilization

Fig. 5.2: Sketch of general land use on farmlands along the River Daua, Mandera District.

Plate 5.4: MPTs deliberately retained by farmers along the Daua River for bank stabilization, Central Division, Mandera District. The species are *F. sur*, *Z. mauritiana*, *L. inermis* and *H. compressa*.

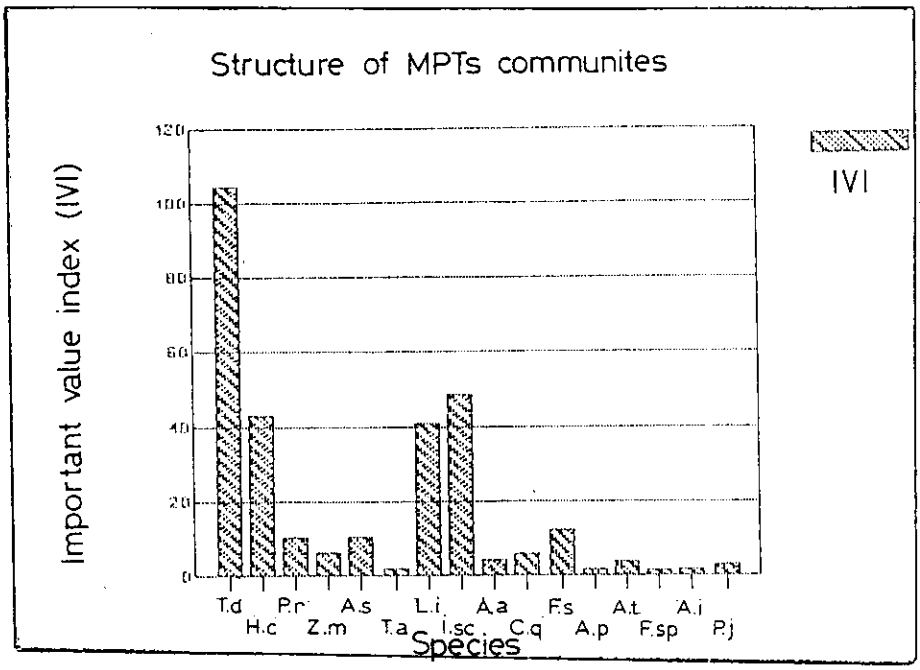


Figure 5.3: The structure of *T. danis - I. schimperii* MPTs community along the River Daua (S1) in Rhamu-Galicha area, Mandera District.

T.d	= *Thespesia danis*	H.c	= *Hyphaene compressa*
P.r	= *Phoenix reclinata*	Z.m	= *Ziziphus mauritiana*
A.s	= *Acacia seyal*	T.a	= *Tamarix aphylla*
L.i	= *Lawsonia inermis*	I.sc	= *Indigofera schimperii*
A.p	= *Acacia paolii*	C. q	= *Cordia quercifolia*
F.s	= *Ficus sur*	A.a	= *Albizia anthelmentica*
A.t	= *Acacia tortilis*	A.i	= *Azidaracta indica*
P.j	= *Prosopis juliflora*	F.sp	= *Ficus* sp

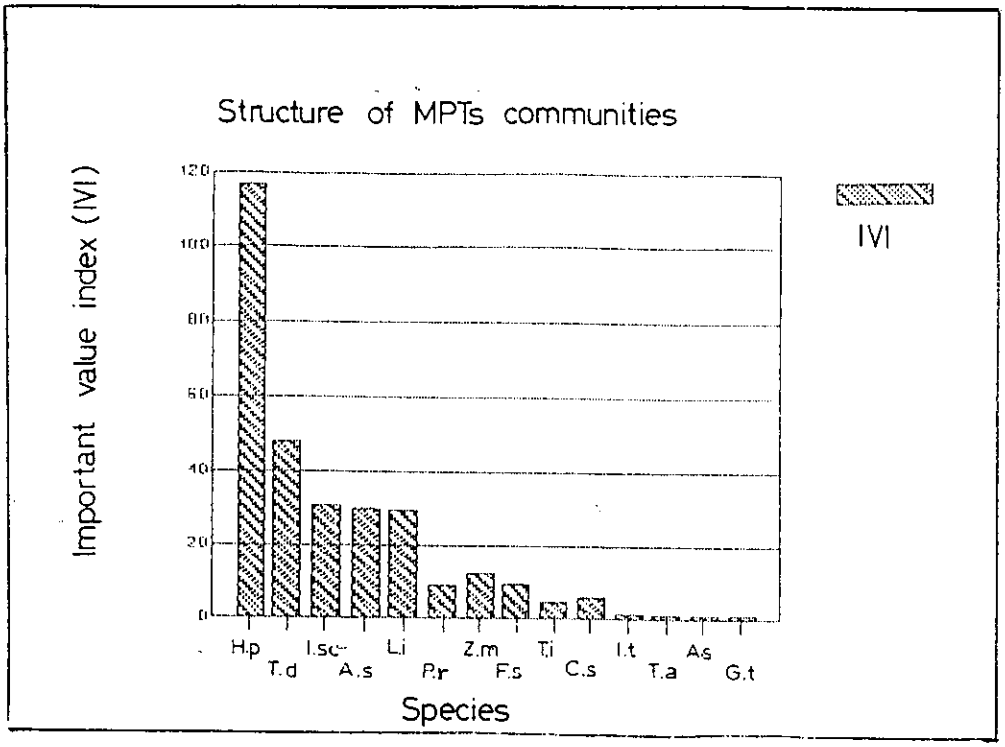


Figure 5.4: The structure of *H. compressa* - *T. danis* MPTs community along the bank of the River Daua (S1) in Khalaliyo-Fiqho area, Mandera District.

H.p = *Hyphaene compressa* L.i = *Lawsonia inermis*
T.d = *Thespesia danis* A.s = *Acacia seyal*
I.sc = *Indigofera schimperii* Z.m = *Ziziphus mauritiana*
F.s = *Ficus sur* P.r = *Phoenix reclinata*
C.s = *Cordia sinensis* I.t = *Indigofera trita*
T.a = *Tamarix aphylla* G.t = *Grewia tenax*
T.i = *Tamarindus indica* A.se = *Acacia senegal*

The farmers also planted exotic MPTs such as *A. indica*, *Mangifera indica*, *P. juliflora*, *E. tirucalli* and *Canocarpus lancifolius* to structurally supplement the indigenous species. This is meant to protect fertile land from river erosion through their deep rooting system (Wenner, 1981). It is also an indirect practice of conservation and protection of the species. The species filters run off and contributes to river water quality, increases soil fertility, prevents flooding damages, maintains fish population, stabilizes water temperature, prevents sedimentation and acts as habitat for wildlife (Simute, 1992; FAO, 1988b; SWCB, 1992). They also provide wood products, shade, fodder, fruits and building materials. In some farms, the river bank has been cleared leading to soil erosion and loss of fertile lands, species diversity and in the long run the drying up of the already seasonal river. However the effect of MPTs along the river is not always positive, they can use large volume of water which is crucial in dry seasons, act as a hiding place for crop and livestock pests and compete with crop for nutrients. The practice is hybrid of traditional and exotic practices. Example are the Seyyid Abass farms in Rhamu Division and Haji Muhamud's farm in Central Division.

5.1.3. Border planting with MPTs

Farmers left deliberately natural MPTs to mark farms internal and external borders. It was noted in all farms surveyed and it is a sign of land ownership. Some of the species are used as bench mark to settle land dispute between neighbouring farmers. The species have to be large enough to be recognized by fellow farmer witnesses. It is not to be cut. Some farmers also planted exotic MPTs along the borders. The species also provide dry fodder, fruits, fuelwood, poles and posts, thatch, shade and wind break. The spacing

between the species vary. The main MPTs are *H. compressa*, *T. danis*, *L. inermis*, *F. sur*, *A. seyal*, *A. tortilis*, *Z. mauritiana*, *K. africana*, *A. indica*, *P. juliflora*, *P. reclinata*, *D. glabra* and *S. persica*. Some of the species with high IVI (Fig. 5.3 to 5.6) were the ones selected by farmers for border planting. The farmers involvement in border planting management is an indigenous initiative and is a step forward in species conservation but it requires diversification. They are also indirectly conserving the soil of the area.

Specific examples in Rhamu-Galicha area are the rain-fed farms between Rhamu and Yabicho where *D. glabra* are deliberately left along farm boundaries.

5.1.4. Silvopastoral practices of MPTs mixed with pastures "Sharmat or Sakar"

This is a form of traditional feed lot which forms part of the farm, usually on less productive part or part of the farm far from the river. Almost all of the farm's surveyed have "sharma "(singular) / "sharmat" (plural) or "Sakar" where the livestock graze and browse (plates 5.5) especially in the dry season. The scattered naturally occurring MPTs are left in the pastures to provide fodder in dry seasons and other uses for example dead fencing material, withes, posts and poles for construction and sale, thatch, sticks, fuelwood, medicine, bee forage, fruits, gums, local wood preservatives and for soil and water conservation. Some times the farmers thin the MPTs if they become too dense to reduce grass cover and at times, fast growing species like *T. danis* and *L. inermis* for poles and post are completely cleared to allow natural regeneration. *F. sur* is pollarded in dry seasons for fodder and the stem of juvenile *H. compressa* is chopped during drought as a last alternative fodder.

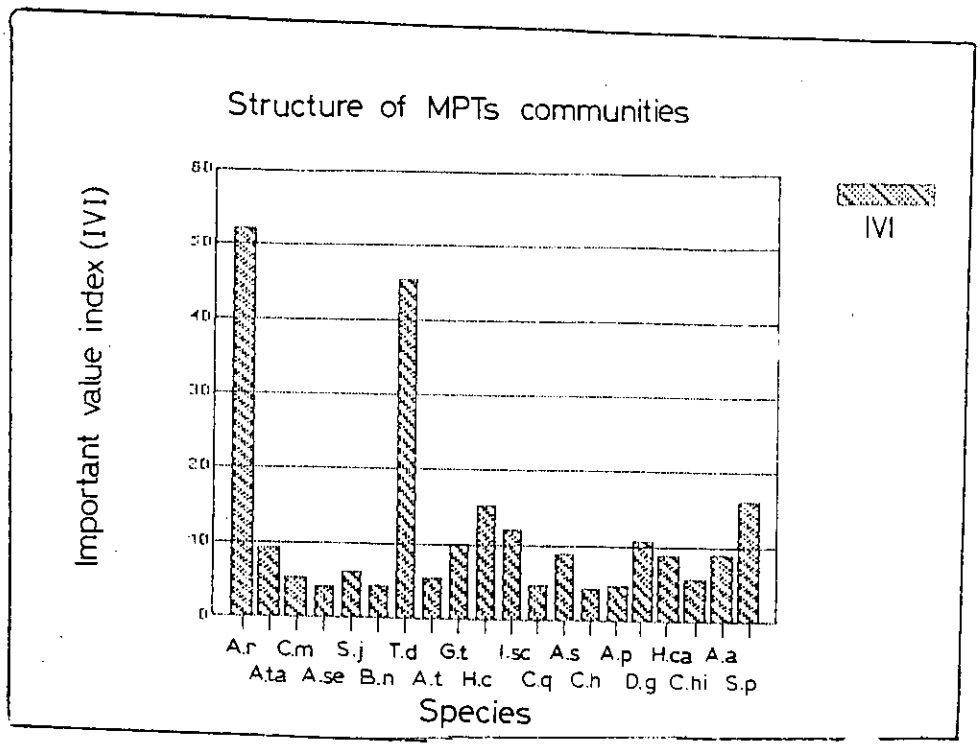


Figure 5.5: The structure of *A. refeciens - T. danis* MPTs community one km from the River Daua (S2) in Rhamu-Galicha area, Mandera District.

I.sc = *Indigofera schimperii*
A.r = *Acacia refeciens*
C.m = *Commiphera myrrha*
S.j = *Solanum jubae*
T.d = *Thespesia danis*
G.t = *Grewia tenax*
C.q = *Cordia quercifolia*
C.h = *Combretum hereroense*
D.g = *Dobera glabra*
A.a = *Albizia anthelmentica*
C.hi = *Clandostigma hildebrantioides*
A.ta = *Anistotes tanensis*
A.se = *Acacia senegal*
B.n = *Boswellia neglecta*
A.t = *Acacia tortilis*
H.c = *Hyphaene compressa*
A.s = *Acacia seyal*
A.p = *Acacia paolii*
H.ca = *Hibiscus calyphyllus*
S.p = *Salvadora persica*

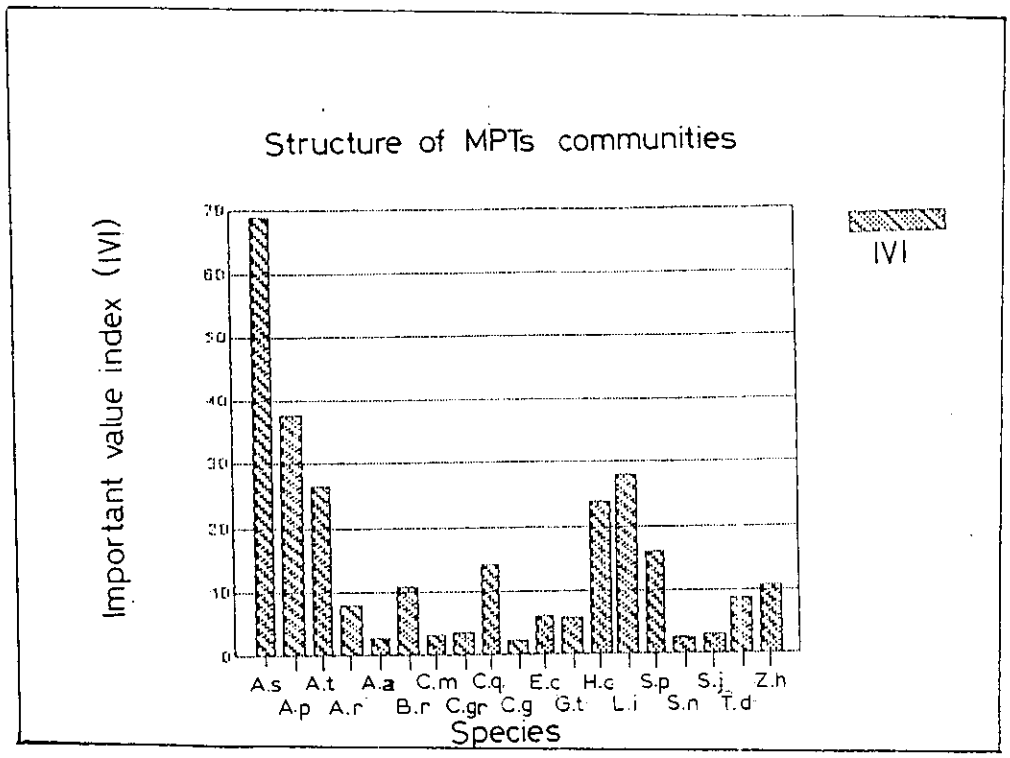


Figure 5.6: The structure of *A. seyal - A.paolii* MPTs community one km from the River Daua (S2) in Khalaliyo-Fiqho area, Mandera District.

A.s = *Acacia seyal* A.p = *Acacia paolii*
A.t = *Acacia tortilis* A.r = *Acacia refeciens*
A.a = *Albizia anthelmentica* B.r = *Balanites rotundifolia*
C.m = *Commiphora myrrha* C.q = *Cordia quercifolia*
C.g = *Cadaba glandulosa* E.c = *Euphorbia cuneata*
G.t = *Grewia tenax* H.c = *Hyphaene compressa*
L.i = *Lawsonia inermis* S.p = *Salvadora V*
S.n = *Solanum* sp S.j = *Solanum jubae*
T.d = *Thespesia danis* Z.h = *Ziziphus hamur*
C.gr = *Commiphora gracilispina*

Plate 5.5: Camel browsing on *Salvadora persica* in "Sharmat" /pasture, Central Division, Mandera District.

Wildlife also utilize the site. In case the farmer has excess pasture, it is sold to other farmers or nomads who need it in dry seasons. The "sharmat" of today has replaced the traditionally dry fodder grazing reserves along the river. Wildlife also utilize the site as a habitat hiding under the MPTs. The practice helps in the conservation of species which would otherwise have been cleared for cropping, hence increases biodiversity. It also acts as dry fodder grazing reserve for the farmer.

The main MPTs species are: *A. seyal*, *A. tortilis*, *A. paolii*, *H. compressa*, *T. danis*, *L. inermis*, *D. glabra*, *S. persica*, *T. aphylla*, *C. quercifolia*, *F. sur*, *L. europaeum*, *G. volkensii*, *Z. mauritiana*, *T. polycarpa* and *B. anguisitifolia*. Some of the species with high IVI (Fig. 5.5, 5.6, 5.7 and 5.8) have also been deliberately left in pastures. During the dry seasons in arid areas, grasses virtually disappear or become fibrous, trees and shrubs then forms an essential part of the livestock diet (Rocheleau *et al*, 1989). Some of the herbs/dwarfy shrubs that are found in the "sharmat" are *Boerhavia erecta*, *Heliotropium steudneri*, *Indigofera* spp. and *Cleome allamani*. The main grass species are: *Sporobulus helvolus*, *Urochloa trichopus*, *Boturiochloa insculpla*, *Enchinocloa haploclada*, *Echinocloa sp.*, *Cenchrus ciliaris* and *Sorghum verticiliforum* (wild Sudan grass). In addition along the river and frequent flood plains, the grasses grow in complex association with *Cypres* sp. In isolated "Sharmat" in the midlands, *Chloris virgata* and *Tetrapogon* sp are common. The grasses under MPTs remain green for along period probably due to shade and extended moisture availability.

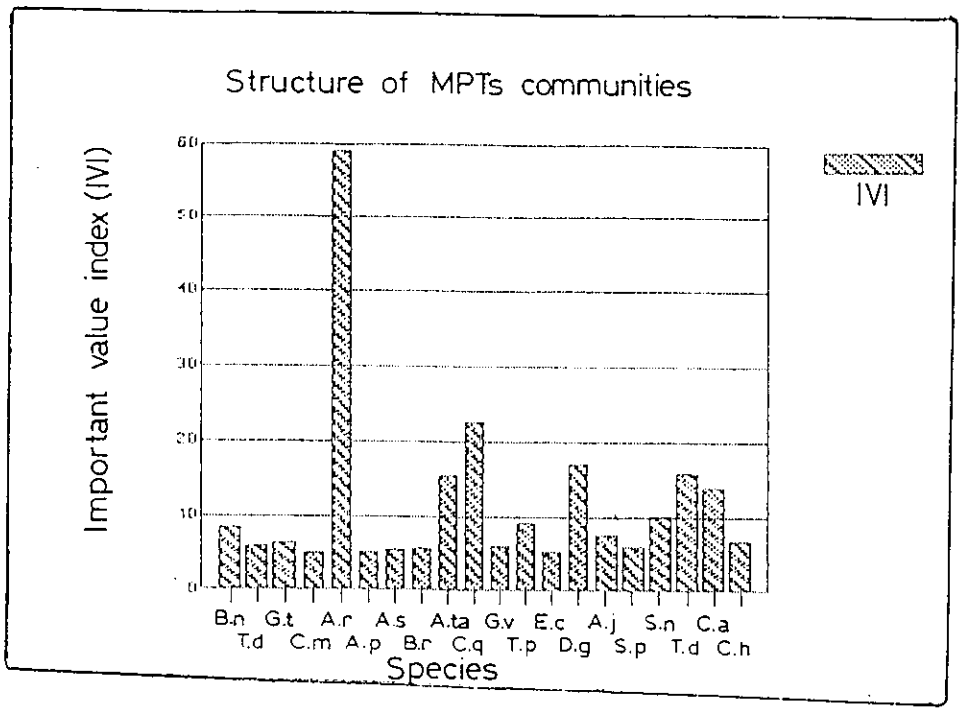


Figure 5.7: The structure of *A. refeciens - C. quercifolia* MPTs community two km from the River Daua (S3) in Rhamu-Galicha area, Mandera District.

T.p = *Terminalia polycarpa*
D.g = *Dobera glabra*
S.p = *Salvadora persica*
T.d = *Thespesia danis*
C.h = *Combretum hereroense*
I.d = *Ipomea donaldsonii*
C.m = *Commiphora myrrha*
A.p = *Acacia paolii*
B.r = *Balanites rotundifolia*
C.q = *Cordia quercifolia*
E.c = *Euphorbia cuneata*
A.j = *Aerva javanica*
S.n = *Solanum sp*
C.a = *Combretum aculeatum*
B.n = *Boswellia neglecta*
G.t = *Grewia tenax*
A.r = *Acacia refeciens*
A.s = *Acacia seyal*
A.ta = *Anistotes tanensis*
G.v = *Gardenia volkensii*

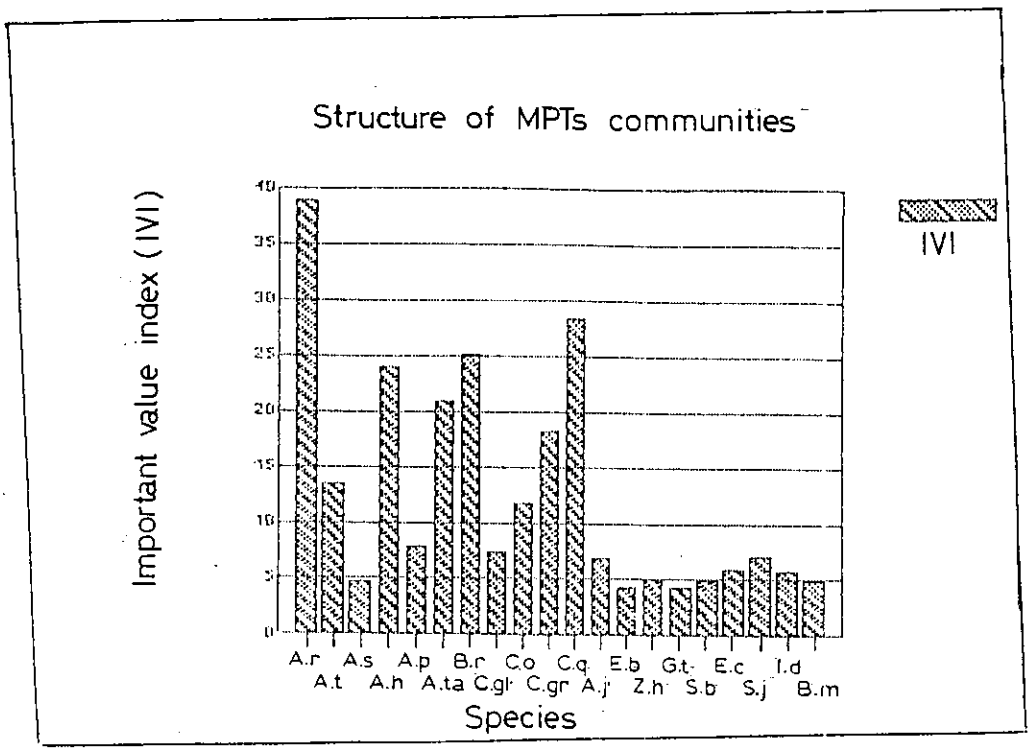


Figure 5.8 : The structure of *A. refeciens - C. quercifolia* MPTs community two km from the River Daua (S3) in Khalaliyo-Fiqho area, Mandera District.

