OPTIMISING SELECTED INCENTIVES FOR COMMUNITIES IMPLEMENTING JOINT FOREST MANAGEMENT IN CATCHMENT FOREST RESERVES IN ULUGURU AND UDZUNGWA MOUNTAINS, TANZANIA

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A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2013

ABSTRACT

Some Catchment Forest Reserves (CFRs) in Tanzania are managed in collabouration between the government and communities through Joint Forest Management Agreements (JMAs). In CFRs, harvesting of timber is strictly prohibited. This has led to minimal incentives for communities. To readdress this, optimisation of honey and carbon were considered to serve as compensation for the foregone timber benefits. The overall objective of the study was to examine means of optimising incentives for communities implementing Joint Forest Management (JFM) in CFRs. Two sites in Morogoro and Iringa regions were selected for the study. About 152 circular plots were sampled for ecological data which was analysed by Microsoft Excel. About 164 households were interviewed. Quantitative data was analysed using SPSS while the qualitative data were subjected to content analysis. Data for modeling were obtained within the ecological and socio-economic data sets and through rigorous literature review. Optimisation of incentives was done by Linear Programming using Microsoft Excel Solver. Stocking levels were higher in forests under JFM than forests without in both Iringa and Morogoro sites and the difference was statistically significant except in woodlands (p= 0.9049). FRs under JFM had slightly new disturbances than those without but the difference was not statistically signifancant (p=0.4752). The optimisation model revealed a return of USD 2 025 per year for Kimboza FR and USD 6 144 per year for NDU FR. Inclusion of illegally harvested wood in the model increased the profit to USD 29 286 per year for NDU FR. When labour was reduced, the profit further increased to USD 37 022 per year. These revenues were potential incentives for communities in forest conservation. Small returns in Kimboza were associated with small size of the forest (405 ha) which limited further analysis from the model. Sensitivity analysis revealed that forest size between 615 and 1 536 ha gives a solution where both honey and carbon are optimally produced. It was concluded that

maximizing incentives through carbon storage in CFRs is worth in forests with more than 615 ha. Therefore, care need to be taken during selection of CFRs to be included in JFM regime.

DECLARATION

I, Anthony Zozimus Sangeda, do hereby declare to the Senate of Sokoine University of Agriculture, that this thesis is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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ACKNOWLEDGEMENTS

This study benefited inputs from many people, to whom I owe special acknowledgement. I would wish to extend my sincere gratitude and appreciation to the Norwegian Programme for Development, Research and Education (NUFU) under the project "Assessing the impact of forestland tenure changes on forest resources and rural livelihoods in Tanzania" for funding this study. The project was implemented in cooperation between the Department of Forest Mensuration and Management, Sokoine University of Agriculture (SUA), Tanzania and the Department of Ecology and Natural Resource Management (INA), Norwegian University of Life Sciences (UMB), Norway.

I am very grateful to my supervisors Prof. George C. Kajembe (main supervisor), Prof. Emmanuel J. Luoga and Dr. Jumanne M. Abdallah of SUA and Prof. Ole Hofstad of INA, UMB for their scientific guidance. Their advice, constructive criticisms, commitments and encoragement throughout the study period were wonderful. I felt privileged and gifted to have worked under their leadership and learnt from their long experience. Similarly, many thanks are due to other project staff in Tanzania and Norway. Special thanks to Prof. Tron Eid, who organized the six months stay in Norway during proposal preparation and who facilitated my participation in Payment for Environmental Services course for PhD students in Copenhagen, Denmark. I also thank Prof. Rogers E. Malimbwi, Dr. Josiah Katani, Dr. Japhet Kashaigili, Dr. Gimbage Mbeyale and Dr. Eliakim Zahabu for their guidance and advice during the research period. Further, am grateful to Prof. Iddi Saidi for his editorial work and comments on the draft thesis.

Moreover, I owe special thanks to the Forestry and Bekeeping Division of the Ministry of Natural Resources and Tourism through the regional catchment offices in Morogoro and

Iringa and subsequently their District offices, Morogoro Rural and Kilolo for giving me a permission to conduct research in their FRs. Thanks are also due to District Executive Directors of Kilolo and Morogoro Rural districts for allowing me to interview local communities in the villages under their jurisdiction. I appreciate the cooperation given by the Kilolo District Forest Officer Mr. Godfrey Mwita and Mama Mwasha, the Morogoro Rural District Cacthment Forest Manager. The work wouldn't have been fulfilled in the villages without the support of leaders in Kibangile and Changa villages in Morogoro Rural District and those of Kidabaga and Luhindo in Kilolo District. The research assistants Theodory Lucas and Aurelian Mhanje and the forest inventory crew in the study villages deserve special thanks for their tireless efforts of going up and down the mountains and villages for data collection.

I also remain indebted to my beloved wife. Catherine. my sons Paul. Gratian and Gasper and my daughters Anthonia and Gloria for their patience, inspiration and prayers during the study. They gracefully accepted my long absence while I was in Norway, Denmark and in the field.. Last but not least, I thank the Almighty GOD for the gift of life and good health for the entire period of this study; thank you LORD!

DEDICATION

This thesis is dedicated to my parents, the late Zozimus Sangeda (*rest in peace*) and Dionatha Felix Sanduku who turned my youth in favour of education. To my beloved wife Catherine, who always encouraged me to work hard and withstood my long absence and long working hours in office, and finally to my children Paul, Anthonia, Gloria, Gratian and Gasper for the opportunity cost they incurred due to my tight schedules.

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LIST OF ABBREVIATIONS

CBFM	Community Based Forest Management
CBOs	Community Based Organizations
CCAR	California Climate Action Registry
CCIAM	Climate Change Impacts, Adaptation and Mitigation
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CFRs	Catchment Forest Reserves
DAWASCO	Dar es salaam Water and Sewerage Corporation
DCFM	District Catchment Forest Manager
EAMCEF	Eastern Arc Mountains Conservation Endowment Fund
EC	European Commission
EPWS	Equitable Payment for Water Services
ES	Ecological services
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FBD	Forestry and Beekeeping Division
FGDs	Focus Group Discussions
FRA	Forest Resources Assessment
FRs	Forest Reserves
GAMS	General Algebraic Modeling System
GHGs	Green House Gases
GPS	Global Positioning System
Ha	Hectares
HIMA	*Hifadhi Mazingira*

IET	International Emissions Trading
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	World Conservation Union
JFM	Joint Forest Management
JI	Joint Implementation
JMAs	Joint Management Agreements
KL	Kisinga Lugalo
KL FR	Kisinga Lugalo Forest Reserve
LP	Linear Programming
LPs	Linear Progammes
MEMA	*Matumizi Endelevu ya Misitu Asilia*
MJUMITA	*Mtandao wa Jamii wa Usimamizi wa Misitu Tanzania*
MNRT	Ministry of Natural Resources and Tourism
MVIWATA	*Mtandao wa Vikundi vya Wakulima Tanzania*
NAFORMA	National Forest Resource Monitoring and Assessment
NDU	New Dabaga Ulongambi
NDU FR	New Dabaga Ulongambi Forest Reserve
NEMA	National Environmental Management Act (in Uganda)
NGOs	Non Governmental Organizations
NOK	Norwegian Kroner
NORAD	Norwegian Agency for Development Cooperation
NRs	Nature Reserves
NSGRP	National Strategy for Growth and Reduction of Poverty
NSW	New South Wales
NTFPs	Non Timber Forest Products

NUFU	Norwegian Programme for Development. Research and Education
OTC	Over the counter (market for carbon offsets)
PBWO	Basin Water Office
PES	Payment for Environmental/Ecological Services
PFM	Participatory Forest Management
PMO-RALG	Prime Minister's Office, Regional Administration and Local Government
PRA	Participatory Rural Appraisal
REDD	Reduced Emissions from Deforestation and Forest Degradation
REDD+	REDD (plus conservation and enhancement of carbon stock)
RGGI	Regional Greenhouse Gas Initiative
RHS	Right hand side
SADC	Southern African Development Co-operation
SIDA	Swedish International Development Cooperation Agency
SNAL	Sokoine National Agricultural Library
SPSS	Statistical Package for Social Sciences
SRS	Stratified Random Sampling
SUA	Sokoine University of Agriculture
TAFORI	Tanzania Forestry Research Institute
TANAPA	Tanzania National Parks Authority
TANESCO	Tanzania Electric Supply Company
tCO_2e	Tonne of carbon dioxide equivalent
TEV	Total Economic Value
TFCG	Tanzania Forest Conservation Group
TFS	Tanzania Forest service
TROFIDA	Tropical Forest Inventory Data Analysis Package

TZS	Tanzanian Shillings
UK	United Kingdom
UMB	Norwegian University of Life Sciences
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
US	United States
USD	United States Dollar
VERs	Verified Emissions Reductions
VLFRs	Village Land Forest Reserves
VNRCs	Village Natural Resource Committees
WMAs	Wildlife Management Areas
WTA	Willingness to Accept
WTP	Willingness to Pay
WWF	Worldwide Fund for Nature

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Globally, forests provide a wide range of benefits supporting human life (Myers *et al.*, 2000; FAO, 2003). Beside wood, they also provide economically important products and services (Myers, 1997; Michie *et al.*, 1999; Mather, 1999; Pearce, 2001), which are enjoyed at international, national and local levels (MNRT, 2001a). Direct benefits from forest products constitute of use values such as woodfuel, building poles, timber and non-timber forest products including wild foods (fruits, roots), honey, fodder and services like recreation (Balmford *et al.*, 2002). Indirect benefits from forest-based products entail non-consumptive use, option and existence values (Emerton, 1996). Forests provide vital indirect benefits in terms of ecological services, which protect natural and human resources. They act as carbon sinks and provide watershed services vital for human and animal survival, industry and energy production (Guthiga and Mburu, 2006; Zahabu, 2008). According to Prahbu *et al.* (1998), natural assets with such values need to be managed wisely in accordance to the criteria of sustainable management as also indicated by Diemer and Alvarez (1995); Sinclair and Smith (1999); Kearney *et al.* (1999). These criteria include contribution of forest resources to global carbon cycles, biological diversity, ecosystem health and vitality, production functions, environmental and conservation functions and socio-economic benefits (Sinclair and Smith, 1999). Ritual forests had also been used for worshiping and other traditional activities. Such forests have been sustainably conserved in fear of ancestors and cultural values of the society (Msuya, 2010). As such there is a move towards involvement of various stakeholders in forest management in Tanzania and elsewhere to meet these criteria.

For several decades, the government assumed the role of the manager and owner of the natural forests with the belief that it would control the use of the resources so that social benefits would be maximised while conserving the resource base (MNRT, 2001a). The government thought to have necessary machinery and muscles to control behaviour of the public in the use of the resources, ensure equity on benefits accruing from forest products and take punitive measures against those who do not comply with the rules, regulation and procedures. The government role on behalf of the public at large has been tested and found ineffective (Holme, 1995; Adams and Hulme, 2001; Brown, 2002).

Many challenges have emerged in surveillance and policing vast areas of forests. This requires substancial resources in terms of funds, personnel and equipment, all of which have not been available as expected. This has resulted in very minimal surveillance and policing in the country, explaining to a great extent the ineffectiveness of the government as sole manager and owner of national forests (MNRT, 2001b). It is obvious that the management of natural forests including CFRs by the government alone has been ineffective. Therefore, the importance of sharing forest management responsibilities with various stakeholders is generally accepted (URT, 1998; Wily, 1999; Mniwasa and Shauri, 2001; URT, 2002).

Participatory forest approaches have been adopted in response to the widespread view that fortress approaches have failed to halt the decline in forest areas in the country as in many other parts of the world. Yet the perspectives on the role of the forest for the society have changed and broadened considerably as a consequence of social, economic, environmental, cultural and political changes (Wily, 1999). Donor supported projects such as "*Hifadhi Mazingira*" (HIMA) in Iringa region, Land Management Programme (LAMP) in Manyara region and other international conservation initiatives like the Rio, United

Nations Conference on Environment and Development have also greatly influenced initiation of participatory natural resources management programmes (Wily, 1999).

The paradigm shift in forest management from the state to local communities or jointly with local communities is reflected in most natural resource management policies and acts such as the National Forest Policy of 1998, Wildlife Policy of 2007 and the Forest Act of 2002 (URT, 1998; Shauri,1999; URT, 2002). The emerged Participatory Forest Management (PFM) includes Joint Forest Management (JFM) and Community-Based Forest Management (CBFM) (URT, 2002). PFM is being regarded as an effective strategy to provide local communities' livelihoods, in terms of environmental services and products (MNRT, 2003a). Consequently, the idea of sharing responsibilities, costs and benefits in a forest management in the form of JFM and CBFM is underscored in the National Forest Policy of 1998 (URT, 1998).

JFM is collaborate management approach which divides forest management responsibilities and returns between the forest owner (usually central or local government but occasionally the private sector) and forest adjacent communities. It takes place on land reserved for forest management such as National Forest Reserves and Local Government Forest Reserves or Private Forest Reserves. It is formalized through the signing of Joint Management Agreements (JMAs) between village representatives and the Government (District Council, Ministry of Natural Resources and Tourism) or private company (Kajembe *et al.*, 2008). The CBFM takes place in forests on 'village land' (land which has been surveyed and registered under the provisions of Village Land Act No.5) and managed by the village council (URT, 1999). Under CBFM, villagers take full ownership and management responsibility for an area of a forest within their jurisdiction and is 'declared' by a respective village and district council as a Village Land Forest Reserve (VLFR)

(URT, 2002). Following bylaws established under the VLFR, villagers can harvest timber and other forest products, collect and retain forest royalties and undertake patrols including arresting and fining offenders and are allowed to keep the fines and revenue from sale of logs and other forest products which act as incentives for conservation.

