EXPLOITATION OF *Brachylaena huillensis* (SILVER OAK) AND ITS IMPLICATION TO REGENERATION OF WOODY PLANTS IN BOMBO WEST FOREST RESERVE, KOROGWE, TANZANIA

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT OF NATURAL RESOURCES FOR SUSTAINABLE AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2009

ABSTRACT

This study was carried out in Bombo West Forest Reserve, Korogwe District, Tanzania to assess the extent of human exploitation of *Brachylaena huillensis* and its implication to regeneration of woody plants. Forest vegetation was stratified into highly, mild and least disturbed areas. Data were collected using forest inventory, questionnaire survey, discussion with key informants and participant observation. The overall average tree density of woody plants was 433 stems ha^{-1} while wood volume and basal area was 36.869 m^3 ha^{-1} and 5.4 m^2 ha^{-1} respectively. Overall average tree density of *B. huillensis* was 47 stems ha^{-1}, basal area (1.813 m^2 ha^{-1}) and volume (14.068 m^3 ha^{-1}). It was observed that *Brachylaena huillensis* is abundant, dominant and frequently occurring in the forest reserve with Importance Value Index of 0.470 compared to the next important species *Scorodophlaeus ficheri* (0.545). *Brachylaena huillensis* was found to be heavily exploited indicating 82 stem ha^{-1}, 2.622 m^2 ha^{-1} and 16.376 m^3 ha^{-1} while density distribution by dbh size classes indicated abnormal trend, which signifies poor recruitment and regeneration failure. The overall average of *Brachylaena huillensis* regenerants was 5076 seedlings ha^{-1} compared to 15 646 seedlings ha^{-1} of all woody plants in the forest reserve. *Brachylaena huillensis* is known by 95.7 % of the respondents whereby 79.7% of the respondents used the species for firewood. The species is intensively utilized as pole for buildings as mentioned by 42 % of the respondents and its poles were claimed to be durable and extremely resistant to termites. Carvings, charcoal, bush fire, trees and poles cutting are main threats of the forest reserve and *B. huillensis* in particular. Moreover, it was also observed in this study that the wood harvesting mainly for carvings and charcoal is an indication that *B. huillensis* and the forest in general are currently threatened and needs effective management strategies to control the illegal activities. It suggests that the

domestication of the species on farmlands could probably reduce the pressure to the species and the forest in general.

DECLARATION

I, Damas Mkonda Mumwi, do hereby declare to the Senate of Sokoine University of Agriculture that, this dissertation is my own original work and has not been submitted for a degree award at any other University.

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30/10/2009
Date

The above declaration confirmed

Prof. S. S. Madoffe
(Supervisor)

30/10/2009
Date

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ACKNOWLEDGEMENT

This work could hardly be accomplished without the contribution of others. I wish to express my heartfelt gratitude to all individuals and organizations who contributed to the successful completion of this work. It is not easy to mention each and every individual by name however, some individuals are worth naming. First and foremost, I am deeply indebted to my supervisor Prof. S.S. Madoffe of the Department of Forest Biology, Sokoine University of Agriculture whose availability, technical guidance and constructive criticism shaped this work to its present form. I sincerely thank the Korogwe District Council, specifically my employer, the District Executive Director for granting me permission to pursue this study. I gratefully acknowledge the financial assistance provided by the Belgium Technical Cooperation (BTC) who funded the study period. I would also like to thank my fellow postgraduate students in the Faculty of Forest and Nature Conservation, Sokoine University of Agriculture particularly Mathew Mthayo Mpanda, Issa Mohamed Kilongo, Zainabu Shabani Bugwa, Deo Shirima, Christina Mohamed, Godfrey Massawe, Joseph Makelo and Alex Isaya Njahani for their valuable advice, cooperation and assistance during my study. My deep gratitude goes to my beloved wife, Sofia for her patience, prayers and encouragement during the time of my study. Last but not least, I am indebted to Juma Ntogolewa and Andrew Mrinji for their great assistance during the field data collection. Above all, my greatest thanks go to Almighty God who kept me both alive and healthy throughout this entire endeavour.

DEDICATION

This work is dedicated to Mumwi Chisele family for their encouragement and unconstrained serenity throughout my study. The work is also dedicated to my beloved wife Sofia Crispin Mpendakazi and daughter Nyehosha Damas Mumwi of whom their prayers and moral support have been noteworthy and appreciated throughout my study.

TABLE OF CONTENTS

ABSTRACT ii

DECLARATION iv

ACKNOWLEDGEMENT vi

DEDICATION vii

TABLE OF CONTENTS viii

LIST OF TABLES xii

LIST OF FIGURES xiv

LIST OF PLATES xv

LIST OF APPENDICES xvi

LIST OF ABBREVIATIONS, ACRONYMNS AND SYMBOLS xvii

CHAPTER ONE 1

1.0 INTRODUCTION 1

1.1 Background Information 1

1.2 Problem Statement and Justification 3

1.3 Objectives 5

1.3.1 Overall objective 5

1.3.2 Specific objectives 5

1.4 Hypothesis 5

CHAPTER TWO 6

2.0 LITERATURE REVIEW 6

2.1 Distribution and Regeneration of *Brachylaena huillensis* 6

2.1.1 Distribution of *Brachylaena huillensis* 6

2.1.2 Regeneration of *Brachylaena huillensis* 7

2.2 Uses of *Brachylaena huillensis* 8

2.3 The Effects of Human Disturbance on Forest Conditions 9

2.4 Effect of Human Exploitation of Forest Resources to Natural Regeneration 10

2.5 Conservation Strategies for *Brachylaena huillensis* 12

CHAPTER THREE 14

3.0 MATERIAL AND METHODS 14

3.1 Study Area Description 14

3.1.1 Location and Status of the Forest 14

3.1.2 Climate 14

3.1.3 Vegetation 14

3.1.4 Population 15

3.1.3 Socio-economic activities 15

3.2 Data Collection 16

3.2.1 Primary data 16

3.2.1.1 Socio-economic data 16

3.2.1.2 Ecological (Inventory) data 16

3.2.2 Secondary data 18

3.3 Data Analysis 19

3.3.1 Socio-economic data analysis 19

3.3.2 Ecological (Inventory) data analysis 19

3.3.2.1 Stand parameters 19

3.3.2.2 Forest resource use intensity 21

3.3.2.3 Shannon-wiener index of diversity 21

CHAPTER FOUR 23

4.0 RESULTS AND DISCUSSION 23

4.1 Stand parameters of *Brachylaena huillensis* and other woody plants 23

4.1.1 Stocking, stand basal area and wood volume of woody plants 23

4.1.2 Stocking, basal area and wood volume of *Brachylaena huillensis* 26

4.2 Removed Stand Parameters of *Brachylaena huillensis* and Other Woody Plants 29

4.2.1 Removed trees, basal area and wood volume of woody plants 29

4.2.2 Removed stump density, basal area and wood volume of *Brachylaena huillensis* 32

4.3 The Main Threats and Uses of Woody Plants in Bombo West Forest Reserve 35

4.3.1 Main threats in Bombo west forest reserve 35

4.3.2 Main Threats of *Brachylaena huillensis* species and other related tree species 37

4.3.3 Uses of *Brachylaena huillensis* around the study area 39

4.3.4 Forest resource use intensity of woody plants in Bombo west forest reserve 44

4.3.5 Forest resource use intensity for *Brachylaena huillensis* 47

4.4 Effects of *Brachylaena huillensis* Exploitation on Woody Plants 49

4.4.1 Effects of exploitation on species distribution and richness 49

4.4.2 Shannon –wiener index of diversity 52

4.4.3 Effects of Exploitation on Regeneration of woody plants 53

4.4.4 Effects of Exploitation on Regeneration of *Brachylaena huillensis* 55

4.5 Conservation Strategies for Bombo West Forest Reserve 57

4.5.1 Current conservation strategies for *Brachylaena huillensis* and forest in general 57

4.5.2 Suggested conservation strategies for *Brachylaena huillensis* 58

4.5.2.1 Use and planting of alternative tree species to *Brachylaena huillensis* 58

4.5.2.2 Domestication of *Brachylaena huillensis* tree species in farm land 60

4.5.2.3 Involvement of local community around Bombo West Reserve in forest management 62

4.5.2.4 Awareness creation on biological and ecological importance of *Brachylaena huillensis* 63

4.5.2.5 Developing management plan of Bombo West forest reserve 63

4.5.2.6 Providing alternative income generating activities 63

4.5.2.7 Forest boundary re-survey and firebreaks construction 64

CHAPTER FIVE 65

5.0 CONCLUSION AND RECOMMENDATIONS 65

5.1 Conclusion 65

5.2 Recommendations 66

REFERENCES 68

APPENDICES 84

LIST OF TABLES

Table 1: Stand parameters of woody plants in Bombo West forest reserve 25

Table 2: Stand parameters for *Brachylaena huillensis* tree species in Bombo West forest reserve 28

Table 3 : Removed tree density, wood volume and basal area of woody plants in Bombo West forest reserve 30

Table 4: Removed stock, wood volume and basal area of *Brachylaena huillensis* in Bombo West forest reserve 33

Table 5: Main forest threats ranking in Bombo West forest reserve 35

Table 6: The main threats of *Brachylaena huillensis* in Bombo West forest reserve 38

Table 7: Peoples' response on different uses of *Brachylaena huillensis* around Bombo West forest reserve 40

Table 8: Forest resources use intensity for woody plants in Bombo West forest reserve 45

Table 9: New cut and old cut woody plants in Bombo West forest reserve 46

Table 10: Forest resources use intensity between new cut and old cut for *Brachylaena huillensis* species in Bombo West forest reserve 48

Table 11: Importance Value Index in Bombo West forest reserve 50

Table 12: Shannon-Wiener index of diversity (H') in Bombo West forest reserve 53

Table 13: Regenerants of woody plants in Bombo West forest reserve 54

Table 14: Regenerants of *Brachylaena huillensis* tree species in Bombo West forest reserve 56

Table 15: Willingness of respondents around Bombo forest reserve to use and plant alternative tree species 59

Table 16: People's awareness on *Brachylaena huillensis* exploitation in Bombo West forest reserve 60

Table 17: Willingness of respondents around Bombo forest reserve to plant *Brachylaena huillensis* in their farmlands 61

LIST OF FIGURES

Figure 1: A plot for disturbance and regeneration assessment 17

Figure 2 : Forest standing stock (stems per ha) distribution of the commonest tree species in Bombo West forest reserve 25

Figure 3: Forest standing stock (stems per ha) distribution by diameter size classes in Bombo West forest reserve. 26

Figure 4 : *Brachylaena huillensis* stock (stems per ha) distribution by diameter size classes in Bombo West forest reserve. 29

Figure 5: Removed woody plant stock distribution by species in Bombo West forest reserve. 31

Figure 6: Removed woody plant stock distribution by diameter size classes in Bombo West forest reserve. 31

Figure 7: *Brachylaena huillensis* removed stock (stems per ha) distribution in different blocks of Bombo West forest reserve. 34

Figure 8: *Brachylaena huillensis* removed stock (stems per ha) distribution by diameter size classes in Bombo West forest reserve. 34

Figure 9: Distribution of tree species in terms of IVI where A –highly, B- mild and C -least disturbed forest areas in Bombo West forest reserve. 51

LIST OF PLATES

Plate 1: *Brachylaena huillensis* logs harvested illegally for carvings in the least disturbed area in Bombo West forest reserve.. 36

Plate 2: Maasai cattle from Mtoni Bombo village grazing in the highly disturbed area in Bombo west forest reserve.. 37

Plate 3: Charcoal remains in the highly disturbed area in Bombo West forest reserve.. 39

Plate 4: Villager from Kijungumoto carrying *Brachylaena huillensis* firewood on bicycle collected from Bombo West forest reserve 41

Plate 5: Villager from Bombo Majimoto cutting illegally *Brachylaena huillensis* in the least disturbed area in Bombo West forest reserve for house construction. 42

Plate 6: *Scorodophloeus fischeri* poles harvested illegally in the mild disturbed area in Bombo West forest reserve.. 43

Plate 7: *Brachylaena huillensis* regenerants in the least disturbed area in Bombo West forest reserve.. 56

LIST OF APPENDICES

Appendix 1: Tree species checklist in Bombo west forest reserve 84

Appendix 2: Stand parameters of woody plants in the highly, mild and least disturbed areas in Bombo West forest reserve 86

Appendix 3: Removed stock of woody plants in Bombo West forest reserve. 89

Appendix 4: Regenerants of woody plants in the highly, mild and least disturbed areas in Bombo West forest reserve 90

Appendix 5: Stand parameters by diameter size classes of woody plants in the highly disturbed area in Bombo West forest reserve 92

Appendix 6: Stand parameters by diameter size classes of woody plants in the mild disturbed area in Bombo West forest reserve 94

Appendix 7: Stand parameter by diameter size classes of woody plants in the least disturbed area in Bombo West forest reserve. 96

Appendix 8: Removed stand parameters by diameter size classes of woody plants in the highly disturbed area in Bombo west forest reserve 97

Appendix 9: Removed stand parameter by diameter size classes of woody plants in the mid disturbed area in Bombo West forest reserve. 98

Appendix 10: Removed stand parameters by diameter size classes of woody plants in the least disturbed area in Bombo West forest reserve. 99

Appendix 11: Inventory forms 100

Appendix 12: Questionnaires for household 101

Appendix 13: Village and ward leaders' checklist 104

Appendix 14: Forest officers checklist 105

LIST OF ABBREVIATIONS, ACRONYMNS AND SYMBOLS

ANOVA	-	Analysis of Variance
ASFMT	-	Arabuko-Sokoke Forest Management Team
BD	-	Basal Diameter
BTC	-	Belgium Technical Cooperation
BWFR	-	Bombo West Forest Reserve
CIFOR	-	Centre for International Forest Research
CV	-	Coefficient of Variation
DBH	-	Diameter at Breast Height
DCFO	-	District Catchment Forest Officer
FAO	-	Food and Agriculture Organization
FR	-	Forest Reserve
G	-	Stand Basal area per hectare
GN	-	Government Notes
GPS	-	Geographical Positioning System
H'	-	Shannon- Wiener Index of Diversity
Ha	-	Hectare
Ht	-	Tree Height
IUCN	-	International Union for Conservation of Nature
IVI	-	Importance Value Index
JFM	-	Joint Forest Management
KDC	-	Korogwe District Council
n	-	Number of Plots
N	-	Number of Stems per Hectare

MNRT	-	Ministry of Natural Resources and Tourism
P	-	Probability Level
PFM	-	Participatory Forest Management
RBA	-	Relative Basal Area
RF	-	Relative Frequency
RMSE	-	Root Mean Squire
SADC	-	Southern Africa Development Cooperation
SAS	-	Statistical Analysis System
SUA	-	Sokoine University of Agriculture
TAFORI	-	Tanzania Forestry Research Institute
URT	-	United Republic of Tanzania
V	-	Wood Volume per Hectare
WCMC	-	World Conservation Monitoring Center

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Humans, like all species exploit their surrounding resources in order to survive. Currently, human exploitation of forest resources is greater than that of other species, and the question whether forest resource extraction will affect natural regeneration is ultimately a question of whether there will be species extinction due to this practice (Catling, 2001; Mark, 2007). Over exploitation of plants and animals can be either legal or illegal but both may threaten the existence of species. Jonsell (2007) showed that heavy exploitation of one species can affect other species composition and the food web, and the loss of one species can lead to the extinction of many other related species. Many studies have shown that endemic species are extirpation or extinction prone (Hill *et al.*, 1995; Lewis, 2001; Cleary and Genner, 2004). Also political and scientific concerns have been experiencing an increase in species extinction rates caused by anthropogenic activities (Ehrlich and Wilson, 1991).

Sharma *et al.* (1992) and Vanclay (1993) estimated that the world lost about 17 million hectares of tropical forest per year in 1980s through human activities while in Tanzania about 92 000 ha/year are lost through deforestation (MNRT, 2002). Field experience and various studies have confirmed that almost all coastal forests in Tanzania mainland are threatened by unsustainable extraction of charcoal, poles, timber, firewood, expanding agriculture and wild fires (Burgess and Clarke, 2000 cited by Kaale, 2004).

In East Usambara Mountains although harvesting was banned in 1986, illegal harvesting has greatly increased in recent years particularly in the lowland forest reserves. The pressure on the lowland forest of the East Usambara Mountain forests has been increased due to increase in human population, expansion of farming land, illegal harvesting for timber, charcoal and firewood collection (Mustalaht, 2002). In this ecosystem and the entire Southern African Development Cooperation (SADC) region, several indigenous tree species have been identified as being under threat. The threat has been on individual species as well as the whole forest ecosystems. *Brachylaena huillensis* is among the most threatened species in SADC region (FAO, 1986).

In 2008 IUCN red list categorized *B. huillensis* as Lower Risk/ Near Threatened based on assessment by WCMC (1998) using 2008 IUCN red list criteria. It means that the species is not critically endangered, endangered or vulnerable, but close to qualifying as vulnerable due to ongoing selective logging and habitat loss (IUCN, 2008). The Lower Risk/ Near Threatened category is almost equivalent to nearly threatened category of new 2001 IUCN red list criteria. Data from World Conservation Monitoring Center (WCMC) show that *B.huillensis* is extinct, endangered, vulnerable or rare in Uganda (African Hardwoods, 2000). *Brachylaena huillensis* wood is heavily exploited in the wood carving industries in Kenya, Tanzania and Mozambique (WCMC, 1998).

In Kenya, much of the habitat of this species has been lost and the remaining trees are subject to increasingly heavy felling (WCMC, 1991). Kigomo (1994) indicated that *Brachylaena huillensis* is the main commercially important species in the central and coastal forests, but has been seriously over cut. Previous studies have reported the scattered existence of *B.huillensis* and other commercially valuable species in southern Tanzania whereby the species had been overexploited to an extent that almost no resources were remaining (Milledge and Elibariki, 2005). In Bombo West forest reserve in Korogwe district where *B.huillensis* is the main dominant species, most open wooded exterior areas of the reserve have been invaded by large herds of livestock and frequent wildfires and these exterior forest fires cause serious problems inside the reserve (Madoffe and Munishi, 2005). Most villagers around the Bombo West forest reserve are poor and depend very much on the forest for firewood, charcoal, timber, poles and non-wood forest products. Madoffe and Munishi (2005) reported that the Bombo West forest reserve has been invaded by Kenyans who extract *B. huillensis* for charcoal and carvings in collaboration with some villagers around the forest reserve. About 135 trees per ha and 73 poles per ha mostly of *B. huillensis* have been cut in the last three years (Madoffe and Munishi, 2005). These rates indicated that *B. huillensis* is heavily extracted from this reserve and could have an impact on its own regeneration, associated tree species and entire forest reserve or ecosystem.

1.2 Problem Statement and Justification

Bombo West forest reserve (BWFR) is one of a typical coastal lowland forest of East Usambara forests which was very much reduced during the late last century (1990s) due to over exploitation. One of the management objectives of this reserve is to protect *B. huillensis* from illegal exploitation (Lovett and Pocs, 1993). Most tree species are illegally exploited for timber, charcoal, poles, carvings and *B. huillensis* is particularly exploited for carvings and charcoal. Bombo West forest reserve is close to Tanga where population pressure and charcoal market exist; also it is found a few kilometers from Tanzania – Kenya boarder where carvings market exists. Chonge (2002) observed that *B. huillensis* was heavily exploited from both Tanzanians and Kenyans. For instance between 1998 and

2001, 34% of all wood used by the wood carving cooperatives in Kenya was by *B. huillensis* logs smuggled from Tanzania. Mustalaht (2002) also reported that illegal harvesting in lower forest of East Usambara was so intensive that valuable trees such as *B. huillensis, Millicia excelsa* and *Dalbergia melanoxylon* were over harvested. Continuation of uncontrolled exploitation (commercial harvesting) of these resources will affect the species abundance and may lead to its extinction. Chonge (2002) reported that currently young *B. huillensis* is being targeted which is the indication of scarcity of the species and this may cause serious ecological threat to its conservation status in the existing source areas.

Exploitation of this species and other valuable tree species may also affect regeneration and development of other species, particularly those close associates of *B. huillensis.* Fore instance Chonge (2002) indicated that the illegal loggers have depleted the forest of mature seed-producing trees and now resort to cutting young *B huillensis* trees that have not reached reproductive maturity, hence leading to serious effects on its regeneration.

Despite the ecological and economic importance of this species, currently there is very little data on the species' stock and rate of exploitation (Mrema, 2006). Most of the conservation activities of indigenous species have concentrated on *Dalbergia melanoxylon* (African Blackwood) through African Blackwood Conservation Project and Mpingo Conservation Project neglecting this economically important threatened tree species (Mrema, 2006). In order to plan for a practical conservation strategy we need to obtain a comprehensive ecological data. This study is therefore intended to generate some baseline information on the stock, the exploitation rate, and use intensity of the species and effects of exploitation on natural regeneration of other woody plants. The information obtained from this study will be used as a basis for management and conservation of *B. huillensis* and related species in BWFR and similar forests in Tanzania.

1.3 Objectives

1.3.1 Overall objective

To assess the extent of human exploitation of *Brachylaena huillensis* (Silver Oak) and its repercussion to regeneration of other woody plants in Bombo West Forest Reserve.

1.3.2 Specific objectives

(i) To document different uses of *Brachylaena huillensis* around the study area.

(ii) To determine the stock of *Brachylaena huillensis* in the forest reserve.

(iii) To assess the effect of *Brachylaena huillensis* exploitation on its regeneration and that of other woody species in the forest reserve.

(iv) To determine the current conservation strategies of the species and its associated woody plants.

1.4 Hypothesis

Null hypothesis (Ho): Exploitation of *B. huillensis* has no significant effect on its regeneration and other woody species.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Distribution and Regeneration of Brachylaena huillensis

2.1.1 Distribution of *Brachylaena huillensis*

Brachylaena huillensis or Silver oak (common name), also known as Muhuhu in Swahili is a member of family Asteraceae in the order Asterales (WCMC, 1998; Choge, 2002). It is a dioecious plant native to Tanzania, Angola, Kenya, Mozambique, Zambia, Malawi, South Africa and Uganda (Kigomo *et al.*, 1994). The species is dominant in ever-green bush, in dry coastal forests and semi deciduous dry upland forests at 1500 m-2000 m above the sea level (FAO, 1986; Mrema, 2006). In Tanzania *B.huillensis* is found both in coastal and highland forests to about 2000 m above sea level (Mbuya *et al.*, 1994) and also in the Usambara steppe (WCMC, 1991).