A.r = *Acacia refeciens*
A.s = *Acacia seyal*
A.p = *Acacia paolii*
B.m = *Boscia minimifolia*
C.gl = *Cadaba glandulosa*
I.d = *Ipomea donaldsonii*
C.q = *Cordia quercifolia*
G.t = *Grewia tenax*
C.gr = *Commiphora gracilispina*
E.b = *Euphorbia breviarticulata*
S.b = *Sesamothamnus busseanus*
A.t = *Acacia tortilis*
A.h = *Acacia horrida*
A.ta = *Anistotes tanensis*
B.r = *Balanites rotundifolia*
C.o = *Commiphora ogandensis*
A.r = *Aerva javanica*
Z.h = *Ziziphus hamur*
E.c = *Euphorbia cuneata*
S.j = *Solanum jubae*

5.1.5 Shade MPTs on farmlands

This is a traditional practice where the species are scattered within the farm (plate 5.6) and along borders purposely to provide shade for the farmer, equipments and livestock. The species have been planted or are naturally occurring and deliberately left within the farms. A good example is *Dobera glabra* scattered in rain-fed farms of Rhamu-Galicha area. The other main MPTs are *Trichilia ementica, M. indica, T. indica, T. aphylla, F. sur, L. inermis, A. indica, A. tortilis, T. danis, S. persica* and *H. compressa*. Some of the species left in the farms for shade have also high IVI (Fig.5.3, 5.4, 5.5, 5.6 and 5.7). Pruning is frequently done to shape the shade. The shade is useful especially in dry season when it reduces the high temperature experienced during the day (Daly, 1984; Simute, 1992). The species also provide edible fruits, fodder (by pollarding), fuelwood, medicine, chewing stick and act as raised beds (on top of the trees) from where wildlife pests (birds and mammals) can be viewed. The beds are also used to escape from wild life predators and mosquitoes at night and it acts as storage site for dry stovers and grasses for use as hay in dry season. The preference of the farmers have conserved the species as a result of their multiple use. The species are protected from indiscriminate cutting and browsing except pollarding.

Plate 5.6: Shade tree (*Trichilia ementica*) on farmland along the River Daua, Central Division, Mandera District.

5.1.6 Live fences and hedges on farmlands

Live fencing on farmland in the Daua Valley involves the use of living plants and/or plant parts to fence off farmer's land within and without. Without is meant to exclude roaming domestic and wild animals and within is meant to partition the farm for various uses, for example division of pasture and crop sections. Most of the farms are fenced with dead fences intercepted by MPTs in between for reinforcement to reduce the time required for fencing and amount of dead fence needed. Some farms for example, Haji Mohamud's farm in Central Division and Seyyid Abass's farm in Rhamu Division have live and dead fences reinforced with barbed wires. Live fence is a cheap method. Dead fence contribute to decrease in soil fertility and deforestation and it has short life span (one to two seasons) and must be constantly replaced. This places high demands on farmers and the environment (ICRAF, 1995). The main MPTs are: *E. tirucalli*, *A. seyal*, *A. tortilis*, *A. senegal*, *H. compressa*, *L. inermis*, *Z. hamur* and *Z. mauritiana* (plate 5.7). Some of the species with high IVI (Fig. 5.3, 5.4, and 5.5) have been left as live fence.

The planting of MPTs for farmland fencing is exotic to the Daua Valley but live fence with naturally occurring *Acacia* spp, *Commiphora* and *Ziziphus* spp is common. Similar observation was made by Nair (1989a) on farms of arid and semi-arid lands. *E. tirucalli* and *Commiphora* spp. are planted from cuttings. The fence are linearly arranged and are frequently pruned especially on the cropland side to reduce competition. They contribute dead fence material, provide fodder, fuelwood, gums, medicinal uses, posts and poles, shade, soil and water conservation and wind break.The MPTs can also have their negative effect of harbouring farm pests and diseases. They also compete with crops for moisture and nutrients, hence reducing crop yield close to the fence.

Plate 5.7: Naturally growing MPTs for live fence on farmland; Central Division, Mandera District. The species are *Z. hamur*, *Z. mauritiana*, *T. danis* and *L. inermis*.

5.1.7 Traditional Bush fallow

The practice of leaving part of a farm to fallow under natural MPTs and grasses is not a new phenomenon in Mandera. Some farmers leave their land fallow for 3-15 years before cropping, depending on the farm size. For example, Seyyid Abass's farm in Rhamu and Yussuf Sheikh's farm in Central Division (plate 5.8). The main natural MPTs that regenerate are composed of leguminous species such as *I. trita*, *I. schimperi* and *A. seyal.* Other species are *T. danis*, *L. inermis*, *H. compressa* and *Z. mauritiana*. The species with high IVI (Fig. 5.3 to 5.6) are dominant in the practice. These plants plus the herb layer add humus in form of litter to the soil.

After the farmer is satisfied that the soil has recovered or that the tiled soil have been exhausted of nutrients, the fallow site is cleared for cropping. some farmers burn the vegetation after clearing to get rid of large sized plant materials and to increase soil fertility. But before burning, valuable parts are salvaged for use or for sale. The fallow zone also act as dry fodder reserve and habitat for wildlife, hence it is away of conserving species diversity for both fauna and flora. The fallow could also helps disrupt the life cycles of crop pests and diseases but it can act as a hiding site for wildlife pests and source of seeds of weeds.

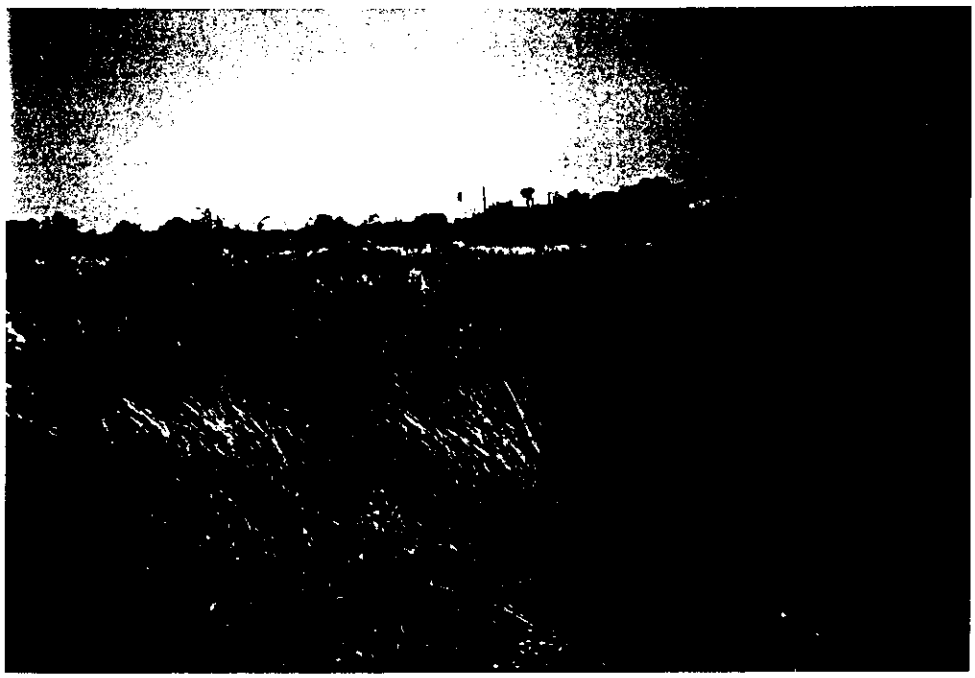


Plate 5.8: Traditional bush fallow (grass) on farmland; Central Division, Mandera District. The grass is *B. insculpla*, the herbs are mainly *B. erecta* and MPTs saplings are *A. seyal*, *C. procera* and *I. trita*.

5.1.8 Apiculture with MPTs

The practice is a hybrid of traditional and exotic knowledge. The MPTs are used by some farmers to make local bee hives, or they are used for placement of the hives. The plants also provide bee forage. Mandera Islamic Centre's farm is an example. Adjacent to the cropland, the farm has MPTs that form good shade for the Kenyan Top Bee Hives. The bee hives are hidden in the crown of MPTs to avoid theft. The main MPTs are: *A. tortilis*, *A. seyal*, *A. senegal*, *D. glabra*, *A. indica*, *C. lancifolius*, *P. juliflora*, *T. indica*, *A. indica*, *F. sur*, *M. indica*, *Z. mauritiana*, *P. guava*, *C. lemon* and *L. inermis*. Apart from MPTs in farm lands, bees also forage from nearby range lands MPTs, for example *A. horrida*, *B. anguisitifolia*, *B. tomentella*, *A. paolii*, *A. refeciens*, *A. mellifera*, *C. quercifolia* and *Grewia* spp. Some for the species for the practice are also the ecologically dominant species in the valley (Fig. 5.3 to 5.14). The MPTs also provide other uses like fodder, fuelwood, windbreak, shade, fruit and ornamental.

The species for making bee hives are Doum palm, *F. sur*, and *K. africana*. Sometimes the bee hives are also placed in "Sharmat" and on MPTs for river bank stabilization.

Problems: Theft and Honey burger.

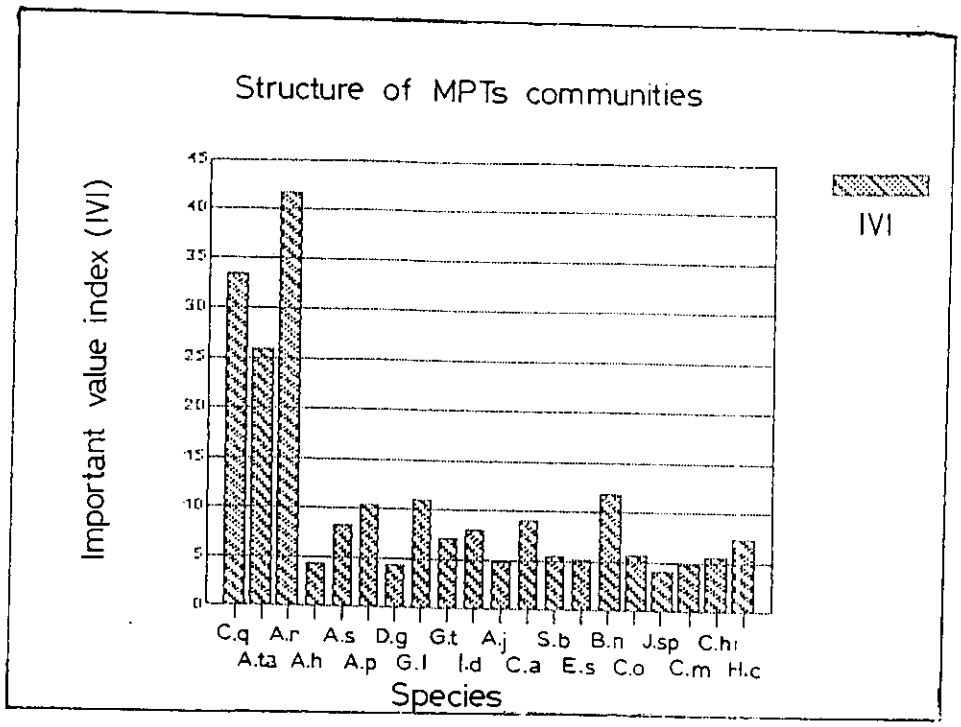


Figure 5.9 The structure of *A. refeciens - C.quercifolia* MPTs community three km from the River Daua (S4) in Rhamu-Galicha area, Mandera District.

A.p = *Acacia paolii*
D.g = *Dobera glabra*
A.r = *Acacia refeciens*
A.s = *Acacia seyal*
G.t = *Grewia tenax*
A.j = *Aerva javanica*
J.sp = *Justicia* sp
S.b = *Sesamothamnus busseanus*
C.m = *Commiphora myrrha*
E.s = *Erythrochlamys spectabilis*
C.a = *Combretum aculeatum*
C.hi = *Clandostigma hildebrantioides*
H.c = *Hibiscus calyphyllus*
C.q = *Cordia quercifolia*
A.ta = *Anistotes tanensis*
A.h = *Acacia horrida*
G.l = *Grewia lilacina*
I.d = *Ipomea donaldsonii*
B.n = *Boswellia neglecta*
C.o = *Commiphora ogandensis*

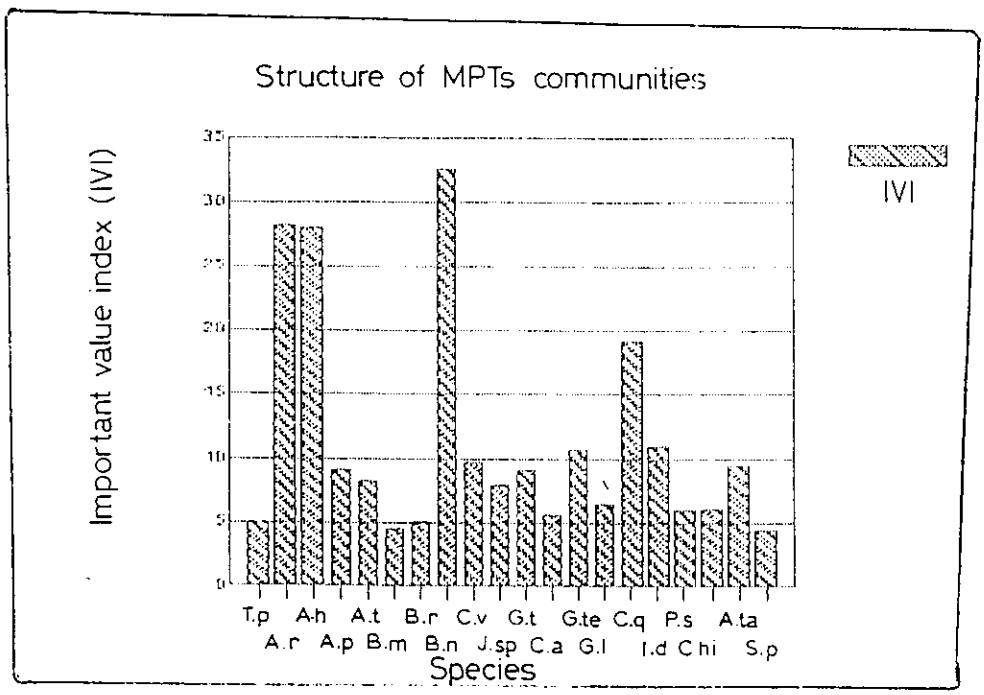


Figure 5.10: The structure of *B. neglecta* - *A. refeciens* MPTs community four km from the River Daua (S5) in Rhamu-Galicha area, Mandera District

T.p = *Terminalia polycarpa*
A.h = *Acacia horrida*
A.t = *Acacia tortilis*
B.r = *Boswellia rivae*
J.sp = *Justicia* sp
C.a = *Caucanthus albidus*
C.q = *Cordia quercifolia*
A.ta = *Anistotes tanensis*
B.n = *Boswellia neglecta*
I.d = *Ipomea donalsonii*
C.hi = *Clandostigma hildebrantioides*
A.r = *Acacia refeciens*
A.p = *Acacia paolii*
B.m = *Boswellia microphylla*
C.v = *Commiphora velutina*
G.t = *Grewia tenax*
G.l = *Grewia lilacina*
P.s = *Parkinsonia scioana*
S.p = *Sericocomopsis pallida*
G.te = *Grewia tembensis*

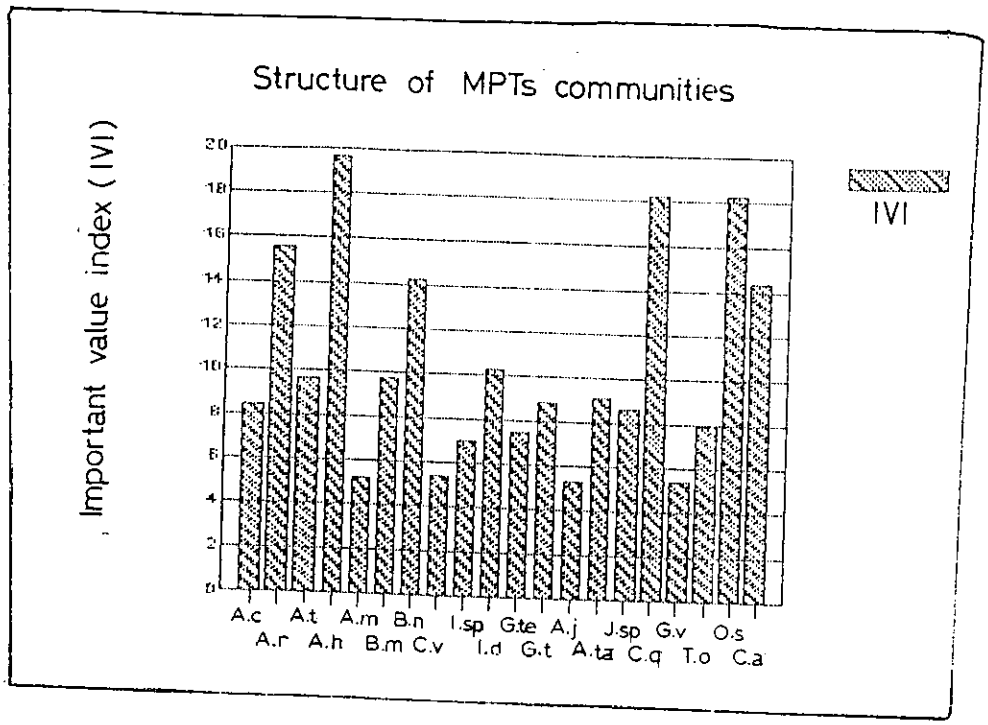


Figure 5.11: The structure of *A. horrida - C. quercifolia* MPTs community five km from the River Daua (S6) in Rhamu-Galicha area, Mandera District.

A.c = *Acacia condyloclada* A.r = *Acacia refeciens*
A.t = *Acacia tortilis* A.h = *Acacia horrida*
A.m = *Acacia mellifera* B.m = *Boswellia microphylla*
B.n = *Boswellia neglecta* C.v = *Commiphora velutina*
I.sp = *Indigofera spinosa* I.d = *Ipomea donaldsonii*
G.te = *Grewia tembensis* G.t = *Grewia tenax*
A.j = *Aerva javanica* A.ta = *Anistotes tanensis*
C.q = *Cordia quercifolia* G.v = *Gardenia volkensii*
T.o = *Terminalia orbicularis* O.s = *Occimum suave*
C.a = *Caucanthus albidus* J.sp = *Justicia* sp

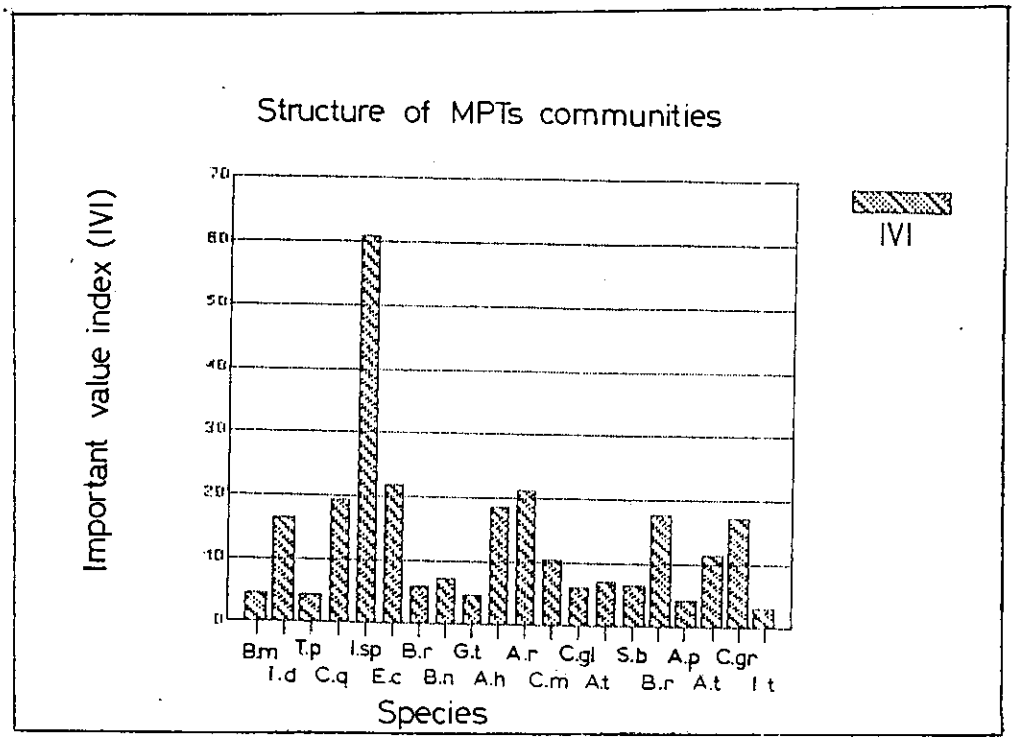


Figure 5.12: The structure of *I. spinosa - E. cuneata* MPTs community three km from the River Daua (S4) in Khalaliyo-Fiqho area, Mandera District.

B.m = *Boscia minimifolia*
T.p = *Terminalia parvula*
I.sp = *Indigofera spinosa*
B.r = *Boswellia rivae*
A.t = *Acacia tortilis*
A.r = *Acacia refeciens*
C.gl = *Cadaba glandulosa*
B.r = *Balanites rotundifolia*
I.t = *Indigofera trita*
C.gr = *Commiphora gracilispina*
S.b = *Sesamothamnus busseanus*
I.d = *Ipomea donalsonii*
C.q = *Cordia quercifolia*
E.c = *Euphorbia cuneata*
B.n = *Boswellia neglecta*
G.t = *Grewia tenax*
C.m = *Commiphora myrrha*
A.ta = *Anistotes tanensis*
A.p = *Acacia paolii*
C.h = *Commiphora habessinica*

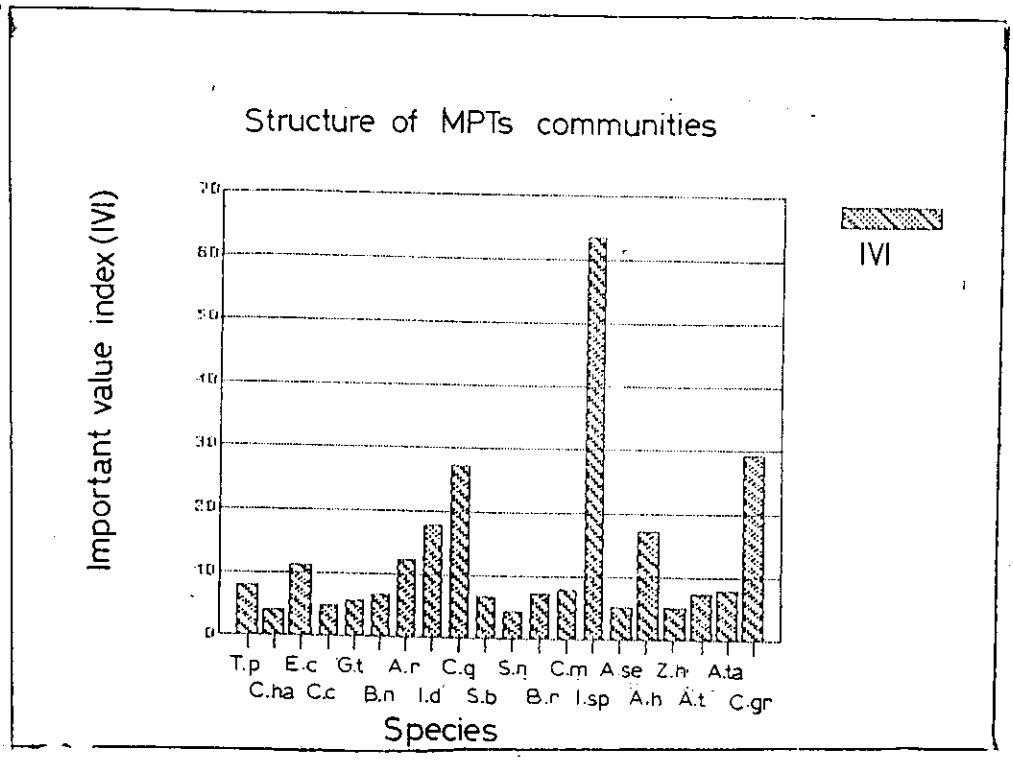


Figure 5.13: The structure of *I. spinosa* - *C. gracilispina* MPTs community four km from the River Daua (S5) in Khalaliyo-Fiqho area, Mandera District.