Michaelsen (1983) defines incentive as a stimulus to encourage a particular form of behaviour which benefits either an individual, society, or both, usually the ultimate goal being the society. Incentive is also defined as a specific inducement designed and implemented to influence government bodies, business, NGOs, or local people to conserve natural resources in a sustainable manner (Emerton, 1999). Kajembe *et al.* (2004) define incentive as anything that incites, motivates or influences forest stakeholders to practise sustainable forest management. The latter definition is adopted for this study because it is more relevant. Disincentive works in the reverse by either affecting benefits or costs of alternative actions open to economic agents, with the effect of influencing their behaviour in a way that is more favourable to the environment than in their absence. Incentives allow a freedom to respond to certain stimuli in a most beneficial way. It is that freedom of choice that makes incentives different from command and control instruments. In this sense, incentives are sometimes referred to as "market-based instruments" or "economic instruments" (NEMA, 2001).

1.2 Problem Statement and Study Justification

1.2.1 Problem Statement

Catchment Forest Reserves in Tanzania supply a number of goods and services (MNRT, 2003a). First, CFRs supply direct use goods to local populations, such as timber, firewood, honey, poles, animal fodder, fruits, vegetables, foods, weaving materials, nuts, wildmeat and medicines. Second, CFRs provide environmental services such as stabilisation of water flows, soil erosion control, biodiversity conservation, and carbon sequestration (Pattanayak, 2004). These forests also attract tourist interests and revenues. Thirdly, non-use values such as existence value are also attached to CFRs (Emerton, 1996). These interests and the groups in which they are vested, are often conflicting (MNRT, 2003b). For example, extraction of NTFPs may be unsustainable and reduce the capacity of CFRs to supply environmental services or to attract tourism.

In Tanzania, Catchment Forest Reserves are managed for water discharge, biodiversity and soil conservation. Some of them are managed through JFM where communities are given limited rights with a number of management responsibilities. JMAs allow them to utilize certain NTFPs. Harvesting of timber and other valuable wood products for domestic and commercial purposes are strictly prohibited. In this way, local communities under JFM are considerered as 'rightful beneficiaries' rather than 'logical source of authority and management' which in most cases the latter rests with the government (Wily, 1998). This is a disincentive to the local communities. According to Wily and Mbaya (2001), the incentive for local communities to manage forest sustainably, is the sense that the forest belongs to them, either as recognized managers, or better still, as the recognized owners. Malimbwi (2002) and Kiss (2004) reported problems including lack of incentives for communities participating in JFM. Tanzania is implementing JFM with varying degrees of success (MNRT, 2001a), yet, in many cases the institutional aspects, incentive system, benefit and cost sharing mechanisms for such management regime are inadequately defined, a feature which threatens its sustainability (Kearney *et al.*, 1999; MNRT, 2003b). Meanwhile, devising mechanisms, which combine not only the diverging interests of key actors involved (international community, forestry department and local communities) but also which take into account various aspects of JFM (economic, institutional, financial, social, cultural and ecological) is a challenging task.

Divergence has been there since PFM was established and still exists within the Government of Tanzania, in terms of attitudes towards local use of CFRs. The JFM process has been positively received by local people. However, the establishment procedures take time and progress in terms of implementation has been rather slow (Kajembe *et al.*, 2004). Local communities need to see greater returns to their efforts in protecting and managing CFRs. This is a major challenge that need to be addressed. Unless local people are given rewards and incentives for their efforts, the JFM process could be halted in its tracks before it has gained momentum (Kajembe and Kessy, 2000). Tourism, even with effective revenue sharing schemes, is unlikely to provide such incentives on its own. Currently, the main problem with JFM is lack of incentives for local communities to participate in controlled, environmentally sound management of CFRs. It is therefore important to consider the strength and legitimacy of these various interests and to search out policy instruments that can provide adequate incentives for profitable forest management.

JFM experiences from various countries have shown that weak incentives for local forest users are a primary cause of the high failure rate of JMAs (Meshack and Raben, 2005). The government of Tanzania has entered into JMAs with communities to conserve CFRs. However, the strength of JMAs is subject to the level of benefits derived from resource use and its contribution to local livelihoods. This in turn, determines the level of motivation to fulfil obligations as laid out in JMAs. Currently, benefits which are granted to local communities as stipulated in the JMAs are too trivial to serve as incentives for active participation, a view which was also echored by Kajembe and Kessy (2000). The net result is the collapse of agreements and a spread of disturbances (Meshack and Raben, 2005).

Experience has also shown that under the current legal framework, implementing JFM in CFRs is increasingly constrained by the protective status of the forests, which absolutely restricts harvesting options and therefore limits opportunities for the local communities to earn cash income (Meshack and Raben, 2005). Furthermore, catchment ecosystem services are not yet qualified for sale. A number of studies (Pfliegner and Moshi, 2005; MNRT, 2006b; Bromley and Ramadhani, 2007; Kajembe *et al.*, 2008; Lugandu, 2010) have attested to the reality that communities are not willing to continue investing their time in JFM where the costs seem to be higher than benefits.

Some mechanisms to optimise incentives in JFM for forest adjacent communities in Tanzania have been discussed (MNRT, 2009) but are not well studied and implemented. Until recently, there are very few beneficiaries of ecological services in Tanzania paying the service providers (local communities). This leads to low incentives to conserve forests. Some efforts to pay for watershed services (DAWASCO and Coca cola Company in Dar es salaam) have been piloted in Wami-Ruvu River basin with Kibungo Juu ward through Equitable Payments for Watershed Services (EPWS), a project implemented by CARE and WWF in the Uluguru Mountains. Carbon payments through REDD+ has also been piloted in Kilosa and Kilwa by Tanzania Forest Conservation Group (TFCG). However, these pilots are small in scale and rely on donor support. According to Bond *et al.* (2009), one possible solution is to create markets or market-like systems that internalise the costs and benefits of supplying environmental services. This study therefore takes up the challange to develop an optimisation model based on sale of carbon (a potential ecological incentive provided by CFRs) and honey (as the most commercialized NTFP in the study area).

1.2.2 Study Justification

The Tanzania National Strategy for Growth and Reduction of Poverty (NSGRP) has an operational target and cluster strategy that states: "Scale up PFM in all districts. as a mechanism for increasing income to rural communities" (URT. 2005: MNRT. 2008). The scaling up will not be viable unless mechanisms to optimise incentives for communities are in place. Some forest policy statements, particularly statement number 39, stipulate the need to promote incentives for local communities in managing forest resources especially in CFRs. There has. however, been a growing dissatisfaction expressed with respect to the long term future of JFM. This is because the final decision regarding sharing of benefits from JFM has yet to be reached in Tanzania. Ideas that were tabled by the Ministry of Natural Resources and Tourism to the Ministry of Finance and Economic Planning with regards to revenue sharing with forest adjacent communities are still pending. However. with lauching of Tanzania Forestry Service (TFS) in July, 2011, the problem of benefit sharing with local communities might be revisited. Lack of clear and binding agreement on how forest benefits and revenues should be shared normally results in dissatisfaction among the local communities. The uncertainty regarding benefit sharing has meant that until 2008. only about 155 out of 863 JMAs have been signed (URT, 2008). The number of signed agreements is only 18 percent (less than quarter) of the total number of villages implementing JFM. This is a clear limitation with regards to scaling up the approach in the absence of an incentive mechanism.

Furthermore, the study coincides with MNRT/FBD review process of the 1998 National Forest Policy. The Policy is silent on the use of market based innovative funds from ecological services, commonly known as 'Payment for Environmental Services' (PES), which is appreciated in many parts of the world including Latin America as a source of financial incentives for conservation (Mayrand and Paquin, 2004; Bond *et al.*, 2009). This study is expected to provide information that can contribute to the debate of the national forest policy review.

1.3 Study Objectives

1.3.1 Overall objective

The overall objective of the study was to examine means of optimising incentives for forest adjacent communities implementing JFM in CFRs in the Uluguru and Udzungwa Mountains, Tanzania.

1.3.2 Specific objectives

The specific objectives were to:

i) Identify existing and potential incentives for communities participating in JFM regime in the study area.
ii) Compare stocking and forest disturbance levels between forests with and without JFM regime in the light of incentives and disincentives.
iii) Assess existing institutional arrangements in implementing JFM in catchment forest reserves.
iv) Develop an optimisation model of incentives for communities implementing JFM in catchment forest reserves.

1.4 Research Questions

i) What are the existing and potential incentives in catchment forest reserves under JFM regime?
ii) What are the levels of stocking and forest disturbance between JFM and non JFM forest reserves in the study area?

iii) How effective are the implementation modalities in JFM? Are the JMAs effective? Are the rules working?

iv) Which model can generate optimal incentives in catchment forest reserves when combining carbon and honey production?

1.5 Conceptual Framework

This study was guided by a conceptual framework (Fig. 1) adopted and modified from FAO (1997). The interactions between resource, community and rules, the incentives and their impact on the resource base are illustrated. The model starts with JFM in CFRs. The reserves contain forest ***resources*** which are managed through a set of ***rules*** by ***communities***. These are three key components (resource, community and rules) and each one has its own characteristics. These characteristics create incentives for behaviour that leads people to make certain choices which in turn result in positive or negative outcomes on the resource base. The downward arrows trace the development of the process while the upward arrows are reminders that these outcomes may create further changes in the characteristics of the resource, the community and the rules. For example, unsustainable outcomes may result in resource shortages and scarcity. Inequitable outcomes may result in conflict which may change characteristics of the community. Also, inefficient use may cause community to change certain rules that govern resource use. Therefore, the system is evolving and constantly changing with time. Since the elements of the framework are interactive, in real world, the analysis may not necessarily follow the sequential order as depicted by Fig. 1.

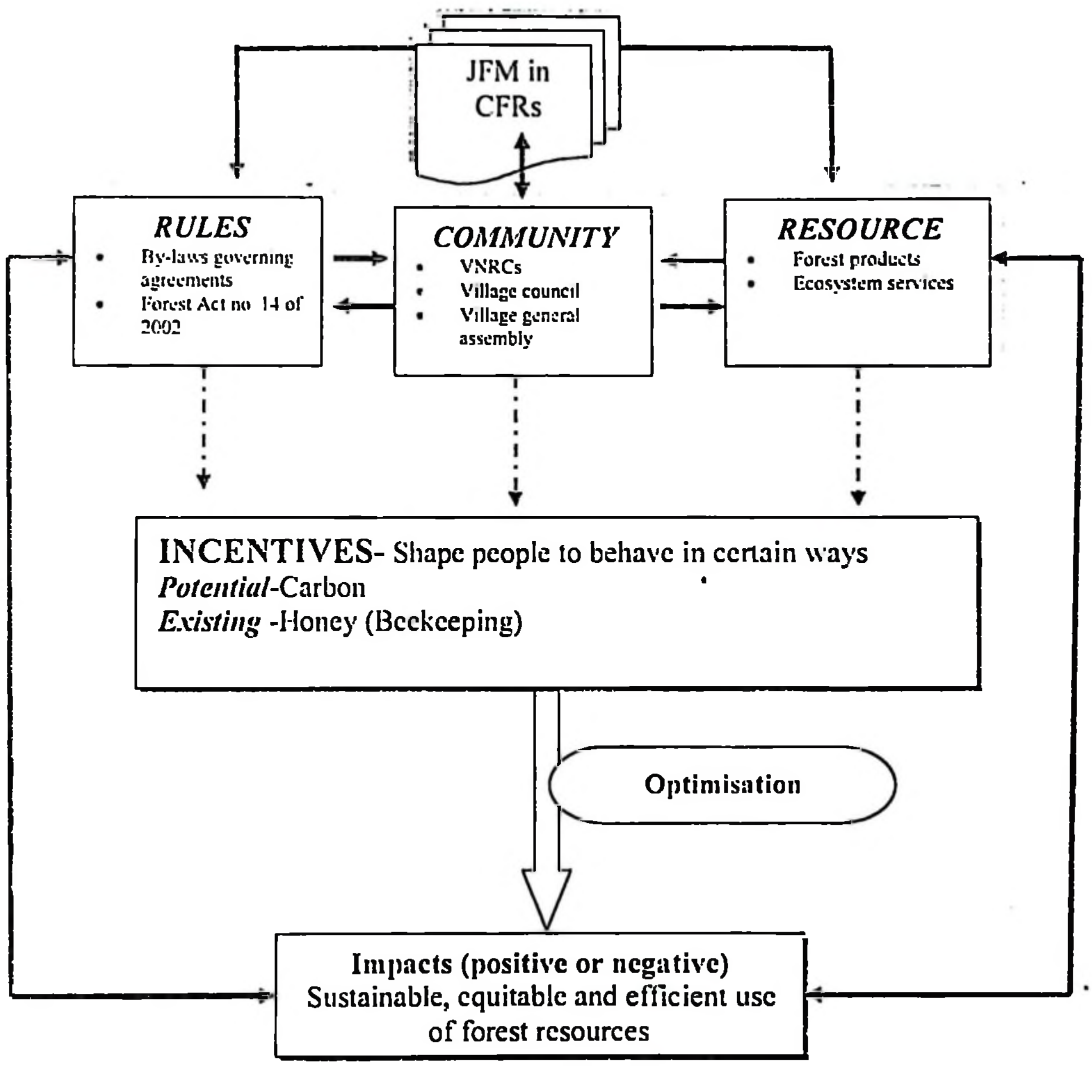

Figure 1: A Conceptual framework showing interactions between rules, community, forest resource, incentives and their impacts.