Silver oak is a dark grey and smooth tree and grows up to 15-35m tall with a maximum diameter of at least 85 cm under favourable conditions (Kigomo *et al.*, 1994). The trunk is about 60 cm and steeply ascending branches forming a narrow crown (Mbuya *et al.*, 1994) with fluted and often curved bole, which makes it difficult to obtain large dimension timber (Kigomo *et al.*, 1994). Adults and seedlings of *Brachylaena huillensis* are patchily distributed or over dispersed (Marshall and Jenkins, 1994). The distribution patterns of plants may reflect intrinsic or extrinsic factors which may be morphological, environmental, or sociological (Kigomo and Stanley, 1991). Among possible explanations are (1) deficient powers of fruit dispersal so that seedlings occur only around parent trees (Jones, 1955 cited by Kigomo *et al.* 1991; Mrema, 2006), (2) patchiness in environmental factors which result in seedling establishment and survival only in certain places (Kigomo *et al.*, 1991), (3) vegetative spread resulting in new shoots being restricted to the vicinity of the parents (Waisel, 1971; Kigomo *et al.*, 1991; Mrema, 2006) or (4) allelopathy effects (Rice, 1984 cited by Mrema, 2006).

2.1.2 Regeneration of *Brachylaena huillensis*

Natural regeneration can successfully occur only if a sufficient amount of growing space is available for seed germination and subsequent growth of seedlings (Panna and Sundriyal, 2008). Canopy trees strongly determine the under storey light regime and tend to reduce the growing space for the recruitment of young trees into the canopy layer, thus consolidating their dominance (Borghetti and Giannini, 2004). In natural forests, the onset of regeneration processes depend on the creation of open patches (gaps) as a result of death and felling of mature trees. Gaps become preferential sites for natural regeneration, and the characteristics of mature forest ecosystems largely depend on gap recruitment dynamics (Borghetti and Giannini, 2004).

In managed forests the onset of natural regeneration depends on the application of appropriate regeneration cuttings, reducing canopy cover and thus creating the necessary growing space for the recruitment of the new generation of trees (Borghetti and Giannini, 2004). The structure and regeneration of tree species is often dependent upon the dynamic balance of many regulative processes (Kasenene, 2007). Reproduction, dispersal, regeneration and survival of *Brachylaena huillensis* are capable in both closed and disturbed forest stands (Kigomo *et al.*, 1991). *Brachylaena huillensis* produces seed twice every year and flower almost continuously throughout the year (Kigomo, 1994). Seeds are difficult to collect because of the small size and many are eaten by insects (Mbuya *et al.*, 1994). The seeds of *B. huillensis* disperse non randomly around female parents and wind direction determines the direction of seed dispersal and the majority is within 14m from the parent tree (Kigomo *et al.*, 1991). The germination is usually poor, about 2-10 % and viability is lost after six months at room temperature while growth rate is slow to medium and grows well with other trees but poorly in the open areas (Mbuya *et al.*, 1994). *Brachylaena huillensis* is normally propagated by seedlings and prefers high rainfall (900m-1,200m) and red soil and there is no evidence of vegetative propagation (Kigomo *et al.*, 1994). *Brachylaena huillensis* regenerate on patches and extending in one direction from the parent and occurred up between 5 m and 17 m from the female parent (Kigomo *et al.*, 1991). The distribution in the patches appears to rule out allelopathy possible due to distribution of female tree, poor fruits dispersal and non random fruits dispersal (Mrema, 2006).

2.2 Uses of *Brachylaena huillensis*

Brachylaena huillensis is a good tree for long–term investment by farmers. The wood has good pale yellow to pale brown colour, with characteristic storeyed structure and straight grained with conspicuous growth rings while its texture is very fine, strong and stiff which make favourite wood for timber and carving artefacts (Mbuya *et al.*, 1994). The species is suitable for charcoal because of its high calorific value. Essential oils distilled from the *B. huillensis* wood have a pleasant, vetiver-like perfume (Cunningham, 1998) and scented smell more less like sandalwood (Mbuya *et al.*, 1994). The species is used for perfumery and toilet preparations (Bryce and Chihongo, 1999). *Brachylaena huillensis* has been used for sleepers, flooring blocks, furniture, and turnery while the timber is used in England for flooring in areas of high pedestrian traffic, in hotels and public buildings because of its attractive look (Marshall and Jenkins, 1994). Moreover, due to its durability, this species is used as fence posts, building poles and transmission poles. In northern Tanzanian near the border with Kenya, the species is planted as an ornamental tree. Also roots are used as medicine for schistosomiasis and leaves for diabetes (Cunningham, 1998).

2.3 The Effects of Human Disturbance on Forest Conditions

Long-term impacts of human disturbance on forest structure and composition in most tropical forests are not well known (Garcia-Montiel and Scatena, 1994) however, many studies have identified some of the effects of human disturbance on forest conditions. Meier *et al.* (1995) revealed that immediately after harvesting event, a set of disturbance-tolerant species often thrive, and these species may subsequently decline with increasing time of disturbance which eventually offset the ecosystem. A set of forest interior species may decrease locally because of direct harvesting impacts (Robert and Gilliam, 1995). Robert *et al.* (2008) reported that disturbance significantly changes the structure of the forest, producing canopy openings, and initially decreasing overstorey density and basal area. Large disturbances generally favour colonizing species, while small disturbances favour competitive native species (Madoffe and Munishi, 2005).

According to Eilu *et al.* (2004), human-induced disturbances and land-use history are important factors in influencing tree species distribution in the tropics. For example the distribution and abundance of *Olea* tree species in Kibale forest reserve is influenced by variations in human-induced forest disturbances. Heavy forest logging is reported to suppress the regeneration of the species (Kasenene, 2007). The study of Ramirez-Marcial *et al.* (2001) showed decreasing density and basal area with disturbance intensity, and Smiet (1992) correlated the basal area with the rate of disturbance. Sagar *et al.* (2003) also indicated that stem density declined with disturbance. The decline in stem density along the disturbance gradient may be due to a gradual increase in the extraction of timber, debarking and rotting of boles. It has been argued that if environmental change produced by disturbance is large, it may become lethal to great numbers of established species than are, or can be, immediately replaced by immigrants (Sheil, 1999).

Disturbance such as logging usually causes an immediate decline in biodiversity followed by a recovery, although not necessarily of the same species (Noble and Dirzo, 1997). According to the intermediate disturbance hypothesis (Sagar *et al.*, 2003) in forests with no or little disturbance, only the competitive dominants species can survive, while at sufficiently high level of disturbance only fugitive species can survive. Therefore, species diversity is at maximum in the intermediate level of disturbance (Abugov, 1982) and the species diversity decline with increasing level of disturbance (Sagar *et al.*, 2003). Synnot (1975) cited by (Bazzaz and Picket, 1980) observed that disturbance creates big gaps, which facilitate growth of a dense ground vegetation cover of herbs and shrubs. Dense ground vegetation cover inhibits germination of seeds of some pioneer tree species and can suppress young tree seedlings (Bazzaz and Picket, 1980). Gaps caused by tree felling have high light availability, relatively low soil compaction, and low initial seedling density (Fredericksen and Mostacedo, 2000).

2.4 Effect of Human Exploitation of Forest Resources to Natural Regeneration

The structure and regeneration of forests is often dependent upon the dynamic balance of many regulative processes (Whitmore, 1990). In order to achieve sustainable use of tropical forests we must understand knowledge of the effects of exploitation on the regenerative processes and response of the residual forest ecosystem components (Pickett, 1983). Undisturbed forests are self-maintaining through dynamic processes of regeneration including recruitment, growth and mortality (James and Kasenene, 2007). Forest trees ensure their perpetuity through natural regeneration. The regeneration may be through seedlings or through vegetative propagation by coppicing or root suckers. The goal of regeneration in any tree species is to establish vigorous and high-valued seedlings that will be capable of ensuring future crop trees (Chaar *et al.*, 1997). All types of regeneration depend on the presence of the mother tree at that particular time or previous years (Ganzhorn, 1995).

The potential regenerative status of tree species often depicts the future composition of forests within a stand in space and time (Henle *et al.*, 2004). Therefore understanding of the processes that affect regeneration of forest species is crucial to both ecologists and forest managers (Slik *et al.*, 2003). Veltheim *et al.* (2002) showed that in Mfundia village forest, the most common size of cut trees was 5-15 cm diameter at breast height (dbh) which corresponds to poles that are used for local construction. The most commonly cut species were *Spirostachys africana, Brachylaena huillensis, Pteleopsis myrtifolia, Dalbergia melanoxylon and Manilkara sulcata.* This may lead to depletion of mother seed trees important for future regeneration of the species.

Matthews, (1989) indicated that partial cutting is generally expected to promote recruitment of regeneration trees by creating canopy openings. Patrick *et al.* (2004) also observed that human disturbance can influence seed dispersal mechanisms, fruiting, germination and regeneration of each of the species. Sukumar *et al.* (1992) showed that the regeneration status of all species in a given stand was considered to be good if numbers of seedlings are greater than saplings, and saplings are greater than adult trees and considering being fair regeneration if seedlings are greater than sapling and saplings are less or equal to adult trees.

Brachylaena huillensis and *Dalbergia melanoxylon* being the most intensively utilized wood carving species in East Africa have experienced the greatest conservation impact in the recent years since the diameter size classes of *Brachylaena* logs entering the woodcarving centers is dominated by logs of 10 – 5 cm diameters (Chonge, 2002). Heinrich (1992) cited by McNabb *et al.* (1997) observed that improper and uncontrolled tree harvesting lead to unnecessary clearing of forests, damages to residual trees and ground cover, accelerates soil erosion and cause soil compaction which hampers natural regeneration. Some of tropical forests current logging practices often destroy up to 40% of the residual trees and kill almost 50% of the young growing stock (Putz *et al.*, 2000). Harvesting impedes forest regeneration by destroying both mature trees and young stock and damaging residual trees in stands (Boot and Gullison, 1995). According to Whitmore (1990) and Chapman and Chapman (1997), effects on forest structure and composition caused by heavy forest disturbance such as heavy mechanical logging results from the destruction of both mature trees and young stock and the alteration of certain environmental conditions which hinder forest regeneration.

2.5 Conservation Strategies for *Brachylaena huillensis*

In order to ensure sustainability of *B. huillensis,* Omenda (2001) suggested that mature reproductive trees must be protected; otherwise there will be a shortage of seeds for regeneration. Adequate populations at all stages of development of this species should be selected and protected to ensure a more stable population structure, and outside the natural forest, *B. huillensis* species should be planted along with other species. Also there is a need to understand the reproductive cycles of the species and the ideal sex ratio in the forest. The main effort is to seek alternative tree species which can be grown outside the forest (Omenda, 2001). Furthermore, experience has shown that adequate levels of forest protection cannot be achieved through confrontation and conflict between the managers and forest-adjacent communities. In practice, both local people and the government have a mutual interest in conserving the forest and utilizing forest products in a sustainable way (ASFMT, 2002).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Study Area Description

3.1.1 Location and Status of the Forest

Bombo West forest reserve is located in Korogwe district, Tanga region. It lies between latitude 4 ° 52' and longitude 4 ° 47' S and 38 ° 39' and 38 ° 43' E. It is situated 60 km from Korogwe town on Lwengera valley about 380 m to 680 m above sea level (Lovett and Pocs, 1993). The forest is surrounded by four villages namely Kijungumoto, Kwetonge and Mtoni –Bombo in Mashewa ward and Bombo- Majimoto in Kizara ward. The reserve is owned by central government and was gazetted in 1959 with a Government Notice (GN) 1 of 1959 and has an area of 3,523.5 ha (Lovett and Pocs, 1993).

3.1.2 Climate

The area is influenced by oceanic rainfall and temperatures. According to the nearest rainfall station in Magoma Sisal Estate, it has an average annual rainfall of 750 mm with two peaks namely February to May (long rains season) and September to November (short rains season). The reserve is located in the Lwengera valley rain shadow on the west of the East Usambara Mountains with the mean annual temperature range from 21^{0}C in July to 26 ^{0}C in February (Lovett and Pocs, 1993).

3.1.3 Vegetation

The vegetation in Bombo -West forest reserve is grassy, pyric climax, open woodland with extensive areas of *B. huillensis* species. The woodlands are composed of tall trees and tree clumps of *Acacia spp., Grewia spp.* and *Sterculia africana.* The thickets are composed of dense scrub dominated by *B. huillensis* with *Adenium obesum, Croton* spp, *Cymomera* spp, *Euphorbia* spp, *Strychnos* spp, *Teclea* spp and *Uvaria* spp. The reserve was created to protect *B. huillensis* stocks and has relatively low catchment value (Lovett and Pocs, 1993; Madoffe and Munishi, 2005).

Major human impacts and threats include *Brachylaena huillensis* harvesting, grazing, firewood collection and fire that greatly affect the grassland (Lovett and Pocs, 1993; Madoffe and Munishi, 2005). Although the big size and more accessible *B. huillensis* individual have been extracted, there may still be some big trees of good form that can act as seed trees. The *Brachylaena huillensis* thickets appear to be species rich in comparison to the wooded grassland and may contain Coastal forest species of restricted distribution (Lovett and Pocs, 1993; Madoffe and Munishi, 2005).

3.1.4 Population

The communities adjacent to Bombo West forest reserve are composed of different ethnic groups. The main ones being Sambaa and Zigua and minor ones are Ngoni, Waha, Hehe, Nyamwezi, Bena and Sukuma (KDC, 2007). Bombo West forest reserve has a population of 7541 people from four villages in two wards (URT, 2002).

3.1.3 Socio-economic activities

Semi-subsistence agriculture is the main economic activity which includes crop production and livestock keeping. The main food crops grown are yams, paddy, banana, sweat potatoes, cassava, maize and beans while sisal, cardamom, groundnuts and fruits such as mango, orange are the main cash crops (KDC, 2007). Other economic activities include petty business and casual labour in sisal and development activities.

3.2 Data Collection

Both primary and secondary data were used in this study were collected.

3.2.1 Primary data

3.2.1.1 Socio-economic data

A purposive sampling of two villages out of four was done based on their accessibility and proximity to the forest. Random sample of a minimum of 5% of the households (equivalent to 47 households) were interviewed (Boyd *et al.*, 1981). Data collection methods used was questionnaire survey, discussion with key informants using checklists and participant observation. Key informants interviewed village chairperson, village executive officers, village environment committee chair person, ward executive officers, councillors and forest staff. The information collected were knowledge about *B. huillensis,* uses of *B. huillensis,* current conservation strategies of the species and its associated species and the main threats to *B. huillensis* and the forest in general.

3.2.1.2 Ecological (Inventory) data

The forest inventory work was preceded by a reconnaissance survey to familiarize with the area and get prior information about forest reserve. The forest reserve was subjectively stratified into highly, mild and least disturbed areas based on visual observation of presence of charcoal kilns, stumps, fire sign, encroachment and grazing sign. Highly disturbed area was categorized by having grazing and fire signs, charcoal kilns, stumps and open area. Mild disturbed area was characterized by encroachment and presence of stumps while inter characterized least disturbed areas.

The disturbance plots of 50m × 10m plot were used for collecting standing and harvested trees information (Madoffe and Munishi, 2005) while nested plot of 3 m×3 m located on the first right corner of the main plots (disturbance plot) were used for enumerating all woody plants regenerants (Veltheim *et al.*, 2002) (Fig. 1).

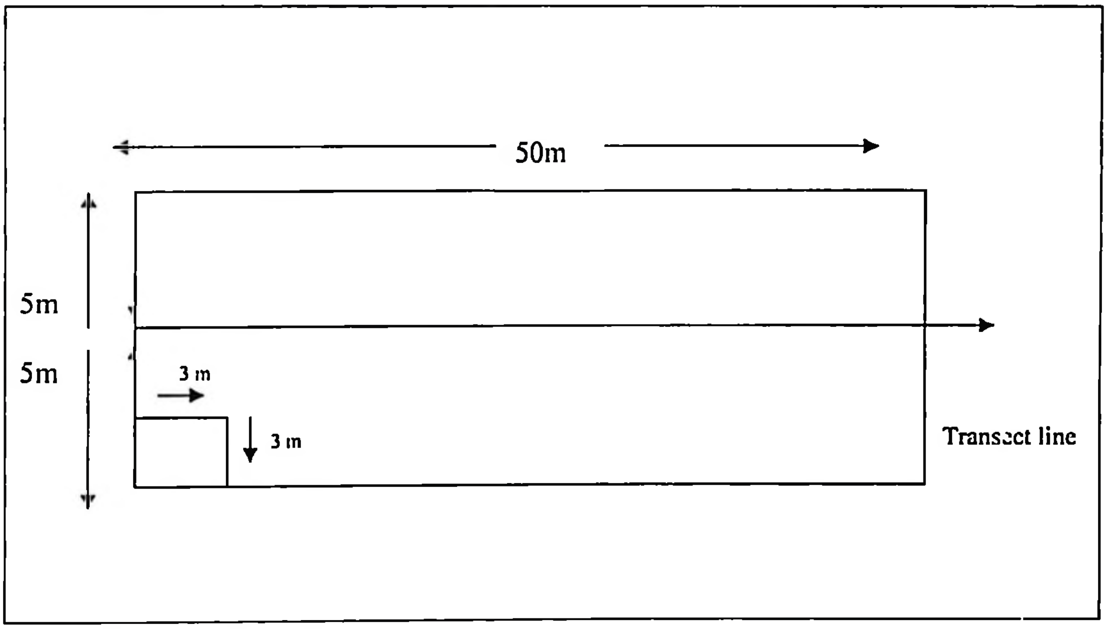

Figure 2: A plot for disturbance and regeneration assessment.

Due to limited finances and time, the sampling intensity of 0.2% was used whereby a total number of 140 sample plots were laid out along the transect : 67 sample plots for highly disturbed area, 37 sample plots for mild disturbed area and 36 sample plots for least disturbed area. Disturbance was assessed in a series along transects located systematically (Oriented East–West) from a randomly chosen starting point on the forest edge (forest beacons) or a path within the forest. The starting point and direction of each transect was recorded using a Geographical Positioning System (GPS) and a compass respectively to allow transects to be relocated in the future. The ends of each transect was also georeferenced for the same purpose. Three people participated in data collection (i.e. one recorder, two walkers one on each side of the strip). Within the plots along transects, all woody plants regenerants, all *B. huillensis* trees, poles and other woody plants were identified and recorded.

The diameter at breast height Dbh (cm) of all tree, poles, basal diameter and height (m) of one dominant tree in each plot were measured using Diameter caliper and Suunto hypsometer respectively. Harvested trees were recorded from identified stumps of *B. huillensis* and other woody plants. In each case, basal diameter (BD) and height (h) of identified stumps were estimated. Stumps were differentiated into new and old cut by assessing the level of blackness at the cut point, whereby new cuts were assumed to be cut within one year period and were pale in colour and the old cut trees had blackish stumps (Madoffe and Munishi, 2005). In this study it was assumed that trees were standing woody plants with straight stems of at least 3m and dbh above 15 cm while poles were all standing woody plants with straight truck at least 2m in length and dbh of 5-15 cm. Tree species regenerants were standing woody plants with less than 2m length and dbh less than 5 cm. All trees, poles, stumps and regenerants were identified on the spot with the help of a botanist and local people. Species that had proved difficult to be identified in the field were taken for identification at Tanzania Forestry Research Institute (TAFORI) in Lushoto by matching with species specimens available in the Herbarium.

3.2.2 Secondary data

Secondary data in terms of uses, main threats, species biology and ecology were collected from journals, articles, scientific papers, books, internet and annual reports.

3.3 Data Analysis

3.3.1 Socio-economic data analysis

Content and descriptive statistical analyses were employed to analyse the socio- economic data. Content analysis was used for analyzing the symbolic content of communication. Content analysis was used as means of summarising the information obtained through communication with respect to conservation strategies, uses of *Brachylaena huillensis* and main threats of *Brachylaena huillensis* and the forest in general.

3.3.2 Ecological (Inventory) data analysis

The MS Excel software was used to analyse quantitative data for use intensity (old and new cuts), species diversity and stand parameters of *Brachylaena huillensis* and other woody plant in terms of woody plants regenerants per hectare, number of stems per hectare, basal area per hectare, volume per hectare and removed stock (number of stump per hectare, removed basal area per hectare and removed volume per hectare). The obtained wood volume, number of stems, basal area and regenerants were subjected to SAS system for comparison to obtain variability and statistically significant different between three strata.

3.3.2.1 Stand parameters

Tree density (Stocking)

Number of stems per hectare (N) in the forest for measured trees (live and cut trees) and woody plants regeneration was calculated using (Philip, 1983) equation

$$N = \frac{n}{PlotArea(ha)} \quad \text{...} \quad (i)$$

Where: n = number of stems occurred in plot and N = Number of stems/ha.

Stand basal area and wood volume

The Diameter at Breast Height (DBH) of removed trees (stumps) was estimated from measured stump Basal Diameter (BD) using following developed equation.

DBH = -0.170205278+0183479148 x BD (r^2=0.87)... (ii)

Whereby:

DBHi =the diameter at breast height (1.3m) for the i^{th} tree (cm) and

BD = basal diameter at 0.3m for the i^{th} stump (cm

The height (Ht) of the few trees measured was fitted in height/diameter equation to construct the formula which was used to estimate the height of other trees (live trees and removed tree). The following equation was developed for height estimation (Ht):

Ht =Exp(0.287447+0.70948 x ln (DBH) (r^2= 0.59)..(iii)

Where:

Ht = the estimated height (m).

In = natural logarithm and

DBH_i = the Diameter at Breast Height (1.3m) for the i^{th} tree (cm).

Basal Area (G) of all trees (live and cut trees /poles) was calculated by using the following equation:

G =0.0000785$(DBH)^2$ .... (iv)

Volume (V_i) of all trees (live and removed trees/ poles) was calculated using functions developed for miombo woodlands (Malimbwi *et al.*, 1994).

$V_i = 0.0001 \times DBH_i^{2.032} \times Ht^{0.659}$ ....(v)

Where:

V_i = the volume of the i^{th} tree (m^3), *DBHi* = the diameter at breast height (1.3m) for the i^{th} tree (cm) and Ht= the estimated height (m).

3.3.2.2 Forest resource use intensity

Current status and the intensity of *B. huillensis* exploited and other woody plants was calculated using utilization pressure gradient (U) of the forest resources formula;

U = (C/S) x100 %,(Madoffe and Munishi, 2005).. ...... (vi)

Where:

U= use intensity, C= cut trees and poles and S=stocking/density

Means of density, basal area, wood volume, regenerants of woody plants and new and old cut trees were compared using one way Analysis of Variance (ANOVA) between highly, mild and least disturbed forest areas.