T.p = *Terminalia parvula*
E.c = *Euphorbia cuneata*
G.t = *Grewia tenax*
A.r = *Acacia refeciens*
A.se = *Acacia senegal*
A.h = *Acacia horrida*
B.r = *Balanites rotundifolia*
C.m = *Commiphora myrrha*
I.sp = *Indigofera spinosa*
S.b = *Sesamothamnus busseanus*
C.gr = *Commiphora gracilispina*
C.ha = *Commiphora habessinica*
C.c = *Commiphora campetris*
B.n = *Boswellia neglecta*
I.d = *Ipomea donaldsonii*
C.q = *Cordia quercifolia*
Z.h = *Ziziphus hamur*
A.ta = *Anistotes tanensis*
A.t = *Acacia tortilis*
S.n = *Solanum* sp

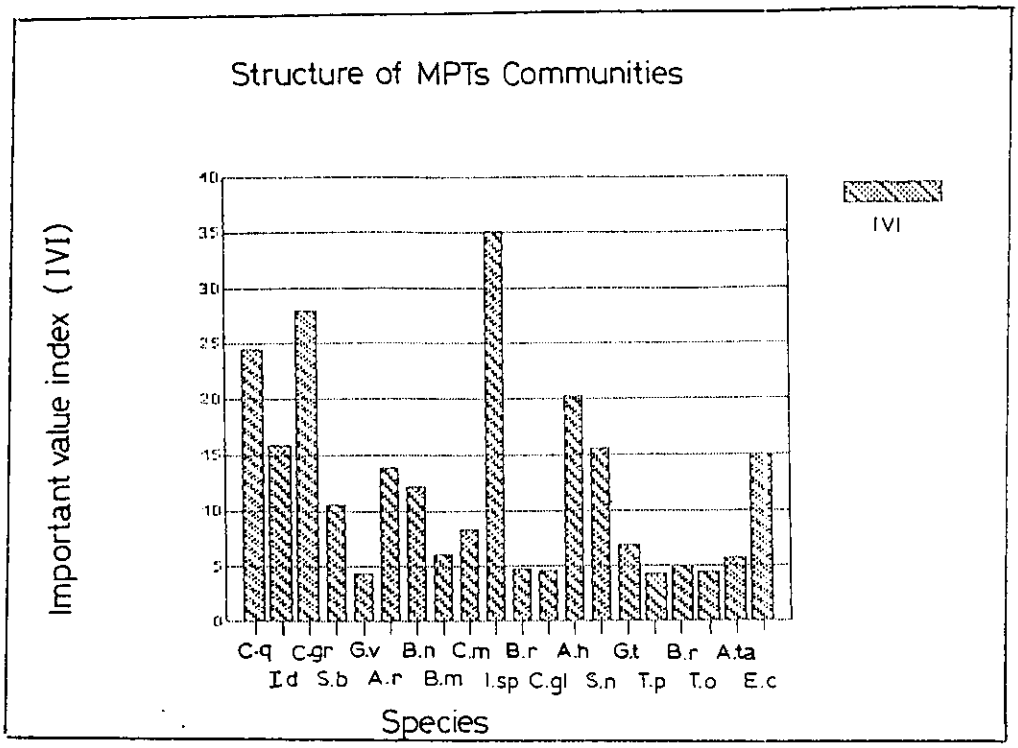


Figure 5.14: The structure of *I. spinosa - C. gracilispina* MPTs community in five km from River Daua (S6) in Khalaliyo-Fiqho area, Mandera District

A.r = *Acacia refeciens*
C.m = *Commiphora myrrha*
B.r = *Balanites rotundifolia*
A.h = *Acacia horrida*
T.p = *Terminalia polycarpa*
T.o = *Terminalia orbicularis*
E.c = *Euphorbia cuneata*
G.v = *Gardenia volkensii*
I.d = *Ipomea donaldsonii*
C.gr = *Commiphora gracilispina*
S.b = *Sesamothamnus busseanus*
B.m = *Boscia minimifolia*
I.sp = *Indigofera spinosa*
C.gl = *Cadaba paisley*
G.t = *Grewia tenax*
B.re = *Boswellia rivae*
A.ta = *Anistotes tanensis*
C.q = *Cordia quercifolia*
B.n = *Boswellia neglecta*
S.n = *Solanum* sp

5.1.9 MPTs for herbal medicine

Certain naturally occurring MPTs are left deliberately in farm lands especially along borders and in "Sharmat" to be used for medicinal purpose. A good example is *Albizia anthelmentica* and a *Cassia* sp (if found). An *Aloe* sp. are planted in farms to provide juice for malaria treatment; the species was noted in two farms (Mandera Islamic Centre and Haji Mohamud's farms). The dried leaves of the *Aloe* sp. are boiled and the juice taken to treat malaria. Sap from the leaves is also used for the same purpose and sold as source of income. Other MPTs are *Azidarachta indica* for malaria treatment and juice from the bark of *Lawsonia inermis* and roots of Paw paw for yellow fever.

Details of species for medicinal uses are in the section of species and their uses. Except for *L. inermis*, medicinal MPTs are not ecologically dominant in the valley may be because they are in high demand and hence harvested. The plants also provide other productive and protective uses.

5.1.10 MPTs for Ornamental and grave yards

Some MPTs are planted or left deliberately around the farms and farmers homestead/villages for mainly aesthetic purposes. They are scattered within homestead/plots and farm or are planted along borders and around homestead and grave yards. Examples are *P. juliflora*, *A. indica*, *T. indica*, *C. lancifolius*, *D. glabra*, *P. aculeata*, *Bouganvillea spectabilis*, *Cassia siamea*, *F. sur*, *A. tortilis* and *C. gracilispina*. The ecological dominance of *C. gracilispina* at 4-5 km a way from the river in Khalaliyo-Fiqho area (Fig. 5.12 to 5.14), could be related to early human settlement as a result of many grave yards in the area with the species as live fence. The species are also used to

hold local meeting (village committees or for education and extension by Forest or Agricultural Officers, Chiefs, DOs, DC) and as shade for livestock.

5.1.11 MPTs in Rangelands

Rangelands in this study include all lands within the valley not individually owned and used as natural pastures. Rangelands cover most of the studied area, and all livestock for all members of the society are free to graze or browse in. It encompasses almost all parts of the uplands and midlands. MPTs in the area provide diverse uses of browse, medicinal, wooden containers, bee forage, fuelwood, poles and post for construction, soil conservation, shade, fruits, gums and products for income generation. The land is free for use, but chiefs, local leaders and Government officials can intervene if an individual is causing mass environmental degradation. The MPTs are scattered throughout the range. The main grass species are: *Aristida kelleri*, *Tetrapogon* spp., *Cenchrus ciliaris*, *Chloris virgata*, *Dactyloctenium australe*, *Sporobolus fimbraitus*, *Chrysopogon plumolesus*, *Digitaria penneta*, *Urochloa trichopus* and *Sorghum verticiliformis*. The last two species are very common along "lagas". The main herbaceous/dwarfy shrubs species are *Heliotropium steudneri*, *I. spinosa* and *Cleome allamanii*.

The main MPTs are *Acacia refeciens*, *Cordia quercifolia*, *Grewia* spp., *Boswellia* spp., *Acacia horrida*, *A. tortilis*, *Delonix* spp., *Balanites rotundifolia*, *Sesamothamnus busseanus*, *Commiphora* spp., *Solanum jubae*, *Anistotes tanensis*, *Euphorbia cuneata*, *Boscia minimifolia* and *B. tomentella*. The dominance of some of the above named species can be noted (Fig. 5.6 to 5.14). As shown in Fig. 5.12 to 5.14, the dominance of *I. spinosa* dwarfy shrub could be related to over-use of useful trees and shrubs by early and present

human settlement. Therefore care is needed not to over exploit the MPTs, otherwise desertification is eminent.

The livestock components are large herds of cattle, camels and goats and flocks of sheep. Donkeys are also common. The livestock feed on the MPTs pods and release their seeds in form that can easily germinate after going through their alimentary canal. The seeds get good germination media in form of manure. Species that are favoured in this form are mainly *Acacia* spp. The constant movement of livestock kraal within the range land also enriches the area with manure. The pastoralists use *Commiphora* species for kraal fencing and in the process help in the vegetative propagation of the species. Shade trees like *A. tortilis*, *T. polycarpa*, *D. glabra* and *Boscia* spp. near the homestead which are used for council of elders meetings and religious ceremonies are not cut. When pastoralists are to move far distances away from the valley especially in dry season and do not have enough animal transport, they put their excess luggages on tree tops of usually the above named species until they come back to the site in rainy season. The pastoralist discourage cutting of whole tree but pollard some evergreen and semi-evergreen species in the dry seasons for fodder, for example *B. tomentella*, *D. glabra* and *T. polycarpa*. Instead of cutting branches, using hooked sticks, pastoralist of the area shake *A. tortilis* for pods liked mostly by goats. Sometimes these pods are sold in the markets. The MPTs are cut for use in building, fencing kraals and fuelwood and the cutting encourages deforestation but they have no alternative. If a pastoralist has developed interest in farming a fertile pocket within the range land, he fences it and puts his clan tattoo/mark on the prominent trees within the site as a land mark claim. Such trees are not to be cut. The leaves, fruits, gum, roots and bark of some of the species are harvested as food. In dry seasons when livestock are dry,

D. glabra, *Grewia* spp and *C. pseudopaolii* provide edible fruits and in rainy seasons fruits of *C. quercifolia* supplement the diet. *Hydnora* root parasite which is associated to *Acacia* spp. and *Commiphora* spp. are harvested as food and medicine. The fibres of *Acacia* spp and *Lannea* spp are used for house mat, sacks and rope making. The trees and shrubs in grave yards within the area are protected and not cut. Similar observation was reported by Niamir (1990) in Boran and Gabbra areas of northern Kenya. The practice is dependent on natural regeneration and the pastoralists do not plant, hence its survival threatened in the long run as a result of increase in the population of both people and livestock.

5.1.12 MPTs in soil conservation and on degraded sites

The Departments of Forest and the Department of Agriculture are in the front line to promote afforestation and agroforestry activities. The departments concentrate in extension activities. The Forest Department runs nurseries, demonstration plots and participates in soil stabilization and conservation on degraded sites like former Refugee Camp in Central Division. Two multipurpose woodlots were established by Forest Department in Rhamu and Central Divisions in 1978 as demonstration plots for tree planting. The woodlots are located on degraded sites about 0.5-1 km from the river along the way to the river for people to see and to be aware about tree planting. The areas are about one km^2 for each site. Exotic MPTs of are *A. indica*, *P. aculeata*, *P. juliflora* and *Senna siamea* were introduced to the sites which had scattered indigenous species of *A. tortilis*, *A. senegal*, *A. seyal*, *Z. hamur*, *Commiphora* spp, *S. persica*, *T. danis* and *B. anguisitifolia*. Bee hives are placed in the woodlots. The trees were weeded and pruned until it established well. The stands provide shade, seeds for the forest nursery, and

conserves the soils. The woodlots are surrounded by barbed wires and thorn fences to keep off roaming animals and intruders. Management operations of pruning and thinning is frequently conducted by Forest Department staff.

Apart from demonstration woodlots, Forest Department works with about twenty local Non-Governmental organizations (Table 5.4) that are involved in afforestation of the formers refugee camp and along "Lagas" within and around Mandera town. The groups are self help assisted through food for work programmes by EDRP (Emergency Drought recovery programme), World Food Programme (WFP), CARE -Kenya and Forest Department.

The groups have nurseries, Public gardens, woodlots for soil conservation and some have demonstration plots along the river. The groups are made up of volunteers members. The members work in shifts and some have one or two permanent employees who do mostly protection (watchmen) role. Other groups work on piece rate, for example watering five plants per person. Some of the groups also own donkey carts for watering. Water is drawn from the River Daua about one to two km away. Tap water rarely flows to be used for watering; it benefits only very few groups, for example Dirir afforestation. Some groups benefited from tools and food provided by EDRP and CARE.

The nurseries are under shades constructed from poles and Doum palm thatch reinforced with sacks (plate 5.9) to reduce the high wind velocity and desiccation by the high temperatures.

Table 5.4: The main self groups in Central and Rhamu areas, Mandera District that were studied.

	Names of groups	No. of seedlings in the nurseries by 1994	No. of seedlings planted
1	Handadu Afforestation	2,500	4,000
2	Sunshine Afforestation	360	300
3	Mandera-Dimtu Afforestation	250	600
4	Shafshafey large scale Afforestation	100	2,000
5	North Eastern Forestry Interlectual	40	650
6	Green Forest	200	900
7	MERAG	6	680
8	Environmental protection programme	1,000	400
9	Environmental Development programme	1,350	800
10	Tawakal Afforestation	200	1,500
11	Busley Women group Afforestation	400	300
12	Dirir Afforestation	900	300
13	Rural Village Afforestation	4,500	7,000
14	Wathajir Afforestation	1,500	400
15	KANU Afforestation	700	1,450
16	Horsed women group Afforestation	500	100

(Source: Field data and District Forestry Office Mandera, 1995)

Plate 5.9: Shaded tree nursery (Rural Village Afforestation Group nursery); Central Division, Mandera District. The main species in the nursery are *A. indica, P. aculeata, P. juliflora*, Paw paw and Mangoes. The back ground shows reinforcement of thatch, poles and sacks to reduce wind desiccation.

When enquiries were made to the group members why they are doing conservation work, the replies centred on four points:

1. **"Sadaqatul - jariya" (expecting reward from God for planting trees).** This is muslim's belief that if you plant a tree, and any living creature benefits from it in any form you get reward in this world and for life after death.

2. **To get assistance to supplement their families income.** The group members did not hide the fact that food for work help them to support their families.

3. **Concern for the environment.** The group members put forward their concern for the degradation of the environment mostly as a result of the refugee Wanton cutting activities and leaving the sites bare.

4. **Future benefits from the MPTs.**

The groups fenced off afforestation sites with dead fence, live fence of *Commiphora* spp. and some groups supported the fence with barbed wire, for example Handadu Afforestation Group. The fields are weeded and crops grown between the MPTs especially when they are tender. The weeding keeps off pests, mainly grasshoppers, mole crickets and cutworms. Some groups created round shaped microcatchments around the MPTs to harvest rain water. The main crops planted between MPTs are: maize, goose necked sorghum, tomatoes, cowpea and watermelon The main MPTs are *M. oleifera, Senna siamea, P. juliflora* (Plate 5.10), *Sesbania sesban, Parkinsonia aculeata, L. leucocephala*, Paw paw, Mangoes, *C. myrrha, C. gracilispina, Z. hamur, F. sur*, bananas and *E. melanocantha.* The practice is new in the area but has taken up very fast and has positive impact at sites which would otherwise have been degraded. The introduced species are fast growing.

Plate 5.10: MPTs for soil conservation and on degraded sites; Central Division, Mandera District. The species are *P. juliflora*, *S. siamea* and *M. oleifera*.

5.1.13 Fruit trees and nappier grass mixture

The practice which is a potential "Protein bank" is a recent innovation in the area and was noted in two farms along the river, both in Rhamu Division. The Nappier grass (*Pennisetum purpureum*) was planted between Mango trees. Although the Nappier grass was doing well, it required proper management to increase productivity. Nappier grass is not an arid and semi-arid land grass but it is known to persist well along rivers (SWCB - Soil and Water Conservation Board, 1992).

In the Africa Muslim agency farm in Rhamu Division, the Nappier was overgrown and not well managed. If this technology is taken up by many farmers it is likely to improve the prospect of zero grazing. There is need to introduce nitrogen fixing MPTs to be planted with the grass. The grass could also be planted in between MPTs for river bank stabilization for effective utilization of land and water.

5.2: THE DISTRIBUTION OF MPTs BASED ON LANDSCAPE CHARACTERISTICS

1. Analysis of landscape characteristics

The landscape characteristics of the sites along the 5 km transects in the study area and the respective species identified are summarized in Tables 5.2, 5.3 and 5.5 to 5.6. The concave-convex (S-shaped) nature of the valley combined with arid climate could be the main abiotic factors affecting the existing soil characteristics and hence the vegetation distribution.

The slope gradient and the presence of gravels, stones and rocks or boulders increases away from the river. Soil texture becomes more coarse towards the uplands could be because they are deposited near the source on their way before reaching the flood plains. The texture on the river bank are more sandy than those at 1 km from the river. This could be as a result of deposition of sandy materials near the river bank while finer particles are transported to the flood plains by slow motional and in some cases very stagnant flood water. Soil drainage improves towards the uplands with increase in slope gradient. The presence of termitarians is more in the midlands and the uplands may as a result of improved drainage, hence aeration.

Table 5.5: The dominant soil and topographic characteristics of the Daua Valley, Khalaliyo-Fiqho area, Mandera District.

ABIOTIC FACTORS	S I T E S					
	S1	S2	S3	S4	S5	S6
pH	Moderately alkaline	Moderatelty alkaline	Moderately alkaline	Moderately to strongly alkaline	Moderately alkaline	Moderately alkaline
EC	Strongly saline	Excessively and strongly saline	Strongly saline and moderately saline	Slightly to strongly saline	Slightly to moderately saline	Moderately to strongly saline
Texture	Silty loam to loamy sand	Clay loam and gravelly silty loam	Silty loam and gravelly loamy sand	Gravelly loamy sand and gravelly silty loam	Gravelly loamy sand, and gravelly and stony silty loam	Stony and gravelly silty loam and stony loamy sand
Colour	Orange (5YR 5/6 to 7.5YR 7/6)	Orange and dull brown (5YR 6/6 to 7.5YR 7/6 and 7.5YR 5/4 to 7.5YR 6/3)	Orange and dull brown (5YR 6/6 to 7.5YR 7/6 and 7.5 YR 5/4 to 7.5YR 7/4)	Orange and bright brown (5YR 5/6 to 7.5YR 7/8 and 2.5YR 5/6 to 5YR 5/8)	Orange and bright brown (5YR 5/8 to 7.5YR 5/6)	Orange and bright brown (5YR 5/6 to 7.5YR 5/6)
Depth	Deep to very deep	Deep to very deep	Moderately deep and shallow	Moderately deep and shallow	Very shallow to shallow	Very shallow
Drainage	Some what excessively well drained	Some what excessively well drained and well drained	Excessively drained and some what excessively well drained	Excessively drained	Excessively drained	Excessively drained and some what excessively drained
Organic matter content	Very low to medium low	Medium low and slightly low	Medium low and very low	Very low to medium low	Medium low and very low	Very low to medium low
Slope	Gently undulating	Gently undulating to undulating	Gently undulating to rolling	Gently undulating to rolling	Gently undulating to rolling	Gently undulating to undulating

Table 5.6: The dominant soil ad topographic characteristics of the Daua valley, Rhamu-Galicha area, Mandera District.

ABIOTIC FACTORS	S I T E S					
	S1	S2	S3	S4	S5	S6
pH	Moderately alkaline	Mildly to moderately alkaline	Moderately alkaline	Moderately alkaline	Moderately alkaline	Moderately alkaline
EC	Excessively and strongly saline	Strongly to excessively saline	Strongly and moderately saline	Moderately to strongly saline	Moderately to strongly saline	Moderately to strongly saline
Texture	Clay loam and loam	Clay and sandy loam	Gravelly loam and clay loam	Gravelly loam and gravelly loamy sand	Gravelly silty loam and gravelly silty clay loam	Gravelly silty loam and gravelly loam
Colour	Bright brown and brown (5YR 5/6 to 7.5 YR 5/6 and 7.5YR 4/4 to 7.5YR 7/6)	Orange and bright brown (7.5YR 5/6 to 7.5YR 7/6)	Bright brown and orange (7.5YR 5/6 and 5YR 5/6 to 7.5YR 8/6)	Orange and bright brown (5YR 6/8 to 7.5YR 6/6 and 7.5YR 5/6 to 7.5 YR 5/8)	Orange and yellow orange (7.5 YR 6/6 to 7.5 YR 7/6 and 10YR 8/4 to 10YR 8/6)	Orange and bright brown (7.5 YR 6/6 to 7.5 YR 7/6 and 7.5 YR 5/6 to 7.5YR 5/8)
Organic matter content	Moderate and slightly low	Moderate and slightly low	Slightly low to moderate	Slightly low	Slightly low	Slightly low
Depth	Deep to very deep	Shallow and deep	Deep and shallow	Moderately deep and very shallow	Very shallow to shallow	Very shallow
Drainage	Some what excessively well drained	Some what excessively well drained and well drained	Excessively well drained and some what excessively well drained	Well drained and excessively well drained	Excessively well drained	Excessively well drained
Slope	Gently undulating to undulating	Gently undulating to rolling	Gently undulating to undulating	Gently undulating to undulating	Undulating to rolling	Undulating to rolling

Soil depth decreases towards the uplands could be as a result of erosion of the soil material by run off. The soil colour is generally orange within the valley as a result of the parent material which is mainly light sandstone, the limited vegetation, the general coarser (sandy) texture and the good drainage (USDA Staff, 1951; Joubert, 1957; Brady, 1974 and Foth, 1990). The valley is poor in organic matter as a result of the thorny vegetation cover (Prichet, 1979) accompanied by high organic decomposition favoured by the high temperature (FAO, 1988b) and good soil aeration. pH of the valley is generally moderately alkaline could be as a result of the strong influence by the limestone (calcium carbonate) parent material.

Salinity is high in lowlands than the uplands and midlands. This is characteristic of arid areas when the water table is near the surface (Foth, 1990).