Source: Modified from FAO (1997)

1.6 Limitations of the Study

1.6.1 Difficulties in estimating carbon sequestration rate

Carbon sequestration rate could not be estimated based on biomass difference because it required baseline and trend data. A lesson learnt from Zahabu (2008) was that calculating biomass difference for two consecutive years in natural forests ended up with wrong estimates due to slow growth rate of natural forests. Very small errors in measurements led to negative difference meaning that trees were shrinking instead of growing, something that was abnormal under normal circumstances. To solve this problem, amounts of carbon stored were used instead of amount sequestered.

1.6.2 Low GPS accuracy

During forest inventory, GPS accuracy was low in cloudy days for plots with heavy canopy cover. The low accuracy led to delays in locating sample plots. In plots where GPS accuracy was very low, distance measurements (using manila ropes) were used insteady to arrive to the next plot while maintaining the transect line using a compass.

1.6.3 Unsatisfactory empirical data in model building

In model building, field data alone could not be satisfactory. For example, it was difficult to quantify all coefficients of the model constraints. To solve this problem, secondary data from literature were used.

1.6.4 Difficulties in obtaining Analytical Software

Difficulties in obtaining suitable analytical software for optimisation delayed results for objective four. A vigorous literature search and networking at a later stage helped to secure a suitable technique and software (Microsoft Excel Solver) which solved the problem.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This chapter starts with a general review of forest resources in the country, followed by description of historical background of forest ownership and management in Tanzania. The chapter also reviews studies that value catchment goods and services and show the current threats to these ecosystems. It reviews various stakeholders in the management and conservation of forests with their conflicting interests. This chapter goes further to identify some management costs and possible areas where income can be generated. Literature on incentives including payments for environmental services, their limitations and markets for such services and various optimisation techniquees and modelling tools were also reviewed.

2.2 Forest Resources in Tanzania

Tanzania has a total area of 94.7 million ha out of which about 94% are covered by landmass and the rest is inland water bodies (FRA, 2010). Formal management of forests in the country was initiated towards the end of the nineteenth century (1890) when the importance of conserving water sources was noted by the Germans. Between 1890 and 1920, efforts were made to reserve as many forests as possible. This brought about reservation of a chain of mountain forests in the northern and southern parts of the country with a total of 0.5 million ha (Hermansen *et al.*, 1985). The British administration (1920-1961) followed up by protecting more catchment and other forests, bringing the total reserved areas into 1.3 million ha.

After independence in 1961, efforts were made to re-survey and demarcate old forest reserves while new ones were gazzetted. Current statistics show that the country has a total of 33.4 million ha of forestland. 11.6 million ha of other wooded lands (FRA, 2010). Forests on General Land are 'open access', characterized by insecure land tenure and hence subject to unsustainable shifting cultivation, annual wild fires, harvesting of wood fuel, poles and timber and heavy pressure for conversion to other competing land uses including agriculture, livestock grazing, settlements and industrial development. It is estimated that, net loss of forestedland is at 403 328 ha per year and about 328 202 ha per year in other wooded lands (FRA, 2010). Efforts towards forest reservation aim at reversing this trend. However, assessment of different forests' condition have revealed a lot of human disturbances including encroachment on forest areas through illegal mining, pit-sawing, illegal harvesting for building materials, firewood collection and medicinal collection (Frontier-Tanzania, 2005; FBD, 2005; Malimbwi *et al.*, 2005a). Therefore, not only forests in General Land are diminishing but also the condition of reserved forests is deteriorating.

2.3 Historical Background of Forest Ownership and Management in Tanzania

Before colonialism in Tanzania, most land including forested land was common property, and was owned and utilized by members of well-defined groups, such as tribes, inhabitants of one village, families or clans. Management of these resources was governed by traditional or customary laws. Water catchments were sustainably managed by the use of traditional taboos and myths.

Given the fact that the northern and eastern part of the country was heavily forested, the gazzetted forests extended from Manyara to Mbeya with approximately area of 5000 km^2. The protected areas included, Nou, Marang, Ngorongoro, Monduli, Mt. Meru, Mt.

Kilimanjaro, and the Eastern Arc Mountains in Kilimanjaro, Tanga, Morogoro and Iringa regions (Msangi, 1986).

The Land Ordinance of 1923 defined and regulated land tenure in Tanganyika, declaring all land occupied and unoccupied as public land. The control and adjudication of such land was vested in the colonial governor. During British rule, the Forest Ordinance of 1957 reinforced central government's exclusive control of all forest resources including catchments, and did not recognize traditional rights to use forest resources by villagers living around the the reserves. Village councils were not designated as local authorities and were not consulted during the granting of licenses to harvest forest resources. Consequently, forest resources were regarded as alien and belonging to the British government. It is during this time when all reserved forests were commonly called '*misitu ya bibi*' which means "forests belonging to the Queen" meaning Queen Elizabeth. From this time local communities had little interest in sustainable forest management (MNRT, 2003).

2.4 Total Economic Value of Forests

2.4.1 Overview

The Total Economic Value (TEV) of a forest is the sum of discounted benefit streams stemming from extracted forest products and environmental services (use values), and non-use values (Turner *et al.*, 1994). Use values are those values derived from the benefits people gain from using the forest resources (Emerton, 1996). These are classified further into direct and indirect use values (Fig. 2). Direct use values arise from consumption of the resource, for example fuelwood and honey. Indirect use values refer to the ecological service benefits generated by a forest. People benefit from these but they do not directly consume them. Such values include things like carbon sequestration and biodiversity conservation.

According to Emerton (1996), non use values are important to people even though the resource is not directly or indirectly used. Non use values include the bequest value and existence value. Bequest value refers to the preservation of the resources and the environment for future generations while existence value is the value for just knowing that a natural resource exist even though they may never see or use it (MNRT, 2003a). Non use values also include option value. This is the value of keeping options open to generate use and non use values in the future (Turner *et al.*, 1994).

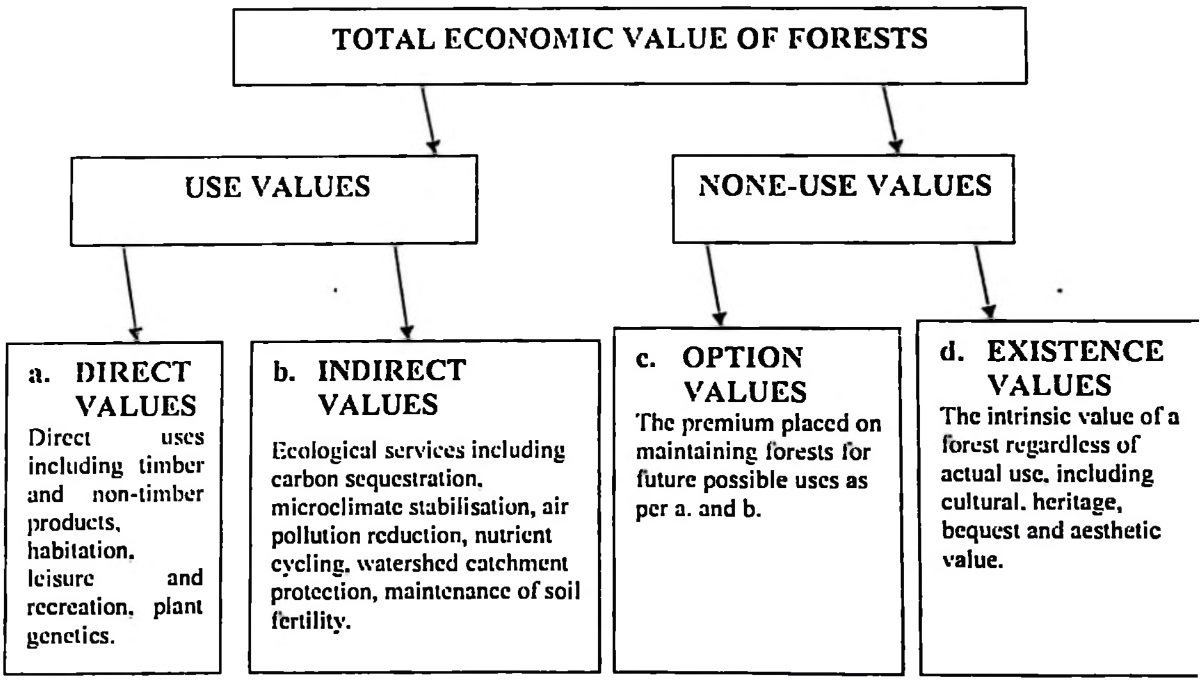

Figure 2: Components of total economic value.

Source: Emerton (1996), IUCN (1998), MNRT (2001b)

2.4.2 Direct and indirect benefits of forests

The catchment capacity of a forest (interception, re-evaporation, stem flow, infiltration, percolation and runoff) depends highly on the structural elements of the canopy and other vegetation layers as well as on meteorological factors (frequency and intensity of rain, temperature and moisture regimes) (Pocs, 1988). An intact catchment forest has the ability to maximize water storage in the ground by facilitating infiltration and also regulates the flow so that water is released over a long period of time. The maintenance of a forest canopy reduces soil erosion and maintenance of surface ground cover and slows surface runoff. The presence of epiphytes in most of the mountain catchment forests has been shown to intercept significant amounts of rain, leading to better conservation as the epiphytic cover minimizes water loss through excess surface runoff, then supplies water continuously ensuring good infiltration and saturation of the ground, at the same time protecting the soil from erosion and desiccation.

A study in Uluguru catcthments by Pocs (1988) found at 2120 m.a.s.l. 13 000 kg of epiphyte per ha were capable of intercepting 60 000 litres of water per ha during a single rain. Furthermore, catchment forests are the origins of the major rivers in Tanzania including Ruvu, Ruaha, Rufiji, Wami and Pangani. The Rivers provide water for hydro-power stations, irrigation, domestic and industrial use. The destruction of the natural forest cover in catchment forests always has negative effects on the catchment capacity. In most cases, surface runoff and soil erosion tend to increase while stream flow tends to show fluctuations with seasonality (Pocs, 1988).

An attempt to estimate total economic value of 715 000 ha of CFRs in four regions (Kilimanjaro, Tanga, Morogoro and Iringa) that were supported by NORAD programme was done in Tanzania (MNRT, 2003a). Direct use benefits such as timber, poles and woodfuels, honey, medicinal plants, fruits and other non-wood products were valued (Table 1). Also, indirect use benefits such as stabilisation of water flows, carbon sequestration, stabilisation of climate, biodiversity, and non-use values which for long have been taken for granted in Tanzania were also quantified to provide the Total Economic Value. Value for water stabilization was based on replacement cost methods; tourism value was derived from data on the number of visitors to various areas; carbon sequestration value was based on growth and biomass figures from literature; erosion control figures were based on data on down slope agricultural areas and soil loss equations for Tanzania; figures for biodiversity and non-use values were derived from the literature. In the calculations, a discount rate of 10% was adopted. Results were aggregated in terms of potential and "actual" values as presented in Table 1.

Table 1: Aggregate potential and "actual" TEV for catchment forest goods and services in Tanzania

Goods and Services	**Potential TEV, (in US$)**	**"Actual" TEV, (in US$)**
Timber and timber-related goods	445 010 000	67 612 498
NTFPs	33 927 110	287 075 461
Water	54 100 000	54 100 000
Soils	18 701 275	18 701 275
Tourism	11 878 330	11 878 330
Carbon	50 872 507	50 872 507
Option value/biodiversity	4 035 262	4 035 262
Non-use	1 834 210	1 834 210
Sum	**620 358 694**	**496 109 543**

Source: MNRT (2003a)

About 70% of the most valuable goods and services in the potential TEV is timber and timber-related goods, reflecting the importance of these products to the adjacent local people. This is however, a paradox since the government banned harvesting of timber in all CFRs of Tanzania for more than two decades now. That means resources with values apart from timber (NTFP's and carbon) need to be sustainably exploited.

2.4.2.1 Non timber forest products

For quite sometime, NTFPs were overshadowed by timber products and have received increased policy and research attention only in the last two decades. According to Arnold and Ruiz-Perez (2001), this attention is based on three main reasons: First, NTFPs contribute significantly to the livelihood and welfare of households living adjacent to catchment forests. Secondly, their exploitation has low ecological distortion than that of timber harvesting. Thirdly, NTFPs production and development in a sustainable manner could reduce deforestation. These reasons were a major motivation for researchers in valuing NTFPs and determining their contribution to overall livelihoods. Studies by Neuman and Hirsch (2000) and Campbell and Luckert (2002) for example, showed that NTFPs contribute from over 50% of the total livelihood income in some areas of Southern America and Asia to less than 20% in other places. Some other studies (Berhanu (2004) and Shackleton and Shackleton (2004) indicated that most rural communities do not depend exclusively on NTFPs for their livelihood, but NTFPs exploitation complements other livelihood activities. The study by Giliba *et al.* (2010) revealed that NTFPs represent very significant component of the household livelihood and income options in Mbulu and Babati Districts, Tanzania. It is therefore clear that these products are extremely important in reducing income and non-income poverty and are considered to be an incentive under PFM.

2.4.2.2 Carbon

One of the mechanisms proposed to mitigate green house gas emissions is implementation of Reducing Emissions from Deforestation and Forest Degradation (REDD) in Developing Countries. The recently agreed REDD+ is the original concept of REDD. plus sustainable management of forests and the conservation and enhancement of forest carbon stocks. The proposed REDD+ mechanism forms part of an international move to include emissions from habitat change (especially the loss of carbon-rich ecosystems such as forests) in a more comprehensive agreement under the United Nations Framework Convention on Climate Change (UNFCCC). which it is hoped will become operational after 2012 (Burgess *et al.*, 2010).

Tanzania is piloting REDD+ activities funded by several donors. These include a 100 million NOK (USD 80 million) commitment from the Royal Norwegian Government to support national REDD+ strategy development. nine sub-national REDD pilot projects, research and capacity building project (including the programme on Climate Change Impacts, Adaptation and Mitigation (CCIAM). investments in National Forest Monitoring and Assessment (NAFORMA), private sector engagement and establishment of a national REDD+ Trust Fund (Milledge. 2009).