3.3.2.3 Shannon-wiener index of diversity

The Shannon diversity index (H') was employed to characterize species diversity in a community. Shannon's index accounts for both abundance (richness) and evenness of the species present and is not affected by sample size (Munishi *et al.*, 2004). The Shannon diversity index (H') computed by the following formula:

$H' = -\sum pi(\ln pi)$ .... (vii)

Where:

H'= Shannon-wiener Index value, ($\ln p_i$). = natural logarithm of the proportional

pi = Proportional of the i^{th} to the total number of species calculated as $IVI / \sum IVI$

The Important value index (IVI) was computed as the summation of relative frequency and relative basal area (relative dominance) of a given species. The formula used was:

$$RF = relative \quad frequency = \frac{Frequency \quad of \quad occurrence \quad of \quad a \quad species}{Frequency \quad of \quad occurrence \quad of \quad all \quad species}.$$

$$RBA = relative \quad basal \quad area = \frac{Total \quad basal \quad area \quad of \quad a \quad species}{Total \quad basal \quad area \quad of \quad all \quad species}$$

$$IVI = \sum RF + RBA \qquad \text{..(viii)}$$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Stand parameters of Brachylaena huillensis and other woody plants

4.1.1 Stocking, stand basal area and wood volume of woody plants

Overall average tree density (stocking) in the forest was 433 stems ha-^{1} whereby the average tree density at each site was 330 stems ha-^{1}, 643 stems ha-^{1} and 327 stems ha-^{1} stems per hectare for highly disturbed, mild disturbed and least disturbed forest areas respectively (Table 1; Appendix 2; Fig. 2). The mild disturbed forest area had greater number of stems while results indicated more or less similar stocking in highly and least disturbed areas. Differences in stem densities in the three forest sites could have resulted from the varying levels of disturbance experienced over the years. The high tree density in mild disturbed area at the moment is not indicative of a better forest in terms of species composition, structure and management. More over, in this study it was observed that there was significant difference ($P<0.05$) in tree density of woody plants between highly, mild and least disturbed forest sites

All strata exhibited similar dbh distribution and follow the reversed J- shaped trend (Fig. 3; Appendix 5, 6, and 7). A characteristic reversed J-shape observed in density distribution of woody species in the forest reserve by dbh size classes indicate a good recruitment and consequently a good regeneration trend of the forest reserve (Philip, 1983). Furthermore, the mild disturbed forest area had similar results as that reported in Katanga - Zaire where the stocking of miombo woodland ranged from 520 to 645 stems ha-^{1} (Malaise, 1978 cited by Malimbwi and Mugasha, 2002). The results indicated a smaller number of stems per hectare than those earlier reported from other miombo woodland studies (Nduwamungu, 1996). In his findings Nduwamungu (1996) reported an average of 691 stems ha^{-1} at Kitulangalo forest reserve, Tanzania. This represents an obvious fact that the forest reserve in Bombo West is suffering from the disturbances due to human exploitation of *B. huillensis* which is the dominant species in the forest reserve. Due to high rate of exploitation, most of the big trees of the species have been removed and forest stock distribution in all sites is dominated by 1-10 and 10.1-20 cm diameter size classes and there were no or very few trees in diameter size classes of 30.1 -40 cm and >40 cm (Fig. 3; Appendices 5, 6, and 7).

The overall average basal area and wood volume in Bombo West forest reserve were 5.455 m^2 ha^{-1} and 36.869 m^3 ha^{-1} respectively. The estimated average basal area were 4.392 m^2 ha^{-1}, 6.091 m^2 ha^{-1} and 5.882 m^2 ha^{-1} while estimate average wood volume were 30.014 m^3 ha^{-1}, 39.353 m^3 ha^{-1} and 41.24m^3 ha^{-1} for highly, mild and least disturbed areas respectively (Table 1, Appendices 2, 3 and 4). The findings revealed that there was significant difference ($P<0.05$) in basal area and wood volume of woody plants between highly, mild and least disturbed forest sites. Conversely, in Kitulangalo forest reserve wood volume and basal area per hectare were 46.3 m^2 ha^{-1} and 7 m^2 ha^{-1} in public land and 78.8 m^3 per ha and 10 m^2 ha^{-1} (Zahabu, 2001). Also the result was lower than that reported by Malimbwi and Mugasha (2002) from Handeni Hill forest reserve with an average volume and basal area per ha of 108 m^3 ha^{-1} and 11.21 m^2 ha^{-1} for miombo woodland and 125.24 m^3 ha^{-1} and 10.94 m^2 ha^{-1} for the semi –evergreen forests respectively. Furthermore, the study reported lower basal area and wood volume than those observed in Dindili forest reserve, Morogoro of 10.78 m^2 ha^{-1} and 83.63 m^3 per ha respectively (Mrema, 2006).

Table 1: Stand parameters of woody plants in Bombo West forest reserve

Forest status/blocks	Mean N (Stems ha^{-1})	Mean G ($m^2 ha^{-1}$)	Mean V ($m^3 ha^{-1}$)
Highly disturbed	327 (0.337)	4.392 (0.004)	30.014(0.037)
Mild disturbed	643(1.457)	6.091 (0.013)	39.353 (0.111)
Least disturbed	330 (0.911)	5.882(0.013)	41.240 (0.103)
Coefficient of Variation (CV)	60.999	53.744	64.481
Root Mean Square(RMSE)	5.651	0.063	0.512
Probability (P)	0.0001	0.0001	0.0001

Number in parenthesis = Standard error

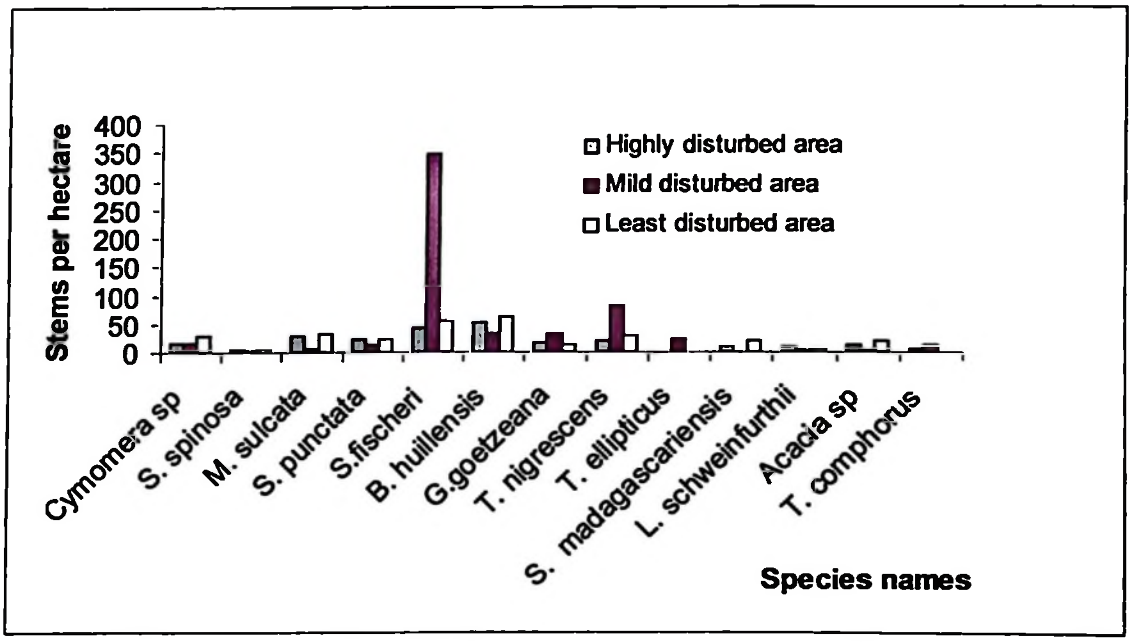

Figure 2: Forest standing stock (stems per ha) distribution of the commonest tree species in Bombo West forest reserve.

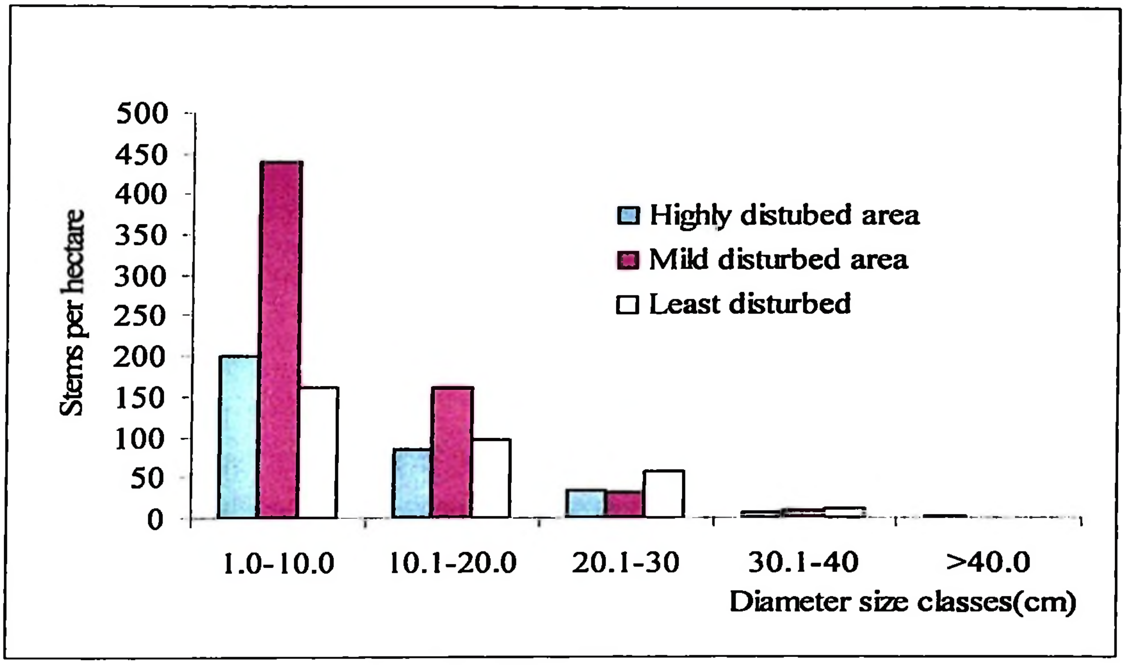

Figure 3: Forest standing stock (stems per ha) distribution by diameter size classes in Bombo West forest reserve.

4.1.2 Stocking, basal area and wood volume of *Brachylaena huillensis*

In all plots surveyed, the overall average density(stocking) of *B. huillensis* was 47 stems per hectare whereby the average density of *B. huillensis* tree species in three sites were 51 stems ha^{-1}, 33 stems ha^{-1} and 62 stems ha^{-1} for highly, mild and least disturbed areas respectively (Table 2) while *Scorodophloeus fischeri* as associated woody species had 41 stems ha^{-1}, 346 stems ha^{-1} and 56 stems ha^{-1} for highly, mild and least disturbed areas respectively (Appendix 2). By considering three strata i.e. highly, mild and least disturbed areas, the density of *B. huillensis* tree species was significant different ($P<0.05$) between the three areas. The results are contrary to Mrema (2006) who reported that *Brachylaena huillensis* had density of 15 stems per hectare while other related species like *Scorodophloeus fischeri* had 46 stems per ha, *Garcinia huillensis* 25 stems per ha, *Combretum schumannii* 22 stems/ha and *Croton pseudopulchellus* 19 stems per ha).

Density distribution of *B. huillensis* woody species by dbh size classes in Bombo West forest reserve did not follow a normal reversed J-shape common in natural forests (Fig. 4). This observation is contrary to the findings by Kigomo *et al.* (1990) in Karura and Ngong forest reserves, Kenya, in which *B. huillensis* density distribution by Dbh size classes had a normal reversed J-shaped curve. The poor representation of *B. huillensis* trees in the of Dbh size classes 1-10 cm and 10.1- 20 cm might be a result of an array of factors including disturbances brought by trees and poles felling for house construction and fire wood. The villagers utilize *B. huillensis* poles of smaller size as beams in house construction.

The exploitation of the species for beams has caused the scarcity of individual trees of Dbh size classes 1-10 cm and 10.1- 20 cm. The irregular representation of *B. huillensis* in higher Dbh size classes (30.1-40 cm and >40 cm diameter classes) is attributed to selective harvesting of large *B. huillensis* trees for charcoal and carvings. The study revealed that most of the big and mature *B. huillensis* and other related trees species in all three sites have been removed few years ago through illegal harvesting (Fig. 4). The study also found that there were very few young *B. huillensis* trees (1.0-10.0 cm diameter) which clearly indicate that there were over exploitation of the species. In the tropical forests most plants are scattered throughout the forest at very low densities due to their vulnerability to over-harvesting (Peters, 1994). Kariuki *et al.* (2006) argued that increased logging intensity was negatively associated with stem densities, species abundance and richness while Sagar *et al.* (2003) indicated that stem density declined with disturbance.

Overall average basal area and wood volume of *B. huillensis* was 1.813 m^2 ha^{-1} and 14.068 m^3 ha^{-1} respectively. The average basal area of *B. huillensis* was 1.649 m^2 ha^{-1}, 0.957 m^2 ha^{-1} and 2.833 m^2 ha^{-1} for highly, mild and least disturbed areas while the average wood volume were 12.326 m^3 ha^{-1}, 7.682 m^3 ha^{-1} and 22.196 m^3 ha^{-1} for highly, mild and least disturbed areas respectively (Table 2, Appendices 2 and 3). The study revealed no significant difference while ($p>0.05$) in basal area of *B. huillensis* tree species and significant difference ($P<0.05$) in wood volume between the three areas. The study revealed higher wood volume compared to that reported at Arabuko-Sokoke forest reserve in Kenya with wood volume of *B. huillensis* of 2.7 m^3/ha (CIFOR info brief, 2002). Mrema (2006) reported that the standing wood volume and basal area of *B.huillensis* in Dindili forest reserve, Morogoro was 5.63 m^3/ha and 0.73 m^2ha^{-1} respectively. The low wood volume and basal area for all sites in the forest reserve may be due to the fact that *B. huillensis* is heavily exploited for carvings, charcoal making, and trees/poles for construction of house and fire wood collection.

Table 2: Stand parameters for *Brachylaena huillensis* tree species in Bombo West forest reserve

Forest status/blocks	Mean N (Stems ha^{-1})	Mean G (m^3 ha^{-1})	Mean V (m^3 ha^{-1})
Highly disturbed	51 (0.122)	1.649 (0.005)	12.326 (0.037)
Mild disturbed	33 (0.164)	0.957 (0.085)	7.682 (0.065)
Least disturbed	62 (0.265	2.833 (0.014)	22.196 (0.115
Coefficient of Variation (CV)	68.008	265.837	94.906
Root Mean Square(RMSE)	1.047	0.204	0.418
Probability Level(P)	0.0025	0.1939	0.0001

Number in parenthesis = Standard error

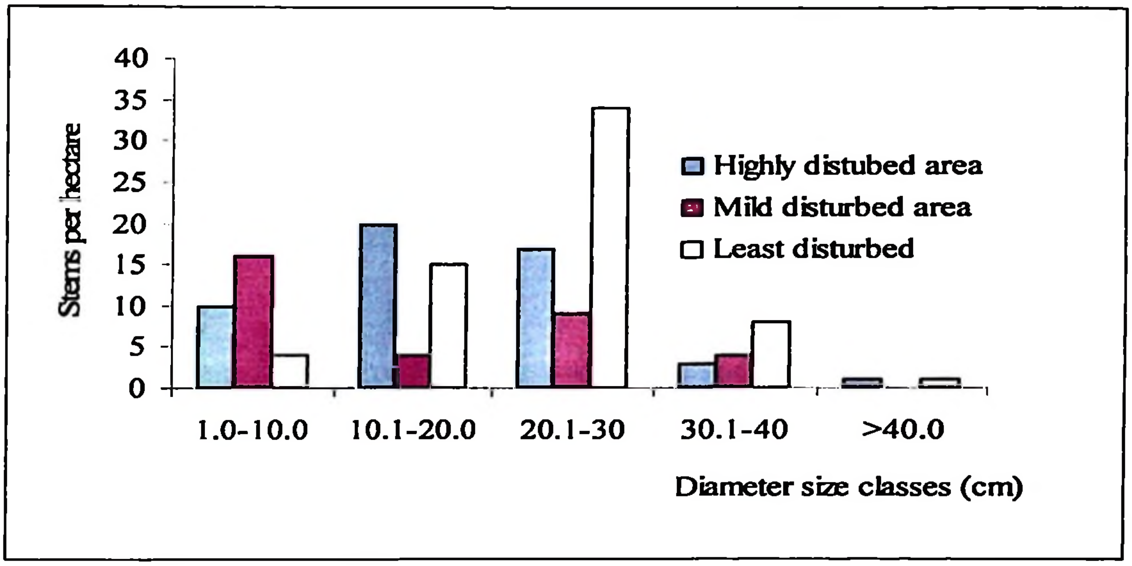

Figure 4: *Brachylaena huillensis* stock (stems per ha) distribution by diameter size classes in Bombo West forest reserve.

4.2 Removed Stand Parameters of *Brachylaena huillensis* and Other Woody Plants

4.2.1 Removed trees, basal area and wood volume of woody plants

A total of 14 tree species were identified to be harvested illegally in the surveyed area of the Bombo West forest reserve (Appendix 3). In all plots surveyed, overall average removed tree densities (stocking) was 100 stems ha^{-1} whereby average density in each site were 79 stems ha^{-1}, 101 stems ha^{-1} and 119 stems ha^{-1} for highly, mild and least disturbed areas respectively (Table 3; Fig. 5; Appendix 3). The results revealed significant difference in tree density ($p<0.05$) between highly, mild and least disturbed forest areas. These figures are higher than those of Nduwamungu (1996) who reported that about 12 stems per ha in miombo woodlands of Kitulangalo SUA Training Forest Reserve were removed. The study also revealed that the most harvested tree species were *Brachylaena huillensis, Scorodophloeus fischeri*, *Acacia* spp, mtimweusi, *Tarrena nigrescens*, *Sutureja punctata*, and *Flocortia indica* and *Cymomera* spp. The results showed that the average diameter size classes illegally harvested mostly in all sites were between 10.1- 20 and 20.1- 30 cm (Fig. 6; Appendices 14, 15 and 16). Similar findings were reported by Chonge (2002) and Ahrends (2005).

The overall average removed stand basal area of woody plants was 2.814 m^2 per ha while wood volume of woody plants was 17.31 m^3 ha^{-1}. The average of removed basal area in three sites were 2.125 m^2 ha^{-1}, 3.243 m^2 ha^{-1} and 3.073 m^2 ha^{-1} for highly, mild and least disturbed forest areas respectively while removed wood volume was 15.413 m^3 ha^{-1}, 24.921 m^3 ha^{-1} and 11.596 m^3 ha^{-1} for highly, mild and least disturbed forest areas respectively (Table 3; Appendix 3). The results revealed significant difference in basal area and wood volume ($p<0.05$) between highly, mild and least disturbed forest areas. The harvested wood volume from the reserve is higher compared to that obtained in Dindili forest reserve which was 11.63 m^3 ha^{-1} (Mrema, 2206) and Kitulangalo forest reserve of 7 m^3 ha^{-1} (Luoga *et al.*, 2002), indicating higher exploitation of the Bombo West forest reserve by local people.

Table 3 Removed tree density, wood volume and basal area of woody plants in Bombo West forest reserve

Forest status/blocks	Mean N (Stems ha^{-1})	Mean G (m^2 ha^{-1})	Mean V (m^3 ha^{-1})
Highly disturbed	79 (0.117)	2.125 (0.004)	15.413 (0.033)
Mild disturbed	101 (0.424)	3.243 (0.016	24.921 (0.123)
Least disturbed	119 (0.380)	3.073 (0.111)	11.596 (0.226)
Coefficient of Variation (CV)	70.203	87.897	115.379
Root Mean Square(RMSE)	1.799	0.0625	0.837
Probability Level (P)	0.0001	0.0001	0.0001

Number in parenthesis = Standard error

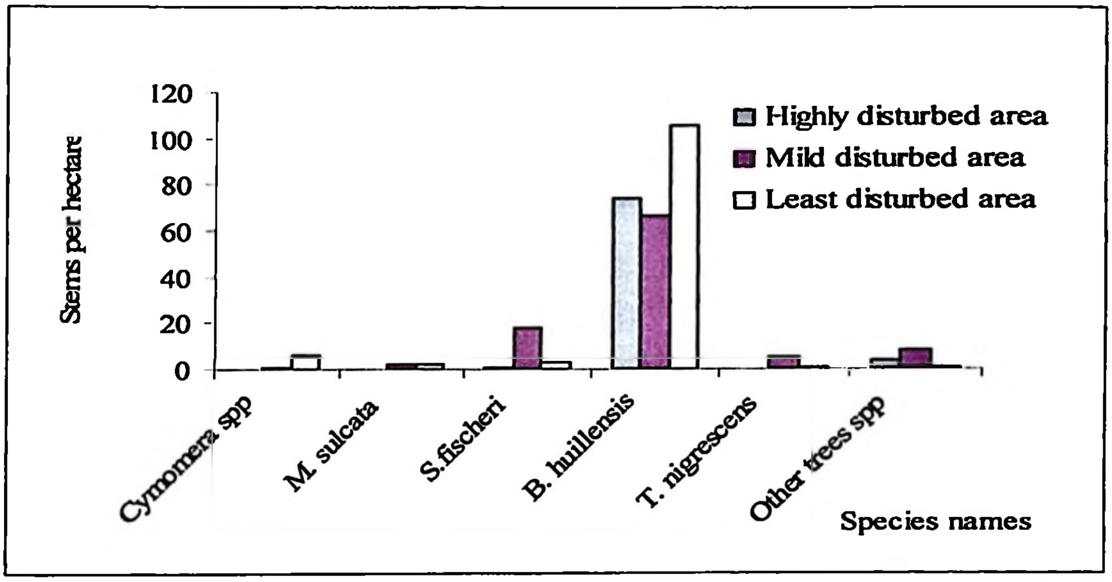

Figure 5: Removed woody plant stock distribution by species in Bombo West forest reserve.