2. Analysis of vegetation characteristics

The area's vegetation had NDVI range mean of -0 10 (bare ground) to 0.40 (vegetated/green sites) in dry and rainy seasons respectively. Only isolated pockets along the river had NDVI of 0.15 to 0.20 throughout the year. This means that the sites have mainly deciduous or annual plant communities except the evergreen riparian pockets that are made up of luxuriant MPTs, mainly *H. compressa*, *T. danis*, *L. inermis*, *I. schimperi* and *A. seyal* (Fig. 5.3 to 5.6). Part of the pockets could also be contributed by the irrigation fields with fruit trees like mangoes, citrus, guava and bananas. The vegetated areas will generally yield high values because of their relatively high near infrared reflectance (Lillesand and Kiefer, 1987). In high vegetated areas, the NDVI typically ranges from 0.1 to 0.6, in proportion to density and greenness of the plant canopy. Rocks and bare soils

reflect light brown colour. Greenness is strongly related to the amount of green vegetation present in the scene.

Using IVI (of the dominant 20 species at each site), MPTs communities at each site were identified (Figures 5.3 to 5.14). 14 and 16 species were identified on the river bank (S1) in Khalaliyo and Rhamu areas respectively. Similarly, 34 and 59 species at S2, 44 and 55 species at S3, 40 and 64 species at S4, 50 and 52 species at S5 and 49 and 64 species at S6 were identified in Khalaliyo and Rhamu areas respectively. MPTs species increase towards the uplands. This could be attributed to changes in the slope gradient, salinity, texture, water holding capacity, depth and drainage. The Rhamu-Galicha area have higher species richness than the Khalalioy-Fiqho area. This could be associated to less human activities and variation in the type of parent materials (Mandera series of Jurassic sediments in Khalaliyo and the Daua limestones of the same sediments in Rhamu).

3. Relationship between landscape and vegetation characteristics

The comparison of the number of MPTs at each site with landscape characteristics of soil properties (alkalinity, organic matter content and salinity) and slope gradient using multiple regression of the SAS scientific package showed that species distribution is affected mainly by slope gradient and slightly by electrical conductivity. For more details, below are the equations:

$E(Y/X_1,..., X_k) = b_0X_0 + b_1X_1 + ...b_kX_k$ (Steel and Torrie, 198[illegible]; Halim and Ahmad, 1987)

where:

E ($Y/X_1,...,X_k$) is the expected mean of the population of Y's (for example the number of MPTs in this case) for a specified set of values of the X's (for example the landscape characteristics in this case)

$X_0 = 1$ always and b_0 represents the Y intercept.

Khalaliyo-Fiqho area

R-square value indicate that about 98% of the variation in the number of species can be explained by the equation:

Number of MPTs per site = 108.289 + 2.23sg + 0.41ec + -13.67pH + -16.65om

where: sg is slope gradient

ec is electrical conductivity (salinity)

pH is intensity of alkalinity and acidity

om is organic matter content.

It means that pH and organic matter have no significant effect on the distribution of the MPTs within the valley; the effect of EC is low while that of slope gradient is high.

Rhamu-Galicha area

R-square value indicates that 94% of the variations in the number of species can be explained by the regression equation:

Number of MPTs per site = 68.52 + 1.24sg + 0.015ec + -7.72pH + -6.19om

It means that pH and organic matter have no significance effect on the distribution of the number of the MPTs within the valley; the effect of EC is low while that of slope gradient is dominant.

Duncan's multiple range test was used to compare the means of the number of MPTs for slope gradient and EC (Tables 5.7 and 5.8).

In Rhamu-Galicha area, slope gradient of 8.2% (S6 - uplands) gave the highest number of MPTs and was significantly different (P = 0.05) from slope of 3.7% at S1 (lowlands) but not from 5.1% (S2), 5.6% (S3), 6.3% (S4) and 7.4% (S5) found between lowlands and uplands (Tables 5.7 and 5.8). In Khalaliyo-Fiqho area, slope gradients of 7.54% (S6) and 7.23 (S5) (Uplands) gave the highest number of MPTs and was significantly different (P=0.05) from the slopes of 2.95% (S1) and 4.6% (S2) (lowlands) but not different from slopes of the midlands (Tables 5.7 and 5.8).

The change in slope gradient seems to affect the soil characteristics of the valley and therefore the distribution of the MPTs. There were more MPTs in the uplands and the midlands than the lowlands. These could be attributed to increase in slope gradient towards the uplands that causes similar increase in drainage and decrease in salinity. Increase in drainage encourages the regeneration of trees (Foth, 1990) adapted to the site and it is known to affect plant distribution (Brady, 1974).

Table 5.7: Duncan's multiple range test comparing slope gradient (%) and EC with respect to the number of species

Site: Rhamu-Galicha area, Mandera District.

Distance from the river	EC (mmhos/cm)	Slope gradient means (%)	Number (means) of trees and shrub species
S1 (0 km)	39.2	3.7	4.73 aprox. 5 a
S2* (1 km)	460.7	5.1	8.67 approx. 9 b
S3 (2 km)	19.2	5.6	8.67 approx. 9 b
S4 (3 km)	15.8	6.3	9.8 approx. 10 b
S5 (4 km)	21.2	7.4	11.47 approx. 11b
S6 (5 km)	22.4	8.2	12.2 approx. 12b

Means bearing the same letter have no significance difference (p = 0.05)

* Almost half the plots of the site had higher slopes (more of midlands characteristics) compared to the other half which had the characteristics of lowlands.

Table 5.8: Duncan's multiple range test comparing slope gradient and EC with respect to the number of trees and shrub species

Site: Khalaliyo-Fiqho area, Mandera District

Distance from the river	EC (mmhos/cm)	Slope gradient means (%)	Number of trees and shrubs
S1 (0 km)	343.9	2.95	6.53 approx. 7 a
S2 (1 km)	428.1	4.6	7.83 approx. 8 a
S3 (2 km)**	17003.7	6.36	11.27 approx. 11 b
S4 (3 km)	208	6.41	11.4 approx. 11 b
S5 (4 km)	236.3	7.23	11.87 approx. 12 b
S6 (5 km)	266.5	7.54	11.93 approx. 12b

Means bearing the same letter have no significance difference (P = 0.05)

** Two sites among the 15 sample plots had a very high EC reading, hence increasing the average EC.

Gradient increase also causes similar increase in the presence of termitarians and of rocks, boulders, stones and gravels improving aeration. Similar result was reported by Niyezimana (1984) in Rwanda. The lowlands had fine texture compared to the coarse soils of the uplands, therefore the lowlands soils had more water holding capacity and soil moisture but with few MPTs. Unlike the results of the Daua Valley, Williams (1969) identified complex species in deep moist soils than xeric sites. This could be related to the difference in climate between the two sites and also the tolerance by few species to frequent and long duration flooding (1 to 2 months) which is common in the Daua Valley. Soils are shallow and less developed on steeper slopes and are accompanied by stunted plant growth while in deep soils of the lowlands, the growth is luxuriant. The difference in growth rates can be related to the effect of depth and texture on water holding capacity (O'Hare, 1988) and probably to depth's effect on root growth. The luxuriant growth is reflected in the NDVI along the river which remains green all the year round. Marsh (1991) noted that in dry areas, flood tolerant species are common on wetter and flood prone valleys.

In Rhamu-Galicha area, EC of 22.4 (S6 - uplands) gave the highest mean number of MPTs and was significantly different from EC of 39.2 (S1 - lowlands) but not from EC at 460.7 (S2), 19.2 (S3), 15.8 (S4) and 21.2 (S5) (Tables 5.7 and 5.8). In Khalaliyo-Fiqho area, EC of 266.3 (S6) and 236.3 (S5) gave the highest number of MPTs and was significant different ($P = 0.05$) from EC at the lowlands (S1 and S2) but not different from EC at S3 and S4 (midlands) (Tables 5.7 and 5.8). Salinity varies with slope gradient. It is highest in the lowlands and decrease with slope increase. Salinity in the valley seems to have also changed with the change in land use. Sombroek *et al* (1973) noted the general

salinity along the river bank to be about 3 mmohs/cm under livestock keeping land use. Today it is reading as high as 4880 mmohs/cm in the lowlands under diverse agricultural land use. This could be related to the removal of the luxuriant natural riparian MPTs and the accumulation of salts on surface horizons caused by irrigation and natural capillary water movement which increases with ground bareness. There are few MPTs in strongly to excessively saline soils of the lowlands than the midlands and uplands. This is because such soils support few halophytes like *A. seyal*, *S. persica* and *T. danis*. Similarly, Fanning and Fanning (1989), observed that in arid areas, shrubs that are not salt tolerant are found on high slopes and few halophytes are found in valleys. Increase in salinity is known to decrease the number of species adapted to the site (Shreve, 1942; Tadros 1953; Kassas 1957; Weber and Stoney, 1986 and Tadros and Atta, 1958).

5.3 USES OF THE MULTIPURPOSE TREES AND SHRUBS OF THE DAUA VALLEY

Trees and shrubs provide indispensable uses of human food and nutrition, animal food and nutrition, wood products and protection and restoration of soil fertility and the quality of the environment. People are not concerned with trees and shrubs themselves but the functions/uses which they garner from them (such as food, fodder, medicine, cooking, shade and shelter). The uses of the MPTs within the valley has been summarized for each species under the heading "Uses" (Appendix IX). These are reported uses (what the local people say they use these plants for) and it has not been possible to verify the accuracy of all the reports. This study has identified many of the common functions/uses MPTs products serve in households in the valley. The functions/uses has been broadly classified as productive (tangible) and protective (service role).

Productive uses

1. *Food and drinks*

The MPTs of the valley provide food in various forms. *C. rostara* has edible leaves while 25 species are used as fruits (for example *Grewia* spp, *Cordia* spp, *M. indica*, *P. gaujava*, *T. indica*, *Lantana* spp); six species have edible seeds (for example *H. compressa*, *C. pseudopaolii*, *D. glabra*, *Delonix* spp and *A. edgeworthii*); juvenile *I. donaldsonii* has edible roots and the tubers of *Hydnora* root parasite that grows in association with roots of many MPTs is edible. Some products are simply gathered and eaten raw (for example fruits *Cordia* spp and *Grewia* spp), while others must go through complex processing to

be edible for example seeds of *D. glabra* and *A. edgeworthii*. Six *Acacia* species (e.g *A. senegal*, *A. seyal*, *A. mellifera*) and *L. inermis* provide edible gums and resins respectively. Resins of *Boswellia* spp are used as chewing gum. *A. tanensis* and *S. paradoxa* provide honey dew and the flowers and nectars of 27 species (e.g *Acacia* spp and *Grewia* spp) act as the major source of honey. Honey are seasonally important foods especially after the rainy seasons. The latex of *W. demartiniana* is used to clot fresh milk indicating the possibilities of its use in dairy industries instead of the use of Bacteria.

Drinks like juice beverages are derived from fruits of *M. indica*, *C. papaya*, *P. guajava*, *T. indica* and *C. lemon* and sold in local cold drinks. Local tea is made from ripe fruits of *A. nilotica* and twigs and fresh barks of *B. microphylla*, *C. pseudopaolii* and *C. ogandensis*. Fresh fibre of *A. refeciens* and stem cuts of *E. melancantha* and *C. rostara* are chewed for refreshments and to derive water. Water is very vital to the survival of the people and wildlife of the valley and its surroundings. Many species have holes that hold rain water over long duration for use by the inhabitants over the dry seasons. Some of these species are *D. elata*, *K. tenuifolia*, *B. microphylla* and *C. pseudopaolii*. *K. tenuifolia* in addition, provides watery root tubers for use by warthogs. Water purification is vital to the health of the rural people. Crushed seeds of *Moringa* spp and root tubers of *Maerua decumbens* can be used for these purpose.

Collectively trees and shrubs provide protein, energy, vitamins and essential minerals to the diet and they add taste and diversity as well supplements staple diet and meet seasonal shortages (FAO, 1989b) of the area's rural and urban poor but the nutritive value of many of the MPTs are unknown.

2. *Materials for shelter, household equipments and utensils*

The MPTs supply myraid of materials for building construction inform of poles, posts and withes; leaves and beams for roofing and binding materials for mats and sacks. 27 species provide poles, posts and withes (for example *Terminalia* spp, *Grewia* spp, *Ziziphus* spp, *H. compressa*, *Boscia* spp, *Combretum* spp, *T. danis*, *B. rotundifolia*, *T. aphylla*, *K. tenuifolia*, *Lannea* spp, *C. quercifolia*, *S. jubae*, *A. tanensis*, *E. spectabilis*, *L. inermis*, *I. schimperii*). *H. compressa* provide leaves for thatch while *C. quercifolia* and *L. inermis* are used as beams for roofing. Juvenile leaves of *H. compressa* and bark fibre of *Acacia* spp and *Lannea* spp provided threads and ropes for making housing mats and sacks. Although housing construction style have changed especially in towns as in West Africa (FAO, 1989b), majority of the rural poor of the valley still rely on the MPTs resources for bulk of their house construction needs. Products of *H. compressa* are commonly used throughout the entire district and its surroundings for wall and roof construction. The other popular used plants for building are *T. polycarpa*, *Grewia* spp, *C. quercifolia*, *Z. hamur*, *T. danis*, *S. jubae*, *A. tanensis* and *L. inermis*. The preference may be related to resource availability and resistance to termites (Kopell, 1990). The roofs are built using Doum palm leaves with petioles slit to form a hook on the roofing beam. Traditional nomadic houses were constructed with mats made of Doum Palm leaves bound with ropes and long flexible withes which are tied together using threads of camel's skin. It is cheaper to construct traditional houses than semi-permanent (muddy walled) and permanent structures (cement construction) (FAO, 1989b).

Local beds are made of withes (for example *Grewia* spp) or leave rachis of *P. reclinata* bound together with skin or fibre threads while bee hives are made from stems

of *H. compressa*, *F. sur* and *K. africana*. Bees in the natural environment prefer to hive in *C. pseudopaolii* and *A. mellifera*.

Local granaries for crop harvest storage are made up of raised plat forms of poles (for example *T. danis* and *L. inermis*) tied with wires and ropes made of juvenile leaves of *H. compressa* and they are covered with thatch of the same species.

There are vast numbers of household utensils that are garnered from the MPTs of the valley such as wooden containers for water and milk storage, drinking and eating (for example *G. hababensis*, *T. orbicularis*, *E. melancantha*, *F. sur*, *Boswellia* spp, *Commiphora* spp, *D. baccal*, *K. africana*, *G. volkensii* and *L. stuhlmanii*); container holders (for example *C. hereroense*); wooden shoes (for example *W. demartiniana*); camel bells (for example *D. elata*, *C. ogandensis* and *C. pseudopaolii*) and ornaments tied to the necks as prestige (for example *H. compressa* and *T. orbicularis*); mortar (for example *D. baccal* and *D. glabra*) and pestle (for example *T. polycarpa*). Mortar and pestle are used to pound food like maize and sorghum. The type of wood that are preferred in mortar and pestle production vary by region as well as country, however the wood used for pestle is always hard (Kopell, 1990).

The MPTs also provided furniture like stools (for example *E. melancantha*), doors (for example *F. sur*, *L. schweinfurthii*) and chairs (for example *D. glabra*, *C. pseudopaolii*). Head rest is made from wood of *C. myrrha* while comb is made of *G. hababensis*.

Lo'h (a wooden board) for writing Quranic tablets is made of *Commiphora* spp, *B. rotundifolia*, *W. demartiniana* and *B. neglecta*. Traditional pens for writing the Quran are made from withes of *Grewia* spp. A local religious tally count is made from the woods of

B. lanceolatum. A local ploughing instrument called "Kababa" which is used for making ridges and furrows for irrigation is made from the woods of *B. rotundifolia*. Walking sticks, clubs, bows and arrows and spear holders are made from *A. tortilis*, *Grewia* spp, *C. quercifolia*, *T. danis*, *T. indica* and *L. inermis* while decorated and undecorated baskets and sleeping mats plus brooms are made from juvenile leaves of Doum and Phoenix Palms.

The wood of *I. donaldsonii*, *Lantana* sp, *C. quercifolia* are used for warming wooden containers; handles for implements are made from *C. quercifolia*, *T. indica*, *C. sinensis* and *T. aphyla* while winowers can be made from the roots of *A. horrida* and *C. ogandensis* and from juvenile leaves *H. compressa*.

Kopell (1990) and Abbiw (1989) reported similar diversity of species used for shelter, household equipments and utensils in West Africa.

3. *Fodder*

Trees and shrubs provide fodder which is collectively termed browse that consists of a combination of leaves, small branches, seed pods and fruits (FAO, 1989a). Browse MPTs are spread throughout the valley. Over 85% of the identified species (for example *Acacia* spp, *Boscia* spp, *Bleripharisperm* spp, *L. inermis*, *Indigofera* spp, *Cordia* spp, *Grewia* spp, *Boswellia* spp, *Commiphora* spp) provided fodder. The range of woody species for fodder is also reported to be wide by Felker and Bandurski (1979) and Le Houreou (1986). The most commonly harvested dry fodder species are *F. sur*, *T. polycarpa*, *D. glabra* and *A. tortilis*.

Livestock is allowed to browse on natural MPTs in rangelands and farmlands. The browse help sustain livestock production and the fodder trees and shrubs form an indispensable part of livestock diet (Le Houerou, 1986; Torres, 1989). This is particularly so in dry season when the nutritional quality of the herbaceous layer is markedly reduced and when it may contribute 30 - 45% of the livestock feed intake (FAO, 1989b).

4. *Fuelwood*

In the study, it was found that over 67% of the species identified (for example *Acacia* spp, *Terminalia* spp, *Grewia* spp, *G. volkensii*, *L. inermis*, *Grewia* spp, *A. anthelmentica*, *Boswellia* spp, *Commiphora* spp, *C. quercifolia*) were valued for fuelwood. Fuelwood affects the quantity, quality of food cooked, hence affecting household nutrition (FAO, 1989a). The availability of fuelwood plants is becoming scarce especially around centres like Mandera as a result of major clearing by refugees and increase in the population of the urban poor. It will take 5 - 7 days for a donkey cart to fetch firewood and its market price goes up to ten shillings per two pieces of splitted wood of about 1 m. The market is composed of the collectors who use donkey carts and rarely lorries and retailers who sale fuelwood at urban markets. The collectors sometimes sale the products directly. Dry sticks of *C. quercifolia*, *T. danis* and *W. demartiniana* can be used as friction sticks for fire ignition where there is no match box.

5. *Medicines*

23 species were used for human medicine, five species for veterinary medicine and five for both human and veterinary medicines. Trees and shrubs provide the only source

of medicines for a vast majority of developing world's population (75 -90%) (Kopell, 1990). The medicinal role of the MPTs for livestock and human diseases means that they are important for maintaining a healthy community and livestock production.

a) Human medicine

Polio is locally treated with smoke from Mistitle (*Loranitus* sp) parasite on *B. minimifolia*. Eye diseases are treated with local ointment from seed oil of *B. tomentella*, fruit juice of *A. nilotica*, gum from *A. tortilis* and resin of *C. myrrha*. Blood related diseases and swellings are treated with decoctions from *M. decumbens*. Resins of *C. pseudopaolii* and *C. myrrha* are used to treat snake and insect bites. Stomach ache is treated with decoctions of *M. borziana*, *T. indica*, *A. mellifera*, *Z. mauritiana*, *T. polycarpa*, *T. orbicularis* and *L. inermis*.

Bleeding is stopped with decoctions from the roots of *T. orbicularis* and *A. javanica*. Rheumatism is treated with decoctions from *M. decumbens*, *T. orbicularis*, *A. tortilis*, *A. anthelmentica* and *L. inermis*. Wounds are treated with decoctions from *T. orbicularis*, *E. brevatiaculata*, *D. elata*, *A. anthelmentica*, *S. buseanus* and *C. rostara*.

Decoction from roots of *A. anthelmentica* is used as dewormer. Knee pains are treated with resins from *E. cuneata* and *C. gracilispina*. Boils are made to ripen faster using resins from *C. gracilispina*, *C. unilobata* and leaves and latex of *C. ogandensis*, *A. tortilis* and *E. cuneata* respectively. Breast pains are treated with latex of *E. cuneata*. Malaria is treated with decoctions from *A. indica*, *T. indica*, *Aloe* spp and *Cassia* spp. Yellow fever is treated with decoctions from the bark of *L. inermis* and roots of *C. papaya*. Gastric is treated with decoctions from fruits of *T. indica*. Reproductive organs are treated

with the gum of *A. senegal*. Bone related diseases are treated with decoction of *A. anthelmentica*. Cold is treated with juice and leaves of *C. rostara*. Nosal blockage and flu are treated with juice from *A. obesum*. The same juice also treats scabies. Tuberculosis is treated with liquor from *H. compressa*.

Thorns of *A. horrida* and *A. seyal* can be used as tooth pegs. Green leaves from *S. busseanus* is used as soap. Chewing sticks (local tooth brush) in form of twigs and roots is harvested from *S. persica*, *C. velutina*, *D. glabra*, *Ficus* spp, *Boswellia* spp and *C. quercifolia*. The smoke from the dry leaves of *I. schiperii* scares away mosquitoes.

b) Veterinary medicine

Camel mange is treated with resins of *C. pseudopaolii* and *C. ogandensis*, juice from root tubers of *Moringa* spp and *A. obesum* and wetted ash of *D. glabra*. The resins from *C. pseudopaolii* and *C. ogandensis* are also used as acaricides.

6. *Income generation*

The MPTs provide a variety of different products (palm products, wild fruits, fuelwood, poles for building) for sale in markets. The products of 24 species (for example *Ziziphus* spp, *Grewia* spp, *C. quercifolia*, *H. compressa*, *P. reclinata*) were noted in markets within the valley. Sale is predominantly seasonal activities for products that of seasonal in nature (for example fruits) but not for products that can be acquired throughout the year (for example fuelwood, poles, posts and withes). The marketing of the products is affected by accessibility to markets (especially for seasonal products for example fruits and products of less present commercial value for example resins and gums) to markets,

over production within certain seasons and low prices. Similar problems were cited by Kopell (1990) in West Africa. The marketing system involves producers (gatherers/farmers) and retail traders. It provides employment for rural and urban people. This means that sale of MPTs products in rural areas is one of the few sources of income (Kopell, 1990).

7. *Fencing and boundary markings*

MPTs provide dead fence (for example *Acacia* spp, *L. inermis*, *Commiphora* spp, *P. juliflora*, *L. europaeum*, *C. aculeatum*) and live fence (for example *E. tirucalli*, *Ziziphus* spp, *S. busseanus*, *Commiphora* spp.) for protection of crops and livestock against destruction and wild animal damages. Along farm boundaries MPTs (for example *H. compressa*, *L. inermis*, *P. juliflora*, *T. danis*) are left.

8. *Dyes, ink, tannins and wood preservatives*

Dyes for colouring containers, withes and poles for the construction of local houses can be obtained from ripe fruits of *A. nilotica*; barks of *C. velutina*, *G. lilacina*, *B. neglecta*, *B. rivae* and *A. seyal* and the dyes also act as wood preservatives against wood borers. Decoctions from the roots of *S. busseanus* and fruits and flowers of *T. danis* can also be used as dye. Decoration of hands and body are made with dyes derived from the leaves of *L. inermis*.

Local ink for writing Quranic tablets is obtained from the mixture of resins of either *C. pseudopaolii* and *C. myrrha* with water or milk.