Tanzania has also received USD 4.28 million from the UN-REDD Programme, which is largely funded by Norway. This is a collaborate partnership between three UN agencies namely Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) (UN-REDD, 2009). The UN-REDD Programme has the overall goal of testing whether carefully structured payment mechanisms, and relevant capacity building, can create incentives to ensure actual, lasting, achievable, reliable and measurable emission reductions while maintaining and improving the other ecosystem services provided by forests. Proposed interventions under the UN-REDD Programme are coordinated with other REDD+ activities through the national REDD Task Force (URT, 2011).

Another support involves the development of a Readiness proposal from the World Bank's Forest Carbon Partnership Facility, the development of a national forest monitoring system from the Government of Finland (about USD 5 million) and improving forest management in the Eastern Arc Mountains from the German Climate Change Initiative (USD 3.5 million) (Burgess *et al*,. 2010).

Therefore, carbon sequestration, unlike other ecosystem services from catchment forests, has recently gained much consideration as a feasible financial incentive to forest owners and managers and thus high possibility of motivating their participation in forest conservation. These processes and initiatives have been a basis of selecting carbon and NTFPs (honey in particular) as decision variables in the optimisation model as discussed in chapter four of this thesis.

2.5 Disturbances in CFRs in Tanzania

Forest disturbances may be referred to as a discrete force that causes significant change in structure and or composition of the forest (Luoga, 2000). Disturbances may be due to natural causes (wildfire, flood, wind or earthquake); mortality (insect and disease outbreaks) or human induced causes. The main threats to catchment forests in Tanzania include forest fires, illegal cutting of timber and poles, encroachment for agriculture, settlements, mining and grazing (FBD, 2005). Commercial logging impacts negatively the livelihoods of poor countries, causing loss of revenues to governments, distorts markets, and trade, and sustains conflicts. Studies carried out by Luoga (2000); Malimbwi *et al.* (2002); FBD (2005) and Frontier-Tanzania (2005) showed varying levels of illegal timber and pole harvesting in all forest types including catchment forests. The average rate of deforestation (1970s-2000s) in catchment forests was estimated at 23.000 ha (Mbilinyi *et al.*, 2005).

Forest fire has been a long standing problem to all types of Tanzania's forests including water catchments. While early fires are part of the management tool in Miombo woodlands (Mapiye *et al.*, 2008). they are disastrous in plantations and CFRs with serious consequences (FBD, 2005). In catchment forests, most fire incidences have been recorded in the Eastern Arc Mountains and in the north-eastern part of the country including Kilimanjaro and Arusha regions. Fires destroy thousands of ha of forests annually during dry seasons. Main sources of these fires are uncontrolled farm preparations (slash and burn), people crossing in paths along the forest (arsonists), hunting and bee honey harvesting by smoking. In addition to causing losses in timber and biodiversity, the catchment values of the forests are compromised (Frontier-Tanzania, 2005). This results in hydrological imbalance which is reflected in reduced water in rivers and streams during dry seasons and floods during rain seasons which leads to more conflicts among water catchment stakeholders in the country (Munishi and Shear, 2004).

Disturnances are major sources of both temporal and spatial heterogeneity in the structure and dynamics of naturally occurring communities (Sousa, 1984). In relating disturbance to biodiversity at community level, it is important to know which species is favoured and which one is disfavoured by disturbance (Bazzaz, 1983). The requirement of disturbance for a continued existence of certain species in a forest shows that disturbances are ecologically significant (Pickett and White, 1985).

2.6 Intermediate Disturbance Theory

The intermediate disturbance theory refers to a situation where disturbances renew resources at a rate sufficient to allow continued recruitment and persistence of species that would otherwise be excluded (Connell, 1978; Huston, 1979; Hobbie *et al.*, 1993). The theory states that periodic or recurrent disturbance at this intermediate level, perpetuate both pioneer and primary species. Under such conditions, species with different life history are able to co-exist and consequently high levels of species richness are maintained. If the intensity of disturbance increases beyond the intermediate level, only colonizing species with high growth or dispersal rates, pioneer species are able to co-exist. This represents lower species diversity. On the other hand, if the disturbances decreases beyond the intermediate level, only the highly competitive 'climax'species which are better at maintaining resources would exist and equilibrium would eventually be attained. Other less competitive species would be excluded and consequently species richness would be maintained at a lower level.

Although the intermediate disturbance theory is widely supported. it has its limitations: (i) The theory does not specify which community and ecosystem parameters will behave in the expected way (Pickett and White, 1985), (ii) the concept of maximum level of disturbance is a relative term and needs to be explicit according to the goals of a study and (iii) It assumes deterministic equilibrium for the trends in species richness rather than mechanisms based on stochastic processes, patch dynamics and non equilibrium states (Auerbach and Shmida, 1987; Turner *et al.,* 1993).

2.7 Stakeholder Interests and Conflicts in the Management of CFRs

Tanzania's CFRs have many stakeholders ranging from global, national to local level. At global level, the main interests are in tourism, biodiversity and carbon emission reductions.

At national level, the main concern is in hydrological values and carbon sink while at local level, livelihoods for individual families are crucial. Local communities surrounding CFRs depend on these reserves for up to 15 % of their incomes. and the poorest are particularly dependent on these resources for their daily living. To a relatively small group of illegal operators, the CFRs are also important sources of income from timber and pole harvesting (MNRT, 2003b).

Conflict lies between the interests of local communities on one hand and conservation interests on the other. Besides incomes foregone because of the prohibitions against direct use of the CFRs, local communities suffer from crop raiding and weed infestations in the neibourhood of the CFRs (Warner, 2000). Conflicts between stakeholders also include those between central and local governments (Mbeyale, 2009). Local politicians often have more sympathy for local people's needs than for strict adherence to laws and bylaws and conflicts also arise over competing claims with respect to harvesting permits, royalties and remission of revenues (MNRT, 2003b).

Furthermore, tensions arise from various stakeholders for a number of other reasons. Water supply authorities and Tanzania Electric Supply Company (TANESCO) do not contribute directly to conservation of CFRs. TANESCO complains about diversion of water for irrigation purposes, since this reduces electricity generation capacity. Tanzania National Parks Authority (TANAPA) would like to convert more CFRs to become national parks, e.g. the Udzungwa and Kilimanjaro National Parks which conflicts with JFM initiative (MNRT, 2003b). Civil servants and politicians at all levels have been reported to be involved in illegal timber harvesting in these ecosystems (Milledge *et al.*, 2007), threatening the legitimacy of the forest governance system in the country.

The formal division of the forest sector into two administrative structures is another area of conflict. Most CFRs are under the Ministry of Natural Resources and Tourism (MNRT), Forestry and Beekeeping Division (FBD) which has been of recent changed to Tanzania Forestry Service (TFS) and therefore have to be managed by TFS staff. However, most of these CFRs are just very close to the District Councils which are administratively under the Prime Minister's Office, Regional Administration and Local Government (PMO-RALG). This causes lack of coherence in forest management and administration (MNRT, 2003b; MNRT 2009).

There are also conflicts within stakeholder groups. For example, there is no coherence in dealing with illegal activities in the CFRs between Village Natural Resources Committees (VNRCs) and foresters in charge of a respective FRs. This leads to lack of effective legal measures to deal with culprits for respective FRs.

Conflicts due to resource utilisation may vary depending on levels of control, ecological variation, proximity to markets, population density, and livelihood options (Warner, 2000). In general, the potential for conflict will increase with stricter control, population density, greater value of CFR resources, increasing proximity to markets and declining availability of alternative income sources (MNRT, 2003b).

Most of the described conflicts can be resolved at lower levels through increasing incentives and few could be dealt by other means at higher political levels.

2.8 Costs and Benefits of Managing Catchment Forest Reserves

There are several management interventions that are important to be done regularly in CFRs. These include boundary survey and demarcation (clearing and planting of trees), forest enrichment (gap identification, planting, climber and brambles cutting on coppice and root suckers) and regular patrols and fighting fire outbreaks. For example, estimated cost for forest catchment management for Kilombero Catchment office is shown in Table 2.

Table 2: Management costs for Kilombero catchment FR, Tanzania

Activity	Cost (TZS)	Cost (USD)
1. Boundary		
Demarcation	68 310 000	42 693.75
Planting	49 680 000	31 050
Survey	1 500 000	937.5
Subtotal	**119 490 000**	**74 681.25**
2. Gap identification		
Transplants	521 640 000	326 025
Labour and Transport	221 430 000	138 393.75
Subtotal	**743 070 000**	**464 418.75**
3. Patrol		
Fuel	2 340 000	1462.5
Allowances	5 400 000	3375
	7 740 000	**4837.5**
Subtotal		
Grand Total	**870 300 000**	**543 937.5**

Source: Kilombero Forest Catchment Office, March, 2006.

Note: 1 USD is equivalent to 1600 TZS.

The cost per ha is estimated to be TZS 6 485.10 per year equivalent to USD 4 Some of the activities such as boundary demarcation are done once and for all; planting costs also decreases every year, therefore the costs for catchment management tend to decrease over time (MNRT, 2003b). Data from Kilombero Catchment office shows that in 2005/2006 they received only 8% of their estimated management costs from FBD, Ministry of Natural Resources and Tourism. Much of the funds however, could not be directed to activities linked with conservation but administration, leaving conservation activities with small operational budget. This shows how much catchment conservation activities are underfunded, a situation which necessitates a call for other mechanisms including use of participatory forest management. However, the perception of costs and benefits in JFM is different for various stakeholders. Table 3 for example, shows perceptions for forest management costs and benefits for various stakeholder groups.

Table 3: Management costs and benefits for JFM as perceived by stakeholders at different levels

Stakeholder Group	Forest Management Costs	Forest Management Benefits
Forest adjacent Communities	**High:** - Time spent planning for and establishing JFM - Undertaking regular patrols inside forest management areas - Co-ordination of forest management activities by VNRCs - Crop raiding and damage to property by wild animals - Opportunity costs of alternative, productive land-use and forgone benefits (such as timber and poles)	**Low:** - Limited access to non-timber forest produce, and water in some locations - Limited revenue from fines, confiscated goods and research fees
National Government	**Low:** - Costs associated with management and protection of forest reserves - Costs associated with facilitating and monitoring Joint Forest Management Agreements	**Medium:** - Water catchment functions are important but are rarely captured in economic terms and even when they are, they rarely come back to the relevant ministries responsible for their management. - Some benefits from tourism revenues
International Interests	**Low:** - Limited support to financing of Joint Forest Management programmes through projects	**High: (Existence value)** - High biodiversity in many of the Eastern Arc Forests - Carbon sinks

Source: MNRT (2009)

2.9 Participatory Forest Management and Land Tenure System in Tanzania

A variety of approaches for involving local people have emerged for about two decades now, in the search for effective natural resource management strategies under the title of collaborate natural resources management (FAO, 1999). Consequently, various programmes and activities have been promoted under CBFM, JFM, Co-management of protected areas, and Integrated Watershed Management (Msuya, 2010). Each of these approaches tends to be associated with a certain body of literature and often with distinct expression. As such, different people tend to have different perspectives and construct the meaning of these concepts in different ways.

Collaborate management of natural resources has been defined by FAO (1999) as the arrangements for management that are negotiated by multiple stakeholders based on set of rights and privileges (tenure) recognised by the government and widely accepted by resource users. It involves processes for sharing power among stakeholders to make decisions and exercise control over resource use. With regard to this, JFM and CBFM approaches have been elaborated along resources ownership and management regimes (Bromley and Cernea, 1989). Various tenure systems are grouped into four main categories in Tanzania. These are state property with regulated access, common property, private property and finally open access property (Matose and Wily, 1996).

The state property regime occurs when the ownership and control of the resource lies with the state. Individuals or groups may be able to make use of the resource but only through the forbearance of the state. The government makes decisions concerning access. About 13% of the total land area in Tanzania falls under this category as state forests called gazetted forests or reserved forests (MNRT, 2001b). The government through FBD increasingly finds difficult to exercise control on its own, a situation which results into encroachment and illegal harvesting.

The essence of private property regime is simply the legal and socially sanctioned right to exclude others (Bromley and Cernea, 1989). Exclusion of other resource users and the regulation of resource use result in the concentration of ownership of land in few hands, often a source of landlessness and conflict (Matose and Wily, 1996). The enthusiasm that was there before as regards to privatisation of resources as a way of ensuring good management of resources is now fading away. It has been reported that privatisation in Southern African Development Co-operation (SADC) countries is not necessarily the means to optimise the use of land or resources and in the case of natural forests and woodlands it may be simply inappropriate (Matose and Wily, 1996). Zimbabwe probably has the highest percentage of woodland on private land and Tanzania has the lowest. In Europe, for example Finland, about 62% of the forests are privately owned but there is everyman's access to the forests (MNRT, 2001b).

Common property regimes are defined as those in which an identifiable community of interdependent users holds resources, in which outsiders to that community are excluded and in which use by members is regulated by cultural norms (Bromley and Cernea 1989). Thus, common property management is based on two necessary conditions: (i) the well working of internal regime arrangements and (ii) the common property should be defended against access of outsiders (de Groot and Tadepally, 2006). This implies that there should be sanctions and incentives for resource use and regulation.

Local institutional arrangements are used to spell out sanctions and incentives for members. Unfortunately, in many areas these local institutions are not operative due to mainly pressures and forces from the government (de Groot and Tadepally, 2006). The colonial government and national states alike did not recognise resource management roles of the local communities. Another reason is socio-economic differentiation, since as people became less homogeneous in socio-economic sense there is divergence of interests and unequal concentration of power. This in turn enables the more powerful to press for exclusionary use and *de facto* appropriation of common resources gradually subverting and eroding the corporate communal institutional arrangements (de Groot and Tadepally, 2006). A political atmosphere has also exposed villages from excluding excess population.