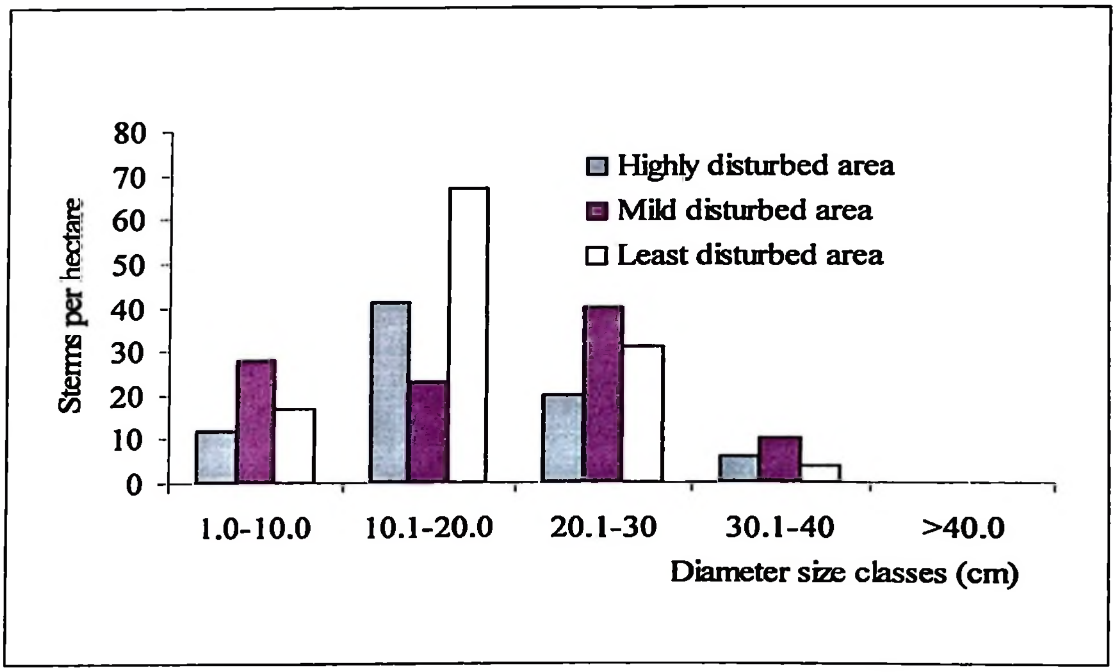

Figure 6: Removed woody plant stock distribution by diameter size classes in Bombo West forest reserve.

4.2.2 Removed stump density, basal area and wood volume of *Brachylaena huillensis*

The overall removed tree density (stocking) of *B. huillensis* in Bombo West forest reserve was 82 stumps ha^{-1}. Proportionally 93.7% (74 stumps ha^{-1}), 66.3 % (67 stumps ha^{-1}) and 89.1% (106 stumps ha^{-1}) were from highly, mild and least disturbed areas respectively (Table 4; Fig. 7). Analysis of variance revealed significant difference in removed tree density ($p<0.05$) between highly, mild and least disturbed forest areas. The figure obtained is higher than that obtained in Dindili forest of 5 stems per hectare (Mrema, 2006) and that reported by Schwartz *et al.* (2002) of harvested *Pterocarpus angolensis* of 8 trees per ha^{-1}. This is an indication that *B.huillensis* tree species is over exploited by human for different purposes in the study area as compared to other tree species (Appendix 3). The high removal of *B. huillensis* individuals present ecological threat to its genetic diversity and it is conceivable that single harvest could cause significant genetic erosion, particularly of individuals which are genetically distinctive. Newton (1996) argued that the removal of large trees could have severe effect on total genetic variation of the population. Ahrends (2005) also found that the intensity of tree cutting had a strong influence on the physiognomy of the vegetation with reduction of the basal area, tree density, average stem diameter, canopy cover, and increasing liana density.

The results also showed that the average diameter size classes of *B. huillensis* harvested illegally in all sites were between 10.1-20 cm and 20.1-30 cm (Fig. 8; Appendices 8, 9 and 10). Chonge (2002) also reported that the diameter profiles of *B. huillensis* logs entering the woodcarving centers in East Africa were dominated by logs of 10 – 15 cm diameters size classes. Illegal logging usually destroys mature and young trees (Whitmore and Sayer, 1992) through extraction and destruction of regeneration (Chapman and Chapman, 1997). This is an indication that there will be deficient of mother trees for seed production for the future regeneration as reported by Sukumar *et al.* (1992). Local extirpation of species also will affect ecosystem processes and economic opportunity (State of British Columbia's Forests, 2006).

Moreover the study observed that the overall removed basal area of *B. huillensis* was 2.622 m^2 ha^{-1} and removed wood volume was 16.376 m^3 ha^{-1}. Considering the three sites, the average *B. huillensis* harvested basal area was 2.091 m^2 ha^{-1} (98.4%), 2.952 m^2 per ha (91%) and 2.823 m^2 ha^{-1}(91.9%) while harvested wood volume was 15.2 m^3 ha^{-1} (98.6%), 23.235 m^3 ha^{-1}(93.2%) and 10.693 m^3 ha^{-1}(92.2%) for highly, mild and least disturbed areas respectively (Table 4; Appendix 3). Analysis of Variance revealed significant difference ($p<0.05$) in basal area and wood volume between highly, mild and least disturbed forest areas. The figures provided here are higher than Mrema (2006) who reported an average harvested volume of 3.25 m^3 ha^{-1} in Dindili forest reserve.

Table 4: Removed stock, wood volume and basal area of *Brachylaena huillensis* in Bombo West forest reserve

Forest status/blocks	Mean N (Stems ha^{-1})	Mean G (m^2 ha^{-1})	Mean V (m^3 ha^{-1})
Highly disturbed	74 (0.138)	2.091 (0.004)	15.162 (0.034)
Mild disturbed	67 (0.362)	2.952(0.015)	23.235 (0.119)
Least disturbed	106 (0.373)	2.823 (0.011)	10.693 (0.042)
Coefficient of Variation (CV)	71.186	81.303	90.501
Root Mean Square(RMSE)	1.634	0.058	0.398
Probability (P)	0.0001	0.0001	0.0001

Number in parenthesis = Standard error

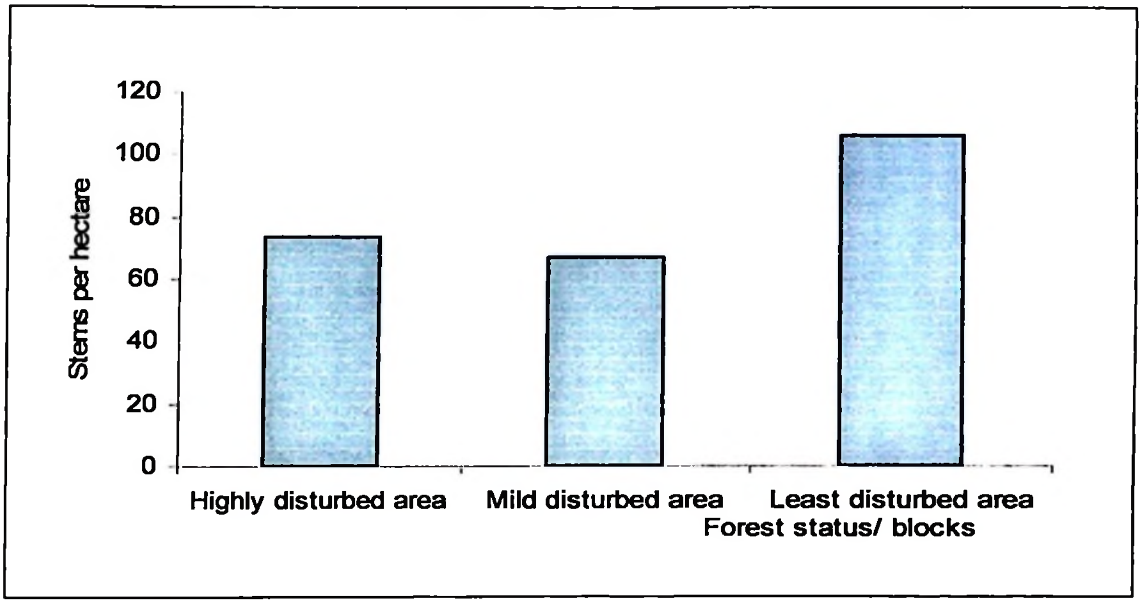

Figure 7: ***Brachylaena huillensis*** **removed stock (stems per ha) distribution in different blocks of Bombo West forest reserve.**

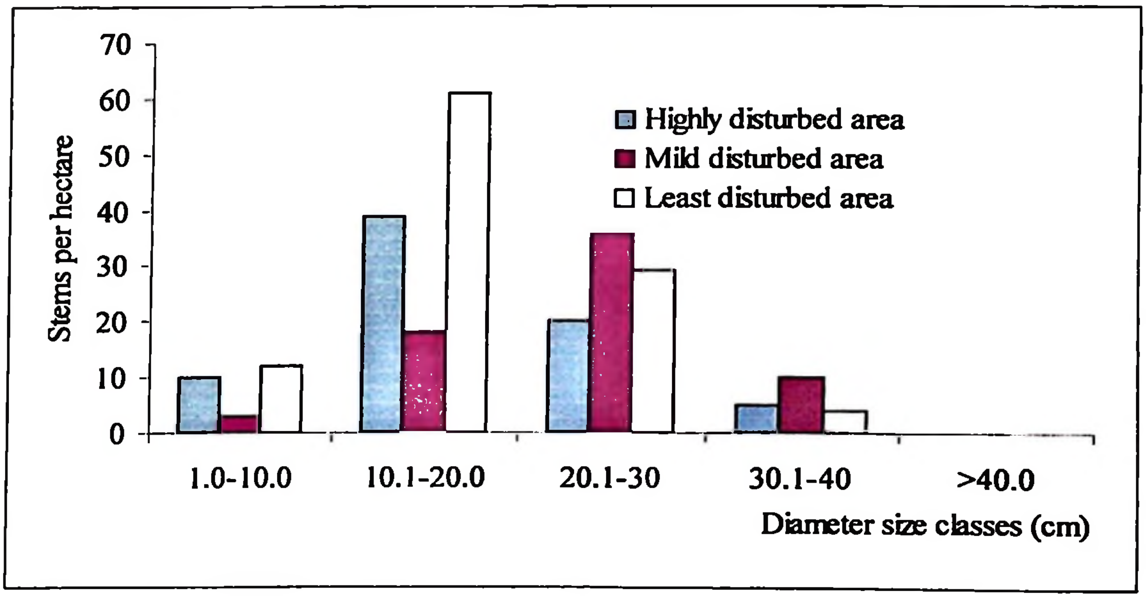

Figure 8: ***Brachylaena huillensis*** **removed stock (stems per ha) distribution by diameter size classes in Bombo West forest reserve.**

4.3 The Main Threats and Uses of Woody Plants in Bombo West Forest Reserve

4.3.1 Main threats in Bombo west forest reserve

The main forest threats identified in Bombo West forest reserve were carving making (27%), fire (22 %) charcoal making (20%), tree/pole cutting (13%), grazing (11% and firewood collection (7%) (Table 5). Similar observation were made by Madoffe and Munishi (2005) who specifically showed that most open wooded exterior areas of Bombo West forest reserve have been invaded by large herds of livestock, charcoal burning, tree/pole cutting and fire. Respondents argued that carving industry was done by people from Kenya in collaboration with some villagers around the forest reserve (Plate 1). The study revealed that there were some political and government officers at village and ward levels who support the carvers by providing shelter and food during the carving exercise.

Table 5: Main forest threats ranking in Bombo West forest reserve

Threat	Total mark	Percentage	Ranking
Carving making	177	27.0	1
Charcoal making	132	20.0	3
Pole and tree cutting	83	13.0	4
Fire	148	22.0	2
Grazing	73	11.0	5
Firewood	49	7.0	6

Plate 1: ***Brachylaena huillensis*** **logs harvested illegally for carvings in the least disturbed area in Bombo West forest reserve.**

Fire which was ranked second forest threat after carving making was in many cases initiated by charcoal makers and livestock keepers. Swaine *et al.* (1992) argued that repeated intensive burning leads to conversion of both forest and woodland to grassland, in which combustion of woody vegetation enables increased light levels to reach the ground, thus allowing the development of dense grass layer which in turn renders the habitat more susceptible to fire. These fires pose a serious threat to the perpetuity of *B. huillensis* in the forest reserve, since it is a shade-tolerant species not favoured by open woodland and grassland formation (Mrema, 2006).

Moreover, the reduction of the forest area due to fire coupled with poor dispersal of *B. huillensis*, which takes around 4 000 years for a population to advance 1km into a new area as reported by Kigomo (1994), present a profound effect on its perpetuity in the forest reserve. About 11% of the respondents revealed that grazing is another main threat the forest reserve. Maasai people from Mtoni Bombo village have been using the forest reserve as grazing place (Plate 2). Although some studies have shown that grazing in miombo woodland to suppress grass land as precaution against fire was necessary (Chidumayo, 1988) it was not certain that it will work at the study area.

Plate 2: Maasai cattle from Mtoni Bombo village grazing in the highly disturbed area in Bombo west forest reserve.

4.3.2 Main Threats of *Brachylaena huillensis* species and other related tree species

About 80 %, 14% and 7% of the respondents reported carving making, trees/ poles cutting and charcoal respectively as the most threats of *B. huillensis* tree species (Table 6).

Table 6: The main threats of *Brachylaena huillensis* in Bombo West forest reserve (n=44)

Threats	Respondents by villages											
	Kijungumoto				Mtoni-Bombo				Total			
	Yes		No		Yes		No		Yes		No	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Carvings	22	50	5	11	13	30	4	9	35	80	9	20
Charcoal	1	5	26	59	2	5	15	34	3	7	41	93
Tree/Pole cutting	4	9	23	52	2	5	15	34	6	14	38	86

The driving forces for carving making may be due to existing of reliable carvings market in Kenya, availability of *B. huillensis* tree species in forest reserve as compared to other areas across Tanzania- Kenya border, poverty and lack of alternative source of income among the villagers around Bombo West forest reserve.

Apart from *B. huillensis* the study also found that there were other tree species closely associated to *B. huillensis* which ware highly exploited for charcoal (Plate 3) and pole cutting, and are now seriously threatened. High demand of charcoal in Tanga City and high demand of trees and poles as building materials by villagers are the main driving force for the exploitation for the same. Exploited trees species include *Scorodophloeus fischeri, Tarenna nigrescens, Trichocladus ellipticus, Grewia goetzeana, and Combretum exalatum* and *Acacia* spp. State of British Columbia's Forests (2006) observed that reducing the number of tree species or changing the species through harvesting may decrease biological diversity and ecosystem resilience.

Plate 3: Charcoal remains in the highly disturbed area in Bombo West forest reserve.

4.3.3 Uses of *Brachylaena huillensis* around the study area

Brachylaena huillensis is used for different purposes in the study area specifically as` firewood, trees and poles for house construction (building materials), charcoal, carvings, timber and medicinal. *Brachylaena huillensis* was mentioned by about 80% of the respondents as being used for firewood (Table 7; Plate 4). The most preferred other woody plants for firewood were *Scorodophloeus fischeri* (Mhande), *Grewia goetzeana* (Mkole), *Lannea amaniensis (*Mumbu*)*, *Combretum sp* (Mlama), *Acacia* sp (Mtusi), *Acacia senegal* (Kikwata), *Acacia polyocantha* (Mgunga) and *Dombeya sp* (Mhati/Mluwati). Women claimed that *B. huillensis* firewood burns very well and for longtime with good scent-smell and have high calorific value, however, it is too difficult to split and produces a lot of ashes. Cunningham (1998) reported that *B. huillensis* species is suitable for charcoal because of its high calorific value.

Table 7: Peoples' response on different uses of *Brachylaena huillensis* around Bombo West forest reserve (n=46)

Uses	Respondent villages											
	Kijungumoto				Mtoni Bombo				Total			
	Yes		No		Yes		No		Yes		No	
	count	%	Count	%	count	%	Count	%	Count	%	Count	%
Fire wood	22	47	7	15	15	33	2	5	37	80	9	20
Charcoal	14	30	15	33	13	28	4	9	27	59	19	41
Building materials	7	15	22	48	13	28	4	9	20	43	25	57
Carvings	14	30	15	33	13	28	4	9	27	59	19	41
Medicinal	1	2	28	61	0	0	17	37	1	2	45	98
Timber	1	2	28	61	0	0	17	37	1	2	45	98

Plate 4: Villager from Kijungumoto carrying *Brachylaena huillensis* firewood on bicycle collected from Bombo West forest reserve.

Brachylaena huillensis was mentioned by 43% of the respondents as being used for poles/trees (Table 7; Plate 5). The respondents claimed that *B. huillensis* poles and trees are durable and very resistant to termites attack. The findings conform to (Bryce and Chihongo 1999; Mrema, 2006) who recorded that the service life of *B. huillensis* poles is over 10 years. The wood is exceptionally resistant to decay, termites and marine borers as confirmed by local tests, where samples in contact with ground remained free of attack after 15 years (Mrema, 2006).

Plate 5: Villager from Bombo Majimoto cutting illegally *Brachylaena huillensis* in the least disturbed area in Bombo West forest reserve for house construction.

Apart from *B. huillensis* other most preferred woody species for poles were *Scorodophlaeus fischeri* (Mhande), *Tarenna nigrescens* (Mshaghashachole), and *Manilkara sulcata* (Mcheji) Trichocladus *ellipticus* (Mkombechi), Strychnos *madagascariensis* (Mkangala), *Albizia anthelmintica* (Mfuleta), *Dobera loranthifolia* (Msiga), *Combretum spp* (Mlama Mweusi) and Combretum *exalatum* (Mwekea) (Plate 6). Malimbwi (2000) reported that the main tree species used for building poles include *Scorodophloeus fischeri* (Mhande), *Combretum spp* (Mlama) *and Terminalia mollis* (Mtanga).

Plate 6: *Scorodophloeus fischeri* poles harvested illegally in the mild disturbed area in Bombo West forest reserve.

The use of *Brachylaena huillensis* for carvings and charcoal making was mentioned by 59% of the respondents. Although respondents knew that *B. huillensis* was used for carvings and charcoal they claimed that they had never used the species for such purposes. Most of the interviewees responded that more than 95% of people around the study area used firewood as the main source of energy, therefore carvers and charcoal makers came from out of the study area (Kenya and Tanga City) and only collaborated with few villagers for illegal harvesting. *Brachylaena huillensis* was found to be the most marketable species in the study area. Its commercial value is attributed to its durable poles and high quality carvings. Besides, absence of the species in the neighbouring villages and towns might have increased its commercial value. The findings are in congruence with Kigomo (1994) who pointed out that *B. huillensis* is the main commercially important tree species in central and coastal forests of East Africa. Moreover, the study observed that *B. huillensis* did not qualify as one of the preferred species for timber. Only very small percentage (2%) of the respondents used the species for timber (Table 7) probably due to its hard grains which make it difficult in difficulty in hammering nails and sawing. Bryce and Chihongo (1999) also argued that planing of *B. huillensis* wood with standard knives was almost impossible due to the interlocked grain, brittle surfaces, and the wood is also difficult to glue and impossible to nail.

4.3.4 Forest resource use intensity of woody plants in Bombo west forest reserve

A total of 3542 trees were identified in 140 plots. Out of these, 2884 (81.4%) trees were live, 43 (1.2 %) were recently cut and 615 (17.4 %) were old cut (Table 8). The average cut trees was 79 stems ha^{-1} for the highly disturbed forest area, 101 stems ha^{-1} for mild disturbed forest area and 119 stems ha^{-1} for least disturbed forest site (overall average of 100 stems ha^{-1}).

Table 8: Forest resources use intensity for woody plants in Bombo West forest reserve

Description	Forest status/blocks			Total	Average
	Highly disturbed	Mild disturbed	Least disturbed		
Total no. of plots	67	37	36	140	47
Total sampled area (ha)	3.35	1.85	1.8	7	2.33
No. of live trees	1105	1190	589	2884	961
Live tree density (N)	330	643	327	1300	433
No. of new cut	28	7	8	43	14
No. of old cut	228	180	207	615	205
Total no. of cut trees (N)	256	187	215	658	219
Tree cut density (N)	79	101	119	299	100
Total density (N)	406	744	447	1597	532
New cut density (N)	8	4	4	16	5
Old cut density (N)	68	97	115	280	93
New cut use intensity (%)	2.06	0.57	1	1.04	1.04
Old cut use intensity (%)	16.75	13.07	25.74	17.55	17.55

The forest use intensity were 18.81% (2.06% new cut and 16.75% old cut) in highly disturbed forest area, 13.58% (0.51% new cut and 13.07% old cut) in mild disturbed forest area and 26.74% (1% new cut and 25.74% old cut) in least disturbed area (Table 8). This showed that there were old cuts than new cuts in all forest areas. The overall average of forest use intensity of the forest reserve was 17.55%. The study revealed significant difference ($p < 0.05$) in stump density in terms of old cut trees while there was no significant difference ($p > 0.05$) in stump density of new cut trees between highly, mild and least disturbed areas (Table 9).

Table 9: New cut and old cut woody plants in Bombo West forest reserve

Forest status/blocks	Old cut (Stem ha^{-1})	New cut (stems ha^{-1})
Highly disturbed	68 (0.076)	8(0.077)
Mild disturbed	97 (0.409)	4(<0.001)
Least disturbed	115 (0.370)	4(<0.001)
Coefficient of Variation (CV)	71.642	22.137
Root Mean Square(RMSE)	1.699	0.233
Probability Level(P)	0.0001	0.5126

Number in parenthesis = Standard error

The figure reported here are higher compared to Bracebridge (2006) who reported that timber tree cutting in Mkindo miombo forest reserve were 3.3 old cut stems and 0.6 new cut stems ha^{-1} with large timber trees having an average of 1.0 old cut stems and 0.2 new cut stems per ha^{-1}. Madoffe and Munishi (2005) also revealed that there were more old cut stems than new cut stems in the same forest. In their findings they reported about 135.4 and 72.9 old cut stems ha^{-1} for trees and poles respectively while new cut stems ha^{-1} were

43 and 20 for trees and poles respectively. This is an indication that all strata namely highly, mild and least disturbed forest areas in Bombo West forest reserve were under utilization pressure from adjacent communities.

4.3.5 Forest resource use intensity for *Brachylaena huillensis*

The study showed that about 904 stems of trees / poles of *B. huillensis* was recorded in all three strata. Out of these 343 (37.9%) were live and 561(62.1%) were cut in which 40 (4.5%) were new cut and 521(57.6%) were old cut (Table 10). The average stems ha^{-1} of tree and poles were 74, 67 and 106 for highly, mild and least disturbed forest areas respectively. The results also revealed that *B. huillensis* use intensity was 59.09% (6.7% new cut and 52.39% old cut) for highly disturbed, 66.84% (2.71% new cut and 63.4 % old cut) for mild disturbed forest area and 63.24% (2.65% new cut and 60.6% old cut for least disturbed forest area while overall average for all strata was 62.84% (3.81% new cut and 59.03% old cut).

Table 10: Forest resources use intensity between new cut and old cut for *Brachylaena huillensis* species in Bombo West forest reserve

Description	Forest status/blocks			Total	Average
	Highly disturbed	Mild disturbed	Least disturbed		
Total No. of plots	67	37	36	140	47
Total sampled area (ha)	3.35	1.85	1.8	7	2.33
No. of live trees	171	61	111	343	114
Live tree density (N)	51	33	62	146	49
No. of new cut	28	5	7	40	13
No. of old cut	219	118	184	521	174
Total No. of cut trees (N)	247	123	191	561	187
Tree cut density (N)	74	67	106	247	82
Total density (N)	125	99	168	392	131
New cut density (N)	8	3	4	15	5
Old cut density(N)	66	64	102	231	77
New cut Use intensity (%)	6.7	2.71	2.65	3.81	3.81
Old cut Use intensity (%)	52.39	64.13	60.6	59.03	59.03

Compared to other woody plants, it appears that *B. huillensis* is heavily exploited. This is an indication of scarcity of the species and ecological threat to its conservation status in the existing forest reserve (Chonge, 2002). The heavy exploitation could be a threat to the species and other associated species. The State of British Columbia' Forests (2006) reported that the area dominated by one species before harvests changed after harvests and the extent of changed in dominance after harvests depends on the selection of species and natural seeding. Change of species diversity can affect ecosystem productivity and stability (State of British Columbia's Forest, 2006). Also Whitty (2007) observed that when one of three closely related species is removed from natural occurrences, there is irrevocably change in habitat which has effects on remaining species.