Protective uses

1. *Shade*

The mean annual maximum temperature for the Daua Valley is 34.5°C, hence no further need to stress the necessity for shade. Shade is very desirable for crops and animal husbandry particularly in hot arid climate (Daly, 1984; Beer, 1987). Suitable shade will reduce water loss and lower respiratory energy use and that is why animals seek any shade available during the periods of the above average temperature. Though shade will tend to reduce forage under trees, this is compensated by the protection a tree affords to animals and human against the hot midday sun (FAO, 1989a). Even single trees are prized in desert or semi-desert situation, such as the sahalian and sudanian zones in Africa, where "every tree is an oasis" (Gorse, 1985). Grasses underneath trees remain green because of the availability of soil moisture (FAO, 1989a). Tree cover can have a considerable influence in moderating air and soil temperature, and increasing relative humidity (Lal and Cummings, 1979). Examples of species with good shade are *T. ementica*, *F. sur*, *B. anguisitifolia*, *A. indica* and *P. juliflora*.

2. *Ornamental*

One wise use of the MPTs (for example *P. juliflora*, *A. indica*, *T. indica*) is planting them near homesteads for beautification. The appreciation of aesthic MPTs are growing within the valley.

3. *Soil and water conservation*

MPTs reduce dust hazard and soil erosion, protect the river bank and are also used to reclaim deforested sites mainly by former refugee sites. Species like *A. indica*, *M. oleifera* and *P. juliflora* have been used for soil conservation while *Z. mauritania*, *M. indica*, *H. compressa* and *L. inermis* have been used for river bank stabilization.

4. *Ecological*

Some of the MPTs are used by the inhabitants of the Daua Valley as indicators of cropping zones (for example *A. paolii* and *A. Paella*) and as indicators of saline soils (for example *S. V* and *C. glandulosa*). Some of the MPTs act as nesting places for birds (for example *A. tortilis*, *C. pseudopaolii*, *B. salicifolia* and *H. compressa*).

CHAPTER SIX

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the study, it was observed that diverse agroforestry practices have evolved over many decades in the Daua Valley and its surroundings as indicated by the retention of natural MPTs in the rangelands and farms and the planting of exotic MPTs in farmlands. The dominant practices are silvopastoral of MPTs on rangelands and pastures "Sharmat". Along the river bank, horticultural trees on farmlands and MPTs for river bank stabilization are very common. Other practices identified in the area are border planting with MPTs, live fences and hedges on farmlands, traditional bush fallow, apiculture with MPTs, MPTs for herbal medicine, MPTs for ornamental, MPTs in soil conservation and on degraded sites and fruit trees and nappier grass mixtures. The practices play a significant role in the conservation of the River Daua and the Valley's naturally important MPTs. They are also helped in the introduction of economically exotic valuable fruit trees of mangoes, guava, bananas, paw paw and lemons thereby improving the nutrition and income of the inhabitants. The pastoralists, farmers and the MPTs are all symbiotic to each other but increase in population of people and livestock are threatening these relationships. Apart from the phytogenetic resource conservation, the agroforestry practices also help in the conservation of the valley's fauna, soils and traditional management of the environment.

Apart from the human influence on the MPTs, landscape characteristics of slope gradient and salinity also affect the distribution of the MPTs. Few flood and high salinity tolerant luxuriant species are common in the flood plain (lowlands) and the number of

species increases towards the uplands with increment in slope gradient that causes similar increase in drainage, coarseness of soil texture and aeration. Therefore it is the combination of human influence, slope gradient and salinity that seem to have influenced to the present distribution of the MPTs in the Daua Valley and its surroundings.

Furthermore, the study established that the valley is covered by deciduous bushland with evergreen riparian woodland vegetation dominating along the river. One hundred and eight useful trees and shrubs of the Daua Valley have been identified. The species provide both protective and productive uses in this fragile and harsh environment and act as a reserve for last alternative use by the local people, refugees and animals. Some of the MPTs provide fruits and edible gum in dry seasons when there are no crops in the field and milk livestock are dry, for example *D. glabra*, *H. compressa*, *P. reclinata*, *T. indica*, *A. seyal* and *A. senegal*. In rainy seasons when crops are not yet ready, *Grewia* spp. and *C. quercifolia* provide edible fruits.

6.2 RECOMMENDATIONS

The arid climate of Mandera is limiting the activities of agroforestry within the Daua Valley. The natural MPTs are threatened by the action of the axe due to unprecedented population explosion especially in and around centres and along the river mainly as a result of refugee influx and change of the livelihood of the people of the area from nomadic pastoralism to sedentary agricultural land use. The erosion of the number of the MPTs implies the dwindling of little known biodiversity while at the same time agriculture has restricted pastoralists and wild fauna access to dry fodder reserve along the river. Population increase is also causing the degradation of the uplands and the midlands.

Agricultural products perish in the valley due to transport and over production problems in the production seasons of the year. Farmers also face floods, theft, poor harvest, pests and diseases problems. Therefore the following recommendations are made:

Integrated land use management plan

The involvement of the local people in working groups/committees in a bottom up approach and the creation of conducive atmosphere of competition between the different locations and divisions in environmental protection and conservation and champions award system per year is needed. The committee should consist of local elders, pastoralists, farmers, chiefs, Government officers and members of local NGOs and their local knowledge should be integrated into the managemet plans.

The MPTs of the valley require different abiotic factors, therefore the midlands and uplands should be used for browse/grazing of wild fauna and livestock and as woodland reserve with natural vegetation. Local environmental committee should run the specific management schemes for the area. Steep slopes require terraces using stones. Natural regeneration should be encouraged by educating the pastoralists on its future importance as source of productive and protective uses. The lowlands can be used for fruit tree production supplemented by crop growing.

Development of appropriate and integrated agroforestry technologies as a strategy for sustainable natural resource management

The integrated agroforestry technologies spells the need to understand, maintain and improve the productivity and sustainability of arid land natural resources through

agroforestry technologies which emphasizes production of food crops, forage for livestock, and trees on the same land base as an effective response.

The Daua River is threatened by deforestation of its "eye brow forests". The clearing of the riparian species will eventually cause the river to dry if agroforestry practices are not intensified and improved to mimic the natural vegetation. The technologies required are fodder bank for dry seasons, fruit trees, river bank stabilization, live hedges, windbreak, fuelwood/poles and improved fallow using species of superior germplasm.

1. Diversification of MPTs (for example fruit plants). Fruit trees should be diversified with species like Date Palm (*Phoenix dactylifera*). It is important to diversify the structure of the MPTs by incorporating grasses, shorter and medium size MPTs. It is also important to adopt the Tana River District methodology of river bank stabilization where horticultural trees are combined with sugarcane (SWCB, 1992). Other species that could help the diversification of MPTs in the valley's lowland are *Mellia volkensii*, *Piliostigma thonningii*, *Terminalia spinosa*, *T. prunoides*, *Acacia holocericea*, *Cajanus cajan*, *Cordeauxia edulis*, *Faidherbia albida*, *Annona senegalensis*, *Gliricidia sepium*, *Casuarina equisitifolia* and *Grevillea robusta*.

2. The incorporation of wind break into farmlands is necessary to increase productivity and reduce wind damages to crops and livestock. Two to three lines of trees and shrubs of less dense structure are needed to be established around farms. The MPTs for this function are *C. lancifolius*, *A. indica*, *P. aculeata*, *P. juliflora*, *T. danis*, *F. sur*, *L. inermis*, *T. aphylla* and *I. schimperi*.

3. Snails, hosts to Bilharzia are common in frequently flooded plains of Rhamu

area, especially in Yabicho. The leaves and fruits of *Balanites* spp are fatal to aquatic snails (SWCB, 1992), hence its introduction is important especially *B. aegytiaca* which is slightly more tolerant to flooding.

4. The self help groups that are concentrating on afforestation of former refugee camps in Mandera is a step forward and is an indicator of people's awareness of the importance of MPTs. However these groups have indicated some constraints of equipments, tools and finance. It is important to assist them to avoid demoralization.

5. Most species in the agroforestry nurseries are exotic and they require more management operations than indigenous species, for example more water. Therefore, there is need to incorporate more indigenous species in nurseries, hence in farms. Research on the indigenous species taxonomy, ecology, silviculture, pests and diseases and their incorporation into farmlands is needed. The knowledge of the pastoralists / farmers has to be incorporated with up to date scientific research work.

6. Research institutions like ICRAF and KEFRI need to be actively involved in the development of the technologies by opening research centre in the area.

7. There is urgent need for the Government commitment to the promotion and research of arid lands agroforestry practices and MPTs through a well set up policies and plans because they are as important as those of high potential areas. Therefore there is need to focus and make constant review of the Government policies in this field and avail funds for the function.

8. There is also need to encourage farmers to increase productivity rather than clearing more land for agriculture through improvements of yield by controlling floods, pests and diseases and by use of high yielding varieties that are salinity and alkalinity

tolerant.

9. Setting up of active cooperative societies is needed so as to facilitate market and input availability and purchase of agricultural products.

10. Theft of fruit trees and other agricultural products and wild life pests can be checked by well trained dogs but care is needed not to offend the farmers faith (Islam) which discourages close association with dogs.

11. Awareness. Farmers also require to know the best farm management methodologies that are environmentally friendly, for example improved agroforestry technologies. It is important to educate farmers on the consequences of clearing riparian vegetation that causes salt accumulation on top fertile soil as a result of capillary action. For stable environment, it is better to plant fruit trees than annual food crops.

Biodiversity conservation

The proposed Malka Mari game reserve covering part of the valley is more of paper work than a reality. It is hoped that leaders in the area will pioneer this work to be run by local environmental committees with only expert assistance from the Kenya Wildlife Service for the interest of the marginalized majority (pastoralists) and wildlife who will use it as dry fodder reserve and it will act as store house for species gene bank.

Marketing MPTs products

Limited or lack of research on MPTs coupled with destruction of their habitat is causing grave danger of losing many species, hence loss of many useful products. MPTs whose products were found in the Daua Valley markets are: *L. inermis*, Doum palm, mangoes, lemons, *Z. hamur*, *Z. mauritiana*, *G.lilacina*, *G. tembensis*, *P. reclinata*, *C. velutina*, *A. seyal*, *A. refeciens*, *A. anthelmentica*, *Hydnora* spp., *C. quercifolia*, *T. Orbicularis*, *T. Polycarpa*, *B. neglecta*, *E. melancantha*, *T. indica*, paw paw, banana, *Cassia* spp. and *Aloe* spp. There is need to enhance marketing of the products within and outside the district. The establishment of fruit based industries is needed to promote fruit growing along the river. *C. pseudopaolii*, *B. microphylla*, *B. neglecta*, *C. myrrha*, doum palm and *P. reclinata* products are also exported unofficially to the Somalia and the Middle East where it is in high demand. *Boswellia* spp. have been noted to support pastoral groups in the whole region of North Eastern Somalia through its frankincense (Farah, 1994) which is exported to the Middle East. Similar groups can be formed by local pastoralists in the Daua Valley and there is bright future for marketing its products in the Middle East. The species which can give gum and resin for commercial gains are *C. pseudopaolii*, *C. myrrha*, *B. neglecta*, *A. senegal* and *A. seyal*. The root parasite, *Hydnora* spp associated to *Acacia* spp, *E. cuneata* and *Commiphora* spp can be a good delicacy when ripe in hotels if promoted. Research on why the root parasite is associated with a specific host species is needed. Some of the products have import substitute potential, for example *C. pseudopaolii* gum can replace acaricides and also used as a pain killer in future medicine activities. Wood preservatives from *C. velutina* can replace wood preservatives against wood borers; the leave rachis of *P. reclinata* can replace metallic and wooden beds

while the thatch of Doum palm can replace iron sheet. Poles of *T. Polycarpa* can replace lentils for building; gum from *C. myrrha* and *C. pseudopaolii* can replace ingredients of ink production and seeds of *Moringa* spp. and roots of *Maerua decumbens* can replace ALUM for water purification.

REFERENCES

Abbiw, D. (1989). Useful plants of Ghana. University of Ghana, Legon, Royal Botanic Gardens, Kew, London, England.

Adelgbehin, J.O and Igboanugo, A.B. (1990). Agroforestry practices in Nigeria. Agroforestry System Journal 10: 1-22. Kluwer Academic publishers, Dordrecht.

Amuyunzu, C.L. (1988). Vegetation Resources and land use in Central Turkana District, Kenya. TREMU (Turkana Resources and Evaluation Monitoring Unit) Technical Report.

Amuyunzu, C.L. and Oba, G. (1991). Vegetation Resources of Central Turkana District, kenya. TREMU Technical Report No. D-2: 1-100.

Ayyad, M.A. and Ammar, M.Y. (1974). Vegetation and environment of the Western Mediterranean Coastal land of Egypt. II. The habitat of inland ridges. Journal of Ecology, 62: 439-456.

Barrow, E. (1991). Evaluation of effectiveness of participatory agroforestry extension programmes in a pastoral system, based on existing traditional values: a case study of the Turkana in Kenya. Agroforestry systems 14: 1-21. Kluwer Academic Publishers, the Netherlands.

Beer, J. (1987). Advantages, Disadvantages and Desirable characteristics of shade Trees for Coffee, Cocoa and Tea. Agroforestry systems 5 (1): 3 -13.

Beaumont, P. (1989). Drylands: Environmental Management and Development. Routledge, London pp. 3-56.

Beentje, H.J. (1994). Kenya Trees, Shrubs and Lianas. National Museums of Kenya, Nairobi. 722pp.

Beets, W.C. (1989). The potential role of Agroforestry in ACP Countries. Wageningen, Netherlands. 55pp.

Bekele - Tesema, A., A., Birnie and Tengnas, B. (1993). Useful Trees and Shrubs of Ethiopia: Identification, Propagation and Management for Agricultural and Pastoral communities. SIDA, Regional Soil Conservation Unit (RSCU). Regional Soil conservation Unit Technical Handbook No.5.

Blundell, M. (1987). Collins Guide to the wild flowers of East Africa. William Collins Sons and Company Limited, London.

Bouyoucos, G.J. (1926). Estimation of colloidal Material. Soil Science 64: 362.

Box, T.W. (1961). Relationship between plants and soils of four range plants communities in South Texas. Ecology, 43: 794 - 810.

Brady, N.C. (1974). The Nature and Properties of Soils. 8th Edition. Macmillan publishing Company, New York.

Braun blanquet (1951). Phytosociology. In: Kuchler, A. W. (1967). Vegetation Mapping. The Ronald Press Company, New York. PP. 231-232.

Braun, H.M.H. and Mungai, D.N. (1981). The agroclimatic zones of Kenya's arid and semi-arid lands. Kenya soil Survey. Paper presented at the International workshop on strategies for developing the Resources of the arid and semi-arid areas of kenya; Kenyatta International Conference Centre, Nairobi 4th - 8th August, 1981.

Budowski, G. (1987). Living Fences in Tropical America, A wide spread Agroforestry Practice. In: Gholz, H. (ed). (1987). Agroforestry : Realities, Possibilities and Potentials. Martinus Nijhoff Publishers, Lancaster in cooperation with ICRAF. PP. 169-177.

Cabido, M., Breimer, R. and Vega, G. (1987). Plant Communities and associated soil Types in a high Plateau of the Cordoba Mountains, Central Argentina. Mountain Research and Development, Vol. 7 (1): 25-42.

Campbell, B.M., Clarke, J.M and Gumbo, D.J. (1991). Traditional agroforestry practices in Zimbabwe. Agroforestry systems Journal 14: 99-111. Kluwer Publishers.

Cline, M.D. (1944). Principles of sampling. Soil Sci. 58: 275-288.

Dale, I.R. and P.J. Greenway (1961). Kenya Trees and Shrubs. Buchanan's Estates Limited and Matchards, London and Nairobi. 654pp.

Daly, J. J. (1984). Cattle need shade trees. Queensland Agricutural Journal 110 (1): 21 - 24.

Davies, B.E. (1974). Loss-on-ignition as an Estimate of Soil Organic Matter. Soil Sci. Soc. of Am. Proc. 38: 150-151.

Fahlstrom, K. (1992/93). Examples of agroforestry systems from Kenyan ASALs. Soil and Water Conservation Branch. Ministry of Agriculture, Nairobi, Kenya. 100pp.

Fanning, D.S and M.C. Fanning (1989). Soil: Morphology, Genesis and Classification. John Wiley and Sons, New York. PP 338-368.

FAO (1988a). Nontimber uses of selected Arid Zone Trees and Shrubs in Africa. FAO conservation Guide 19: 1-20.

FAO (1988b). Traditional Food Plants: A resource book for promoting the exploitation and consumption of food in arid, semi-arid and sub-humid lands of East Africa. FAO Food and Nutrition paper 42: 537. FAO, Rome.

FAO (1988c). Arid zone forestry: A guide for field technicians. FAO conservation Giude 20. 130pp.

FAO (1989a). Forestry and food security. FAO Paper 90. FAO of the United Nations, Rome.

FAO (1989b). Forestry and nutrition: A reference Mannual. FAO of the United Nations. pp 3 -15.

Farah, A.Y. (1994). The Milk of Boswellia Forest: Frankincense Production among the Pastoral Somali. Environmental Policy and Society, Department of Social and Economic Geography, Uppsala University. 142pp.

Felker, and Bandurski, R.S. (1979). Uses and potential uses of leguminous trees for minimal energy input agriculture. Economic Botany 33(2): 172 - 184.

Fernandes, E.C.M., A., O'kting'ati and Maghembe, J. (1989). The Chagga Homegardens: A multistoreyed agroforestry cropping system on Mount Kilimanjaro (Northern Tanzania). In: Nair, P.K.R (ed) (1989). Agroforestry Systems in the Tropics. ICRAF, Nairobi and Kluwer Academic Publishers, London. PP 309-324.

Flower, S. and Evans, F.R. (1966). The Flora and Fauna of the Great Salt Lake Region, Utah. Salinity and Aridity, Monographiae Biologicae, Vol. 16: 367-393.

Foth, H.D. (1990). Fundamentals of soil science. 8th Edition. John Wiley and Sons, New York. PP. 26-266.

Forezen, P. and Oberholzer, E. (1984). Use of Multipurpose Trees in hill farming systems in Western Nepal. In: Nair, P.K.R. (ed) (1989). Agroforestry Systems in the Tropics. PP. 87-98. ICRAF, Nairobi.

Getahun, A. (1989). Agroforestry for development in Kenya: In: Agroforestry Development in Kenya. Proceedings of the Second Kenya National Seminar on Agroforestry held in Nairobi, Kenya. 7th - 16th November, 1988. PP. 84-109.

Getahun, A. and Reshid, K. (1989). A Field Guide: Agroforestry in Kenya. 2nd Edition. Motif Creative Arts Limited, Nairobi. PP. 7-8.

Gicheru, P. T. and Wanjogu, S. N. (1990). Characteristics and Utilization of some Arid and very Arid Soils in Kenya. Kenya Soil Survey. A paper presented to the Third Desert Conference "Desert Development Balancing Economic and Ecological Constraints" 16th - 21th July, 1990 Beijing, China.

Goodall, D. W. and Perry, R. A. (ed) (1981). Aridland Ecosystems: Structure, Functioning and Management. Vol. 2. Cambridge University Press, Cambridge. PP. 9-25.

Gorse, J. (1985). Desertification in the Sahalian and Sudanian Zones of West Africa. Unisylva 150, 37 (4):2 - 18.

Government of Kenya (1974 - 78; 1979 - 1983; 1984 - 88; 1989 - 1993; and 1994 - 1996). Mandera District Development Plans, Ministry of Planning and National Development.

Government of Kenya (1993). Environmental Action Plan for Mandera District. Ministry of Land Reclamation, Regional and Water Development. Department of Land Reclamation. p. 25.

Grainger, A. (1990). The Threating Desert: Controlling Desertification. Earthscan Publications Ltd, London in Association with UNEP. pp 1-64.

Halim, R.A and Ahmad, S.H. (1987). Using SAS - PC for Agricultural Experiments. Jabatan Agronomi dan Kulturakebunan Fakulti Pertanian Universiti Pertanian, Malaysia.

Huxley, P.A. (1979). Classification of Plant Aspects of Agroforestry Systems. ICRAF, Nairobi. 9pp.

ICRAF (1992). A selection of useful trees and shrubs for Kenya: Notes on their identification, propagation and management for use by agricultural and pastoral communities. ICRAF, Nairobi. 223pp

ICRAF (1995). Agroforestry for natural resource management and food production in the Sahel - A research strategy. ICRAF, Nairobi. 25pp.

Jambulingam, R. and Fernandes, E.C.M. (1989). Multi-purpose trees and shrubs on farmlands in Tamil Nadu state (India). In: Nair, P.K.R. (ed) (1989). Agroforestry Systems in the Tropics. ICRAF and Kluwer Academic publishers, London. PP.121-136.

Joubert, P. (1957). Geology of Mandera - Damassa Area. Geology Survey of Kenya. PP.1-28.

Kassas, M. (1957). On the Ecology of the Red Sea Coastal Land. Journal of Ecology, 45: 187-203.

Kassas, M. and Girgis, W.A. (1964). Habitat and plant communities in the Egyptian desert. V. The limestone Plateau. Journal of Ecology, 42: 424-442.

Kassas, M and Imam, M. (1954). Habitat Plant Communities in the Egyptian desert. III. The Wadi bed ecosystem. Journal of Ecology 42: 424-441.

Kenya Soil Survey Staff (KSS). (1987). Manual for Soil Survey and Land Evaluation Vol. 1 - Miscellaneous Soil Paper Number, M24, 1987. PP. 1-124.

Kershaw, K.A. and Looney, J.H.H. (1985). Quantitative and Dynamic Plant Ecology. 3rd Edition. Edward Arnold, London. PP. 29-30.

Kinyua, P.I.D. (1989). Agroforestry in arid and semi-arid areas. In: ICRAF (1989). Agroforestry Development in Kenya: Proceedings of the Second Kenya National seminar on Agroforestry held in Nairobi, Kenya. 7th - 16th November 1988. p.442-450.

Kopell, C.R.S. (ed.). 1990. The major significanc of "minor" forests in the West African Humid forest zone. FAO Community Forestry Note 6: 5 -37. FAO Rome. pp 5 -37.

Lal, R. and Cummings, D. J. (1979). Cleaning a Tropical Forest I. Effect on soil and microclimate. Field crop research 2 (2): 91 -107.

Lang-Brown, J.R. and Harrop, J.F. (1962). The ecology and soils of the Kabale Grasslands, Uganda. East African Agricultural and Forestry Journal No. 2: 264-272.

Le Houerou, H. N. (1986). Browse in Africa: The current state of knowledge. IBPGR and Royal Botanical Gardens, Kew, London.

Lehmann, J. and D'anzer, J. (1987). Soil Evaluation of the Western Slopes of Jebel Marra, Darfur, Sudan with Special Reference to Plantation Forestry and Agroforestry. Journal of Applied Geography and Development. Vol.40. Institute of Scientific Cooperation, Tiibingen, Germany.

Lillesand, T.M. and Kiefer, R. W. Remote Sensing and Image Interpretation. 2nd Edition. John Wiley and Sons, New York.