Regarding open access, or commonly known as general land or unreserved land in Tanzania, there are no well-defined property rights such that access is unregulated or open to everyone. The state tried to put some restrictions on the general land by protecting some valuable tree species (reserved species) (MNRT, 2001b). That is for these particular tree species users are required by law to request and pay for use permits of the tree in question to the forest authorities. For the rest of the resources, the conditions have been those associated with open access. The 16 million ha in the general land are forests experiencing pressures of open access (MNRT, 2001b).

Common property regime has been confused with open access situation (a free for all). This confusion influenced government decisions thereby discouraging common property regime due to high vulnerability of open access regimes to degradation (Mbeyale, 2009). As such, colonial governmental and national states that emerged denied the very possibility for resource users to act together and institute checks and balances, rules and sanctions, for their own interaction within a given environment. Interest in CBFM is perhaps related to the resurgence of interest in grassroots democracy, public participation and local level planning (Chingonikaya, 2010). CBFM is often described as initiative that is primarily controlled and legitimated within a community. Externally initiated activities with varying degrees of community participation are usually not referred to as community-based, at least not until the community exercises primary decision-making authority. CBFM is therefore one form of common property regime (Chingonikaya, 2010).

Given the fact that resources often have multiple uses and conflicts occur at various levels (Warner, 2000), it has been seen that complete devolution may not be appropriate. It therefore makes sense for the state to continue playing a role in resource conservation and allocation among communities of users. Shared governance or state regulation jointly with user self-management is thus a viable option. This amalgamation of property regimes is referred to as JFM. Such management can capitalise on the local knowledge and long-term public interest (Kajembe *et al.*, 2008).

In JFM, forest division and local communities share products, responsibilities and control over forestlands. Joint management agreements specify the distribution of authority, responsibility and benefits (Kajembe *et al.*, 2008). JFM is thus a process that involves the owner of a particular resource to share power with another partner in the management of that resource based on agreed conditions. In case of local and central government forest reserves, JFM entails concession of power on the part of the government to enable local people to plan, budget, control, implement, and evaluate benefit from the resource in a way that is agreed by both parties. It should be noted here that JFM entails one legal owner of resource on his own free will deciding to surrender some of his powers to another partner for better management of the resource (MNRT, 2001a).

The legal owner of forest resources as spelt out in the forest policy of 1998 is Central Government (National), Local Government, Village Government or Community and

Private agency. The legal rights of establishing ownership of FRs as stipulated by the National Forest Policy fall within one of the three categories. These are Central Government (National) Forest Reserves, Local Authority Forest Reserves and Village Land Forest Reserves. However, in view of practical management of the reserves the owner can invite partners to manage the forest with the given agreement and sharing the costs and benefits (Kajembe *et al.*, 2008).

2.10 Key Challenges and Lessons Learned in Implementing JFM in Tanzania

2.10.1 Implementation challenges underlying joint forest management

The problem of sharing costs and benefits is compounded by the fact that JFM has been heavily promoted across CFRs with high conservation status. The protection status of some of the most critical CFRs are now being upgraded to Nature Reserves. which further provides them with additional protection status. For one decade, there are about nine FRs (including Amani, Uluguru, Nilo, West kilombero Scarp, Mkinga, Shume Magamba, Uzungwa Scarp and Chome) that have been promoted to Nature reserves in the country.

While these forests deliver a range of crucial environmental services to the nation through conservation of water sources for domestic and industrial uses, irrigation and power generation, they are also beneficial to the global community through conservation of biodiversity and carbon sinks. Despite all these benefits to the nation and the global community, their contribution at local level is highly limited due to high protection status (MNRT, 2009). That means, the management costs placed on communities living around CFRs, outweighs the benefits gained locally. This is illustrated in Table 3 which shows how management costs and benefits are asymmetrically distributed between international, national and local stakeholder groups with regard to the management of CFRs in Tanzania (MNRT, 2009). Therefore, JFM is challenged by two major factors; Firstly, there is no legal mechanism that provides the basis for sharing management costs and benefits between the government and participating communities. Secondly, many of the forests being managed through JFM are of high biodiversity values where their protection status severely limits the availability of local benefits and therefore restricts many kinds of local benefit streams.

2.10.2 Key lessons learned in implementing joint forest management

The following are some of the key lessons learned in the implementation of JFM in the country over the last 20 years:

(i) JFM has been promoted by projects or organizations with a strong conservation interest and has largely taken place in "protection forests" where local use options are extremely limited. The positive impacts on forest quality and protection of water catchments are apparent, but incentive flows to communities and sustainability after the exit of donor support appear to be limited (Pfliegner and Moshi, 2005). A good example of this is JFM in CFRs supported by NORAD in 1990s in Morogoro region.

(ii) The Forest Act no. 14 of 2002 states that forests may be managed through a range of partnership arrangements between a wide range of players within government, NGOs, private sector and community groups. To date, the vast majority of JMAs have been developed between villages and central government and cover mainly the montane catchment forests with high biodiversity and other ecosystem-service values. Despite the major efforts of government to support JFM over the past 20 years, its long term viability remains in the balance. Given the high biodiversity nature of many forests under JMAs, the total level of permitted benefits is significantly less than the range of benefits people obtained prior to JFM being established, even though illegal in nature. So far, opportunities exist for extractive use of forest reserves (such as in production forests where timber harvesting is permitted), the relative share of benefits captured by communities has yet to be agreed on and the mechanism for sharing of benefits has never been in place (MNRT, 2009).

(iii) Forest governance has increasingly become an issue for public debate over the past 10 years. with the public media campaigns against the illegal logging scandals in Morogoro, Pwani, Lindi and Mtwara regions. JFM as a forest management strategy has not been able to facilitate improved local level governance, by opening dialogues over access and control over resources, financial management and the role of elected committees (Milledge *et al.*, 2007).

(iv) There is increasing "legal literacy" among rural forest managers on how they can legally benefit, own and utilize forests and woodlands as stipulated in the Forest Act No. 14 of 2002. Rural households have appreciated the financial value of forest resources on their lands as well as the legal basis for them to secure ownership or management rights over them. Through this growing awareness and understanding, rural households have began to demand services from JFM initiatives and hold their elected leaders more accountable for ensuring sustainable forest management and equitable incentives (Lund, 2007).

(v) There is a need to engage with responsible private sector forestry enterprises in ways that can provide incentives to both the forest industry and rural communities. Currently, there are many examples of the private sector behaving in an irresponsible way and being hostile to moves that can empower communities with skills and knowledge regarding sustainable forest management (Bromley and Ramadhani, 2007).

2.11 Types of Rules in Participatory Approaches

In order for the community to improve forest governance in JFM, they need to create and enforce rules which provide incentives for people to change their behaviour towards resource base. Incentives created by rules are the easiest to understand intuitively (FAO, 1997). In practise, everyone faces incentives related to rules in one's daily life which create a situation characterized by alternating reward or punishment. However, rules do not enforce themselves. Some people (community leaders or VNRC members in case of JFM) must monitor behaviour regulated by the rules and enforce sanctions in the case of non-compliance. It implies that, all rules do not create the same kinds of incentives. An incentive created by a rule that is enforced, is different from the incentive created by one that is selectively enforced or one that is not enforced at all (FAO, 1997).

The first type of rule, in which enforcement is predictable, will certainly lead people over time to comply with the rule. The second, in which enforcement is intermittent, may not discourage people from carrying out illegal activities and may encourage them to attempt corruption when caught. The third, in which enforcement is non-existent, probably will not affect peoples' behaviour at all. In addition to the frequency of enforcement, the severity of the sanction is a factor in determining how a rule affects behaviour. A rule that when violated can result in a person's exclusion from a community, creates different incentives from one that results in nothing more than a fine (Thomson, 1977).

To understand how rules affect behaviour change at individual and community levels, it is important to review the various kinds of existing rules. There are differences between formal and informal rules and between working and non-working rules (Table 4). These distinctions can help to identify all the existing rules in a community. It also helps to understand rules which have impact on people's behavior (Thomson, 1977). This in turn may lead to the identification of non-working rules (formal or informal) that need to be converted into working rules if effective forest governance is to be achieved.

Table 4: Formal and informal rules

Type	Working	Non working
Formal	**Codified Texts that Are Enforced** e.g. rule prohibiting commercial wood cutting on state lands without a permit	**Codified Texts, Not Enforced** e.g. rule stating that if an owner leaves his land for more than 12 years un developed, the land reverts to village ownership
Informal	**Customs/Non-written, Enforced** e.g. customary rule concerning land loans prohibiting borrower from making permanent improvements	**Non-written Rules Not Enforced** e.g. custom of the ancestors (no longer in practise) providing that land borrowers give 10 percent of their produce to the owner

Adopted with modification from FAO (1997)

There are other types of rules that affect people's behaviour directly or indirectly. These are operational rules, collective decision-making rules and constitutional rules. Each of these types of rules affects a different type of decision (Ostrom, 1990).

Operational rules: Inlude rules that are intended to affect individuals' behaviours and their activities. What people are allowed to do, what they are required to do, and what they are prohibited from doing. These might be considered 'surface level' rules because they are closest to the behaviours that affect the resource base (Ostrom, 1990).

Collective decision-making rules: Include those which determine how the operational rules are established: Who makes the rules and how are the rules established and changed?

Constitutional rules: Are the most fundamental rules in any political system. They determine who can participate in the political system, what the offices in the system are, how office holders are selected, and what powers and authority they can exercise. They also determine the procedures for establishing new units of governance and what needs to be done in order to make and change collective decision-making rules (Thomson, 1977).

Revising the rules involve costs in terms of time, effort and finance. Enforcing the rules creates further demand on the community. Such costs are known as transactions costs. They have a major impact on the feasibility of implementing rule changes in participatory forest management.

2.12 Participatory versus Modenization Theories

Participatory theories and principles condemned the modernization theories on the argument that they promoted a top-down, ethnocentric and paternalistic view of development. The argument insists that the diffusion model proposed a conception of development associated with a western development vision. Development communication was informed by a theory that became a science of producing effective messages (Quarmyne, 1991). The top-down approach believed that the knowledge of governments and agencies was always correct, and that local communities either did not know or had incorrect understanding. Because programmes came from outside the villages, communities felt that innovations did not belong to them but to the government and thus expected the latter to fix things when they went wrong. The sense of disempowerment was also rooted in the fact that local communities did not have the choice to reject interventions or introduce some modifications (Servaes, 1989).

Modernization theories also criticized traditional approaches for having been designed and executed in the cities by local elites with guidance and direction from foreign experts (Mody, 1991). Local communities were not involved in preparing and implementing development interventions. These interventions were considered by local residents as passive receivers of decisions made from outside. It is the governments which decided what was best for farmers, without giving them a sense of ownership in the introduced systems (White, 1994).

Participatory practitioners and theorists agree that development communication required sensitivity to cultural diversity and specific context that were ignored by modernization theories (Gumucio, 2001). The lack of such sensitivity caused problems and failures of many development projects. Many experts came to learn that development was not restricted to just building roads, piping water and distributing electricity. It was neither not limited to increased farm yields nor switching to cash crops. In the Uluguru eastern slopes for example, agricultural projects failed because farmers were reluctant to abandon their traditional ways for innovative methods. Local communities were also nervous about planting exotic crops that they could not eat but had to sell for money to buy food (McKee, 1992). Modernization projects undermined the importance of local knowledge and the consequences of the interaction between local cultures and new ideas.

Participatory theories considered necessary a redefinition of development communication (Quarmyne, 1991). One set of definitions stated that, the systematic utilization of communication channels and techniques to increase people's participation in development and to inform, motivate, and train rural populations mainly at the grassroots. For others, development communication needed to be human rather than media centered (Agunga, 1997). This implied the abandonment of the persuasion bias that development communication had inherited from propaganda theories, and the adoption of a different understanding of communication.

According to Agunga (1997) communication means a process of creating and stimulating understanding as the basis for development rather than information transmission. Communication is the articulation of social relations among people. People should not be forced to adopt new practises no matter how beneficial they seem to be in the eyes of agencies and governments. Instead, people need to be encouraged to participate rather than adopt new practises based on the information. This understanding of communication was central to the ideas developed by Brazilian educator Freire (1970), whose writings and experiences became an influential strand in participatory communication. Freire's work in northeastern Brazil in the 1960s and early 1970s challenged dominant conceptions of development communication, particularly as applied to literacy training. He argued that development programmes had failed to educate small scale farmers because they were interested in persuading them about the benefits of adopting certain innovations. Development programmes tried to domesticate foreign concepts, to feed information, to force local populations to accept western ideas and practises without asking how such practises fit existing cultures. In the Uluguru slopes of Tanzania for example, this habit led to strong conflicts between introducers of the interventions and local communities which led to some killings due to reluctance of local people to accept new innovations which necessitated changing their farming cultures (Bangati, H.N. personal communication, 2010).

2.13 Participatory Theories and Critics

According to Kavinya *et al.* (1994), communities should be encouraged to participate in decision-making, implementation, and evaluation of projects. This would give a sense of involvement and provide them with a sense of ownership and skills that they can use beyond the span of development projects. Community empowerment has become one of the main contributions of participatory theories to development. Empowerment is possible only if community members critically reflect on their experiences and understand the reasons for failure and success of interventions (Purdey *et al.*, 1994; Bradford and Gwynne 1995).