4.4 Effects of *Brachylaena huillensis* Exploitation on Woody Plants

4.4.1 Effects of exploitation on species distribution and richness

A total of 63 tree and shrub species were recorded from all of the three strata whereby 42 species were recorded from the highly disturbed area, 39 species from the mild disturbed area and 24 species from the least disturbed area (Appendix 1). The species richness (63) reported in this study is more or less similar to Munishi (2001) cited by Munishi *et al.* (2008) who reported 69 tree species in the natural forest of Mazumbai and Kisimagonja in West Usambara. The study revealed that higher number of different species was recorded in the highly disturbed area compared to mild and least disturbed areas.

This could indicate high plant diversity of the highly disturbed area than other areas of the forest reserve. (Denslow, 1995) noted that forest gaps caused by disturbance can increase tree density because a few large individuals are replaced by several small trees. Furthermore, assessment of the most dominant tree species in the forest was performed using individual Species Importance Value Index (IVI). Importance value index is an important parameter that reveals ecological significance of species in a given ecosystem (Lamprecht, 1989). The study revealed that all three strata had the same Importance Value Index (IVI) whereby *S. fischeri* was the most dominant species followed *B. huillensis, T. nigrescens, M. sulcata, Acacia spp, Cymomera sp, G. goetzeana* and *S. punctata* (Table 11, Fig. 9). The Importance Value Index rank species in terms of their importance to the forest and therefore the higher the IVI, the more important of the species is to forest ecosystem. The study showed that the *S. fischeri* and *B. huillensis* species are important in characterizing the Bombo West forest ecosystem as they are abundant, dominant and frequently occurring with IVI of 0.545 and 0.47 respectively. However the IVI of *B. huillensis* of this study was lower than those reported from previous studies. Mrema (2006) reported IVI of *B. huillensis* to be 13.87 and Kigomo *et al.* (1990) reported IVI of 54 and 43 in Karura and Ngong forests in Kenya respectively.

Table 11: Importance Value Index in Bombo West forest reserve

Importance Value Index (IVI)				
Species names		Forest status/blocks		
Local name	Botanical name	Highly disturbed	Mild disturbed	Least disturbed
Kipangasasu	*Cymomera sp*	0.073	0.129	0.098
Mdimudimu	*S. punctata*	0.105	0.026	0.088
Mcheji	*M. sulcata*	0.122	0.014	0.138
Mhande	*S. fischeri*	0.337	0.944	0.353
Mkarambati	*B. huillensis*	0.530	0.208	0.670
Mkole	*G. goetzeana*	0.065	0.126	0.056
Mshaghashachole	*T. nigrescens*	0.084	0.240	0.117
Mtusi	*Acacia sp*	0.103	0.013	0.142
	Other tree species	0.581	0.299	0.340

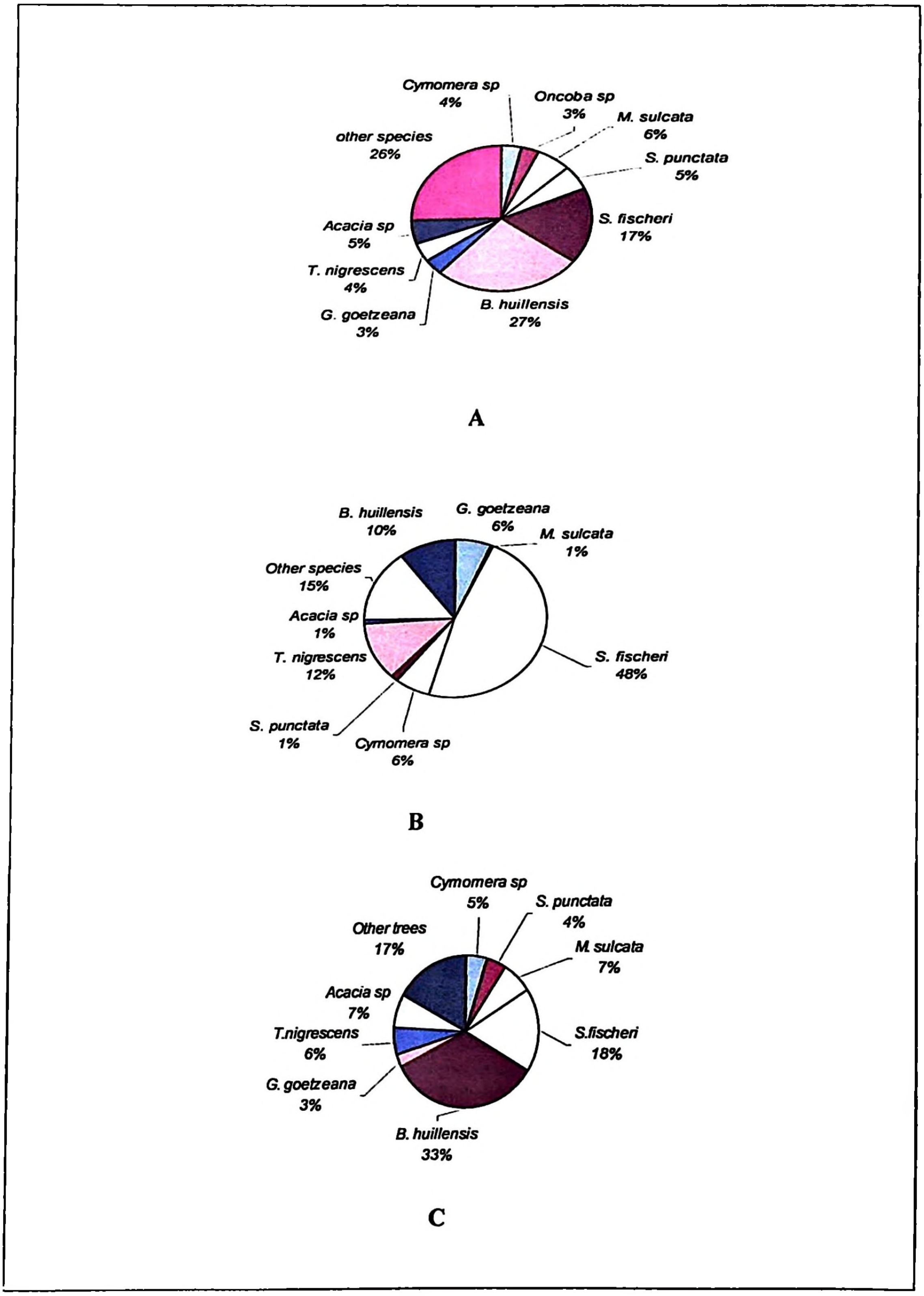

Figure 9: Distribution of tree species in terms of IVI where A –highly, B- mild and C -least disturbed forest areas in Bombo West forest reserve.

4.4.2 Shannon –wiener index of diversity

Shannon –Wiener Index of Diversity (H') is a commonly used index in measuring biodiversity because it combines species richness and evenness and is not affected by sample size. The larger the value of H,' the greater is the diversity of the community (Khan, 2009). The calculated Shannon-Wiener Index of Diversity (H') stand values in this study were 2.719, 1.999 and 2.239 for highly, mild and least disturbed forest areas respectively (Table 12). This indicates that there was high species diversity in the highly disturbed forest area compared to mild and least disturbed forest areas.

The results corresponded to Sheil (1999) who reported that a disturbance of a reasonable intensity will increase species richness in old-growth forest and contrary to Kariuki *et al.* (2006) who argued that increased logging intensity was negatively associated with species abundance and richness. However the results were similar to Munishi *et al.* (2008) who reported H' values of 2.8 on-farm tree resources in the West Usambara, Tanzania. In another study H' values for miombo woodland were observed to be 2.9 and 3.1 in public land and reserved SUA training forest at Kitulangalo area respectively (Zahabu, 2001), Moreover, in Handeni Hill Forest Reserve Shannon-Wiener Index of Diversity (H') values of 2.425 and 2.657 for miombo woodland and semi –evergreen respectively were recorded (Malimbwi and Mugasha, 2002).

The H' of this study was also within the acceptable range as reported by Khan (2009) that the value of Shannon –Wiener Index of Diversity is usually found to fall between 1.5 and 3.5 and only rarely it surpasses 4.5. The presence of maximum number of species with only one or 1–10 individuals in all forest sites may indicate the mixed nature of the forest (Richards, 2002), and a marked diversity. Shannon-Wiener diversity values were subjected to one way Analysis of Variance, the results revealed significant difference ($p<0.05$) in species diversity between highly, mild and least disturbed forest areas. This could be explained by the fact that most of the disturbed forest area was heavily logged illegally for carving making charcoal making and pole cutting. Contrary, Huana *et al.* (2003) found that there were no significant differences in overall species numbers between intact mature natural forest and former logged, burned or cultivated forest in East Usambara Mountains.

Table 12: Shannon-Wiener index of diversity (H') in Bombo West forest reserve

Forest status/blocks	Shannon –Wiener Index of Diversity (H')
Highly disturbed area	2.719 (0.267)
Mild disturbed area	1.999 (0.015)
Least disturbed area	2.239 (0.021)
Coefficient of Variation (CV)	46.643
Root Mean Square (RMSE)	1.002
Probability Level (P)	0.001

Number in parenthesis = Standard error

4.4.3 Effects of Exploitation on Regeneration of woody plants

Overall average of woody plants regenerants in the Bombo West forest reserve was 15646 seedlings ha^{-1} with the average for each site of 20 100, 11 376 and 15 463 seedlings ha^{-1} for highly, mild and least disturbed areas respectively (Table 13; Appendices 8, 9 and 10).

Table 13: Regenerants of woody plants in Bombo West forest reserve

Forest status/blocks	Mean regenerants (seedlings ha^{-1})
Highly disturbed	20 100 (69.735)
Mild disturbed	11 376 (64.198)
Least disturbed	15 463 (169.109)
Coefficient of Variation (CV)	115.493
Root Mean Square(RMSE)	537.387
Probability Level(P)	0.071

Number in parenthesis = Standard error

The figure obtained was higher as compared to Mrema (2006) in his study at Dindili forest reserve which reported 11 168 seedling per ha. The regeneration pattern of the tree species varied in each forest stratum, whereby the higher number of regenerating species in the highly disturbed area could have been due to high level of disturbance caused by exploitation of *B. huillensis* for poles, firewood, carving and charcoal making as reported by Matthews (1989) that disturbances such as harvesting of trees in forest reserve induce natural regeneration. The most dominant tree species in terms of regeneration were *B. huillensis* with average regenerants of 5076 stems per ha followed by *Trichocladus ellipticus* 4929 stems per ha, *Scorodophloeus fischeri* 2084 stems per ha, *Manilkara sulcata* 1180 stems per ha and *Tarenna nigrescens* 785 stems per ha (Appendix 4).

The study further revealed that the regeneration of woody plants was not significantly different ($p > 0.05$) between the three forest sites. The results given here were higher compared to those reported by Mrema (2006) who observed that the number of seedlings per hectare in Dindili forest reserve were 11 168 seedlings per ha whereby *Brachylaena* *huillensis* had 407 seedlings per hectare, *Scorodophloeus fischeri* (3892), *Diospyros consolatae* (1086), *Teclea simplicifolia* (640), *Blighia unijugata* (567), *Zanthoxylum chalybeum* (504), *Croton pseudopulchellus* (431), *Flueggea virosa* (363) and *Acacia pentagons* (175).

On the other hand, the study also observed the poor regeneration of some woody plants about 17 seedlings per ha (Appendix 4). This could indicate depletion of seed sources due to harvesting of mature trees for carvings and charcoal (Appendices 14, 15 and 16). Chapman and Chapman (1997) observed that heavy forest disturbance may destruct both mature trees and young stock, and may also result in the alteration of certain environmental conditions which hinder forest regeneration. The destruction of plants opening canopy gaps often stimulate growth of dense herbaceous and semi-woody tangle that suppress tree regeneration (Patrick *et al.*, 2004).

4.4.4 Effects of Exploitation on Regeneration of *Brachylaena huillensis*

Overall average regenerants per hectare of *B. huillensis* from the three sites in the Bombo West forest reserve was 5076 recorded as follows: 5025, 481 and 9722 seedlings per ha for highly, mild and least disturbed areas respectively (Table 14; Appendix 4; Plate 7). The study further revealed that there was no significant different ($p>0.05$) in regeneration of *B. huillensis* between highly, mild and least disturbed forest areas (Table 14). This may be due to that fact that the forest experience more or less similar disturbances.

Table 14: Regenerants of *Brachylaena huillensis* tree species in Bombo West forest reserve

Forest status/blocks	Mean regenerants (seedlings ha^{-1})
Highly disturbed	5025 (82.158)
Mild disturbed	481 (18.833)
Least disturbed	9722 (252.172)
Coefficient of Variation (CV)	178.175
Root Mean Square(RMSE)	566.595
Probability Level(P)	0.162

Number in parenthesis = Standard error

Plate 7: *Brachylaena huillensis* regenerants in the least disturbed area in Bombo West forest reserve.

The figures recorded here are higher than Mrema (2006) who found that *Brachylaena huillensis* had 407 seedlings per hectare in Dindili forest reserve. There was higher number of regenerants in the least disturbed area followed by highly disturbed area. The study revealed that there ware many mature seed producing *B. huillensis* trees in the least disturbed forest area compared to highly and mild disturbed areas (Appendices 8, 9 and 10) and the natural regeneration of the forests in least disturbed area appeared to be recovering from the impacts of intensive tree harvesting of *B. huillensis* which happened a few many years ago. The relatively low number of *B. huillensis* regenerants in mild disturbed forest area could be attributed to either the depletion of mother trees (Fig. 3; Appendix 2) which was 33 stems per hectare or creation of few large gaps which could result to abundant weedy undergrowth including natural regeneration of other tree species. Also lower regenerants of *B. huillensis* may attribute to intensive harvesting of female trees. Local people know and prefer the female *B. huillensis* individuals, they produce consistently harder wood than male tree and identify female tree through its deeply fissured bark (Mrema, 2006).

4.5 Conservation Strategies for Bombo West Forest Reserve

4.5.1 Current conservation strategies for *Brachylaena huillensis* and forest in general

The study revealed that there were no specific conservation strategies for *B. huillensis* tree species and for Bombo West forest reserve in general, although there is evidence that the forest resources of Bombo West forest reserve have been degrading drastically over the last two decades through illegal harvesting. In this study it was observed the forest is usually visited or patrolled once every month due to financial constraints and lack of reliable transport consequently exposing the forest resource to illegal activities.

Also the study observed that although the villagers around the forest reserve are allowed to collect dead trees for firewood from the forest reserve twice per week (Wednesday and Saturday), some villagers cut and collect live trees perhaps due to lack of proper mechanism for supervising and monitoring the exercise. Observation was similar to Marshall and Jenkins (1994) who reported in the Arabuko-Sokoko forest reserve that although licences are issued for collection of *B. huillensis* dead wood, but most of the trees removed are either newly dead (possibly ring-barked trees) or illegally cut trees. More over, since the forest boundary is not clearly marked, is giving a loophole to conduct illegal activities in the forest.

4.5.2 Suggested conservation strategies for *Brachylaena huillensis*

In developing forest management strategies for Bombo West forest reserve, it would be important to focus on the protection of B. *huillensis* tree species from depletion. The observed wood harvesting mainly for carvings, charcoal, poles and trees cutting indicates that *B. huillensis* and the forest in general are currently under pressure and therefore needs more effective management strategies in order to control illegal activities in the protected forest. The following are some of the suggested conservation strategies for *B. huillensis* and forest reserve in general.

4.5.2.1 Use and planting of alternative tree species to *Brachylaena huillensis*

The study revealed that about 53.2% of the surveyed households in Kijungumoto and 34 % in Mtoni Bombo were willing to use and plant alternative tree species to *B. huillensis* for building material, charcoal, carvings, and fire wood. Contrary to that, 13.8% of respondents were not willing to use and plant alternative tree species (Table 15).

Table 15: Willingness of respondents around Bombo forest reserve to use and plant alternative tree species (n=47)

Respondent village	Willingness to use and plant alternative tree spp				Total	
	Yes		No			
	Count	%	Count	%	Count	%
Kijungumoto	25	53.2	4	8.5	29	59.7
Mtoni Bombo	16	34.0	2	4.3	18	40.3
Total	41	87.2	6	13.8	47	100

Refraining from planting and use alternative tree species to *B. huillensis* could be due to land scarcity which was to be an average of 3 acres per household and some farmers don't accept to mix trees and crops (maize and beans) on the same piece of land with fear that trees can destroy their crops. These problems could however be solved by introduction of agroforestry production system. Munishi *et al.* (2004) reported that on- farm tree planting means some of the desired forest products such as fuel wood and poles could be obtained from on farm sources hence reduce pressure on the natural forests. Also on-farm tree resources make high contributions to household forest product needs (Kaoneka and Solberg, 1997; Munishi *et al.*, 2004). Therefore, limiting the number of trees cut per season or encouraging the carving and charcoal makers to plant and explore alternative tree species with similar acoustic properties may achieve the conservation of *B. huillensis* and the whole forest. Carvers in the Akamba Handicraft Cooperative in Mombassa, Kenya and local farmers have now developed alternative materials for carving needs using alternative species such as *Azadirachta indica* (neem) and *Mangifera indica* (Mango) referred to as good woods (Susanne, 2000).

4.5.2.2 Domestication of *Brachylaena huillensis* tree species in farm land

In this study 95.7% of the respondents interviewed were aware on *B. huillensis* trees exploitation and they were willing to plant the species in their farmlands (Table 16 and 17).

Table 16: People's awareness on *Brachylaena huillensis* exploitation in Bombo West forest reserve (n=47)

Respondent village	Awareness on *B. huillensis* exploitation				Total	
	Yes		No			
	Count	%	%	%	Count	%
Kijungumoto	27	57.4	2	4.3	29	61.7
Mtoni Bombo	16	34.0	0	0.0	18	38.3
Total	45	95.7	2	4.3	47	100.0

Table 17: Willingness of respondents around Bombo forest reserve to plant *Brachylaena huillensis* in their farmlands (n=47)

Respondent villages	Willingness to plant					
	Yes		No		Total	
	Count	%	Count	%	Count	%
Kijungumoto	29	61.7	0	0.0	29	61.7
Mtoni Bombo	16	34.0	2	4.3	18	38.3
Total	45	95.7	2	4.3	47	100

The findings are contrary to Mrema (2006) who reported that 100% of the respondents claimed not to plant *B. huillensis* in homesteads, farms and private woodlots. On- farm domestication of this species in the long term is very important since domestication has saved many other plants, especially those threatened in their natural habitats (Madoffe *et al.*, 2007; Msuya *et al.*, 2008). Domestication involves both retaining some plant species of forest origin in the farms during the process of opening up land for cultivation and/or bringing forest plants to the farms or homesteads with an intention of tending such valuable species for various purposes (Madoffe *et al.*, 2007; Msuya *et al.*, 2008).

Encouraging villagers to establish woodlots for fuel wood, building poles, carvings and charcoal production could minimize the daily walking routine of villagers into the reserve in search of those materials and could be supplementary time for production. Although the tree would not be available for local people in the near future since it is slow growing tree, take long to mature about 100 years to attain 40 cm dbh (0.40 cm dbh per year), 130 year to attain 45 cm dbh (0.38 cm dbh per year), or 60 cm dbh (0.34 cm dbh per year) in approximately 175 years which is very good growth rate in natural conditions (Kigomo, 1994). Tree planting in agroforestry systems outside of the forest to develop alternative stocks would help to reduce further degradation of the forest and depletion of the species. Therefore for sustainable use of the species in future, *B. huillensis* should be planted in small scale specifically for conservation purpose in Bombo West forest reserve (Korogwe DCFO pers comm, 2008).

4.5.2.3 Involvement of local community around Bombo West Reserve in forest management

Collaborative management approaches between Central Government and community will attempt to readdress the imbalance between negotiated rights of access and agreed responsibilities for the conservation of resources on which those rights are based (Blomley *et al.*, 2008). Ongoing Participatory Forest Management (PFM) programme under Korogwe District Council could be extended to Bombo West Forest Reserve. Participatory Forest Management have had some positive impacts on forest condition, which entails improvement in the natural resources. Past ecological/biological studies in Iringa and Tanga regions reported improved forest condition in terms of both forest regeneration and biodiversity (Luoga *et al.*, 2006; Sauer and Abdallah, 2007). Luoga *et al.* (2006) reported increased tree species stocking, volume and reduced human disturbances in Handeni Hill forest reserve in Tanga region after five years of Joint Forest Management (JFM) implementation. Therefore introduction of PFM especially JFM approach in Bombo West forest reserve could reduce illegal harvesting of forest resources and hence improve forest condition.

4.5.2.4 Awareness creation on biological and ecological importance of *Brachylaena huillensis*

It was noted that one of the main causes of over harvesting of *B. huillensis* in the area was inadequate awareness, knowledge and skills on biological and ecological importance of the species by local communities. The study showed clearly that most people in the study area were aware of the presence of the forest reserves. Besides the general awareness on the presence of forest reserves, farmers interviewed also showed a clear knowledge as regards to the economic benefits of *B. huillensis* tree species. Awareness on conservation education on the ecological/biological importance of species is very important for conservation purpose. Therefore for the conservation of *B. huillensis* to be successful we need to empower the local communities especially through awareness raising and environmental education on biological and ecological impact of over exploitation of the species.

4.5.2.5 Developing management plan of Bombo West forest reserve

It was noted that during the survey, the forest reserve did not have a management plan. Efforts should be made to encourage the development of management plan. The management plan should indicate clearly the objectives, roles, cost and benefit sharing and responsibilities of different stakeholders. Preparation of management plan could be facilitated by the governments (local and central governments) in close collaboration with local community using JFM approach. In this management plan more emphasis should be on sustainable conservation of *B. huillensis*.