Lesile, A.D. (1987). Agroforestry Survey of Somalia. British Forestry Project. Somalia Research Section, Working Paper Number 9. PP. 13-34.

Loth, P.E. and Prins, H.H. (1986). Spatial Patterns of the Landscape and Vegetation of Lake Manyara National Park. International Institute for Aerospace Survey and Earth Sciences (ITC) Journal 1986-2: 115-130.

Lundgren, B.O. (1982). Introduction, Agroforestry systems, I: 3-6.

Lundgren, B.O. and Raintree, J.B. (1983). Sustained Agroforestry. In: B. Nestel (ed), Agricultural Research for Development: Potential and Challenges in Asia. p.37-39, ISNAR, The Hague.

Marsh, W. M. (1991). Landscape Planning Environmental Applications. 2nd Edition. John Wiley and Sons, Brisbane, Australia. PP. 51-274.

Meigs, P. (1953). World distribution of arid and semi-arid homoclimates. Cited in: Graf, W.L. (1988). Fluvial processes in dryland Rivers. Springer-Verlag, London. PP. 1-10.

Mellink, W., Y.S, Rao and MacDickson (Eds.)(1991). Agroforestry in Asia and Pacific. Regional Office for Asia and the Pacific (RAPA) Publication: 1991/5. FAO and Winrock International Institute for Agricultural Development, Bangok.

Misra, R. (1968). Ecology Work Book. Oxford IBH Publishing Company. Calcutta, India. 244pp.

Muchena, F. N. (1985). The extend and Management of "Problem Soils" (Planosols, Solonetz, Solonchaks - eroded and degraded soils) in Kenya. Sixth meeting of the Eastern African Sub-committee for soil correlation and land evaluation, Maseru, Lesotho, 9th-18th October, 1985. The Kenya soil survey, National Agricultural Laboratories, Nairobi, Kenya.

Muchena, F. N. and Pouw, Van der (1981). The Soil Resources of the Arid and Semi-arid Areas of Kenya. Kenya Soil Survey, National Agricultural Laboratories, Nairobi. Paper Presented at The International Workshop on Strategies for Developing the Resources of the Arid and Semi-arid Areas of Kenya at Kenyatta Conference Centre, Nairobi 4th - 8th August, 1981. PP. 1-15.

Muller - Samann, K.M. and Kotschi, J. (1994). Sustaining Growth: Soil Fertility Management in Tropical Small holdings. Margraf Verglag, Weikersheim, Germany. PP 1-131.

Mungai, D. N. and Wamicha, W.N. (1985). The Major Soils of Arid and Semi-arid Areas of Kenya in Relation to Soil and Water Conservation. Paper Presented at Soil Conservation Workshop on grazing lands, 9-12 April 1985, Utalii College, Nairobi.

Mutangali, J.G., Mwangangi, O.M. and Mwaura, P.K. (1993). Mau Forest Complex Vegetation Survey. Kenya Indigenous Forest Conservation Programme Centre for Biodiversity, National Museums of Kenya, Nairobi and KIFCON, Karura Forest Station, Nairobi PP. 1-36.

Nair, P.K.R. (1985). Classification of Agroforestry Systems. ICRAF Reprint No. 23. PP 97-128.

Nair, P.K.R. (1989a). Agroforestry Systems, practices and Technologies. In: Nair, P.K.R. (ed)(1989). Agroforestry Systems in the Tropics. ICRAF, Nairobi and Kluwer Academic publishers. p.53-72.

Nair, P.K.R. (ed). 1989b). Agroforestry systems in the Topics. Kluwer Academic Publishers in Co-operation with ICRAF, London. Forestry Sciences Vol. 31: 609.

Ndiang'ui, N. (1989). Exploration and Documentation of "Lesser-Known" Trees and shrubs with Agroforestry Potential. In: ICRAF (1989). Agroforestry Development in Kenya. Proceedings of the Second Kenya National Seminar on Agroforestry held in Nairobi, Kenya. 7th-16th November, 1988. p.483-490.

Ngumy, J.G. (1992). Teacher's Manual on Agroforestry in Dryland Africa. Soil Conservation Unit, RSCU, Nairobi. Training Material No. 1.

Niamir, M. (1990). Community Forestry - Herder's decision - making in natural resource management in arid and semi-arid Africa. FAO. Community Forestry Note 4, FAO, Rome. PP. 20-42.

Niyezimana, E. (1992). Soil and Soil-Landscape Relationship in the North Central region of Rwanda, East Central Africa. Soil Science: 225-236.

Noad, T. and Birnie, A. (1992). Trees of Kenya. Third edition . T.C. Noad and A. Birnie, Nairobi, Kenya. 292pp.

Noy-Meir, I. (1973). Desert ecosystems. Environment and Producers. Annual Review of Ecology and Systematics, 4: 25-51.

Noy-Meir, I., Tadmor, N.H. and Orshan, G. (1970). Multi-variate analysis of desert vegetation. I. Association analysis at various quadrat sizes. Isreal Journal of Botany, 19: 191-561.

Nunow, A.A. (1994). The Structure and Functioning of the Somali Pastoral Economy: With Specific References to Agro-pastoralism: A Case Study from Central Division, Garissa District, Kenya. M. Phil Thesis, Moi University. 199pp.

Oba, G. (1991). The Ecology of the Floodplain Woodlands of the Turkwel River, Turkana, Kenya. In: Amuyunzu, C.L. and Oba, G. Vegetation Resources of Central Turkana District, Kenya. TREMU Technical Report No. D-2: 38-101.

O'Hare, G. (1988). Soils, Vegetation, Ecosystems: Conceptual Frameworks in Geography. Oliver and Boyd, Harlow UK. PP. 1-93.

Ojany, F.F. and Ogendo, R. B. (1973). Kenya: A Study in Physical and Human Geography. Longman - Kenya, Nairobi. PP. 18-38.

Oslon, C.G. and Hupp, C.R. (1986). Coincidence and spatial variability of Geology, Soils and Vegetation, Mill run watershed, Virginia. Earth surface processes and landform Journal. Vol. 11 No. 6: 619-629.

Padoch, C. and Jong, W. (1987). Traditional agroforestry practices of native and Ribereno Farmers in the lowland peruvian Amazon. In: Gholz, H.L. (ed), Agroforestry: Realities, Possibilities and Potentials. Marttinus Nijhoff, Dordrecht. PP. 179-194.

Pratt, D.J. and M.D., Gwynne (1977). Rangeland management and Ecology in East Africa. Hodder and Stroughton, London. P. 310.

Pratt, D.J., Greenway, P.J. and Gwynne, M. D., (1966). A Classification of East African Rangelands, with an Appendix on Terminology. Journal of Applied Ecology No. 3, Nov. 1966. Black well Scientific Publication, Oxford. PP. 369-382.

Pritchett, W. (1979). Properties and Management of Forest Soils. John Wiley and Sons, New York. PP. 43-48.

Punam, A. and Khosla, P.K. (1990). The Classification of Traditional Agroforestry Systems. Department of Horticulture and Forestry, Palampur, India. PP 1-15.

Ritchie, W., Wood, M., Wright, R. and Tait, D. (1988). Surveying and Mapping for Field Scientists. Longman Scientific and Technical, U.K. PP. 39-41.

Rocheleau, P., F., Weber and Field - Juma, A. (1988). Agroforestry in Dryland Africa. ICRAF, Nairobi PP. 15-16 and 73-213.

Sanchez, P.A. (1976). Properties and management of soils in the Tropics. John Wiley and Sons. New York. 618pp.

Shaabani, S.B., Walsh, M., Herlocker, D.J. and Dierk, W. (1992). Ministry of Livestock Development Range management Handbook of Kenya Vol. II, 4. Mandera District. 135pp.

Shreve, F. (1942). The desert vegetation of North America. Botanical Review, 8: 195-246.

Simute, S. (1992). Agroforestry: Manual for extension workers with emphasis on small scale farmers in Eastern Province, Zambia. The Regional Soil Conservation Unit, RSCU, SIDA. RSCU Technical Hand book No. 2. PP 15-30.

Sombroek, W. G., H.M.H., Braun and Kibe, J.M. (1973). A preliminary evaluation of the irrigation suitability of the soils in the Mandera - Rhamu area (North Eastern Province). Kenya soil survey project, site evaluation no. 10, 1973.

Sombroek, W.G., J.P., Mbuvi and Okwaro, H.W. (1976). Soils of the Semi-arid Savanna zone of North-Eastern Kenya. Kenya soil survey, Miscellaneous soil paper M2, 1976.

Soil and Water Conservation Board (SWCB). (1992). Soil and water conservation in ASAL, Field Manual - Vol. 3: Agroforestry. Ministry of Agriculture, Nairobi, Kenya. PP. 1-40.

Steel, R.G.D and Torrie, J.H. (1981). Principles and Procedures of Statistics: A biometrical Approach. Second edition. McGraw-Hill, London. 315pp.

Tadros, T.M. (1953). A phytosociological study of halophilous communities from Mareotis (Egypt). Vegetatio, 4: 102-24.

Tadros, T.M. and Atta, B. M. (1958). Further contribution to the sociology and ecology of halophilous communities of Mareotis (Egypt). Vegetatio, 8: 137-24.

Tadmor, N.H., G. Orshan and Rawittz, E. (1962). Habitat Analysis in the Negev of Israel. Bulletin of Research council of Israel, 11: 148-173.

Thomas, A.S. (1941). The vegetation of the Sese Islands, Uganda. An illustration of edaphic factors in tropical ecology. Journal of Ecology 31-2: 149-177.

Thornthwaite, C. W. (1948). An approach towards a Rational Classification of Climate, Geographical Review, 38: 55-94.

Torres, F. (1989). Tree-fodders and Silvopastoral Systems. In: Nair, P.K.R. (ed) (1989). Agroforestry Systems in the Tropics. ICRAF, Nairobi and Kluwer Academic publishers, London. p. 553-562.

UNEP. (1992). World Atlas of Desertification. Edward Arnold, London PP 4-5.

United States Department of Agriculture (USDA) Soil Survey Staff (1951). Soil Survey Manual. USDA Scs. US Government printing office, Washington, D.C.

Van Doorne, J.H. (1989). Agroforestry in arid lands: Range and Catchment Management. In: ICRAF (1989). Agroforestry Development in Kenya: Proceedings of the Second Kenya National Seminars on Agroforestry held in Nairobi, Kenya, 7-16 November 1988. PP. 275-282.

Von Maydell, H.J. (1986). Trees and Shrubs of the Sahel: Their Characteristics and Uses. Eschborn. PP. 26.

Walter, H. (1964). Die Vegetation Der Erde in Oko-Physiolozischer Betrachtung. In: Muller - Samann and J. Kotschi (1994): Sustaining Growth - Soil Fertility Management in Tropical Small Holdings. Margaf Verlag, Weikersheim, Germany. PP. 43-47.

Weber, F.R. and Stony, C. (1986). Reforestation of arid lands. Volunteers in Technical Assistance. Virginia, USA. PP.31-47.

Wenner, C.G. (1981). Soil conservation in Kenya especially in small-scale farming in high potential areas using labour intensive methods. 7th Edition. Farm management Branch. Project Management and Evaluation Division. Ministry of Agriculture, Nairobi. 213pp.

West, N.E. and Ibrahim, K.I. (1968). Soil-Vegetation relationships in the Shade Scale Zone of Southeastern Utah. Ecology, 49: 445-456.

Williams, J.S. (1969). Gradient in Species Composition of Desert Vegetation near EI-Paso, Texas. In: C.C. Hoff and M.L., Riedesel (ed). Physiological Systems in semi-arid environments. University of New Mexico press, Albuquerque.

Zou, N and Sanford, R.L. (Jr.) (1990). Agroforestry Systems in China: A Survey and Classification. Agroforestry systems 11:85-94. Kluwer Academic Publishers, the Netherlands.

APPENDICES

APPENDIX I: SLOPE GRADIENT DETERMINATION

PRINCIPLE: The gradient of a slope uses the principle of "triangle" (Ritchie *et al* 1988). The gradient was measured at each quadrat. To get the average slope gradient for example for the section between sampling point (S1) to sampling (S2), the gradient of the two points were added and divided by two. Slope gradient in degrees were converted to percentage to suit the KSS classes.

Slope Classes of the surrounding area (KSS, 1987)

Slope class	Macrorelief	Gradient
A	Flat to very gently	0 - 2%
B	Gently undulating	2 - 5%
C	Undulating	5 - 8%
D	Rolling	8 - 16%
E	Hilly	16 - 30%
F	Mountainous	> 30%

APPENDIX II: DETERMINATION OF SOLUBLE OF SALTS BY ELECTRICAL CONDUCTIVITY

Principle - The salt content of a soil can be estimate roughly from an electrical conductivity measurement of a dilute suspension in water. Conductivity increases with the salt content but varies with the nature of ions. In its measurement a high frequency alternating voltage is applied by a conductivity meter to two electrodes placed at distance apart and having a sample of liquid in between them. The resistance across the electrodes is recorded by the meter in Siemens (1 siemen = 1 micromhos/cm).

Method - 20 grams of air dried soil was scooped in a 250 ml of plastic shaking bottle. 50 ml of distilled water was added. The soil water mixture was shaken for two hours and electrical conductivity was measured using a conductivity meter (Model AGB 1000)

Electrical Conductivity Classes (KSS, 1987)

Class	EC (mmhos cm^{-1})
I	0 - 4 Salt free
II	4 - 8 Slightly Saline
III	8 - 15 Moderately Saline
IV	15 - 30 Strongly Saline
V	> 30 Excessively Saline

APPENDIX III: DETERMINATION OF pH OF SOIL SUSPENSIONS

Principle - The pH is a measure of hydrogen ion concentration. Since the hydrogen ion concentration can vary from about 10^{0} in a normal solution of a strong acid to 10^{-14} in a strongly alkaline solution, the negative logarithm of the hydrogen ion concentration is used. It is written in short hand as pH.
The pH of a soil suspension in pure water is an estimate of active acidity. The hydrogen ions of the soil suspensions, which are associated mainly with the clay colloid and organic colloid or humus, functions as mixture of weak to moderately strong acids.

Method the method used was the same as for electrical conductivity and a pH meter model CORNING ION ANALYZER 250 was used for the measurement.

pH (The intensity of soil acidity and alkalinity) classes (KSS, 1987)

CLASS	pH READING	
I	< 4.5	Extremely acid
II	4.5 - 5.0	Very strongly acid
III	5.1 - 5.5	Strongly acid
IV	5.6 - 6.0	Medium acid
V	6.1 - 6.5	Slightly acid
VI	6.6 - 7.3	Neutral
VII	7.4 - 7.8	Mildly alkaline
VIII	7.9 - 8.4	Moderately alkaline
IX	8.5 - 9.0	Strongly alkaline
X	> 9.0	Very strongly alkaline

APPENDIX : MEASUREMENT OF ORGANIC MATTER IN SOILS

Principle The sample is ignited slowly in muffle furnace to final temperature of 550° C. The loss in weight represents the moisture and organic content of the sample.

Method (Procedure)
10 ± 0.1 g of air dry soil that was passed through 2 mm sieve was placed in dry porcelain crucible. The soil was placed in a furnace and heated slowly raising the temperature in steps of 100, 200 and 550° C and was maintained for 8 hours. The crucible containing the soil is removed and cooled in a desiccator and weighed.
Calculation:

Weight of dry crucible alone	= W1
Weight of dry crucible + soil	= W2
Weight of dry crucible plus soil after ignition	= W3
% organic matter	= W2 - W3.

NB It was assumed that the carbon is available to the plant. It is what is potentially available to plants.

Organic Matter Content in % (Modified form of Mungai and Wamicha, 1985)

CLASS	% ORGANIC MATTER CONTENT
I	0 - 0.2 Extremely low
II	0.2 - 0.4 Very low
III	0.4 - 0.6 Medium low
IV	0.6 - 1.0 Slightly low
V	1.1 - 14 Moderate
VI	> 14 Very high

APPENDIX V: PARTICLE SIZE ANALYSIS (TEXTURE) USING THE MECHANICAL ANALYSIS - HYDROMETER METHOD

Apparatus and Materials - Apparatus and materials include a ASTM 152 H Hydrometer, reciprocal shaker, brass plunger{ dispersion reagent 5% calgon solution consisting of sodium hexometaphosphate plus 5 g sodium carbonate per litre; 500 ml plastic bottles and 1000 ml graduated cylinder.

Method - 50 g of evenly air dried soil (40 - 50 ° C) that was passed through a 2 mm sieve is placed in plastic shaking bottles and 300 ml water was added followed by 50 ml dispersing reagent. The bottles were tightly stopped and placed on a shaker and shacked overnight.

The next day, the soil suspension was transferred into 1000 ml graduated cylinder filled with water up to the mark. In another cylinder, 50 ml of the 5% calgon solution was added and it was also filled with water up to the mark. It was thoroughly mixed with a plunger to bring the temperature of the soil suspension. 40 seconds after stirring ceased the hydrometer was carefully lowered into the solution and the scale reading taken as "R". The reading is used to determine silt plus clay. At the same time reading "Rb" was taken from a blank solution which is used as a control. After two hours from the time stirring ceased, a second hydrometer reading was taken. This reading was used to determine clay fraction.

CALCULATION

$C = R - Rb$

where C = the corrected reading of the suspension in grams per litre.

R = the first reading of the hydrometer in suspension

Rb = reading from the blank

The summation percentage "p" from the equation:

$$P = 100 \frac{(C)}{CO}$$

where CO is the weight of the soil.

The concentration percentage at the end of 40 seconds was the percentage of material still in suspension at the end of 40 seconds, that is silt plus clay. This was recorded as percentage sand:

100 - P = % Sand

The concentration percentage at the end of 2 hours is the percentage of clay:

$$\% \text{ clay} = \frac{C - Rb \times 100}{CO}$$

C is in grams per litre

CO is 50 g

% silt = 100 -% clay + % sand.

If the soil contain gravels, stones or boulders it is indicated.

APPENDIX VI: SITE CLASS TERMINOLOGY FOR PARTICLES LARGER THAN 2MM (KSS, 1987)

Percentage	Particle size in cm		
	Gravel 0.2 - 7.5	Stones 7.5 - 25	Boulders >25
2 - 15	Slightly gravelly	Slightly stony	Slightly bouldery
15 - 50	gravelly	Stony	Bouldery
50 - 90	very gravelly	Very stony	Very bouldery
> 90	gravel*	Stones*	Boulders*

(*) Used without additional textural classification.

APPENDIX VII: SOIL DEPTH CLASSES (KSS, 1987)

Class	Depth (cm)	Description
0	<10	Extremely shallow
1	10 -25	Very shallow
2	25 - 50	Shallow
3	50 - 80	Moderately deep
4	80 - 120	Deep
5	120 - 180	Very deep
6	>180	Extremely deep

APPENDIX VIII: SOIL DRAINAGE CLASSES (KSS, 1987)

CLASS	DESCRIPTION
0 Very poorly drained	Water is removed from the soil so slowly that water table remains at or near the surface for most of the year. Soils are usually peaty or very humic and show gley; the level sites are flooded for most of the year.
1 Poorly drained	Water is removed slowly so that the soil remains wet for a large part of the year. The water table is commonly at or near the surface for a large part of time. Mottles occur from the surface onwards, gley starts at 30 - 40 cm depth.
2 Imperfectly drained	Water is removed from the soil slowly enough to keep it wet for significant periods but not all the time. Mottles occur 30 cm onwards.
3 Moderately well drained	Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. Mottles occur at 60 cm deep.
4 Well drained	Water is removed from the surface rapidly. The soils commonly retain considerable amounts of moisture for plant growth after rain or application of irrigation water.
5 Some what excessively drained	Water is removed from the surface rapidly. Many of these soils are sandy and very porous.
6 Excessively drained	Water is removed from the soils very rapidly. The soils are usually very shallow and may be situated on steep slopes or may be very porous.

APPENDIX IX: USEFUL TREES AND SHRUBS OF THE DAUA VALLEY

The MPTs not only provides indispensable uses of human and animals but also protects and helps in the restoration of soil fertility and the quality of the environment. The people of the valley value MPTs so much that they named towns like Mandera (after Mader - *C. quercifolia*) and Khalaliyo (after Khalaiyo - *E. breviaticulata*).

1. *Boscia anguisitifolia* A. Rich
Local name: Chieh (Somali)
Family: Capparaceae
An evergreen small tree to 4 m with creamy flowers and edible fruits to birds.
Habitat: Scattered 1 to 3 km from the river with moderately alkaline; strong to excessively saline soils and gently undulating slope.
Uses: Source of good poles and posts, wood for warming containers, bee forage, nice shade and leaves for browse especially by camels.

2. *Boscia coriacea* pax
Local name: Ghalanghal (Somali)
Family: Capparaceae
Evergreen shrub with edible fruits to birds.
Habitat: Noted at 5 km from the river in Khalaliyo area, with excessively saline, moderately alkaline and gently undulating slope.
Uses: Dry season fodder to camels and goats, bee forage and Wood for warming containers.

3. *Boscia minimifolia* chiov.
Local name: Megag (Somalia)
Family: Capparaceae
Evergreen tree to 5 m with round conical crown.
Habitat: Scattered 1 km to 5 km from the river throughout the valley. Common on gravelly, shallow, moderately alkaline and strongly saline soils.
Uses: Bee forage, wood for warming containers, firewood, shade, poles and posts, browse for camels and goats. The mistitle (*Loranitus* spp) which grows on it is used to smoke polio patients for treatment.

4. *Boscia salicifolia* oliv
Local name: Lamloch; lamblesha (Somali)
Family: Capparaceae
Deciduous tall tree to 10 m with fragile branches.
Habitat: Uplands, especially on gravelly sites, liked by crows for nesting.
Uses: Firewood, browse to camels and warming containers.

5. *Boscia tomentella* chiov
Local name: Towsi, tosi (Somali), Duse (Boran)
Family: Cappraceae
Evergreen tree to 10-15 m with round crown. Flowers are yellow green and fruit is round and creamy when ripe.
Habitat: Scattered from 2 km away from the river and extend towards the surrounding uplands, especially on well drained to excessively drained soils.
Uses: Browse for all animals especially camels and goats and it is lopped in dry season for fodder. The flowers provide bee forage. Fruits are edible (in Somalia). Provides posts, poles and firewood. Seed oil as eye ointment.

6. *Cadaba glandulosa* Forssk
Local name: Dughdughow (Somalia)
Family: Capparaceae
Evergreen shrub with gynophore (stalked ovary) flowers.
Habitat: Scattered 1 km from river and extends into uplands zone in Khalaliyo area especially between rocks cracks. The plant is an indicator of excessively saline soils with pH of at least 8.0
Uses: The foliage is appreciated by camels due to its salt content. Wood as firewood.

7. *Maerua decumbens* (Brogn) De Wolf
Local name: Abar mog (Somali)
Family: Capparaceae
Evergreen shrub to 1 m with a large swollen root, yellow green flower and yellow fruit when ripe.
Habitat: Grows about a km away from the river on alluvium sandy loam soils especially around Mandera-Neboi area.
Uses: Ripe fruits are edible. The root tubers are used for water purification. The roots boiled in meat, to provide juice for treating pains in private parts and against Rheumatism. Roots are also used to reduce size of swollen parts of the body and it treats blood sickness.