Some scholars argued the models were elaborated at a theoretical level and did not provide specific guidelines for interventions (White, 1994; Bradford and Gwynne, 1995). One problem in participatory models is the fact that, it is not clear when and at what levels communities should be involved for certain results to be achieved. In some cases such as epidemics and other public health crises, quick and top-down solutions could achieve positive results. Participatory communication ignores that expediency may also positively contribute to development. Going through grassroots decision-making process is slower than centralized decisions, and thus not advisable in cases that require prompt resolutions. Participation might be a good long-term strategy but has shortcomings when applied to short-term and urgent issues (Purdey *et al.*, 1994).

Another thing particularly for Asia and Africa is that, participatory models are premised on western ideas of democracy and that it does not fit political cultures elsewhere. Individualism rather than community and conflict rather than consensus lie at the heart of participatory models developed in the West (White, 1994). Participation can also promote division, confusion, and disruption that do little to solve problems. It may privilege powerful and active members of the community (local ellite) at the expense of the community as a whole. To these criticisms, advocates of participatory models admitted that divisions and conflicts might result but, they argue, the answer should be teaching negotiation and mediation skills rather than opting for interventions that disempower people in the name of consensus-building. Although advocates of participatory theories view their critics as favouring government centralization and leaving power inequalities intact, they admit that some original premises need to be revised (White, 1994).

2.14 Incentives and Related Concepts

2.14.1 Incentives

In the context of this study, incentive is defined as something which incites or motivates forest adjacent communities to participate in the conservation of catchment forests through JFM. More broadly, an incentive is a form of state assistance to encourage a particular form of behavior (e.g. forest or soil conservation); it is a temporary stimulus, directly or indirectly to encourage behaviour which benefits either an individual or a society (Bombin, 1975; Michaelsen, 1983).

An incentive can be any encouragement on the part of the state which will allow the peasants to absorb additional investments and gradually substitute income because of the works that one has to carry out on his/her property, to change the traditional methods with techniques and methods which will ensure sustained yield of renewable natural resources within their area of influence which would also contribute to higher productivity (Botero, 1979; FAO, 1980; FAO/SIDA, 1980). Incentives try to temporarily divert land, capital and labour resources towards certain ends, and encourage the integration of certain activities into the community, or facilitate participation of certain groups of people in an activity which would benefit the community or the country (Larrobla, 1983).

Incentives are a macroeconomic and/or sectorial policy tools and can be applied to various monetary, fiscal, foreign trade, foreign investment, consumption, labour, or natural resource matters (McGaughey and Thorbecke, 1981). Incentives are worthwhile if they can stimulate involvement at a lower economic cost than that of the economic benefits received. The advantages of diversifying rural economy justify the use of a broad range of incentives. On occasions, it is the communities themselves who call for diversification. For example, valuable and useful timber may be commodified; it does not necessarily underpin each and every forest production system. Some societies need help to develop their forests for purposes which have very little to do with wood production, fuelwood, honey, beeswax, chewing-gum, handicraft fibres, gum collection, mushrooms, resins, food, fodder, dyes and extracts. It is quite common, particularly in tropical forests, for all these minor products to make up the bulk of production, so that the community life is very dependent on the forests (Adeyoju, 1978).

Depending on how incentives are applied, a whole series of important objectives can be achieved. Engaging a community on conservation works on its own land, stimulating production through higher yields, making up financial losses arising from production cutbacks during conservation works, compensating for restrictions against certain crops which are inappropriate for the site, ensuring that peasants receive a minimum wage until permanent crops establish themselves or new structures are operational, not to mention diversifying economic activities, remunerating community members who agree to take an active part in a plan or project, stimulating production of certain goods and services, extending community activities and furthering community development (social infrastructure, teaching, training, improved food, medical care and cultural activities (Bochet, 1983; Flinta, 1983).

According to Flinta (1983), the real incentive lies in giving communities the opportunity to improve their source of production, organize ther work to the best use, and eventually increase productivity. A number of measures have come under the heading of incentives. For the sake of clarity, however, this study will make a distinction between two main concepts which are often wrongly treated as being the same: Grants and Subsidies.

2.14.2 Grant and subsidy

It is important to understand grants and subsidies because these two concepts are sometimes confused with incentives, but the three are different. A grant is defined as a benefit paid by somebody or organization to make up an income of an individual or family (Garcia-Pelayo, 1981), or an income supplement, usually temporary, which the state gives to assist large families (Salvat, 1977). These definitions point clearly to grants as emergency income support measures for use at particularly difficult times such as unemployment or natural disaster.

A subsidy differs from a grant in both meaning and application. A subsidy is a sum of money given to individual or community by the state to encourage works for the public interest (Garcia-Pelayo, 1981). In broader and more legalistic terms, a subsidy is government economic assistance given directly or indirectly to individuals or administrative bodies. State subsidy is a tool for encouraging activities designed to satisfy the needs of the public. Subsidies, which in this broad sense also include prizes, bonuses, fellowships and other forms of personal assistance, can be subjected to stricter legal controls than the other forms of direct financial assistance mentioned above. It is discretional and revocable and is conditional upon certain rules being observed. Special funds are normally set aside for the purpose. Subsidies may be given unilaterally, or by agreement and may be optional or compulsory (Salvat, 1977). Therefore grants and subsidies are not the same as incentives even though they are related. To make the distinction clearer, incentives are elaborated more, based on their elements.

2.14.3 Elements of incentives

According to Gregersen (1978), incentives provide a policy tool for overcoming major constraints to community involvement in conservation plans; such constraints include lack of awareness of the benefits of such plans and projects, lack of interest in participating due to limited financial appeal, lack of financial and technical capacity, legal difficulties arising from land use problems and shortcomings in service and marketing infrastructures.

The effects of incentive scheme or package, on securing community participation, may be expressed as a function of a number of elements:

EI = f (I, CI, O, M, Cn, T, D, R)

Where:

EI = Effect of incentive scheme/package

I = Initial situation of target community as regards to both natural resources and significant sociological aspects

CI = Class or category of incentive(s)

O = Main objective of the incentive or incentive scheme envisaged

M = Motivation of community

Cn = Constraint which the incentive is intended to remove

T = Effect of time on the incentive

D = Method of distributing the incentive to the community

R = Method of recovering the incentive.

Many other variables could probably be defined as well, although the main ones are those listed above (Gregersen, 1978; FAO/SIDA, 1980; Hidalgo, 1981; McGaughey and Thorbecke, 1981; Bochet, 1983; Flinta, 1983).

Variable (I) (the initial situation of the community to which an incentive or incentive scheme is to be applied) refers in particular to the community's level of socio-economic development. According to FAO (1984), incentives should be designed as temporary policies bridging the gap between impoverishment and relative prosperity. The effect of an incentive for community involvement in a plan or project will be very different in a rural society with a low income, than in a community of smallholders with larger incomes. A crucial factor here will be the extent to which the population is or can be organized and any experience they may have of conservation and reforestation plans and projects (Adeyoju, 1978).

For the incentive class (CI), there is a strong connection not only with the impact of the incentive, but also with the community's initial general situation. For example, in a poor and disorganized community, it is obvious that short-term bank loans would not only be inappropriate but quite impracticable as well.

The objective variable (O) is a trickier matter. An upland reforestation and conservation programme can have many possible objectives. As reference has already been made to incentive packages, it is probably more appropriate to talk about a package of objectives, containing one or more of the following elements: soil conservation, rehabilitation of degraded resources, protection of farm land and downstream works, income redistribution, commodity production, industrial timber production, increased productivity, increased output and diversification (Gregersen, 1978; Bochet, 1983 and Flinta, 1983). There is undoubtedly a direct correlation between a community's initial situation (I), the class of incentive (CI) and the final objective of the plan or project.

The degree of motivation (M) has an enormous influence on the success of incentive packages in conservation projects. A plan or project usually requires some kind of promotion campaign to arouse sufficient interest before any concrete measures can be implemented. However, the time taken to motivate a group of individuals or a community depends to a great extent on its initial situation (the I variable).

The variable (Cn) refers to the constraints on implementing the plan or project. Gregersen (1978) identified several constraints: lack of awareness of the benefits, lack of interest and inability to take the necessary action. Additions to this list might include rights which have not been granted and lack of fair access to the market (Government of Mexico, 1979).

The obstacle posed by an unawareness of the benefits of a plan or project depends on the initial level of development (I) of the group of individuals or community and can be overcomed by greater motivation (M). The inability to take the necessary action can stand in the way of measures that would benefit the individual or community; financial and/or technical reasons may be the cause. Much will depend on the class of incentive (CI). The lack of rights may arise when individuals or communities wish to participate in a plan or project but are unable because they have no legal rights to occupy the land; such situations will need clarification if the obstacle is to be overcomed. In this connection, the community's initial situation (I) will be directly affected by whether or not land rights exist. The lack of such rights may be classified as a risk factor. The lack of fair access to the market. This is frequently the case for the poorest and least organized individuals and/or communities. Small and inaccessible communities often have to depend on unscrupulous middlemen who, although they take no part in the hardest stage of the production process, emerge as the chief beneficiaries and therefore have little to gain by giving a fair deal.

Time (T) affects the impact of incentives in two ways: the time it takes to apply the incentive and to recover it (FAO/SIDA, 1980). The former mainly concerns assistance of a temporary nature, the duration of which largely depends on the community's stage of development. In poor communities where natural resources are seriously degraded, this period may be comparatively long; for refundable incentives, such as loans, it will depend on when the investment matures and on whether there are any financial constraints.

Variable (D) relates to how the state delivers the incentive to the community i.e. whether to the individual or to a community organization. As this affects the incentive's impact, the choice depends on the community's initial stage of development (I), the objectives pursued (O), and the degree of motivation (M).

Incentive recovery (R) depends on the initial situation (I), the kind of incentive (CI) and constraints facing the community (Cn). The incentive may take the form of an outright grant or be channeled back into the community via a revolving fund, or revert to the government to be invested as general funds or in special renewable natural resources development funds.

Apart from elements, incentives have also been categories into several classeses based on wheather they are received directly or indirectly.

2.14.4 Classification of incentives

2.14.4.1 Direct incentives

Direct incentives provide an immediate impact on individuals and/or the community. This is because they are given directly in cash or in kind, or they improve rural life very quickly (Flinta, 1983). As shown in Fig. 3, direct incentives may be classified according to whether they are granted in cash, in kind or a combination of the two (mixed). However incentives are, always mixed, a situation which complicates the classification. According to FAO (1984), apart from loans, direct incentives are a common feature of economically viable activities, although their long term nature means that it is often difficult to secure their financing on the regular capital market. Financing difficulties tend to expand the timely on action to counter natural resources degradation (Bochet, 1983). This study also identified a number of direct incentives in the study area as presented in chapter four.

2.14.4.2 Indirect incentives

Indirect incentives are in the form of fiscal, service or social (Fig. 3). They are legal measures designed in line with protectionism or development policy aimed at encouraging communities to carry out things including watershed conservation, reforestation and integrated rural development activities.

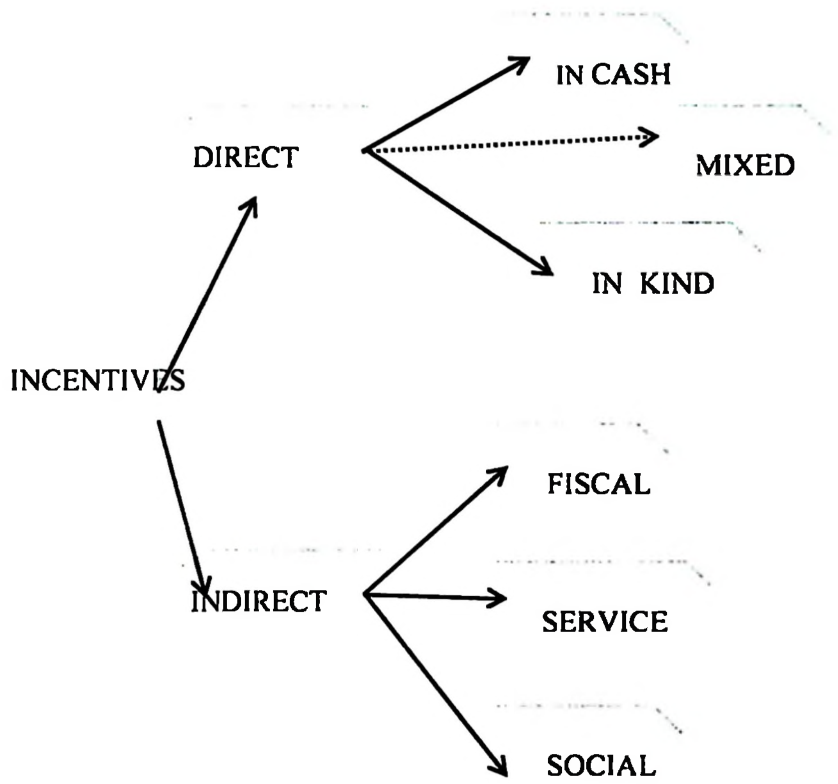

Figure 3: General classification of incentives. Adopted from Michaelsen (1983).