4.5.2.6 Providing alternative income generating activities

Key informants reported that the problem of unsustainable forest management in Bombo West forest reserve was also attributed to poverty. The forests adjacent communities are quite poor and own small farms with an average of three acres yielding an average of 2 to 4 bags (one bag equivalent to 100 kg) of maize, which cannot cater for their annual demands. As a result some people have been involved in illegal activities which are associated with forest resources such as charcoal making, firewood business and carving making. It is therefore suggested that supporting the community by providing non-destructive income generating activities like beekeeping, gardening, mushroom cultivation, poultry farming and ecotourism by taking the opportunity of Nilo nature reserve could reduce the pressure to *B. huillensis* species and the forest in general. It is also suggested that the existing farming systems in study area should be economically sustainable by improving farming technology which could increase crop production through improvement of land productivity. The agricultural extension officers should insist on proper farming techniques so as to increase the farm productivity which will ultimately increase the farmers' income and improve their livelihood of the communities.

4.5.2.7 Forest boundary re-survey and firebreaks construction

Forest boundary should be clearly known to all people around the study areas. This could be achieved through boundary re-survey followed by planting of trees around the forest reserve. Also education on the adverse impact of fire should be done to the villagers in the study area followed by the firebreaks (fire lines) construction around the forest reserve to protect the reserve from accidental fires from the farmlands and surrounding grasslands. Firebreaks have been used for preventing fires from moving into protected areas (Dyer *et al.*, 2001).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Generally, Bombo West forest reserve had lower average stand parameters (433 stems per ha, 36.869 m^3 per ha and 5.455 m^2 per ha) as compared to other previous studies in miombo woodlands. The mild disturbed area recorded higher tree density (643 stems per ha) than least (330 stems per ha) and highly (327 stems per ha) disturbed areas while woody volume was higher in the least disturbed area (41.24 m^3 ha^{-1}) followed by mild disturbed area (39.353 m^3 ha^{-1}) and highly disturbed area (30 m^3 ha^{-1}). All strata exhibited similar dbh distribution and follow the reversed J- shaped trend. *Brachylaena huillensis* was relatively important in terms of density, basal area and volume as compared to other woody plants however its dbh distribution does not follow inverted J-shaped trend. *Scorodophloeus fischeri* and *B. huillensis* were the most dominant trees species as by having high Importance Value Index (IVI) compared to other woody plants. This could indicate that the two species are closely associated in the forest reserve; hence harvesting one species could have adverse effects on others.

Multipurpose use of *B. huillensis* and its resistant to pest and diseases have made the tree more vulnerable to exploitation. The study revealed that *B. huillensis* tree is highly harvested for different uses in the forest reserve as compared to others woody plants as evidenced by removal of 82 stems ha^{-1}, (16.376m^3 ha^{-1}) of woody plants. Unfaithful villagers around the forest collaborate with people from Kenya and Tanga City in illegal harvesting of *B. huillensis* for carvings and charcoal making. Most harvested trees were in diameter size class of 10.1-30.1 cm indicating that both young and mature *B. huillensis* are illegally harvested from the forest reserve.

The study recorded high numbers regenerants of woody plants in the highly disturbed area (20 100 seedlings) than mild disturbed area (11 376 seedlings) and least disturbed areas (15 463 seedlings) while least disturbed area indicated higher *B. huillensis* regenerants (9722 seedlings) followed by highly disturbed area (5025 seedlings) and mild disturbed area (481 seedlings). *Brachylaena huillensis* does not show good recruitment and regeneration trend in the forest reserve, and therefore, harvesting of both young and mature *B. huillensis* poses a serious threat to future natural regeneration of this species. Lastly, carvings, fire, charcoal, grazing, tree and poles cutting are main threats to the forest reserve and *B. huillensis* in particular.

5.2 Recommendations

Based on the results from this study the following are recommended in order to mitigate the problem of regeneration in Bombo West Forest Reserve (BWFR).

(i) Natural regeneration of *B. huillensis* species should be enhanced through effective management by minimizing human disturbance while increase regular patrols and forest visits at least twice per week.

(ii) Since harvesting is done to both mature and young trees of *B. huillensis* there is a need to barn harvesting of the species in Tanga region.

(iii) The village governments should be mandated to monitor all activities done by foreigners, particularly the Kenyans who have been implicated as the main exploiters of *B. huillensis*. Any illegal act must be reported and dealt henceforth according to the law of the land.

(iv) District Disciplinary and Leadership Committee should take disciplinary action to government officers who collaborate with Kenyans in carving business.

(v) The local communities should be facilitated to plant alternative tree species to *B. huillensis* and domesticate the same on their farmlands in order to reduce the pressure in the forest reserve.

(vi) Ongoing Participatory Forest Management (PFM) programme under Korogwe District Council (KDC) could be extended to Bombo West forest reserve since it has been proved to increase tree species stocking, volume and reduced human disturbances in some forest reserves.

REFERENCES

Abugov, R. (1982). Species diversity and phasing of disturbance. *Ecology* 63:289 – 293.

African Hardwoods (2000). Understanding the Data. [http://www.zanzibarconnection.com/specs.htm#muhuhu] site visited on 14/3/2009.

Ahrends, A. (2005). Patterns of degradation in lowland coastal forests in Coast region, Tanzania. Thesis for Award of MSc Degree at University of Greifswald, Germany.[http://www.york.ac.uk/res/kite/people/ahrends/Ahrends_Thesis_Diplom.pdf] site visited on 20/5/2009.

ASFMT (2002). Arabuko-Sokoke strategic forest management plan 2002-2027: Kenya Forest department, Nairobi. 66pp. [http://www.birdlife.org/action/ground/arabuko/arabuko sokoke _ plan.pdf] site visited on 22/7/2008.

Bazzaz, F. A. and Picket, S. T. A. (1980). Physiological succession: A comparative review. *Annual Review of Ecology and Systematics* 11:287-310.

Blomley, T., Pfliegner, K., Isango, J., Zahabu, E., Ahrends A. and Burgess, N. (2008). Seeing the wood for the trees: An assessment of the impact of participatory forest management on forest condition in Tanzania. *Fauna and Flora International* 42(3): 380 – 391.

Boot, R. G. A. and Gullison, R. E. (1995). Approaches to developing sustainable extraction systems for tropical forest products. *Ecological Applications* 5: 896 – 903.

Borghetti, M. and Giannini, R. (2004). *Natural Regeneration in Woodland Management.* [http://www.eolss.net] site visited on 26/3/2009.

Boyd, H. K. (1981). *Marketing Research, Text and Cases.* Richard D. Publishers, Illinois. 813pp.

Bracebridge, C. (2006). *Mkindo Forest Reserve: Report for Tanzania forest conservation group and participatory environmental management programme, Dar es Salaam, Tanzania.* [http:// www.tfcg.org/downloads/Mkindo-Forest-Disturbance-Report-FINAL.pdf] site visited on 23/3/2009.

Bryce, J. M. and Chihongo, A. W. (1999). *The Commercial Timbers of Tanzania.* KAD Publishers, Dar es Salaam. 293pp.

Catling, P. M. (2001). *Extinction and the importance of history and dependence in conservation.* [http://www.tc-biodiversity.org/sample-extinction.pdf] site visited on 10/4/2009.

Chaar, H., Colin, C. and Collet, C. (1997). Effects of environmental factors on the shoot development of *Quercus petraea* seedlings: A methodological approach. *Forest Ecology and Management* 97: 119 - 131.

Chapman, A. C. and Chapman, L. J. (1997). Forest regeneration in logged and unlogged forest of Kibale National Park. *Biotropica* 29: 396 – 412.

Chidumayo, E. N. (1988). Early post- felling response of Marquesian woodland to burn in Zambia copper belt. *Journal of Tropical Ecology* 4: 361 – 372.

Chonge, S. K. (2002). Study of economic aspects of the wood carving industry in Kenya: Implications for policy development to make the industry more sustainable. Thesis for Award of Msc Degree at University of Natal, Natal, South Africa, 55pp.

CIFOR (2002). Planning for Wood Carvings in the 21st Century. [http://www. cifor.cgiar.org/publications/pdf_files/infobrief/001-Infobrief.pdf] site visited on 30/3/2009..

Cleary, D. F. R. and Genner, M. J. (2004). Changes in rain forest butterfly diversity following major ENSO-induced fires in BorneoGlob. *Ecology Biogeography* 13: 129 – 140.

Cunningham, A. B. (1998). Kenya's carvings, the ecological footprint of the wooden Rhino. *Africa Wildlife and Environment* 6(2): 43 – 50.

Denslow, J. S. (1995). Disturbance and diversity in tropical rainforests. The density effects. *Ecological Applications* 5: 962 – 968.

Dyer, R., Jacklyn, P., Partridge, I., Russell-Smith, J. and Williams, R. (2001). *Savanna Burning: Understanding and using Fire in Northern Australia.* CRC Press, Darwin. 88pp.

Ehrlich, P. R. and Wilson, E. O. (1991). Biodiversity studies: Science and policy. *Science* 253: 758 – 762.

Eilu, G., Hafashimana, D. L. N. and Kasenene, J. M. (2004). Density and species diversity of trees in four tropical forests of the Albertine rift Western Uganda. *Diversity and Distribution* 10: 303 – 312.

FAO (1986). Data Book on Endangered Tree and Shrub Species and Provenances.[http://www.vedamsbooks.com/no10313.htm] site visited on 24/4/2009.

Fredericksen, T. S. and Mostacedo, B. (2000). Regeneration of timber species following selection logging in a Bolivian tropical dry forest. *Forest Ecology and Management* 131: 47 – 55.

Ganzhorn, J. U. (1995). Cyclones over Madagascar: Fate or fortune. *Ambio* 24:124 – 25.

Garcia-Montiel, D. C. and Scatena, F. N. (1994). The effect of human activity on the structure and composition of a tropical forest in Puerto Rico. *Forest Ecology Management* 63: 57 – 78.

Henle, K., Sarre, S. and Wiegand, K. (2004). The role of density regulation in extinction processes and population viability analysis. *Biological Conservation* 13: 9 – 52.

Hill, J. K., Hammer, K. C., Lace, L. A. and Banham, W. M. T. (1995). Effects of selective logging on tropical forest butterflies on Buru, Indonesia. *Journal of Applied Ecology* 32: 754 – 760.

Huana, W., Pohjonen, V., Johansson, S., Nashanda, M., Katigula, M. I. L. and Luukkanen, O. (2003). Species diversity, forest structure and species composition in Tanzanian tropical forests. *Forest Ecology and Management* 173:11 – 24.

IUCN (2008). IUCN Red List of Threatened Species. [http://www.iucnredlist.org] site visited on 26/4/2009.

Kasenene, J. (2007). Post logging structural changes and regeneration of *Olea welwitschii* (Knobl) Gilg and Schellemb. In the Kibale National Park, Uganda. *African Journal of Ecology* 45(3):109 – 115.

James, K. and Kasenene J. M. (2007). A comparative study of regeneration under live and dead canopy trees in a tropical rain forest ecosystem of Kibale National Park, Uganda. *African Journal of Ecology* 45(3):11 – 17.

Jonsell, M. (2007). Effects on biodiversity of forest fuel extraction, governed by processes working on a large scale. *Biomass and Bio Energy Journal* 31(10): 726 – 732.

Kaale, B. K. (2004). *Review of Trade Issues for Management of Tanzania's Coastal Forests.* Mkuki na Nyota Publishers, Dar es Salaam. 84pp.

Kaoneka, A. R. S. and Solberg, B. (1997). Analysis of deforestation and economically sustainable farming system under pressure of population growth and income constraints at the village level in Tanzania. *Applied Soil Ecology* 62: 59 –7 0.

Kariuki, M., Kooyman, R. M., Smith, R. G. B., Wardell-Johnson, G. and Vanclay, J. K. (2006). Regeneration changes in tree species abundance, diversity and structure in logged and unlogged subtropical rainforest over a 36-year period. *Forest Ecology and Management* 236:162 – 176.

Khan, S. A. (2009). Methodology for Assessing Biodiversity: Centre of advanced study in marine biology. [http://www.ocw.unu.edu/international–network–on-water-environment-and-health/unu-inweh-course-1-mangroves/Methodology-for-Assessment-Biodiversity.pdf] site visited on 7/5/2009.

Kigomo, B. N. (1994).The rates of diameter increment and age-diameter relationship of *Brachylaena huillensis* O. Hoffm in semi-deciduous forests of central Kenya. *African Journal of Ecology* 32: 9 – 15.

Kigomo, B. N., Savill, P. S. and Woodell, S. R. (1990). Forest composition and its Regeneration dynamics: A case study of semi-decidous tropical forests in Kenya. *African Journal of Ecology* 28: 174 – 188.

Kigomo, B. N., Peter S. S. and Stanley J. R. W. (1991).The pattern and distribution of *Brachylaena huillensis* in semi-deciduous dry forests in Kenya. *African Journal of Ecology* 29: 275 – 288.

Kigomo, B. N., Woodel, S. R. and Savill P. S. (1994). Phenological patterns and some aspects of reproductive biology of *Brachylaena huillensis*. *African Journal of Ecology* 32: 296 – 307.

KDC (2007). *Korogwe District Environmental Profile*. Government Printers, Dar es Salaam, Tanzania.39pp.

Lamprecht, H. (1989). *Silviculture in the Tropics: Tropical forest ecosystems and their tree species; possibilities and methods for their long-term utilization*. GTZ Press, Eschborn. 296pp.

Lewis, O. T. (2001). Effect of experimental selective logging on Tropical butterflies. *Conservation Biology* 15: 389 – 400.

Luoga, E. J., Witkowski, E. T. F. and Balkwill, K. (2002). Harvested and standing wood stocks in protected and communal miombo woodlands of Eastern Tanzania. *Forest Ecology Management* 164: 15 – 30.

Luoga, E. J., Kajembe, G. C. and Mohamed, B. S. (2006). Impact of Joint Forest Management on Handeni Hill forest reserve and adjacent communities in Tanga, Tanzania.[http://dlc.dlib.indiana.edu/archive/00001956/00/Luoga_c_impact. pdf] site visited on 23/3/2009.

Lovett, J. C. and Pocs, T. (1993). *Assessment of the Condition of the Catchment Forest Reserves: A botanical appraisal.* Government printers, Dar es Salaam. 300pp.

Madoffe, S. S. and Munishi, P. T. K. (2005). *Eastern Arc Mountains Forest Management and Forest Condition Assessment.* GEF/UNDP. Morogoro, Tanzania. 129pp.

Madoffe, S. S., Andrew, D. and Mombo, F. (2007). *Developing a Strategy for Sustainable Income Generation from a Valuable Medicinal Plant, Prunus africana in Kilimanjaro, Tanzania.* Sokoine University of Agriculture, Morogoro, Tanzania. 36pp.

Malimbwi, R. E. (2000). *Forest Inventory Report for the Rufiji forests.* FOR CONSULT, SUA, Morogoro, Tanzania. 48pp.

Malimbwi, R. E. and Mugasha, A. G. (2002). Reconnaissance Timber Inventory of Handeni Hill Forest Reserve in Tanga Tanzania. *Journal of Tropical Forest Science* 13(3): 123 – 134.

Malimbwi, R. E., Solberg, B. and Luoga, E. (1994). Estimate of biomass and volume in miombo woodland at Kitulangalo forest reserve, Tanzania. *Journal of Tropical Forest Science* 7(2): 230 – 242.

Mark, M. G. (2007). Human impacts on the biodiversity of the Arctic. Conservation, biology, biodiversity and ecology. [http://canadianbiodiversityMcGillice/English/conservation activity] site visited on 16/12/ 2007.

Marshall, N. T. and Jenkins, M. (1994). *Hard Times for Hardwood: Indigenous timber and the timber trade in Kenya.* Traffic International, London. 53pp.

Matthews, J. D. (1989). Silviculture Systems.[http://www.forestresearch.gov.uk/fr/infd-63ccqb - 25k] site visited on 20/3/2009.

Mbuya, L. P., Msanga, H. P., Ruffo, C. K., Birniel, A. and Tengnas, B. (1994). *Useful Trees and Shrubs for Tanzania: Identification, propagation and management for agricultural and Pastoral Communities.* Region Soil Conservation Unit. SIDA., Arusha. 542pp.

McNabb, K. L., Miller, M. S., Lockaby, B. G., Stokes B. J., Clawson R. G., Stanturf, J. A. and Silva, J. N. M. (1997). Selection harvests in Amazonian rainforests: long-term impacts on soil properties. *Forest Ecology and Management* 93: 153 – 160.

Meier, A. J., Bratton, S. P. and Duffy, D. C. (1995). Possible ecological mechanisms for loss of vernal-herb diversity in logged eastern deciduous forests. *Ecological Applications* 5: 935 – 946.

Milledge, S. A. H. and Elibariki, R. (2005). The status of logging in southern Tanzania: East Africa Coastal forests ecoregion programme. [http://www.policyforum-tz.org/node/6954.org] site visited on 17/4/2009.

MNRT (2002). *Forestry in Figures.* Government Printers, Dar es Salaam. 75pp.

Mrema, J. P. (2006). Conservation of *Brachylaena huillensis* O.Hoffm (Asteraceae) in Dindili Forest Reserve, Morogoro, Tanzania. Thesis for Award of Msc Degree at Addis Ababa University, Addis Ababa, Ethiopia, 100pp.

Munishi, P. K. T., Shear, T. H., Wentworth, T., Temu, R. P. C. and Maliondo, S. M.(2004). Sparse distribution pattern of some plant species in two afromontane rain forests of the Eastern Arc Mountains of Tanzania. *Tanzania Journal of forestry and Nature Conservation* 75: 74 – 90.

Munishi, P. K. T., Philipina, F., Temu, R. P. C. and Pima, N. E. (2008).Tree species composition and local use in agricultural landscapes of West Usambara Tanzania: *African Journal of Ecology* 46(1): 66 – 73.

Mustalaht, I. (2002). *Recommendation on the way forward in Participatory Forest Management in Korogwe and Muheza Districts, Tanzania*. Government Printers, Dar es Salaam. 95pp.

Msuya, T. S., Mndolwa, M. A. and Kapinga, C. (2008). Domestication: An indigenous method in conserving plant diversity on farmlands in west Usambara Mountains, Tanzania. *African Journal of Ecology* 46(1): 74 – 78.

Nduwamungu, J. (1996). Tree and shrub diversity in miombo woodlands: A case of Kitulangalo Forest Reserve, Morogoro, Tanzania. Dissertation for Award of Msc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 135pp.

Newton, A. C. (1996). The Sustainability of Uses of Trees: Consultancy report to IUCN.[http://www.unep-cmc.org/trees/Background/docs/Sustainable% use%20of%20trees%20 report.rtf] site visited on 7/5/2009.

Noble, I. R. and Dirzo, R. (1997). Forests as human-dominated ecosystems. *Science* 277: 522 – 525.

Omenda, T. O. (2001). Natural Regeneration of *Brachylaena huillensis* and *Brachystegia spiciformis* in Arabuko-Sokoke Forest. [http://www.birdlife.org/action/ground/ arabuko/arabuko_sokoke_plan pdf] site visited on 26/5/2008.

Ramirez-Marcial, N., Gonzalez-Espinosa, M. and Williams-Linera, G. (2001). Anthropogenic disturbance and tree diversity in montane rain forest in Chiapasa Mexico. *Forest Ecology and Management* 154(1-2): 311 – 326.

Richards, P. W. (2002). *Composition of Primary Rain forest (II)*. The University of Chicago Press, Chicago. 544pp.

Panna, D. and Sundriyal R. C. (2008). Tree regeneration and seedling survival patterns in old-growth lowland tropical rainforest in Namdapha National Park, North-East India. *Forest Ecology and Management* 255: 3995 – 4006.

Patrick, O., Joseph, O. and Cunningham A. B. (2004). Regeneration, density and size class distribution of tree species used for drum making in central Uganda. *Africa Journal of Ecology* 42:129 – 136.

Peters, C. M. (1994). *Sustainable Harvest of Non - Timber Plant Resources in Tropical Moist Forest.* USAID Press, Washington D C. 48pp.

Philip, M. S. (1983). *Measuring Trees and Forests*. University of Dar es Salaam Press, Dar es Salaam. 338pp.

Pickett, S. T. A. (1983). Different adaptation of tropical tree species to canopy gaps and its role in community dynamics. *Tropical Ecology* 24: 68 – 84.

Putz, F. E., Dykstra, D. P. and Heinnrch, A. (2000). Why poor logging practices persist in the Tropics. *Conservation Biology* 14(4): 951 – 956.

Robert, I. M., Glenn, M. and David, R. F. (2008). The effect of logging on vegetation composition in Western Massachusetts. *Forest Ecology and Management* 255: 4021 – 4031.

Roberts, M. R. and Gilliam, F. S. (1995). Patterns and mechanisms of plant diversity in forested ecosystems: Implications for forest management. *Ecological Applications* 5: 969 – 977.

Sagar, R., Raghubansh. A. S. and Singh. J. S. (2003). Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management* 186: 61 – 71.

Sauer, J. and Abdallah, J. M. (2007). Forest diversity, tobacco production and resource management in Tanzania. *Forest Policy and Economics* 9(5): 421 – 439.

Schwartza, M. W., Carob, T. M. and Banda-Sakalac, T. (2002). Assessing the sustainability of harvest of *Pterocarpus angolensis* in Rukwa Region, Tanzania. *Forest Ecology and Management* 170: 259 – 269.

Sharma, N. P., Rowe, R., Openshaw, K. and Jacobson, J. (1992). World Forests in Perspectives. Kandall and Hut Publishers Company, Lowa. 132pp.

Sheil, D. (1999). Tropical forest diversity, environmental change and species augmentation after intermediate disturbance hypothesis. *Journal of Vegetation Science* 10: 851 – 860.

Slik, J. W. F., Kebler, P. J. A. and Van Welzen, P. C. (2003). *Macaranga* and *Mallotus* species (euphorbiaceae) as indicators for disturbance in the mixed lowland Dipterocarp forest of east Kalimantan (Indonesia). *Ecological Indicator* 2: 311 – 324.

Smiet, A. C. (1992). Forest ecology on Java: Human impact and vegetation of montane forest. *Journal of Tropical Ecology* 8:129 – 152.

State of British Columbia Forests (2006). Species Diversity. [http://www.for.gov.bc.ca/hfp/sof/] site visited on 12/5/2009.

Sukumar, R., Dattaraja, H. S., Suresh, H. S., Radhakrishnan, J., Vasudeva, R., Nirmala, S. and Joshi, N. V. (1992). Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, Southern India. *Current Science* 62(9): 608 – 616.

Susanne, S. (2000). Kenya Program Takes Hard Line on Hardwood Carvings. [http://www.fsc.org/ en/whats_new/news/news_notes/] site visited on 16/4/2009.

Swaine, M. D., Lieberman, D. and Hall, J. B. (1992). The effect of fire exclusion on Savannah vegetation at Kipong, Ghana. *Biotropica* 24 (2a): 166 – 172.

URT (2002). *Tanzania Census.* Government Printers, Dar es Salaam. 203pp.

Vanclay, J. K. (1993). Saving the tropical forest: Needs and prognosis. *Ambio* 22(4): 25 – 31.

Veltheim, T., Kijazi, M. and Killenga, R. (2002). *Participatory forest inventory of proposed Mfundia village forest reserve.* Government Printers, Dar es Salaam. 63pp.