8. *Moringa borziana*
Local name: Wame or Mawe, Ghorente (Somali)
Family: Moringaceae
Deciduous shrub to 1.5 m. Leaves are bipinnate and with capsule fruit.
Habitat: Moderately alkaline, moderately to strongly saline and stony loamy sand and stony and gravelly silty loam.
Uses: The root tuber is crushed and smeared on camels to remove Mange disease. The root decoction is taken for stomach ache treatment. Crushed seed could purify water.

9. *Moringa longituba* Engl.
Local name: Wame, Mawe, Ghorente (Somali)
Family: Moringaceae
Deciduous shrub to 2 m with brittle branches and 2-3 pinnate.
Habitat: Moderately alkaline, moderately to strongly saline soils and stony and gravelly silty loam. In Rhamu area it can be found about 1.5 km from the river especially in

Yabicho area.
Uses: Same as *Moringa borziana*. The leaves are good fodder especially for goats.

10. *Moringa oliefera* Lam
Standard name: Horse Radish Tree
Family: Moringaceae
Small tree originally from India. Introduced by the Forestry Department for afforestation and soil conservation in early 1990s, especially in Mandera town and former refugee camp site.
Uses: Leaves, green fruits and flowers are used for vegetables in India. Root used as substitute for horse radish sauce. Elsewhere the seed is used to purify water and the plant is used for soil conservation in Mandera.

11. *Tamarix aphylla* (L.) Karst
Local name: Duur (Somali)
Family: Tamaricaceae
Tree to 6 m. Resembles *Casuarina* plant.
Habitat: Riparian (grows along laggas and the river) with preference to sandy and saline soils.
Uses: Shade and river bank stabilization (Plate 5.11), firewood, aesthetic, handles for tools (especially farm tools like jembes, hoes and axe), poles, posts. The plant releases salt from its glands at night hence, soil below it is too salty for crops.

12. *Combretum aculeatum* vent.
Local name: Eddishabel (Somali), Gabbe (Boran)
Family: Combretaceae
A tree with twining branches to 8 m with recurved spines and pale yellow winged fruit.
Habitat: It grows along "laggas" with loamy clay soil and is common in Rhamu-Galicha area.
Uses: Fodder, poles for mobile nomadic huts, firewood and as dead fence.

13. *Combretum hereroense* schinz
Synonym: *Combretum volkensii*
Local name: Ghoghon (Somali)
Family: Combretaceae
Shrub to 5 m with leaves concentrated to ends of drooping branches and with yellowish fruits.
Habitat: Common in Galicha area between 1 to 4 km from the river, mainly on gravely sandy loam soils.
Uses: Leaves and fruits provide fodder, the small size poles are used for making wooden container holders. The poles are used in house and plot building and as firewood.

14. *Terminalia polycarpa* Engl & Diels
Local name: Hareri (Somali)
Family: Combretaceae
Tree to 10 m. leaves are concentrated at the growing terminals. Flowers are white and in

Plate 5.11: *Tamarix aphylla* with *Echinocloa haploclada* grass for river bank stabilization along the Daua River, Central Division, Mandera District.

spike inflorescence, producing pink fruit.
Habitat: It is common along "laggas" / runnels in the study area.
Uses: Wood provides number one building posts and poles (it is termite resistant and highly marketable), provision of shade, charcoal, pestle making, leaves provide excellent fodder for young camels and the flowers are excellent for bee forage. Boiled bark juice is used to treat stomach ache for maternity mothers.

15. *Terminalia parvula* pampan
Local name: Massar jibbis (Somali)
Shrubby tree to 3 m. Common on gravelly sites 2 to 5 km from the river.
Uses: Fodder and building materials.

16. *Terminalia orbicularis* Engl.& Diels
Local name: Bisiig (Somali)
Family: Combretaceae
Tree to 6 m, spreading at a low level to form a thicket, with sub cordate leaves and creamy winged fruit.
Habitat: Common in gravelly loamy sites 3 to 5 km from the river.
Uses: Root decoction is used to stop bleeding especially metallic cuts. Leaves provide fodder, wood for making food containers. The plants ash is used to colour houses. Bark is boiled and juice taken to treat stomachache and mouth wounds. The bark of the roots are boiled and juice taken to treat rheumatism. The wood has a beautiful pattern, nomads curve it to make ornamentals which are tied to prominent camels. The wood is also a good firewood source.

17. *Grewia bicolor* Juss
Local name: Debi, Dowee (Somali)
Family: Tiliaceae
Shrub to 1.5 m with smooth stick like branches. It has simple leaves, yellow flowers and orange fruit (when ripe).
Habitat: It was noted along a rocky runnel near Rhamu, 4 km from the river bank.
Uses: Fruits edible, beeforage and firewood. It provides sticks and withes for building local houses. Leaves provide fodder. The wood provides quality stick. Through the sale of its poles, it generates income.

18. *Grewia lilacina* K. Schum
Local name: Ohob, hobeche (Somali)
Family: Tiliaceae
Much branched shrub of upto 2.5 m with four lobed reddish fruit. It is common on stony/gravelly sites with a slope gradient of undulating to rolling.
Uses: Fruit is edible and act as excellent drought food reserve, withes are used in plot and house building and wood are "rural area night candle " to light houses. Provision of fodder especially goats and camels. Withes for local bed construction and sale. The flowers provide bee forage. The plants root provided deep red tannin which is used as wood preservative against insects and fungi plus decoration of household wooden containers.

The withes provide traditional pen for writing Quranic tablets.

19. *Grewia tembensis* Fres.
Synonym: *Grewia erythraea* schweinf
Local name: Dumeg, Demeg (Somali)
Family: Tiliaceae
Shrub to 3 m with white solitary flowers giving way to red-orange 2-4 lobed fruits when ripe. The species is very common on very shallow, gravelly, bouldery or stony sites especially 2-4 km from the river.
Uses: Bee forage, building and sale, firewood, stick, traditional pen for writing Quranic tablets, fodder for goats and camels, fruits are edible. Turkanas use root decoction against cough (Beentje 1994:158)

20. *Grewia villosa* Willd.
Local name: Kobish (Somali)
Family: Tiliaceae
Shrub to 2.5 m with cordate (heart shaped) leaves and tomentose (hairy) terminal buds. The hairy fruit turns yellow when ripe (especially after the cover is removed).
Habitat: It is common in well drained sites with shallow laggas (depression/runnel)
Uses: Fodder, bee forage, building materials, firewood, local pens and edible fruits.

21. *Grewia tenax* (Forssk.) Fiori
Local name: Danfarur, Deka (Somali)
Family: Tiliaceae
A shrub to 2 m with glabrous ovate leaves and white solitary flowers that end up in producing 2 - 4 lobed green fuits that turns orange when ripe.
Habitat: common along water courses and welld rained soils of the entire Daua Valley
Uses: Firewood, bee forage, edible fruits, fodder, building materials and local pens. Elsewhere within the country it is used for making bows and arrows.

22. *Bombax rhodognaphlon* K. Schum
Local name:Get suuf (Somali)
Trade name: East African Bombax
Family: Bombacaceae
Tall trees to 30 m with digitate leaves. It is riparian and planted along the river by some farmers.
Uses: Shade, ornamental, river bank stabilisation and timber. Seed floss used as kapok and bark yield a red dye (Beentje, 1994:169).

23. *Thespesia danis* Oliv
Local name: Kobhan (Somali)
Family: Malvaceae
Shrubby tree to 5 m with solitary yellow flowers. Fruit is creamy when ripe. The leaves have cordate base. The species occur along the river bank and 1-3 km away from the river in areas where river flooding is frequent and has clayey soils.
Uses: Firewood, ripe fruit is eaten by children, fodder, provides building materials, income

generation and handles for hoes (jembes). The species is fast growing and provides large biomass for fallow but it can become a weed. The stems are used to make rungus, bows and arrows; and also employed as fire (friction) sticks, dye is made from flowers and fruits (Beentje, 1994:174)

24. *Caucanthus albidus* (Niedenzu) Niendenzu
Family: Malphigiaceae
Scrambling shrub to 2 m with spirally arranged leaves and creamy flowers. Common in Rhamu-Galicha area, 1 to 5 km from the river bank on an undulating slopes and hill tops with soils of moderately saline and gravely silty loam.
Uses: Fodder and firewood.

25. *Croton somalensis* Vatke & Pax
Family: Euphorbiaceae
Shrub to 3 m with silvery leaves underneath. It grows along lagas and runnels in Galicha area.
Uses: Building materials and poles and posts

26. *Euphorbia tirucalli* L.
Family: Euphorbiaceae
Local name: Dana (Somali)
Succulent multi branched shrub to 5 m with green and smooth branchlets. It is planted in farms and in plots in farm villages.
Uses: Live fence for marking border. Good fodder for camels. If weak camels feed on the plant, its health improves and becomes fat. It provides shade and it is also used for plots and grave marking.

27. *Jatropha dichtar* Macbr
Local name: Digdar (Somali)
Family: Euphorbiaceae
Spiny shrub to 2 m. It is common in Khalaliyo area especially 2-5 km from the river on sandy loam or loamy sand soils with very low organic matter.
Uses: Dry leaves provide fodder and fence.

28. *Euphorbia cuneata*
Synonym: *Euphorbia spinescens*
Local name: Darander, gharbegharbe (Somali)
Family: Euphorbiaceae
Commiphora like armed shrub to 2 m. Common on loamy soils with or with out gravels and slope gradient of >3.5%.
Uses: Live fence, latex is used to treat knee pains, boils and breast pains. Roots are boiled in water and juice taken to treat stomach ache. The *Hydnora* sp. parasite that grows on the plant's root is edible and relatively sweet. The leaves and twigs are liked by camels and goats.

29. *Euphorbia brevianticulata* Pax
Synonym: *Euphorbia grandicornis*
Local name: Khalaliyo (Somali)
Family: Euphorbiaceae
Spiny shrub with winged branches constricted into segments growing in bunches. It is restricted to 1 km around Khalaliyo centre. The site has undulating slope; strongly saline and alkaline loam soils.
Uses: Its juice is used to treat complicated wounds and tooth (molar) aches. It can also be used for fencing.

30. *Delonix baccal* (chiov) Bak F.
Local name: Bakal (Somali), Balanga (Boran)
Family: Caesalpiniaceae
Tree to 20 m with umbrella shaped crown (plate 5.12), pinnate leaves and yellow-white flowers. It is closely associated to soils derived from Daua Limestone Series. It usually grows near lagas especially in Galicha area.
Uses: Fodder, bee forage, wood for container making and mortal. Wet seeds are edible.

31. *Delonix elata* (L.) Gamble
Local name: Lebi, lowee (Somali)
Family: Caesalpiniaceae
Round tree to 10 m. with spreading branches, yellow-white flowers and knife-like pods. It is common in Khalaliyo area and seems to have
been replaced *D. baccal* in Rhamu-Galicha area. It is associated to sites 5 km away from the river especially on brownish silty loamy or sandy loam soils.
Uses: Fodder, edible seeds (when wet), bee forage, wood for camel bells, mortal and containers. Gum treats wounds. Holes in the trunks hold water which people use in dry season.

Plate 5.12: *Delonix baccal* in association with *E. cuneata*, *Acacia* spp. and *C. albidus*, Galicha area, Rhamu/Ashabito Division, Mandera District.

32. *Tamarindus indica* L.
Local name: Hamar, Roqe (Somali)
Family: Caesalpiniaceae
Round ever green spreading tree to 20 m. with bipinnate leaves and brown rusty fruits when ripe. It is common within 1 km from the river bank.
Uses: Fruit is edible and its juice is used to treat stomach ache, malaria and gastric diseases. It also provides refreshment drink. The wood produces charcoal, walking stick and handles for axes and hoes. Its salty leaves are eaten by children and livestock and it provides bee forage.

33. *Acacia condyloclada* Chiov
Local name: Edad geri (Somali)
Family: Mimosaceae
Plant with creamy flowers and powdery yellow bark. It is common on rocky steep slopes of Rhamu-Galicha area. It is classified as rare species (Beentje, 1994).
Uses: Fodder (leaves and pods), shade, firewood, charcoal, bee forage and edible gum.

34. *Acacia edgeworthii* T. Anders
Local name: Ghude, Gomor Jiring (Somali)
Family: Mimosaceae
Spiny shrub with pubescent fruits that grows on undulating slopes and on gravelly silty loam soils.
Uses: Firewood, fodder, dead fence, wet seeds are mottled and boiled for a day, then eaten. It also provides bee forage

35. *Acacia horrida* (L.) willd
Local name: Sarman (Somali), Chachanneh (Boran)
Family: Mimosaceae
Low spreading shrub armed with white thorns that prefers shallow gravelly and loamy soils and common on midland zones.
Uses: Fodder, bee forage, firewood, roots used to tie up other woods for building and in Somalia they are used for making winowers. Helps in soil conservation and thorns may be used as tooth pegs.

36. *Acacia mellifera* (Vahl) Benth.
Local name: Bilil, Bil-el (Somali), Sabansa - Gurach (Boran)
Family: Mimosaceae
Shrubby tree to 5 m which is armed with prickles. Flowers are creamy white and leaves are pinnate. It is not common but can be found 5 km from the river especially on gravelly loam or sandy soils.
Uses: Firewood, charcoal, bee forage, dead fence and fodder. Stingless bees like to hive in it. Gum is edible and the bark is boiled and taken by maternity mothers to reduce stomach upset. The decoction is also used against malaria (Beentje, 1994). It supports edible *Hydnora* root parasite.

37. *Acacia nilotica* (L.) Del
Local name: Tuwer, Tuger (Somali), Burguge (Boran)
Family: Mimosaceae
Tall umbrella shaped evergreen tree to 12 m with yellow globose head inflorescence. It is found on clay soils about 1 km from the river, usually on flooded sites.
Uses: Fodder (leaves and pods), shade (liked by wild animals), firewood, fruit is used to produce local dye/tannin for dying calabashes. The fruit is boiled to make local tea. In other parts of the country, Beentje (1994) reported its use as stimulant, eye medicine (fruit juice) and juice from the roots as chest medicine.

38. *Acacia nubica* Benth.
Local name: Gummr (Somali), Wanga (Boran)
Family: Mimosaceae
Shrub to 3 m with greenish bark. Flowers in creamy heads. The species are common on gravelly loamy sand with gently undulating slopes.
Uses: Edible gum, bark for local mat making, firewood, dead fence and leaves as fodder.

39. *Acacia paolii* Chiov
Local name: Gommor (Somali)
Family: Mimosaceae
shrub to 4 m with flat spreading crown. Flowers when it has no leaves and they are born on globose head inflorescence. Fruits are densely pubescent. It is common on clay-loam soils with low to moderate organic matter and on gently undulating slopes, mainly in lowlands and midlands.
Uses: Bee forage, fodder, firewood, indicator of potential cropping zone, dead fence, and gum is edible. Beentje (1994) reported the bark infusion as remedy for skin diseases.

40. *Acacia refeciens* Wawra subsp. *Misera* (Vatke) Brenan
Local name: Qhansaa, Qase (Somali), Sigirso (Boran)
Family: Mimosaceae
Shrubby tree to 5 m with obconical and flat topped canopy. Flowers are creamy white in spikes. leaves are bipinnate. It is common on gravelly sites of the midlands with undulating to rolling slopes.
Uses: The bark (cambium) is chewed as refreshment. It also provides fibre for mat and local sack making. The gum is edible and its firewood is of high quality. It provides fodder, bee forage and it supports edible *Hydnora* root parasite.

41. *Acacia senegal* (L.) Willd
Local name: Edad (Somali), Idado (Boran)
Family: Mimosaceae
Round to conical crown tree to 5 m. Leaves are bipinnate and flowers are white or creamy in spikes. It is scattered from river bank to 5 km away mainly on sandy clay and silty clay.
Uses: Income from the sale of its gum, raw gum or boiled with milk is edible and it is taken to treat males reproductive organs. There is a saying in Somali community which says "man should not cut *A. senegal* with axe" due to its medical use. It accommodates edible *Hydnora* root parasite. The plant provides one of the best dead fence materials. It

also provides fuelwood, fodder and bee forage.

42. *Acacia seyal* Del.
Local name: Fulai (somali), Wachu (Boran)
Family: Mimosaceae
A spiny tree to 12 m usually associated with riverine conditions. It has powdery yellowish bark. Flowers are on yellow globose head.
The plant does well on sandy loam and clay loam soils and on gently undulating sites.
Uses: The gum is edible and sold to generate income. Local wood preservative called "Asal" is derived by boiling the bark in water. The tree provides fodder, bee forage, fuelwood, dead fence and income from sale of its fuelwood.

43. *Acacia tortilis* (Forssk.) Hayne
Local name: Abaq (Somali), Dadach (Boran)
Family: Mimosaceae
Umbrella shaped thorny tree to 20 m. The leaves are in globose head inflorescence. The fruit is twisted pod. The species does well on deep soils 1 - 3 km from the river bank and along lagas and runnels.
Uses: Roots provide walking sticks, leaves and pods are excellent animals fodder. The tree also provides shade, bee forage, fuelwood, fibre for local house mat making, handles for tools (like hoes and axes) and dead fencing materials. The fresh leaves if crushed and put on boils, makes it ripe and heal fast. The pod is used to treat Rheumatism and the plants gum that oozes from the bark is used as eye ointment. The pods are significantly important as dry fodder reserve and it fattens animals. It forms association with edible *Hydnora* sp. root parasite.

44. *Albizia anthelmentica*
Local name: Reidap (Somali), Howacho (Boran)
Family: Mimosaceae
Deciduous tree to about 6 m with compound pinnate leaves and white flowers. It is commonly found on strongly saline to excessively saline, deep soils of 2-3 km from the river bank.
Uses: The bark of the root is boiled with meat or milk to be taken to treat Rheumatism, bone disease and it is given to wounded person for faster recovery. The boiled root juice is used as dewormer. During the treatment, all cold foods and water have to be avoided. Women are not encouraged to take it. The plant also provides fodder, shade and firewood.

45. *Leucaena leucocephala* Lam de wit
Standard name: Leucaena
Family: Mimosaceae
Shrub to 5 m. It has bipinnate leaves and white creamy flowers in globose head. The species is planted in former refugee camps near Mandera town and in farms along the river.
Uses: Firewood, nitrogen fixation, fodder and for soil conservation.

46. *Erythrina melancantha* Harms
Local name: Buri (Somali), Walena (Boran)
Family: Papilionaceae
Tree to 10 m with corky bark, red flowers and elliptic leaflets. The seed is bean-like It is one of the best and highly valued plant in Mandera. It is planted in farms along the river.
Uses: The wood is used for making milk and water containers, local chairs, and all utensils that nomads require. Holes in the tree retain water for many years for use in very seasons by pastoralists. The fresh stem cuts are chewed to quench thirst. It also provides fodder, shade and can fix nitrogen.

47. *Ficus* sp.
Local name: Rumi nabi (Somali)
Family: Moraceae
A riparian shrub to 1.5 m with synocium inflorescence (Fig) and lanceolate leaves. It grows on the bank of the river.
Uses: Fodder, tooth brush and for river bank stabilization.

48. *Ficus sur* Forssk
Local name: Berde (Somali), Oda (Boran)
Family: Moraceae
Tree to 25 m with spreading and round crown. Leaves are sand papery and ovate. It is riparian and restricted within a kilometre from the river bank especially on flood prone sites.
Uses: Fodder, excellent shade, firewood, edible figs, good natural bee hive and for construction of artificial bee hive, building materials, making of doors and containers.

49. *Dobera glabra* (Forssk) poir
Local name: Garas (Somali), Cheri (Boran)
Family: Salvadoraceae
An evergreen tree to 10 m with leathery shiny leaves, white flowers and creamy fruits (when ripe).
It is very common around laga flood plains with strong to extreme saline soils and moderately well drained clay soils. The slope is undulating.
Uses: Edible fruits and seeds, shade, mortal making, ash used to treatment camel manage, dry fodder and leaves used as temporary spoon. It also provides shade, chair construction, firewood and tooth brush.

50. *Salvadora persica* L.
Local name: Adhei (Somali), Ade (Boran)
Family: Salvadoraceae
Evergreen tree to 3 m with flesh shiny leaves, white flowers and pink fruits (when ripe).
Uses: Firewood, fodder (fruits and leaves), shade, tooth brush (root and branches), and indicator of extremely saline and clayey soils.

51. *Ziziphus hamur* Engl.
Local name: Hamur (Somali)
Family: Rhamnaceae
Thorny deciduous shrub to 3 m with elliptic dark green leaves. Flowers are greenish and fruits are purple to brown (when ripe). It is found 3-5 km from the river on strongly saline, shallow sandy soils.
Uses: Firewood, edible fruits, fence, fodder and building material.

52. *Ziziphus mauritiana* Lam
Local name: Hamur-gob (Somali), Qurguba (Boran)
Family: Rhamnaceae
Thorny shrubby-tree to 6 m with leaves that are silvery underneath. Fruit is creamy (when ripe). The plant is common along water courses with high flood frequency within 1 km from the river.
Uses: Fodder, edible fruit, firewood and shade. Root decoction is used for stomach ache and it provides building material.

53. *Kirkia tenuifolia* Engl.
Local name: Orog, Donfarghot (Somali), Biss duga (Boran).
Family: Simaroubaceae
A deciduous tree to 8 m with pinnate leaves, green creamy flowers and angled fruit.
Uses: Good poles for building. Holes in the tree holds water for use in very dry seasons, firewood, warming containers, camels like its fodder, bee forage and warthog eat its watery root tubers.

54. *Balanites rotundifolia* (Van Tiegh) Blatter
Local name: Kullan (Somali), Badan (Boran)
Family: Balanitaceae
Evergreen shrub to 5 m with obovate leaves and greenish flowers and orange fruit (when ripe). The species are very common in Khalaliyo area than Rhamu. It is mainly associated with sandy loam that has strongly alkaline soil characteristics.
Uses: Edible fruits, for making board used in Quranic writing and poles as building materials. Local ploughing instrument called "Kababa" is constructed from it plus parts of oxen plough instrument, shade and fodder especially in dry season.

55. *Boswellia microphylla* chiov
Local name: Bebeh (Somali), Mogole (Boran)
Family: Burseraceae
A deciduous tree to 5 m which is common on steep slopes and rocky sites. It produces white flowers just at the onset of rainy season.
Uses: Its bark provides one of the best tannin and the bark plus twigs are used as refreshment if boiled with milk. It produces resin for sale, chewing and smoking of houses for aromatic smell. The tree provides firewood and has holes that hold water which can be used in dry season. It is a source of fodder especially for goats and camels and can be used as chewing stick.

56. *Boswellia neglecta* S. Moore
Synonym: *Boswellia hildebrantii* Engl.
Local name: Magafur, mathafur (Somali), Dakhara (Boran, Gabra)
Family: Burseraceae
Deciduous tree to 5 m with imparipinnate leaves, greenish white followers.
The species is common in mid and uplands with stones and gravels, shallow and excessively drained soils. It is common 2-5 km from the river.
Uses: The resin is locally called "Lobathin" and it is used as chewing gum, sold for income and smoked in houses and water pots for aromatic smell. The bark provides "asal" (a local dye and wood preservative). Leaves and fruit are Fodder and wood as firewood, containers making and curving of local board for Quranic writings.