Indirect incentives involve applying the instruments of monetary, consumer, service, social, and natural resources policy (McGaughey and Torbecke. 1981) to concrete problems affecting the development, conservation and rehabilitation of land and communities (FAO/SIDA. 1981; Michaelsen, 1983). Fig. 4 and Fig. 5 illustrate the various categories of direct and indirect incentives

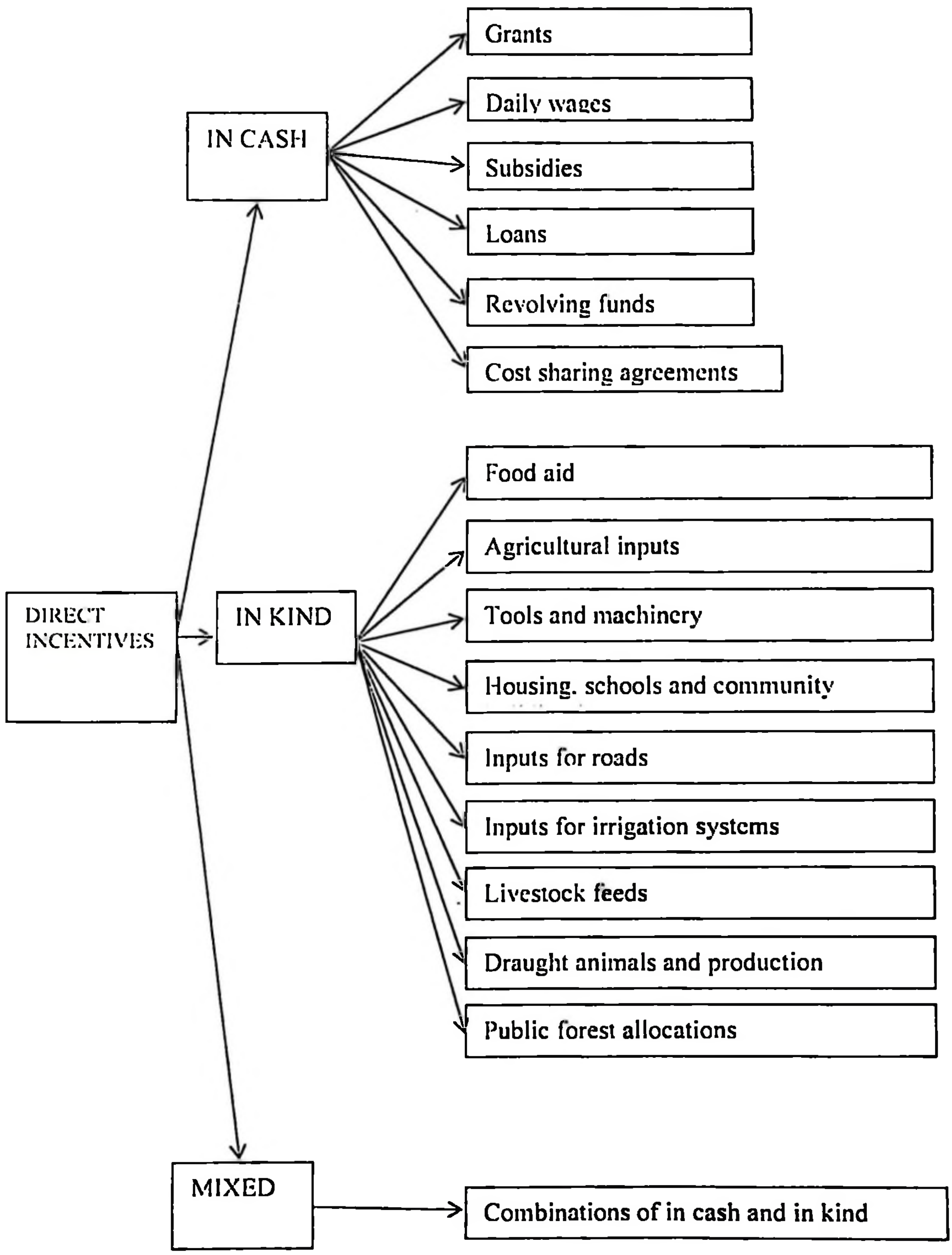

Figure 4: Categories of direct incentives adopted from Michaelsen (1983).

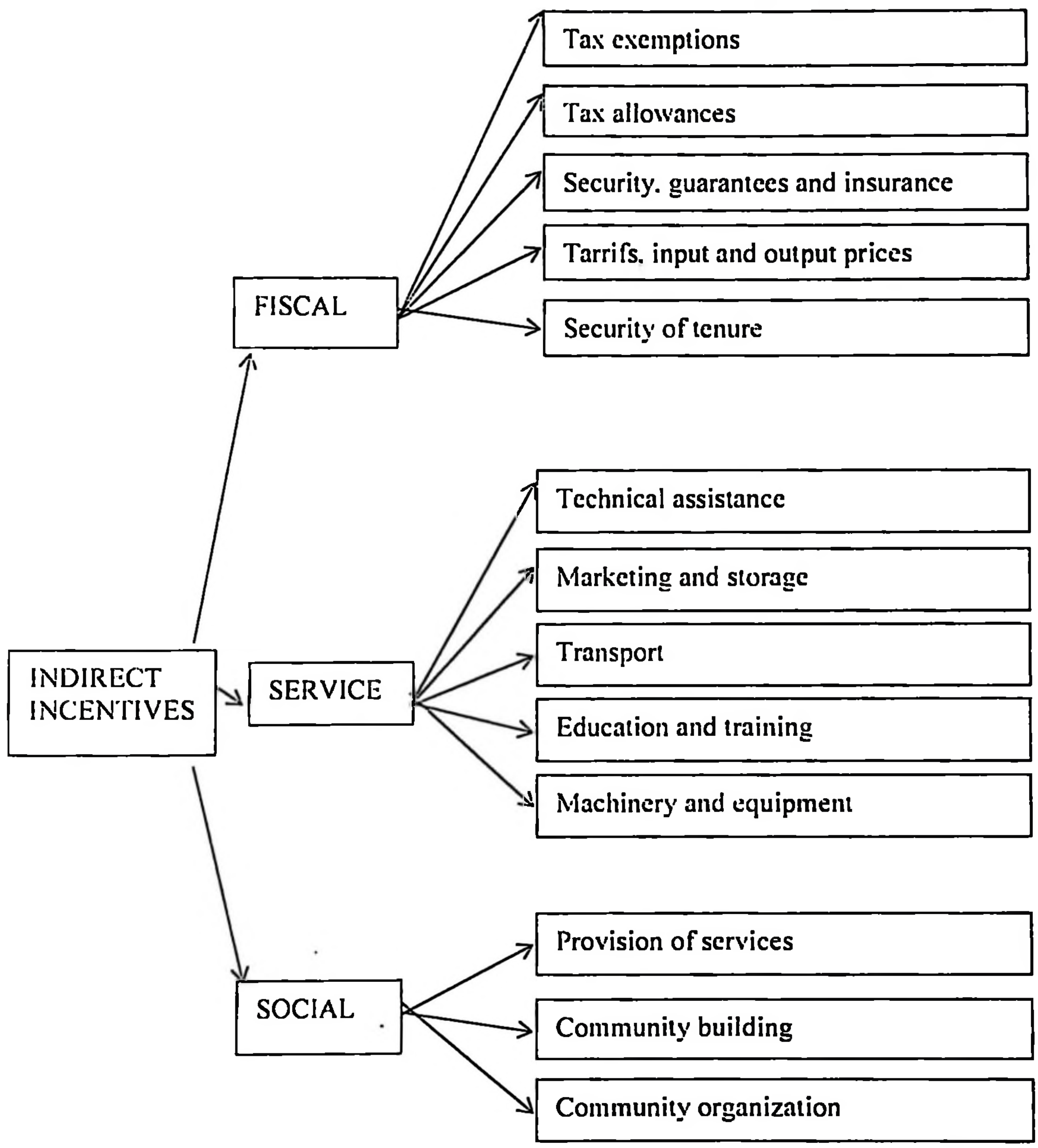

Figure 5: Categories of indirect incentives adopted from Michaelsen (1983).

2.15 Potential Incentives for JFM in Catchment Forest Reserves

2.15.1 Payment for Environmental Services (PES)

Forest management practises through JFM generate a number of environmental services including water catchment, scenic beauty, biodiversity, and carbon sequestration, which in principle are potential incentives that could be valued and paid for by various consumers ranging from local to international. Financial resources from environmental services payment systems are one option for provision of the required tangible economic benefits and hence incentives to local people participating in JFM (Zahabu, 2008).

A proposal of neo-market natural resources economists is that, new ways and institutional set-ups be developed to supply for such required incentives (Winrock International, 2004). This implies that for environmental services to be provided, remunerative incentives have to be made available by international, national and local actors. These required remunerative incentives for environmental services provision are referred to as Payments for Environmental Services (PES). These initiatives are expected to complement past forest reforms thereby contributing to provision of incentives for communities adjacent to CFRs. Local communities managing catchment forests by avoiding deforestation suffer from opportunity costs that have to be compensated in order to attain their commitment to conserving catchment forests at the same time maintain their livelihoods.

This study follows a definition by Wunder (2005) that Payment for Environmental Services (PES) is a voluntary transaction to conservation based on the twin principles that those who benefit from environmental services should pay for the services, and those who generate these services should be compensated for providing them. In a PES mechanism, service providers receive payments conditional on their providing the desired environmental services (or adopting a practise thought to generate those services). The

PES approach is attractive in that it generates new financing, which would otherwise not be available for conservation, it can be sustainable, as it depends on the mutual self-interest of service users and providers and not on the whims of government or donor funding (Wunder, 2005). It is efficient if it generates services whose benefits exceed the cost of providing them.

Most PES schemes in developing countries focuses on retaining forests, but interest is growing in applying the approach to agricultural areas (Engel *et al.*, 2008). In developing countries, PES remains inadequately tested (Wunder, 2007). There are many new PES initiatives but those with practical experience are found in Costa Rica and a couple of dozen other pioneer experiences, mostly in Latin America (Landell-Mills and Porras 2002; Pagiola *et al.*, 2002). There are still few practical working schemes in Africa with some emerging in Tanzania.

Until now, literature report four main types of environmental services: (1) watershed protection (downstream water users paying upstream providers for adopting land uses that limit soil erosion or flooding risks), (2) carbon sequestration and storage (northern companies paying tropical communities to plant or maintain trees), (3) biodiversity protection (conservation donors paying landholders for creating set-aside areas for biological corridors), and (4) protection of landscape beauty (tourism operators paying game adjacent local communities not to hunt in a zone used for wildlife) (Pagiola *et al.*, 2002). However, there are three main obstacles to PES schemes in developing countries: (1) Problem of demand, in the sense that there are few service users who are well informed and sufficiently convinced to pay. This leads to lack of willingness to pay (James *et al.*, 2001; Balmford andWhitten, 2003). (2) Very little is known about the supply-side dynamics (what are preconditions needed and how will the benefit transfer affect livelihood dynamics in poor communities) and lastly, (3) the problem of communicating the PES concept (Wunder, 2007).

Payments from the service users can help to make conservation an attractive option for service providers, giving them the resources to conserve. PES thus seeks to internalize what would otherwise be an externality (Pagiola and Platais, 2007). In effect, PES programmes attempt to put into practise the Coase theorem, which stipulates that the problems of external effects can, under certain conditions, be overcome through private negotiation between affected parties (Coase, 1960). PES programmes can also be seen as an environmental subsidy to service providers and also as user fee for service users.

2.15.1.1 Carbon sequestration and storage

Carbon sequestration and storage are PES mechanisms that can benefit from international schemes since these provide regional and global benefits. Conservation of catchment forests and landscapes may benefit from national compensation schemes by national governments and NGOs at national and at local level. JFM provides opportunities for communities to benefit from the carbon markets expected after the inclusion of tropical forest management within global climate negotiations. For example payments for REDD+ is one such opportunity and could provide tangible economic incentives to unprivileged JFM communities (URT, 2008).

Financial gains from carbon storage provide direct and tangible incentive for participating parties in forest conservation. The financial value of carbon storage is gained through carbon trading (a process of buying and selling of carbon credits). According to Walker *et al.* (2008), carbon credits (quantities of sequestered carbon claimed against CO_2 emissions) are being traded at between US$5 and US$20 per ton of CO_2e. The carbon trade is principally based on the fact that dry forest biomass consists of 50% carbon and a ton of carbon is about 3.67 tCO_2 (Brown. 1997). It is estimated that a mature forest area in Africa may contain about 550 tCO_2 (or more) sequestered per ha (Walker *et al.*, 2008). Hence for every hectare protected from deforestation and forest degradation. a financial incentive of between USD 1,650 and USD 8,250 per ha could have been gained.

2.15.1.2 Watershed Protection

As CFRs are degraded. their conservation capacity for water is reduced and water supply for towns with increasing population faces critical shortages. At the same time, many poor people are dependent on forest biodiversity for wood-fuel, food, honey, medicines, building poles, timber, animal fodder and farming (Luoga *et al.*, 2000: Turpie *et al.*, 2005). In Tanzania, more and more people start talking about Payment for Environmental Services (PES). In July 2005, a large stakeholder meeting was hold in Dar es Salaam to discuss about initiating PES in catchments. It was observed that in Tanzania there was no mechanism in place for people to contribute to catchment management. The Government capacity to manage catchments was limited and donor funding not sustainable and cannot be guaranteed. Funds allocated to forest conservation were inadequate, given the state of the catchment and their importance to water availability (MNRT, 2006a). Incentives packages and water users' contribution are crucial. Payment for water as an environmental service is therefore a potential mechanism.

A pilot project "Making PES Work for Nature and People," by WWF and CARE International is piloting PES at Kibungo juu ward in Uluguru Mountains. This PES, especially with regards to water, have the potential to shift the incentive-structure of local people and authorities from damaging to preserving forests in the Uluguru Mountains and at the same time will be part of efforts that aim at the promotion of environmental sustainability that become fully integrated into poverty reduction efforts. Potential buyers of watershed services would be the cities of Dar es Salaam and Morogoro Urban Water Authorities/Companies. Revenues raised from PES are expected to generate a substantial and sustainable impact on local livelihoods especially through improved land use/husbandry, agricultural and horticultural productivity and organizing communities into CBOs for obtaining other/additional sources of incomes. PES in the Uluguru Mountains is likely to have considerable conservation impact because it can readily focus on upland communities that are directly involved in the degradation of forest resources. (Lopa. personal communication, 2010).