Waisel, Y. (1971). Patterns of distribution of some xerophytic species in Negev, Israel. *Israel Journal* 20:101 – 110.

WCMC (1991). *Provision of Data on Rare and Threatened Tropical Timber Species.* Chapman and Hall Ltd., London. 58pp.

WCMC (1998). *Brachylaena huillensis*: 2008 IUCN red list of threatened species. [http://www.iucnredlist.org] site visited on 26/4/2009.

Whitmore, T. C. (1990). Introduction to Tropical Rainforests. [http://catalogue.nla.gov.au/Record/2067497] site visited on 10/5/2009.

Whitmore, T. C. and Sayer, J. A. (1992). Tropical Deforestation and Species Extinction. [http://www.geocities.com/mockturtl/forests] site visited on 14/4/2009.

Whitty, J. (2007). Animal extinction- the greatest threat to mankind. by the end of the century half of all spp will be extinct. [http://www.independent.co.uk/ environment/] site visited on 5/5/2009

Zahabu, E. (2001). Impact of charcoal extraction on the Miombo Woodlands: The case of Kitulangalo Area, Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 106pp.

APPENDICES

Appendix 1: Tree species checklist in Bombo west forest reserve

Spp code	Species names		Forest status/blocks		
	Local name	Botanical Name	Highly disturbed	Mild disturbed	Least disturbed
1	Bambara	*Hyphaene parvula*	√	√	√
2	Ganga	*Euphorbia quinquecostata*	√	√	x
3	Kiuwi	*Synadenium glaucescens*	√	x	x
4	Kikwata	*Acacia senegal*	√	x	x
5	Kipangasasu	*Cymomera sp*	√	√	√
6	Kitongachanyika	*Oncoba sp*	√	x	√
7	Kikulagembe	*Dischrostacys cinerea*	x	x	√
8	Mbambakofi	*Afzelia quanzensis*	x	√	x
9	Mbwewe	*Lecaniodiscus fraxinifolius*	√	√	x
10	Mcheji	*Manilkara sulcata*	√	√	√
11	Mdimudimu	*Satureja punctata*	√	√	√
12	Mdudu	*Thylachium africanum*	√	x	x
13	Mfuleta	*Albizia anthelmintica*	√	√	x
14	Mfumbili	*Lonchocarpus bussei*	x	√	√
15	Mgunga	*Acacia polycantha*	x	√	x
16	Mhafa	*Millettia dura*	√	√	x
17	Mhande	*Scorodophloeus fischeri*	√	√	√
18	Mhati/ mluwati	*Dombeya spp*	x	√	x
19	Mhukwi	*Diospyros mespiliformis*	x	√	x
20	Mjivujivu		√	x	x
21	Mkaga	*Manilkara sp*	x	x	√
212	Mkangala	*Strychnos madagascariensis*	√	x	√
23	Mkarambati	*Brachylaena huillensis*	√	√	√
24	Mkerefu	*Acacia schweinfurthii*	x	√	√
25	Mkingili	*Flacourtia indica*	√	x	√
26	Mkole	*Grewia goetzeana*	√	√	√
27	Mkombati	*Croton pseudopulchellus*	x	√	x
28	Mkombechi	*Trichocladus ellipticus*	√	√	√
29	Mkongodeka	Grewia forbesii	x	√	x
30	Mkwaju	*Tamarindus indica*	√	√	x
31	Mkwanguo/Mnguonguo	*Neoboutonia macrocalyx*	√	x	x
32	Mlama mweusi	*Combretum gueinzii*	x	√	x
33	Mlawa	*Canthium spp*	√	√	x

34	Mlenga	*Vernonia obeonica*	√	√	x
35	Mlimbolimbo	*Maytenus lancifolia*	√	x	√
36	Mnemela	*Milletia sacleuxii*	√	x	x
37	Mng'ombeng'ombe	*Setaria chevalieri*	√	x	√
38	Mntindi	*Cussonia spicata*	x	√	√
39	Mshaghashachole	*Tarenna nigrescens*	√	√	√
40	Mshashu	*Microglossa obliongifolia*	x	√	x
41	Mshofu/ Msofu	*Uvaria kirkii*	x	√	√
42	Msiga	*Dobera loranthifolia*	√	x	x
43	Msowezi	*Manilkara sp*	√	x	x
44	Msufimwitu		√	x	x
45	Msumarimwitu	*Terminalia sp*	√	x	x
46	Mtambakuzimu	*Deinbollia borbonica*	x	√	x
47	Mti mweusi		x	√	x
48	Mtonga	*Strychnos spinosa*	√	√	√
49	Mtula	*Solanum spp*	x	x	√
50	Mtusi	*Acacia sp*	√	√	√
51	Mbugwe	*Olinia usambarensis*	√	√	x
52	Muhoza/ mwoza	*Sterculia rhynchocarpa*	√	x	x
53	Muhula	*Syzgium quineense*	x	√	x
54	Mumbu	*Lannea schweinfurthii*	√	√	√
55	Munungu	*Zanthoxylun sp*	x	√	x
56	Muungunyika	*Erythrina sp*	x	√	x
57	Mungu-magoma	*Erythria abyssinica*	x	√	x
58	Mvumo	*Ficus natalensis*	√	x	x
59	Mvumowanyika	*Ficus sp*	√	x	x
60	Mwekea	*Combretum exalatum*	√	√	x
61	Mwimbiti	*Hymenodictyon floribundum*	√	x	√
62	Mzea/Mzezea	*Tarahonanthus comphorus*	√	√	x
63	Ngereza	*Euphorbia sp*	√	x	x

Appendix 2: Stand parameters of woody plants in the highly, mild and least disturbed areas in Bombo West forest reserve

(a) Highly disturbed forest area

Species name		Stand parameters		
Local names	Botanical names	N (stems ha^{-1})	G (m^2 ha^{-1})	V (m^3 ha^{-1})
Ganga	*Euphorbia quinquecostata*	1	0.004	0.022
Kikwata	*Acacia senegal*	3	0.033	0.177
Kipangasasu	*Cymomera sp*	15	0.133	0.789
Kitongachanyika	*Oncoba sp*	14	0.079	0.373
Kiuwi	*Synadenium glaucescens*	2	0.005	0.026
Mbugwe	*Olinia usambarensis*	2	0.007	0.028
Mbwewe	*Lecaniodiscus fraxinifolius*	2	0.003	0.011
Mcheji	*Manilkara sulcata*	29	0.128	0.566
Mdimudimu	*Satureja punctata*	24	0.122	0.577
Mdudu	*Thylachium africanum*	5	0.017	0.068
Mfuleta	*Albizia anthelmintica*	4	0.067	0.561
Mhafa	*Millettia dura*	1	0.009	0.048
Mhande	*Scorodophloeus fischeri*	41	0.903	6.372
Mhukwi	*Diospyros mespiliformis*	1	0.001	0.003
Mjivijivu		6	0.022	0.093
Mkangala	*Strychnos madagascariensis*	10	0.068	0.381
Mkarambati	*Brachylaena huillensis*	51	1.649	12.326
Mkingili	*Flacourtia indica*	8	0.062	0.365
Mkole	*Grewia goetzeana*	16	0.073	0.332
Mkombechi	*Trichocladus ellipticus*	1	0.001	0.002
Mkwaju	*Tamarindus indica*	1	0.004	0.019
Mkwanguo/mguoguo	*Pouteria alnifolia*	2	0.007	0.029
Mlawa	*Canthium sp*	2	0.010	0.040
Mlenga	*Vernonia obeonica*	2	0.004	0.013
Mlimbolimbo	*Maytenus lancifolia*	1	0.008	0.040
Mnemela	*Milletia sacleuxii*	1	0.001	0.002
Mng'ombeng'ombe	*Setaria chevalieri*	15	0.077	0.363
Mshaghashachole	*Tarenna nigrescens*	20	0.103	0.492
Msiga	*Dobera loranthifolia*	2	0.057	0.521
Msumarimwitu		3	0.060	0.587
Mtonga	*Strychnos spinosa*	6	0.021	0.097
Mtusi	*Acacia sp*	12	0.296	2.276
Muhoza/Moza	*Sterculia rhynchocarpa*	4	0.034	0.211
Mumbu	*Lannea amaniensis*	11	0.249	1.805
Mvumo	*Ficus natalensis*	1	0.003	0.016

Mvumowanyika	*Ficus sp*	2	0.004	0.018
Mwimbiti	*Hymenodictyon floribundum*	1	0.002	0.007
Mzea/Mzeza	*Tarahonanthus comphorus*	5	0.014	0.053
Ngereza/Mnyaa	*Euphorbia sp*	2	0.009	0.049
Total		**330**	**4.392**	**30.014**
(b) Mild disturbed forest area				
Bambakofi	*Afzelia quanzensis*	1	0.029	0.229
Bambara	*Hyphaene parvula*	2	0.011	0.064
Ganga	*Euphorbia quinquecostata*	10	0.136	0.808
Kikwata	*Acacia senegal*	1	0.001	0.002
Kipanguasasu	*Cymomera sp*	17	0.626	5.925
Mbugwe	*Olinia usambarensis*	1	0.001	0.005
Mbwewe	*Lecaniodiscus fraxinifolius*	1	0.009	0.052
Mcheji	*Manilkara sulcata*	6	0.032	0.035
Mdimudimu	*Satureja punctata*	12	0.053	0.266
Mfuleta	*Albizia anthelmintica*	1	0.014	0.078
Mfumbili	*Lonchocarpus bussei*	1	0.002	0.006
Mgunga	*Acacia polycantha*	2	0.022	0.1232
Mhande	*Scorodophloeus fischeri*	346	2.434	13.370
Mhati /Mluwati	*Dombeya sp*	18	0.058	0.290
Mkarambati	*Brachylaena huillensis*	33	0.957	7.682
Mkerefu	*Acacia schweinfurthii*	2	0.004	0.016
Mkole	*Grewia goetzeana*	33	0.452	2.910
Mkombechi	*Trichocladus ellipticus*	22	0.032	0.110
Mkwaju	*Tamarindus indica*	1	0.043	0.372
Mlama mweusi	*Combretum gueinzii*	3	0.037	0.243
Mlawa	*Canthium sp*	8	0.014	0.050
Mntindi	*Cussonia spicata*	3	0.047	0.371
Mnungumagoma	*Erythrina abyssinica*	1	0.0007	0.002
Mshaghashachole	*Tarenna nigrescens*	83	0.649	3.339
Mtambakuzimu	*Deinbollia borbonica*	2	0.002	0.006
Mtonga	*Strychnos spinosa*	4	0.018	0.077
Mtusi	*Acacia sp*	3	0.048	0.321
Muhula	*Syzgium quineense*	1	0.004	0.018
Mumbu	*Lannea amaniensis*	2	0.097	0.794
Muungunyika	*Erythrina sp*	1	0.036	0.303
Mwekea	*Combretum exalatum*	9	0.030	0.1652
Mzea /Mzeza	*Tarahonanthus comphorus*	13	0.192	1.222
Total		**643**	**6.091**	**39.253**

(c) Least disturbed forest area				
Bambara	*Hyphaene parvula*	3	0.097	0.793
Katongachanyika	*Oncoba sp*	7	0.045	0.230
Kikulagembe	*Dischrostacys cinerea*	2	0.064	0.486
Kipangasasu	*Cymomera sp*	30	0.419	2.680
Mcheji	*Manilkara sulcata*	33	0.161	0.729
Mdimudimu	*Satureja punctata*	22	0.110	0.557
Mhande	*Scorodophloeus fischeri*	56	1.097	7.564
Mkaga	*Manilkara sp*	1	0.003	0.012
Mkangala	*Strychnos madagascariensis*	20	0.109	0.536
Mkarambati	*Brachylaena huillensis*	62	2.833	22.196
Mkerefu	*Acacia schweinfurthii*	1	0.003	0.016
Mkingili	*Flocortia indica*	2.8	0.018	0.088
Mkole	*Grewia goetzeana*	13	0.091	0.448
Mkombechi	*Trichcladus elliptical*	1	0.002	0.008
Mlimbolimbo	*Maytenus lancifolia*	9	0.048	0.217
Mntindi	Cussonia spicata	2	0.016	0.098
Mshaghashachole	*Tarenna nigrescens*	28	0.181	0.883
Mtonga	*Strychnos spinosa*	6	0.027	0.126
Mtusi	*Acacia sp*	21	0.456	3.103
Mumbu	*Lannea schweinfurthii*	5	0.092	0.607
Mwimbiti	*Hymenodictyon floribundum*	2	0.008	0.033
Total		327	5.882	41.240

Appendix 3: Removed stock of woody plants in Bombo West forest reserve.

(a) Highly disturbed forest area

Species name		Stand parameters		
Local names	**Local names**	**N (stems ha^{-1})**	**G (m^2 ha^{-1})**	**V (m^3 ha^{-1})**
Mhande	*Scorodophloeus fischeri*	1	0.002	0.01
Mkarambati	*Brachylaena huillensis*	74	2.091	15.2
Mkingili	*Flacourtia indica*	2	0.004	0.02
Mtimweusi		1	0.004	0.02
Mtusi	*Acacia sp*	1	0.023	0.2
Total		**79**	**2.125**	**15.413**
(b) Mild disturbed forest area				
Kipangasasu	*Cymomera sp*	1	0.019	0.134
Mcheji	*Manilkara sulcata*	2	0.016	0.078
Mdimudimu	*Satureja punctata*	1	0.003	0.012
Mhande	*Scorodophloeus fischeri*	18	0.115	0.551
Mkarambati	*Brachylaena huillensis*	67	2.952	23.235
Mkombcchi	*Trichocladus ellipticus*	2	0.035	0.281
Mlimbolimbo	*Maytenus lancifolia*	2	0.011	0.057
Mshaghashachole	*Tarenna nigrescens*	5	0.064	0.367
Mumbu	*Lannea amaniensis*	1	0.0002	0.0004
Mzea/Mzea	*Tarahonanthus comphorus*	2	0.028	0.205
Total		**101**	**3.243**	**24.921**
(c) Least disturbed forest area				
Kipangasasu	*Cymomera sp*	6	0.188	0.712
Kitongachanyika	*Oncoba sp*	1	0.005	0.015
Mcheji	*Manilkara sulcata*	2	0.014	0.044
Mhande	*Scorodophloeus fischeri*	3	0.039	0.123
Mkarambati	*Brachylaena huillensis*	106	2.823	10.693
Mshaghashachole	*Tarenna nigrescens*	1	0.004	0.011
Total		**119**	**3.073**	**11.596**

Appendix 4: Regenerants of woody plants in the highly, mild and least disturbed areas in Bombo West forest reserve.

(a)Highly disturbed forest area

	Species names	
Local names	**Local names**	**N (seedlings per ha)**
Bambara	*Hyphaene parvula*	17
Kipangasasu	*Cymomera sp*	83
Kitongachanyika	*Oncoba sp*	33
Mcheji	*Manilkara sulcata*	2305
Mdimudimu	*Satureja punctata*	149
Mfuleta	*Albizia anthelmintica*	17
Mhafa	*Millettia dura*	17
Mhande	*Scorodophloeus fischeri*	4163
Mkangala	*Strychnos madagascariensis*	133
Mkarambati	*Brachylaena huillensis*	5025
Mkingili	*Flocortia indica*	17
Mkombechi	*Trichocladus ellipticus*	5191
Mkongodeka	*Grewia forbesii*	17
Mnemela	*Milletia sacleuxii*	1426
Mshaghashachole	*Tarenna nigrescens*	945
Msowezi		17
Mtimweusi		332
Mwekea	*Combretum exalatum*	216
Total		**20100**
(b) mild disturbed forest area		
Mhafa	*Millettia dura*	50
Mhande	*Scorodophloeus fischeri*	2090
Mhukwi	*Diospyros mespiliformis*	33
Mhati/Mluwati	*Dombeya spp*	66
Mkarambati	*Brachylaena huillensis*	481
Mkerefu	*Acacia schweinfurthii*	33
Mkole	*Grewia goetzeana*	17
Mkombati	*Croton pseudopulchellus*	133
Mkombechi	*Trichocladus ellipticus*	6202
Mkongodeka	*Grewia forbesti*	17
Mlawia	*Magnistipulia butava*	166
Mlenga	*Vernonia obeonica*	17
Mnungu	*Zanthoxylun sp*	33
Mshaghashachole	*Tarenna nigrescens*	1410

Mshashu	*Microglossa obliongifolia*	381
Mshofu/Msofu	*Uvaria kirkii*	17
Mti mweusi		149
Mtusi	*Acacia sp*	17
Muungumagoma	*Erythrina abyssinica*	66
Total		**11376**
(c) Least disturbed forest area		
Mcheji	*Manilkara sulcata*	1235
Mdimudimu	*Satureja punctata*	586
Mkarambati	*Brachylaena huillensis*	9722
Mkombechi	*Trichocladus ellipticus*	3395
Mlimbolimbo	*Maytenus lancifolia*	123
Mng'ombeng'ombe	*Setaria chevalieri*	62
Mshofu/Msofu	*Uvaria kirkii*	31
Mtula	*Solanum spp*	185
Mwimbiti	*Hymenodictyon floribundum*	62
Kipangasasu	*Cymomera sp*	62
Total		**15463**

Appendix 5: Stand parameters by diameter size classes of woody plants in the highly disturbed area in Bombo West forest reserve

Local name	Botanical name	Dbh size classes (cm)															Total		
		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Bambara/Bamba	*Hyphaene parvula*	1	0.002	0.009	1	0.016	0.109	0	0	0	0	0	0	0	0	0	1	0.019	0.118
Ganga	*Euphorbia quinquuecostata*	0	0	0	1	0.004	0.022	0	0	0	0	0	0	0	0	0	1	0.004	0.022
Kikwata	*Acacia senegal*	1	0.006	0.026	2	0.027	0.151	0	0	0		0	0	0	0	0	3	0.033	0.177
Kipangasasu	*Cymomera sp*	9	0.036	0.150	4	0.060	0.351	2	0.038	0.289	0	0	0	0	0	0	15	0.133	0.789
Kitongachanyika	*Oncoba sp*	11	0.046	0.193	3	0.033	0.180	0	0	0	0	0	0	0	0	0	14	0.079	0.373
Kiuwi	*Synadenium glaucescens*	1	0.002	0.010	1	0.003	0.016	0	0	0	0	0	0	0	0	0	2	0.005	0.026
Mbugwe	*Olinia usambarensis*	2	0.007	0.028	0	0	0	0	0	0	0	0	0	0	0	0	2	0.007	0.028
Mbwewe	*Lecaniodiscus fraxinifolius*	2	0.003	0.011	0	0	0	0	0	0	0	0	0	0	0	0	2	0.003	0.011
Mcheji	*Manilkara sulcata*	26	0.093	0.381	3	0.035	0.185	0	0	0	0	0	0	0	0	0	29	0.128	0.566
Mdimudimu	*Satureja punctata*	21	0.075	0.307	3	0.048	0.270	0	0	0	0	0	0	0	0	0	24	0.122	0.577
Mdudu	*Thylachium africanum*	5	0.017	0.068	0	0	0	0	0	0	0	0	0	0	0	0	5	0.017	0.068
Mfuleta	*Albizia anthelmintica*	1	0.006	0.026	1	0.008	0.055	1	0.011	0.068	0	0	0	0	0.041	0.412	4	0.067	0.561
Mhafa	*Millettia dura*	1	0.002	0.008	1	0.007	0.040	0	0	0	0	0	0	0	0	0	1	0.009	0.048
Mhande	*Scorodophloeus fischeri*	15	0.058	0.247	17	0.308	1.875	8	0.391	2.972	2	0.146	1.278	0	0	0	41	0.903	6.372
Mhukwi	*Diospyros mespiliformis*	1	0.001	0.003	0	0	0	0	0	0	0	0	0	0	0	0	1	0.001	0.003
Mjivijivu		6	0.018	0.072	0	0.004	0.021	0	0	0	0	0	0	0	0	0	6	0.022	0.093
Mkangala	*Strychnos madagascariensis*	8	0.027	0.106	1	0.018	0.107	1	0.023	0.169	0	0	0	0	0	0	10	0.068	0.381
Mkarambati	*Brachylaena huillensis*	10	0.033	0.135	20	0.439	2.818	17	0.927	7.17	3	0.210	1.813	1	0.040	0.390	51	1.649	12.326
Mkingili	*Flacourtia indica*	6	0.022	0.089	1	0.021	0.119	0	0.019	0.158	0	0	0	0	0	0	8	0.062	0.365
Mkole	*Grewia goetzeana*	14	0.051	0.212	2	0.022	0.120	0	0	0	0	0	0	0	0	0	16	0.073	0.332
Mkombechi	*Trichocladus ellipticus*	1	0.001	0.002	0	0	0	0	0	0	0	0	0	0	0	0	1	0.001	0.002
Local name	Botanical name	Dbh size classes (cm)															Total		

		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Mkwaju	*Tamarindus indica*	1	0.001	0.004	0	0.003	0.015	0	0	0	0	0	0	0	0	0	1	0.004	0.019
Mkwanguo/mnguonguo	*Neoboutonia macrocalyx*	2	0.007	0.029	0	0	0	0	0	0	0	0	0	0	0	0	2	0.007	0.029
Mlawa	*Canthium sp*	2	0.006	0.024	0	0.003	0.016	0	0	0	0	0	0	0	0	0	2	0.010	0.040
Mlenga	*Vernonia obeonica*	1	0.004	0.013	0	0	0	0	0	0	0	0	0	0	0	0	1	0.004	0.013
Mlimbolimbo	*Maytenus lancifolia*	1	0.004	0.016	0	0.004	0.024	0	0	0	0	0	0	0	0	0	1	0.008	0.040
Mnemela	*Milletia sacleuxii*	1	0.001	0.002	0	0	0	0	0	0	0	0	0	0	0	0	1	0.001	0.002
Mng'ombeng'ombe	*Setaria chevalieri*	12	0.042	0.175	3	0.035	0.188	0	0	0	0	0	0	0	0	0	15	0.077	0.363
Mshaghashachole	*Tarenna nigrescens*	16	0.055	0.229	4	0.048	0.262	0	0	0	0	0	0	0	0	0	20	0.103	0.492
Msiga	*Dobera loranthifolia*	0	0	0	0	0	0	1	0.020	0.167	1	0.037	0.353	0	0	0	2	0.057	0.521
Msumarimwitu		1	0.004	0.016	0	0.004	0.020	0	0	0	0	0	0	1	0.052	0.551	3	0.060	0.587
Mtimweusi		3	0.006	0.022	1	0.019	0.112	0	0	0	0	0	0	0	0	0	4	0.025	0.135
Mtonga	*Strychnos spinosa*	5	0.016	0.062	1	0.006	0.035	0	0	0	0	0	0	0	0	0	6	0.021	0.097
Mtusi	*Acacia spp*	3	0.016	0.072	6	0.077	0.437	1	0.062	0.491	1	0.140	1.277	0	0	0	12	0.296	2.276
Muhoza/Moza	*Sterculia rhynchocarpa*	2	0.009	0.035	1	0.010	0.061	1	0.015	0.115	0	0	0	0	0	0	4	0.034	0.211
Mumbu	*Lannea amaniensis*	1	0.008	0.039	7	0.124	0.768	1	0.072	0.553	0	0	0	1	0.044	0.444	11	0.249	1.805
Mvumo	*Ficus natalensis*	1	0.003	0.016	0	0	0	0	0	0	0	0	0	0	0	0	1	0.003	0.016
Mvumowanyika	*Ficus spp*	1	0.001	0.004	1	0.003	0.014	0	0	0	0	0	0	0	0	0	2	0.004	0.018
Mwimbiti	*Hymenodictyon floribundum*	1	0.002	0.007	0	0	0	0	0	0	0	0	0	0	0	0	1	0.002	0.007
Mzea/Mzeza	*Tarahonanthus comphorus*	5	0.014	0.053	0	0	0	0	0	0	0	0	0	0	0	0	5	0.014	0.053
Ngereza/Mnyaa	*Euphorbia sp*	1	0.002	0.009	1	0.006	0.040	0	0	0	0	0	0	0	0	0	2	0.009	0.049
Total		201	0.708	2.912	85	1.395	8.246	34	1.579	12.152	7	0.533	4.721	3	0.177	1.797	330	4.392	30.014