57. *Boswellia rivae* Engl.
Local name: Mathefur, magafur (Somali)
Family: Burseraceae
A tree to 6 m which grow on stony and gravelly parts of the hills surrounding the River Daua. The plants leaves are ashy and flowers are pink.
Uses: The bark is used for tanning leather. The gum is used for chewing, sale and for smoking houses to get aromatic smell.
The wood is used as firewood, making of containers and leaves and fruit provide fodder.

58. *Commiphora rostara* Engl.
Local name: Danusagar (Somali), Diraa (Boran)
Family: Burseraceae
Deciduous spiny shrubby tree with black bark that produces aromatic oily juice. Leaves are elliptic. It is not very common but can be found in areas with gravelly and stony loamy soils in midlands.
Uses: The juice is used against cold and to treat wounds. Leaves for fodder and are edible and used against cold. The twigs are chewed as refreshment.

59. *Commiphora gracilispina* J. B. Gillet ined.
Common name: Gharangharba, warabreb (Somali)
Family: Burseraceae
A spiny shrub that forms thick bush with black bark which peels transversely. It exudate gum which is put to various uses.
The plant is common around former settlements and on sandy soils which are sometimes gravelly.
Uses: Lives fences around plots and graves, firewood and fodder for goats and camels. The plant exudate gum which is used to treat boils, knee pains, tonsils and removal of thorns from the body. The gum is boiled in goats milk for the above uses.

60. *Commiphora habessinica* (O. Berg) Engl.
Local name: Warabreb (Somali), Jalanga (Boran)
Family: Burseraceae
Spiny shrub to 4 m that has yellowish papery bark which peels to release green under bark. The leaves are three-foliate.

Habitat: Common on undulating to rolling sites 2-5 km from the river with gravelly sandy soils.
Uses: firewood, fodder and fencing

61. *Commiphora campetris* Engl.
Local name: Hamesa (Somali and Boran)
Family: Burseraceae
Deciduous spiny tree with yellowish bark which peels to reveal green underback.
Habitat: Common on gravelly loamy sand soils with moderately alkaline and saline and strongly saline characteristics.
Uses: Fodder, fence and firewood

62. *Commiphora danduensis* Gillet ined
Local name: Rosse (Somali), saje (Boran)
Family: Burseraceae
Short deciduous tree with spines and branches coming low to the ground. Bark is yellowish and flakes to reveal green under bark. Leaves are obovate.
Habitat: Undulating to rolling sites with stony and gravelly loamy sand soils.
Uses: Its gum is used to treat camel mange. The wood is used for making containers and is used as firewood. The plant also provides shade and fodder. The gum is used for continuous lighting of fire for a long period by pastoralists.

63. *Commiphora velutina* Chiov
Local name: Arihagatow, Kassan (Somali)
A deciduous shrub to 4 m. Leaves are three-foliate. Bark is grey and fruit ovoid.
Habitat: Rocky and rolling sites with moderate to strongly saline soils.
Uses: Branchlets are used as tooth brush and provides firewood. It is a good fodder and the bark is liked by giraffe and goats. The resin is edible. The bark is used to provide "asal" (Local wood preservative and dye). Plate 5.13 shows how to prepare "asal" from *Commiphora velutina* and its application to poles for local house constructions.

64. *Commiphora myrrha* (nees) Engl.
Local name: Malmal (Somali), Kumbi (Boran)
Family: Burseraceae
Deciduous spiny tree to 5 m with silvery yellowish bark peeling to reveal green underbark. Flowers are greenish yellow and fruit is ovoid.
Habitat: Gentle to rolling landscape with gravelly sandy soils that are excessively saline.
Uses: The plant exudate resin which is sold for income. The resin is also used to treat snake bites, as eye ointment, and as a local ink ingredient. The ink is not easy to erase and can last long. Only water is added to the ink any time it is required for use. The wood is used for making of containers, head rest and as firewood. The resin is traditionally used to put on the heads of babies to harden it. The seed is edible. The plant also provides fodder and shade. In short it is one of the most valued plants in rural areas "Badia" of Mandera.

Plate **5.13a:** Preparation of "asal" wood preservative made from the bark of *Commiphora velutina.* It is boiled with water and frequently mixed for about 30 minutes.

Plate 5.13b: The application of "asal" wood preservative made from the bark of *Commiphora velutina* to poles for local houses construction. The broom which is used as a brush is made of Doum Palm. In the background are traditional houses with mats made from Doum Palm.

65. *Commiphora ogadensis* Chiov
Synonym: *Commiphora hildebrantii*
Local name: Hagar jerer (Somali), Hagarsu ferda (Boran)
Family: Burseraceae
A deciduous crooked short tree to 4 m with peeling papery yellowish bark to reveal blue underbark. Terminal parts are pubescent and leaves are trifoliate.
Habitat: 2-4 km from the river on undulating slopes.
Uses: The fresh bark is boiled and taken for refreshment like tea, the wood is used for container making, the leaves provide fodder and is used to quicken ripening of boils. In Somalia the roots are used for making of winnower. The bark is also used for making of "asal" (local preservative and dye). The wood is also used for making of camel bells and local boards for Quranic writings and as firewood. The plant exudate resin which is used to kill ticks (acaricides) and to treat Mange and scabies. For the above treatments the gum is boiled in a solution of camels urine and milk and then smeared on the affected or attacked parts of the animals.

66. *Commiphora pseudopaolii* Gillet.
Local name: Hagar (Somali), Hagersu (Boran)
Family: Burseraceae
Deciduous, spiny tree to 10 m with bark peeling in scrolls to reveal blue underbark. Leaves are trifoliate and fruit is pea like.
Habitat: Undulating site with stony and gravely silty loam soils.
Uses: Leaves and fruiting body provide excellent fodder. The unripe seeds are used to fatten young camels. The wood is used to make containers, Loh', chairs, camel bells and it is also used as firewood. The wood is liked by bees as natural bee hive. The tree has holes which is used as nesting places by horn bill birds. The holes also act as storage of rain water for use later by pastoralists and travellers. But care is needed against snakes. The plant exudate resin which is used as natural acaricide and treatment against mange, scabies and its number one treatment for snake bites: the resin is mixed with water and taken orally and it acts immediately. The fresh bark is boiled for use as tea. The fresh cambium is eaten by children. It has oily edible seeds in extremely dry conditions. It can be used as live fence.

67. *Commiphora unilobata* Gillet & rollesen
Local name: Booror, Boror (Somali)
Deciduous shrub or tree on alluvium soils that grows to 4 m. Bark is yellow peeling to reveal green underbark. Leaves are pinnate and it flowers when it has no leaves just at the onset of the rainy season. Flowers are reddish and fruits are smooth and green.
Uses: The resin is poisonous to eat but treat boils (on people and camels). The unripe fruit is sour and edible.

68. *Trichilia ementica* Vahl.
Local name: Anona (Boran)
Family: Meliaceae
Evergreen riparian tree to 10 m. The bark is smooth grey and leaves pinnate, with elliptic and shiny leaflets. Flowers are green and the seed

is black and the size of a bean but with orange oily aril.
Habitat: It was noted only on the bank of the river with silty-clay soil.
Uses: Shade. In other parts of the country the oil seed is used for making soap, the timber for furniture-making and an infusion of the root is emetic but may be lethal in over dose (Beentje, 1994).

69. *Lannea malifolia* (Chiov) Sacl.
Local name: Wanre (Somali)
Family: Anacardiaceae
A tree to 10 m, classified as rare by Beentje (1994). It has pinnate leaves with elliptic leaflets. Fruit is ovoid.
Habitat: It was noted in Galicha area in stony runnels.
Uses: Fodder and the bark provides fibre for rope, local sack and mat making, the wood is used for container making and as firewood. The fruit is edible.

70. *Lannea schweifurthii* (Engl.) Engl.
Synoname: *Lannea stuhlmanii* (Engl) Engl.
Local name: Deen (Somali)
Evergreen tree to 10 m with dense crown. Leaves are pinnate, glabrous and elliptic. Flowers are greenish yellow and fruit is ellipsoid.
Habitat: It was noted in Kalmab area near Galicha along stony runnels.
Uses: Leaves provide fodder for camel and goats. The fruit is edible and the wood is used for making of containers and doors. The plant also provides shade.

71. *Mangifera indica* L.
Standard name: Mango
Local name: Amba (Somali)
Family: Anacardiaceae
Evergreen cultivated tree to 10-15 m with fissured greyish-brown bark. Leaves are simple and elliptic to lanceolate. Flowers are creamy pinkish and fruit round to ovoid and yellow or green when ripe.
Habitat: It is restricted from the river bank to one km from the river bank in farms. it is mainly planted on the river bank especially on loamy sand soils.
Uses: Edible fruit, income, bee forage, shade and for river bank stabilization. The wood is used as firewood. The leaves is used as fodder for goats.

72. *Adenium obesum* (Forssk) Rowm & Schutt
Local name: Obe (Somali), Obbe (Boran)
Family: Apocynaceae
Deciduous succulent shrub with swollen stem to 1.5 m. Leaves are elliptic and glabrous and flowers are pink; fruit open up when dry to release winged seeds.
Habitat: Undulating sites mainly along runnels that has gravelly loam to silty loam
Uses: Stem's juice is used to treat camel mange and scabies. The fluid if diluted can be used to treat nozzle blockage and flu. Concentrated fluid is poisonous. The plant can be used as ornamental.

73. *Wrightia demartiniana* Chiov
Synonym: *Piaggiaea demartiniana*
Local name: Haya, Hanya (Somali), Takadaua (Boran)
Family: Apocynaceae
Deciduous shrub to 2 m. Bark is smooth and grey. Terminal branchlets are pubescent and leaves are elliptic. Flowers are white tube like and fruit follicles.
Habitat: Undulating sites with stony/gravelly silty soils.
Uses: The bark produces while latex which is used to clot fresh milk the reaction is immediate. Branches are used as (friction) fire sticks. The wood is used for making high quality loh', wooden shoes and wooden spoon.

74. *Calotropis procera* (Ait) Ait f.
Local name : Boah (somali), K'obbo (Gabra)
Family: Asclepiadaceae
Evergreen shrub to 5 m with corky bark and soft wood. The leaves are sessile ovate and light green with whitish dirt. Flowers are purple and fruit is globose.
Habitat: It is common along lagas and depressions.
Uses: Leaves are eaten by goats when dry. Fruit/flower is a preference for goats. The plant has been used to mark plots and graves. The wood is used for temporary buildings.

75. *Carphalea glaucescens* (Hiern) Verdc.
Synonym: *Dirichletia glaucescens*
Local name: Burbur, Garde (Somali), Burbur (Boran).
Family: Rubiaceae
A deciduous shrub to 2 m with ovate leaves and white tube-like flowers.
Habitat: In runnels with gravelly loamy sand soils.
Uses: Wood provides firewood and for warming milk and water containers. The leaves provide excellent fodder.

76. *Gardenia volkensii* K. Schum
Local name: Mathah madal, Marmadol (Somali), Gambeila (Boran)
Family: Rubiaceae
Deciduous short tree to 3 m. The branches are many. Bark is grey and it flacks. Leaves are glabrous in pairs. Flowers are white.
Habitat: It is common along lagas.
Uses: Leaves provide fodder and wood as firewood and for making wooden spoon.

77. *Bleripharispermum lanceolatum* Chiov
Synoname: *B. fruitcusum*
Local name: Bainyetusbah (Somali), Abune (Boran)
Family: Compositae
Deciduous, slender shrub with obovate leaves and creamy-white flowers in heads.
Habitat: Along runnels in Khalaliyo area.
Uses: Wood is used for firewood and making of "tusba" (religious beads for tally count). Leaves provide excellent fodder for camels.

78. *Blepharispermum pubscens* S. Moore
Local name: Banye (Somali)
Family: Compositae
A shrub to 1.5 m. It is deciduous with ovate leaves and white flowers that turn black when ripe.
Habitat: Gently undulating sites with gravelly silty loam.
Uses: Wood provide firewood to lit nomadic houses at night as lamp. The leaves are excellent fodder for camels.

79. *Cordia quericifolia* Klotzsch
Synonym: *C. gharaf*
Local name: Marer (Somali)
Deciduous shrub to 2 m with oblong to elliptic sand papery leaves. Flowers are white and fruits orange when ripe.
Habitat: Variable but it dominates 3-5 km from the river.
Uses: Fruit is edible and firewood. Wood provides firewood and building materials for houses and plots, walking stick and clubs and handles for hoes. Dry wooden sticks are used for as friction sticks for fire production. The leaves are used as fodder when dry or wet. The twigs of the plant can be used as chewing stick.

80. *Cordia sinensis* Lam
Local name: Marer (Somali), Mader (Boran)
A tree to 5 m which is riparian and not very common. Leaves are elliptic and sand papery. Branchlets dropping. Flowers are creamy white and fruits orange.
Habitat: Along the river bank.
Uses: Wood for firewood, handles for hoes and sticks and building materials. Leaves are for fodder. Fruit is edible.

81. *Lycium europaeum* L.
Family: Solanaceae
A deciduous spiny shrub to 4 m. Leaves are obovate, flowers white and fruit orange.
Habitat: Along runnels with silty soils. It can also be found on old river levees.
Uses: Wood provides firewood, fence and fodder (twig and leaves). In other parts of the country, root decoction is used against backache and cough (Beentje; 1994).

82. *Solanum jubae* Bitter
Family: Solanaceae
Unarmed, deciduous shrub to 3 m. Leaves are ovate and pubescent and flowers are pale lilac.
Habitat: Very shallow stony and gravelly silty loam with very low organic matter.
Uses: Leaves provide fodder and the wood is used to construct houses and plots.

83. *Ipomea donaldsonii* Rendle
Local name: Barii borte (Somali), Jirmosho (Boran)
Family: Convolvulaceae
Deciduous shrub with spiny branches, black bark, white bell shaped flower with purple

centre and cordate base leaves.
Habitat: Gently to rolling sites with gravelly and stony silty soils.
Uses: Firewood, leaves provide fodder, juvenile plants roots are edible and the wood is used to warm containers.

84. *Kigelia africana* (Lam) Benth
Local name: Bukural (Somali)
Family: Bignoniaceae
Evergreen, riparian tree with brown bark and sausage shaped fruit, and imparipinnate leaves and with obovate sand papery leaflets.
Habitat: It was common one km from the river especially on clay soils.
Uses: Shade, leaves provide dry fodder. Wood is used for fuelwood, container making and construction of bee hives.

85. *Sesamothamnus busseanus* Engl.
Local name: Langeed, selelma (Somali), Lalaftu (Boran)
Family: Pedaliaceae
Deciduous tree with soft wood, spiny and copper green bark. Leaves are obovate and pubescent below. Flowers are dirty white, well shaped and with black dehiscent fruit.
Habitat: Distributed from one to five km away from the river mainly on gravelly sandy soils.
Uses: Leaves provide fodder and it is used as soap. The plant is used for live fence. Rheumatism is treated by using decoction of roots. The decoction is also used to treat wound caused by metal cuts. Local dye is made from water plus the plant's root and iron bar.

86. *Anisotes tanensis* C. Baden.
Local name: Merdis (Somali), Tutu (Boran)
Family: Acanthaceae
Deciduous shrub to 3 m, leaves are ovate and flowers are bright red.
Habitat: Gravelly sandy soils in gentle to rolling sites.
Uses: Leaves provide fodder, the flowers contain honey dew liked by children and the plant's wood is used for construction of houses and as firewood.

87. *Justicia* sp
Local name: Gormai (Somali)
Family: Acanthaceae
Deciduous shrub to about 1 m. The leaves are glabrous sessile and elliptic. Flowers are white with blackish centre.
Habitat: It was noted on stony soils of Galicha area and seem to like the Daua Limestone Series.
Uses: Twigs and leaves are browsed by cattle, goats and camels. Flower as bee forage. The wood is used as firewood. The plants full identification is waiting for specialist from Botanical Gardens of Kew.

88. *Satanocrater paradoxa* (Lindau) Lindau
Local name: Malabow (Somali)
Family: Acanthaceae
Spineless shrub to about 1 m, leaves obovate and pubescent, flower is solitary and orange. The plant has aromatic smell.
Habitat: It is rare and noted near Fiqho and Koromey (close to Mandera town). I was told by East African Herbarium staff that my collection was the first in Kenya.
Uses: The plant is used for construction, firewood, leaves provide fodder and flowers contain honey dew which is sweet to suck.

89. *Lantana* sp
Local name: Gathegathe (Somali)
Family: Verbenaceae
Quadriangular deciduous aromatic shrub to about 3 m. Leaves are ovate, flowers white and fruit purple when ripe.
Habitat: Rocky sites and along runnels near Galicha.
Uses: The wood is used for firewood and warming of containers. The leaves provide fodder and fruit is edible.

90. *Erythrochlamys spectabilis* Giirke
Local name: Daidub (Somali)
Family: Labiatae
Deciduous, quadriangular and aromatic shrub to about 3 m. Leaves are simple, pubescent, subsessile and opposite. Flowers are purple coloured.
Habitat: Along runnels 5 km from the river in Rhamu-Galicha area.
Uses: Leaves and flower are useful fodder and the wood is used for construction of plots and houses and as firewood.

91. *Ocimum suave* Willd
Local name: Reehan (Somali), Anchabbi (Boran)
Family: Labiatae
Woody aromatic herb or dwarfy shrub that is common in stony and bouldery uplands with elliptic leaves and whitish flowers.
Uses: The plants leaves and fruiting body are put in oils/ghee to give it aromatic (perfume like smell) for body application. The plant is a good fodder especially for goats and sheep.

92. *Hyphaene compressa* H. Wendl.
Local name: Bar (Somali), Kone (Boran)
Family: Palmae
Forked palm to 20 m. Leaves are spiny and fan like and flowers are brownish and fruit is round and shiny brown.
Habitat: Restricted to water courses especially up to 2 km from the river. Sometimes it is common along lagas.
Uses: Leaves are used for thatching and mat making, wood (poles) are used for house and plot construction and for beehive construction. The liquor from the terminal bud is believed to treat tuberculosis (TB). The fruit is edible. The seed is decorated and tied to

camels for beauty. The germinating seed provides edible cotyledon. The young leaves are used for making local housing mats and brooms and juvenile stem is chopped as the last alternative fodder for livestock. The palm is liked by riverine birds like Hammerkop for nesting.

93. *Phoenix reclinata* Jacq.
Standard name: Wild date palm
Local name: Maleqa, alol (Somali), Meti (Boran)
Palm to 8 m with persistent leaf base. The leaves rachis is very long to 2 m and spiny. Flowers are creamy brown and seeds with brown coat and slitted seed like that of date palm.
Habitat: It is restricted to the river bank.
Uses: The leaf rachis is used for construction local beds. The leaflets are used for making local sleeping mats and baskets. The fruit is edible.

94. *Lawsonia inermis* L.
Local name: Erip, Elan (Somali)
Family: Lythraceae
A deciduous, spiny, riparian tree to 10 m. The leaves are glabrous, simple and ovate. Flowers are creamy-white and sweet scented and the fruit is capsule. It is mostly restricted to flood plains of the river and occasionally in "lagas" a way from the river.
Uses: Firewood, dead fence, bee forage and edible resin. The leaves and fruiting body provide fodder for livestock when wet and dry. The wood provides poles and posts; bows and arrows and sticks for spears. The leaves when dried and lemon juice or tea is added, it forms dye for body decoration and clothes plus leather. A decoction from the roots is used to treat rheumatism and stomach aches. Juice from the bark is used to treat yellow fever. The plant is used for river bank stabilization.

95. *Gynocarpus hababensis* Chiov.
Local name: Yuoob, Yub (Somali)
Family: Hernandiaceae
Deciduous tree to 7 m. with obovate glabrous leaves found in Galicha area on gravelly clay loam, moderately to strongly saline soils and slope of gently undulating to undulating.
Uses: Fodder; wood for container making, camel bells, comb and for firewood and poles.

96. *Azadirachta indica*
Local name: Get kharerow (Somali)
Family: Meliaceae
An exotic tree introduced by NCCK and Forest Department between 1977 and 1978 to the District mainly for afforestation activities. The tree which now naturalized grows to 15 m and has oval to conical shaped crown with coarsely toothed leaflets. Flowers are creamy - white and produces green fruits that turn yellow when ripe.
Uses: The fruit is appreciated by birds, monkeys, baboons and children. The wood is used as firewood and poles. The leaves act as fodder for goats and when boiled with water is used to treat malaria. The plant is also used for afforestation. It also provides bee forage, nice shade and beauty around homesteads.

97. *Prosopis juliflora*
Local name: Aligorob (Somali)
Family : Mimosaceae
A tree to 5 m that was introduced to the district by NCCK and Forest Department in 1977 and 1978 mainly for afforestation. The plant which has now naturalized is an aggressive weed and its thorns give donkey carts allot of tyre punctures. It has golden - yellow flowers in spikes and the leaves are compound bipinnate.
Uses: Excellent species for afforestation of degraded sites like former refugee camps, bee forage, fodder, fuelwood, poles, river bank stabilization, live fence, border planting, aesthic and shade.
Note: The species has become vigorous weed and its thorns are reported to be poisonous if it pierces into the body. It is also reported that around water ponds the plant causes discolouration of water and affects the test. People are developing negative attitude towards the plant because of the above effects.

98. *Indigofera schimperii*
Local name: Darqhe (Somali)
Family: Papilionaceae
A riparian shrub to 4 m with hairy pinnate leaves and with pinkish flowers and dehiscent pods. It is restricted up to one Km from river bank especially in flooding zones with clayey soils and genlte slopes.
Uses: Fodder; withes for construction of houses and firewood. Smoke leaves is reported to scare away mosquitoes.

99. *Psidium guajava*
Local name: Zeitun (Somali)
Family: myrtaceae
An exotic small tree to about 4 m introduced by Farmers and Department of Agriculture for fruit production. The leaves are elliptic and the flowers are solitary with numerous white stamens. Ripe fruit is yellow, fleshy and is known to be rich in Vitamin C (Noad and Birnie, 1992). Its bark peels and flacks
Uses: River bank stabilization, edible fruits, bee forage, firewood and aesthic in homesteads with water tap.

100. *Hydnora* spp.
Local name: Lakee, dingah (Somali)
Family: Hydnoraceae
An underground root parasite that forms special association with *Acacia* and *Commiphora* spp. The plant has wart coverage and numerous nipples that can potentially form flowering parts in the rainy seasons. The aerial flowers have 4 lobes and perish within 1-2 months after the onset of the rains. Once the flowers shed without being plugged, a second phase of growth takes place immediately underground forming huge and round tuber (plate 5.14). The tuber is full of edible seeds. After about another month, the tuber cracks and the soil above it releases sweet "ripe Ugali" like smell, a sign of welcome for animal customers including man, fox and wild dogs. There is another variety of *Hydnora* spp. (local name: Dinsi) which the flowering part is used as medicinal especially for stomach problems.

Plate 5.14: Root tubers and reproductive parts of *Hydnora* sp. (Hydnora root parasite) that grows in association with roots of *Acacia* and *Commiphora* spp. It was collected in Rhamu Division, Mandera District.