Appendix 6: Stand parameters by diameter size classes of woody plants in the mild disturbed area in Bombo West forest reserve

Local name	Botanical name	Dbh size classes (cm)															Total		
		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Bambakofi	*Afzelia quanzensis*	0	0	0	0	0	0	1	0.029	0.229	0	0	0	0	0	0	1	0.029	0.229
Bambara	*Hyphaene parvula*	1	0.001	0.002	1	0.010	0.062	0	0	0	0	0	0	0	0	0	2	0.011	0.064
Ganga	*Euphorbia quinquecostata*	2	0.016	0.072	7	0.090	0.496	1	0.030	0.240	0	0	0	0	0	0	10	0.136	0.808
Kikwata	*Acacia senegal*	1	0.001	0.002	0	0	0	0	0	0	0	0	0	0	0	0	1	0.001	0.002
Kipanguasasu	*Cynomera sp*	6	0.021	0.088	7	0.141	0.876	2	0.079	0.562	1	0.091	0.802	1	0.294	3.597	17	0.626	5.925
Mbugwe	*Olinia usambarensis*	1	0.001	0.005	0	0	0	0	0	0	0	0	0	0	0	0	1	0.001	0.005
Mbwewe	*Lecaniodiscus fraxinifolius*	0	0	0	1	0.009	0.052	0	0	0	0	0	0	0	0	0	1	0.009	0.052
Mcheji	*Manilkara sulcata*	5	0.026	0.006	1	0.006	0.029	0	0	0	0	0	0	0	0	0	6	0.032	0.035
Mdimudimu	*Satureja punctata*	10	0.031	0.122	1	0.005	0.025	1	0.017	0.118	0	0	0	0	0	0	12	0.053	0.266
Mfuleta	*Albizia anthelmintica*	0	0	0	1	0.014	0.078	0	0	0	0	0	0	0	0	0	1	0.014	0.078
Mfumbili	*Lonchocarpus bussei*	1	0.002	0.006	0	0	0	0	0	0	0	0	0	0	0	0	1	0.002	0.006
Mgunga	*Acacia polycantha*	1	0.004	0.014	1	0.018	0.109	0	0	0	0	0	0	0	0	0	2	0.022	0.123
Mhande	*Scorodophloeus fischeri*	259	0.914	3.790	78	1.094	6.249	8	0.345	2.636	1	0.081	0.696	0	0	0	346	2.434	13.370
Mhati /Mluwati	*Dombeya sp*	16	0.026	0.095	2	0.033	0.196	0	0	0	0	0	0	0	0	0	18	0.058	0.290
Mkarambati	*Brachylaena huillensis*	16	0.046	0.183	4	0.064	0.375	9	0.438	3.411	4	0.409	3.714	0	0	0	33	0.957	7.682
Mkerefu	*Acacia schweinfurthii*	2	0.004	0.016	0	0	0	0	0	0	0	0	0	0	0	0	2	0.004	0.016
Mkole	*Grewia goetzeana*	14	0.060	0.271	16	0.255	1.480	2	0.077	0.594	1	0.060	0.565	0	0	0	33	0.452	2.910
Mkombechi	*Trichocladus ellipticus*	22	0.032	0.110	0	0	0	0	0	0	0	0	0	0	0	0	22	0.032	0.110
Mkwaju	*Tamarindus indica*	0	0	0	0	0	0	0	0	0	1	0.043	0.372	0	0	0	1	0.043	0.372
Mlama mweusi	*Combretum gueinzii*	1	0.004	0.020	1	0.015	0.100	1	0.018	0.123	0	0	0	0	0	0	3	0.037	0.243
Mlawia	*Magnistipulia butava*	8	0.014	0.050	0	0	0	0	0	0	0	0	0	0	0	0	8	0.014	0.050
Mnlindi	*Cussonia spicata*	1	0.0002	0.0003	1	0.010	0.060	1	0.037	0.311	0	0	0	0	0	0	3	0.047	0.371
Mnungumagoma	*Erythria abyssinica*	1	0.001	0.002	0	0	0	0	0	0	0	0	0	0	0	0	1	0.001	0.002

Local name	Botanical name	Dbh size classes (cm)															Total		
		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Mshaghashachole	*Tarenna nigrescens*	49	0.194	0.824	34	0.455	2.515	0	0	0	0	0	0	0	0	0	83	0.649	3.339
Mtambakuzimu	*Deinbollia borbonica*	2	0.002	0.006	0	0	0	0	0	0	0	0	0	0	0	0	2	0.002	0.006
Mtonga	*Strychnos spinosa*	4	0.018	0.077	0	0	0	0	0	0	0	0	0	0	0	0	4	0.018	0.077
Mtusi	*Acacia sp*	1	0.004	0.014	1	0.020	0.122	1	0.024	0.184	0	0	0	0	0	0	3	0.048	0.321
Muhula	*Syzgium quineense*	1	0.004	0.018	0	0	0	0	0	0	0	0	0	0	0	0	1	0.004	0.018
Mumbu	*Lannea amaniensis*	0	0	0	0	0	0	1	0.055	0.430	1	0.042	0.363	0	0	0	2	0.097	0.794
Muungunyika	*Erythria spp*	0	0	0	0	0	0	1	0.036	0.303	0	0	0	0	0	0	1	0.036	0.303
Mwekea	*Combretum exalatum*	8	0.013	0.043	0	0	0	1	0.018	0.123	0	0	0	0	0	0	9	0.030	0.165
Mzea /Mzeza	*Tarahonanthus camphorus*	7	0.024	0.103	4	0.075	0.422	2	0.093	0.697	0	0	0	0	0	0	13	0.1918	1.222
Total		440	1.445	5.864	161	2.303	13.183	32	1.296	9.961	9	0.726	6.512	1	0.294	3.597	643	6.091	39.253

Appendix 7: Stand parameter by diameter size classes of woody plants in the least disturbed area in Bombo West forest reserve.

Local name	Botanical name	Dbh size classes (cm)															Total		
		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Bambara	*Hyphaene parvula*	0	0	0	1	0.019	0.112	1	0.023	0.170	1	0.056	0.510	0	0	0	3	0.097	0.793
Katongachanyika	*Oncoba sp*	6	0.023	0.098	1	0.022	0.132	0	0	0	0	0	0	0	0	0	7	0.045	0.230
Kikulagembe	*Dischrostacys cinerea*	0	0	0	1	0.005	0.026	1	0.059	0.460	0	0	0	0	0	0	2	0.064	0.486
Kipangasasu	*Cymonera sp*	14	0.063	0.268	12	0.179	1.056	4	0.177	1.356	0	0	0	0	0	0	30	0.419	2.680
Mcheji	*Manilkara sulcata*	28	0.101	0.41	5	0.059	0.315	0	0	0	0	0	0	0	0	0	33	0.161	0.729
Mdimudimu	*Satureja punctata*	19	0.058	0.224	3	0.053	0.333	0	0	0	0	0	0	0	0	0	22	0.110	0.557
Mhande	*Scorodophloeus fischeri*	16	0.076	0.336	27	0.463	2.776	12	0.377	2.864	2	0.182	1.589	0	0	0	56	1.097	7.564
Mkaga	*Manilkara sp*	1	0.003	0.012	0	0	0	0	0	0	0	0	0	0	0	0	1	0.003	0.012
Mkangala	*Strychnos madagascariensis*	17	0.063	0.262	3	0.045	0.275	0	0	0	0	0	0	0	0	0	20	0.109	0.536
Mkarambati	*Brachylaena huillensis*	4	0.020	0.085	15	0.303	1.891	34	1.724	13.050	8	0.710	6.404	1	0.077	0.766	62	2.833	22.196
Mkerefu	*Acacia schweinfurthii*	1	0.003	0.016	0	0	0	0	0	0	0	0	0	0	0	0	1	0.003	0.016
Mkingili	*Flacourtia indica*	2	0.011	0.047	1	0.007	0.042	0	0	0	0	0	0	0	0	0	3	0.018	0.088
Mkole	*Grewia goetzeana*	8	0.036	0.156	5	0.055	0.292	0	0	0	0	0	0	0	0	0	13	0.091	0.448
Mkombechi	*Trichocladus ellipticus*	1	0.002	0.008	0	0	0	0	0	0	0	0	0	0	0	0	1	0.002	0.008
Mlimbolimbo	*Maytenus lancifolia*	8	0.036	0.153	1	0.012	0.064	0	0	0	0	0	0	0	0	0	9	0.048	0.217
Mntindi	*Cussonia spicata*	1	0.004	0.019	1	0.012	0.079	0	0	0	0	0	0	0	0	0	2	0.016	0.098
Mshaghashachole	*Tarenna nigrescens*	21	0.101	0.444	7	0.080	0.439	0	0	0	0	0	0	0	0	0	28	0.181	0.883
Mtonga	*Strychnos spinosa*	5	0.021	0.089	1	0.007	0.036	0	0	0	0	0	0	0	0	0	6	0.027	0.126
Mtusi	*Acacia sp*	6	0.028	0.125	10	0.208	1.311	4	0.174	1.272	1	0.045	0.394	0	0	0	21	0.456	3.103
Mumbu	*Lannea amaniensis*	1	0.006	0.029	3	0.058	0.367	1	0.027	0.212	0	0	0	0	0	0	5	0.092	0.607
Mwimbiti	*Hymenodidictyon floribundum*	2	0.008	0.033	0	0	0	0	0	0	0	0	0	0	0	0	2	0.008	0.033
	Total	**161**	**0.664**	**2.818**	**96**	**1.587**	**9.546**	**57**	**2.562**	**19.214**	**12**	**0.993**	**8.898**	**1**	**0.077**	**0.766**	**327**	**5.882**	**41.241**

Appendix 8: Removed stand parameters by diameter size classes of woody plants in the highly disturbed area in Bombo west forest reserve

Local name	Botanical name	Dbh size classes (cm)															Total		
		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Mhande	*Scorodophloeus fischeri*	1	0.002	0.008	0	0	0	0	0	0	0	0	0	0	0	0	1	0.002	0.008
Mkarambati	*Brachylaena huillensis*	10	0.058	0.262	39	0.720	4.418	20	0.859	6.478	5	0.454	4.003	0	0	0	74	2.091	15.162
Mkingili	*Flacourtia indica*	1	0.001	0.0047	1	0.003	0.015	0	0	0	0	0	0	0	0	0	2	0.004	0.019
Mtimweusi		0	0	0	1	0.004	0.022	0	0	0	0	0	0	0	0	0	1	0.004	0.022
Mtusi	*Acacia sp*	0	0	0	0	0	0	0	0	0	1	0.023	0.201	0	0	0	1	0.023	0.201
	Total	12	0.061	0.275	41	0.727	4.455	20	0.859	6.478	6	0.477	4.205	0	0	0	79	2.125	15.413

Appendix 9: Removed stand parameter by diameter size classes of woody plants in the mid disturbed area in Bombo West forest reserve.

Local name	Botanical name	Dbh size classes (cm)															Total		
		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Kipangasasu	*Cymomera sp*	0	0	0	0	0	0	1	0.019	0.134	0	0	0	0	0	0	1	0.019	0.134
Mcheji	*Manilkara sulcata*	1	0.006	0.028	1	0.010	0.051	0	0	0	0	0	0	0	0	0	2	0.016	0.078
Mdimudimu	*Satureja punctata*	1	0.003	0.012	0	0	0	0	0	0	0	0	0	0	0	0	1	0.003	0.012
Mhande	*Scorodophloeus fischeri*	16	0.088	0.378	1	0.010	0.048	1	0.018	0.125	0	0	0	0	0	0	18	0.115	0.551
Mkarambati	*Brachylaena huillensis*	3	0.016	0.071	18	0.377	2.371	36	1.691	12.990	10	0.869	7.803	0	0	0	67	2.952	23.235
Mkombechi	*Trichocladus ellipticus*	1	0.001	0.003	0	0	0	1	0.034	0.278	0	0	0	0	0	0	2	0.035	0.281
Mlimbolimbo	*Maytenus lancifolia*	1	0.004	0.020	1	0.007	0.037	0	0	0	0	0	0	0	0	0	2	0.011	0.057
Mshaghashachole	*Tarenna nigrescens*	3	0.016	0.074	3	0.048	0.293	0	0	0	0	0	0	0	0	0	5	0.064	0.367
Mumbu	*Lannea amaniensis*	1	0.0002	0.0004	0	0	0	0	0	0	0	0	0	0	0	0	1	0.0002	0.0004
Mzea/Mzea	*Tarahonanthus comphorus*	1	0.003	0.011	0	0	0	1	0.026	0.195	0	0	0	0	0	0	2	0.028	0.205
Total		**28**	**0.137**	**0.598**	**23**	**0.451**	**2.799**	**40**	**1.787**	**13.720**	**10**	**0.869**	**7.803**	**0**	**0**	**0**	**101**	**3.243**	**24.921**

Appendix 10: Removed stand parameters by diameter size classes of woody plants in the least disturbed area in Bombo West forest reserve.

Local name	Botanical name	Dbh size classes (cm)															Total		
		1-10			10.1-20			20.1-30			30.1-40			>40					
		N	G	V	N	G	V	N	G	V	N	G	V	N	G	V	N	G	V
Kipangasasu	*Cymomera sp*	2	0.006	0.013	2	0.086	0.286	2	0.096	0.413	0	0	0	0	0	0	6	0.188	0.712
Kitongachanyika	*Oncoba sp*	0	0	0	1	0.005	0.015	0	0	0	0	0	0	0	0	0	1	0.005	0.015
Mcheji	*Manilkara sulcata*	1	0.003	0.006	1	0.012	0.039	0	0	0	0	0	0	0	0	0	2	0.014	0.044
Mhande	*Scorodophloeus fischeri*	1	0.007	0.017	2	0.032	0.106	0	0	0	0	0	0	0	0	0	3	0.039	0.123
Mkarambati	*Brachylaena hutllensis*	12	0.066	0.160	61	1.127	3.734	29	1.271	5.122	4	0.358	1.677	0	0	0	106	2.823	10.693
Mshaghashachole	*Tarenna nigrescens*	1	0.004	0.011	0	0	0	0	0	0	0	0	0	0	0	0	1	0.004	0.011
	Total	17	0.086	0.206	67	1.262	4.179	31	1.367	5.535	4	0.358	1.677	0	0	0	119	3.073	11.596

Appendix 11: Inventory forms

Date..................Recorder............... Forest Name...............District............... Name of stratum.....................Altitude......... Eastings...... .....Northing.......................Transect No............. Plot No.....................

(i) Data sheet for recording live trees and poles

Code	Local (Tribe)/ Botanical Name	DBH (Cm)	Code	Local (Tribe)/ Botanical Name	DBH (Cm)	Remarks

(ii) Data sheet for recording sampled trees and poles

Code	Local / Botanical Name	Basal Diameter (cm)	DBH (Cm)	Height(m)

(iii) Data sheet for recording Stumps (cut trees and poles)

Code	Local/Botanical Name	Trees	Poles	New cut	Old cut	Stumps Diameter (cm)	Stumps Ht(cm)	Possible uses

(iv) Data sheet for recording plant woody regenerants

Code	Local (Tribe)/ Botanical Name	Tally

Appendix 12: Questionnaires for household

A: General information

Village…………………Date………………Enumerator………………Name of the household head …………………Gender: .Male……Female………Age……….years

Education: (i) No formal education……….. (ii) Adult education…………… (iii) Primary education………….. (iv) Secondary education……….

B Farming system

1) What crops do you grow on your farm and specify whether grown for food, Cash or both?

2). How farms are prepared? (i) Clearing all vegetation …… (ii) Retaining a few trees

(ii) Burning…………..

3). Are you retaining some trees? (i) Yes…….. (ii) No……….

4). If yes mention species retained and give reason for retaining? …………………………..

Tree species retained	Reason for retaining

C Forest produce utilization

1). Where do you get your forest-based products and which forest?

Products	Public land	Forest reserve	Both
Firewood			
Charcoal			
Building poles			
Building timber			
Medicine			
Furniture			
Carvings			
Fodder			
Fruits			
Mushroom			
Others (specify)			

2) What kind of fuel do you use in your household? (i) Firewood………………………… (ii).Charcoal…………… (ii) Kerosene……………………..

3). If firewood and/or charcoal, which tree species, do you prefer to collect or burn respectively? Give reason for preference

(i)Tree species for firewood	**Reasons for preference**
(ii)Tree species for charcoal	

4). What type of wood do you collect? (ii). Dry............ (ii). Live ....

5). If live, which part of tree is cut? 1. Branches................2. Whole tree..........................

6). Which trees/shrubs and what parts of them do you use for medicine............................?

Tree for medicine	Stem	Bark	Roots	Leaves	Fruits

7) Where do you collect them? (i)Public land......... (2) Reserve................ (3) Both.........

8) Which trees/shrubs do you use for carvings? Give reason for preference

Tree species for making carvings	Reasons for preference

9). Where do you collect them? (1).Public land............ (2) Reserve.......... (3).Both.... ....

10). Which species do you use mostly in house construction? Give reason for preference

Tree species for house construction	Reason for preference

10). Where do you get material for construction of your houses? (i).Public land....... (ii).Reserve.......... (iii).Both public land and reserve....................

11). How often do you re-build your houses? ....years

12) Which tree species do you use to make domestic items?

Item	Tree species
Chairs /Tables	
Beds	
Walking sticks	
Tool handle	
Beehives	
Mortal and pestle	
Others (specify)	

13). Do you have your own-planted trees? Yes......... No...................

14) If yes, what did you planted for..?

15) Do you know these exploited species? Yes ...... No............

16) Does your household use these species for different purposes? (i)Yes........ (ii)No.......

17). If yes mention the uses

Exploited tree species	Uses

18). If you were told that these species are exploited, and they may go extinct, would you consider them more important? Yes..............No..............

19). If yes are you willing to use alternative species? Yes............No..........

20). Are you willing to plant then in your farms? Yes.........No......................

21). In your opinion what do you think are the most destructive activities to the forests?

(i) Pitsawing (ii) Mining, (iii) Medicinal plants collection (iv) Fire (v) Fuel wood collection, (vi) Grazing, (vii) Construction material cutting (viii) Non wood forest products collection (ix).Carvings (x). Charcoal (xi) others (specify)

22). Are aware of the *Brachylaena huillensis* tree species? Yes...........No............

23). What are the uses of *Brachylaena huillensis* tree species......................................?

24). What are the main threats of *Brachylaena huillensis* tree species.....................?

Appendix 13: Village and ward leaders' checklist

A. General information

Name of village............Ward.........District.........Total village population...............

Actively working adults: male .... female............Children (< 16 yrs)....................

Elders (> 60 yrs)...............Number of households......... Average family size..................

B. Socio- economic activities in the village

1).What is the main economic activities in the village

(i) Farming.................. (ii)Livestock keeping............ (iii)Pitsawing...........

(iv) Mining.......... Beekeeping............ Carvings............Charcoal making ....

2). How farms are cleared: (i) Burning......... (ii)Clear all vegetation......... (iii) Villagers leaving some few trees...............

3).Is farm size adequate? ....If not, why? ....

B. Forest produce utilization

1). Are local people aware of the exploited plant species? Yes............No.............

2). what are exploited tree species in Bombo west forest reserve? ....

3). what are diving forces for species exploitation? Mention for each item

(i)What are the driving forces for poles cutting? .... (ii) What are the driving forces for pitsawing? ....(iii) What are the driving forces for charcoal making? .... (iv)What are the driving forces for carving making? ....

4) What activities do you consider most detrimental to the forest reserve? ....

5). Are local people aware of the *Brachylaena huillensis* tree species? Yes............No.............

6) What are the uses of *Brachylaena huillensis* tree species? ....

7) What are the main threats of *Brachylaena huillensis* tree species?. ....

8) Are there any special conservation strategies for *Brachylaena huillensis* and forest in general?

9) Suggest any conservation strategies for *B. huillensis* and forest in general.......................

Appendix 14: Forest officers checklist

A. General information

Name of respondent.........................Sex.........Age...........Occupation.................

Education level (i) Primary education.............. (ii) Secondary education.........

(ii) Certificate in forestry........ (v) Diploma in forestry......... ... (vi)Higher education.........

B. Forest produce utilization

1) Are you aware on exploited plant species? Yes......No....

2) Is there exploited tree species in Bombo west forest reserve? Yes.............No.........

3) If yes, mention few..

4) How did you know they are exploited? ....

5) What are the main threats to plant species in Bombo West Forest Reserve? (Rank by priority)

(i)Poles and tree cutting........... (ii)Fire......... (iii) Debarking and uprooting (medicine)............... (iv) Grazing......... (v) Carving making........... (v) Charcoal making............ (vi) Others (specify)........................

6) What are the driving forces (i) for poles cutting? .... (ii) For pitsawing? .... (iii) For carving making? .... (iv) For charcoal making? .... (v) For pitsawing? ....

(7). What activities do you consider to be the most detrimental to the Bombo West forest reserve? ....

8). Are there any special strategies for exploited plant species conservation? Specify..............

9). Are you aware on *Brachylaena huillensis* plant species? Yes......No....

10).What the main uses of *Brachylaena huillensis*..

11).What is the main threats of *Brachylaena huillensis* tree species?...............

12).What is species associated with *Brachylaena huillensis* tree species and what are uses?........

13).Are there any special conservation strategies for *Brachylaena huillensis* and its associated plants? Specify..

14). Suggest any conservation strategy for *B. huillensis* and forest in general................