According to a study done in Pangani basin, opportunity costs not only exist in urban water supply, but also in power generation and commercial irrigation. A formula was developed to determine the willingness to pay for environmental services (MNRT, 2006a). The results indicated that a significant amount of money can be mobilised in excess of the current allocations to Arusha, Kilimanjaro and Tanga regions for catchment conservation and collections by Pangani Basin Water Office (PBWO). The study proposed an Environmental Services Management Fund to be managed by the PBWO for the stakeholders of the Pangani Basin conservation.

In the East Usambaras and Sigi catchment (Pangani basin) a general willingness to pay was found (Kulindwa, 2005). Important observations include the fact that the international community has been funding forest management based on the "global values of biodiversity" and locally the benefits have been consistent flows of cheap water. Consideration must be given to rewarding upland communities around the forests to obtain sustainable management of the catchment. Part of the revenues collected from water users should be used to establish various social services and boost economic status of the upland communities (Kulindwa, 2005). Most water users see the idea of watershed management as critical and have shown an interest to contribute to it. However, payment modalities are yet worked out.

2.15.2 Beneficiaries of PES in Tanzania

Potential sellers of environmental services are the people who are able to safeguard the delivery of the service desired (Engel *et al.*, 2008). That is to say, potential sellers are the landholders who may be individuals, groups and governments. However, in some occasions, local communities have joint agreements with government (like the case of JFM in Tanzania) through which they have user and management rights hence they act as collective service providers (Rojahn and Engel, 2005). In this way communities with signed JMAs in Tanzania qualify for PES. Many land users in developing countries do not have formal land titles (Wunder, 2007). The main pre-occupation for environmental service buyers should not be the *de jure* land rights, but the *de facto* land and resource use control. Communities acting as direct local guardians have a vital stake and hence need compensation (Wunder, 2007).

2.15.3 PES Limitations

Whenever buyers are asked to start paying for the environmental service they receive, the primary question they ask is whether the PES scheme has a sufficiently "additionality" (the difference in service provision between the "with-PES scenario" and the "without-PES scenario" or the incremental service delivered through PES versus the counterfactual baseline) (Wunder, 2007). This question "Does PES really makes a difference?" has also been under discussion for forestry's status in the Clean Development Mechanism (CDM) of the Kyoto Protocol (Pagiola and Platais, 2007). Until 2012, only reforestation and afforestation schemes were eligible for carbon credits. The current rules in CDM are a good example of a static baseline shown in Fig. 6. Forest carbon stocks are assumed to remain constant in a historically extrapolated laissez-faire scenario.

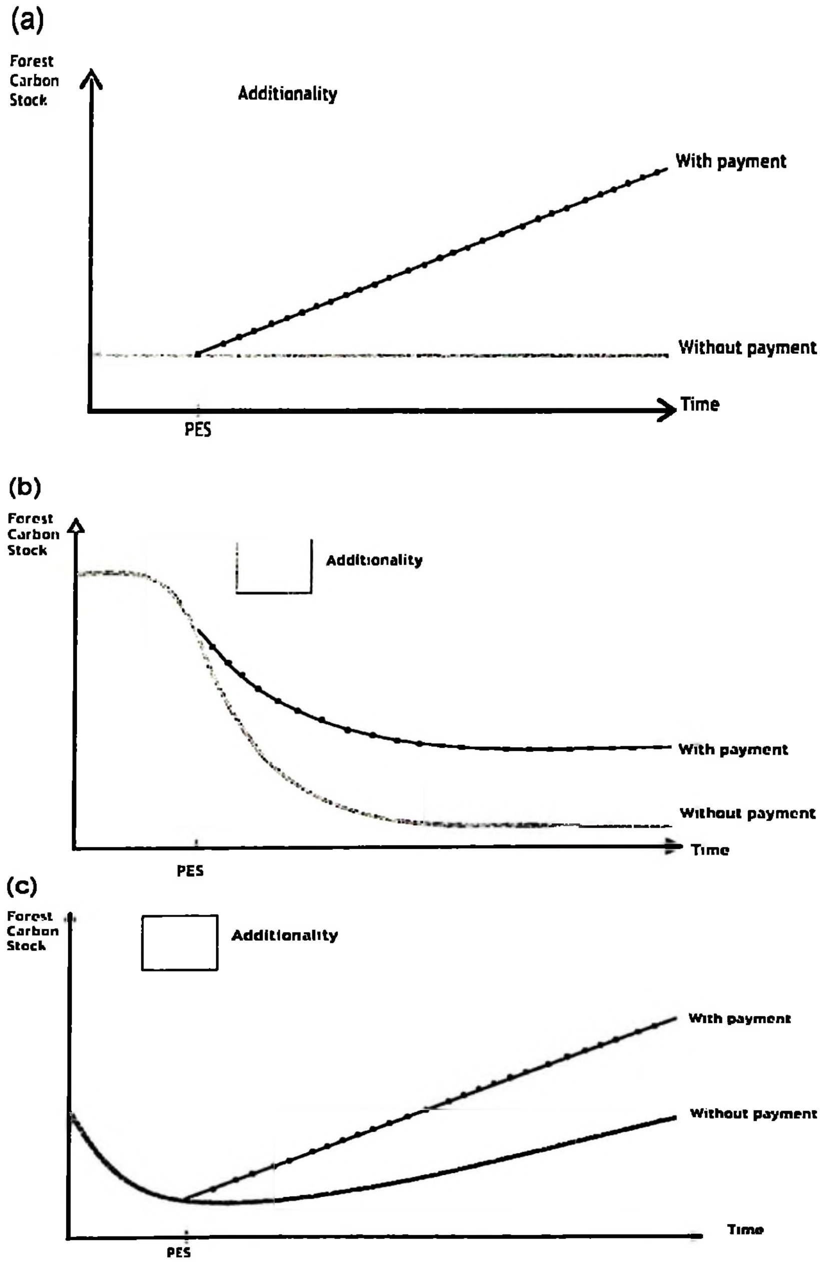

Figure 6: Three different PES scenarios: (a) static, (b) deteriorating and (c) improving service-delivery baseline.

Dotted lines show de facto service delivered "with PES"; solid lines show counterfactual baseline "without PES." Adopted from Wunder (2007).

The difference in static baseline is then attributed to specific interventions that qualify for carbon credits (Wunder, 2007). Many authors argue that in developing countries deforestation happens as an integral part of the development process. Developing countries adopt a declining baseline instead (Fig. 6). In such scenario a halt or even slow-down in deforestation would then qualify for additionality and carbon credits (REDD policy). There are other situations with improving service delivery baseline (Fig. 6) like in Costa Rica, where a historical turnaround of deforestation started before the PES system was implemented from 1996 onward. Fig. 6 shows that appropriate selection of baseline is of tremendous importance for the evaluation of the environmental impacts of PES. Adopting the wrong baseline can thus lower PES financial efficiency or, in the worst case, waste all the money spent: if no *de facto* change in behavior is achieved, no additional environmental services will be produced (Wunder, 2007).

PES efficacy depends on transaction costs, such as the costs to starting up the scheme including communication, negotiation, valuation and making contracts. Also the running costs of PES scheme like administration, monitoring and enforcement. Transaction costs should be distributed among service buyers, intermediaries and sellers. Direct payments should also exhibit competitive transaction costs (Ferraro and Simpson, 2002). In other words, people may look to PES as a source of just reward for poor communities (fairness) who take care of the environment and continuously produce environmental services since the beginning of the world until now, for free (Gutman, 2003; Rosa *et al.*, 2003; van Noordwijk *et al.*, 2004). In efficiency point of view, however, only those who constitute a credible threat to service provision or are likely to actively increase provision of service should be paid. Schemes for PES face intrinsic contradictions, having to balance additionality and financial efficiency goals with fairness and stewardship-reward considerations.

2.16 Markets for Carbon and NTFPs

2.16.1 Carbon markets

Government ban to harvest timber from catchment forests in Tanzania has led to minimal incentives for the participating communities who have signed JMAs with central government. The current study proposes that some mechanisms should be developed to supply for such needed incentives through payments for environmental services and forest goods. Possible services in Tanzania currently include; carbon sequestration and watershed protection, biodiversity conservation, and landscape beauty. This study is however limited to carbon due to some development and investiment in REDD+ piloting projects. Carbon sequestration can excite far-reaching effects at a global scale and have immediate effects at national as well as at a local level. For example, a molecule of carbon dioxide, regardless of where it is emitted, can be anywhere on the planet in little more than a week (Trexler, 2003). Similarly, a reduction of greenhouse gas emissions has the same effect on the atmosphere no matter where the reduction occurs (Winrock International, 2004). Markets for carbon are therefore expected to be at global level. Since the ratification of the Kyoto Protocol in 2004, several carbon markets have been developed. Some of the markets are regulatory while others are voluntary.

2.16.1.1 Regulatory markets

a) The Kyoto Protocol set up the International Emissions Trading (IET) Scheme, which is a cap-and trade system that allows Annex I countries to trade allowances with other Annex I countries.

To create flexibility in the market, the Kyoto Protocol created two mechanisms:

i. The first mechanism is referred to as Joint Implementation (JI), under which an emissions reduction project located in an Annex I country generates offsets that can be purchased by other Annex I countries and used for compliance in a regulatory cap-and- trade system.

ii. The second mechanism is the Clean Development Mechanism (CDM), which allows Annex I countries to purchase offsets generated by activities implemented in a developing nation that is a party to the Kyoto Protocol. The purchasing Annex I nation may then use those offsets for compliance in a regulatory cap-and-trade system (Capoor and Ambrosi, 2008). The Kyoto mechanisms were created to stimulate sustainable development through technology transfer and investment, help countries with their Kyoto commitments to meet their targets in a cost-effective way, and encourage the private sector and developing countries to contribute to emission reduction efforts (Cortez and Stephen, 2009).

b) The European Union Emissions Trading Scheme (EU ETS) (2005-2012) is a cap-and-trade scheme to help EU nations meet their Kyoto targets. Under the EU ETS, the governments of EU member states agree to national emission caps that must be approved by the European Commission (EC). Governments allocate allowances to their regulated industries and entities operating in the country, track and validate actual emissions in accordance with the relevant assigned amount, and require that allowances be retired after the end of each year. The EU ETS accepts credits from CDM and JI to be traded in the market (Capoor andAmbrosi, 2008). The EU ETS is the largest multinational carbon market currently in existence. Some years ago, the EU voted to exclude carbon offsets from forestry projects from the ETS as these were considered uncertain due to risk of forest fire, disease or other natural disasters. Ongoing negotiations regarding a post-Kyoto climate change treaty indicate, however, that the EU is in fact poised to consider forest-based carbon offsets in the future (Cortez and Stephen, 2009).

c) The New South Wales GHG Abatement Scheme (NSW) (2003-2012) creates emissions benchmarks for electricity retailers in Australia. This scheme establishes annual statewide greenhouse gas reduction targets, and requires individual electricity retailers and certain other parties who buy or sell electricity in NSW to meet mandatory benchmarks based on their share of the electricity market. If these parties, who are referred as "benchmark participants" fail to meet their benchmarks, a penalty is assigned. Monitoring the performance of benchmark participants is undertaken by the Independent Pricing and Regulatory Tribunal of NSW. This system has gone through a transition into a National Emissions Trading scheme for Australia (Cortez and Stephen, 2009).

d) The Regional Greenhouse Gas Initiative (RGGI) is an agreement among 10 Northeastern and Mid-Atlantic states in the U.S. that implemented a market-based cap-and-trade system in 2009. The agreement mandated a cap and reduction in carbon dioxide emissions from power plants. RGGI is the first mandatory cap-and-trade programme in the U.S. that addresses emissions responsible for climate change, and it is viewed as a potential model and precedent for a broader federal programme to limit emissions of greenhouse gases in the U.S. (Capoor and Ambrosi, 2008).

e) The California Climate Action Registry (CCAR) was established in California in 2001 through legislative action. CCAR is a non-profit public-private partnership that serves as a voluntary greenhouse gas registry to protect, encourage, and promote early actions to reduce greenhouse gas emissions. The expectation is that early actions reported under CCAR will be eligible for crediting under future California emissions regulations. (Capoor and Ambrosi. 2008).

2.16.1.2 Voluntary Markets

There are two large voluntary markets. The Chicago Climate Exchange and the Over-the Counter Market (Butzengeiger. 2005; Taiyab. 2006)

a. The Chicago Climate Exchange (CCX) creates a market based on a cap-and-trade system in which participation is voluntary. Once an entity chooses to participate in the CCX, emissions reduction commitments become legally-binding. The CCX allows members who take on commitments to trade allowances with one another, and to purchase offsets from projects developed outside the membership cap (Taiyab. 2006).

b. Heightened public awareness of climate change has greatly increased participation to the over the counter (OTC) market for carbon offsets and this market has progressed and developed alongside regulatory markets. Many sources of GHG emissions, such as travel, household activities and special events, which are not addressed by existing policy instruments, can be mitigated through offset purchases on the OTC markets. While it is not practically feasible to reduce one's emissions to zero, purchasing offsets can help individuals or companies "neutralize" their emission levels (Butzengeiger, 2005). Participants in the OTC market include companies, governments, organizations, organizers of international events, and individuals, all who purchase or sell carbon offsets for reasons other than regulatory compliance. These retail offsets or credits, commonly referred to as Verified Emissions Reductions (VERs), are often purchased from retailers. Retailers consist of organizations that invest in a portfolio of offset projects and subsequently sell slices of the resulting emission reductions "portfolio" to customers in relatively small quantities, and at a higher price than purchased. There are approximately 30 to 40 such retail providers worldwide, most of them based in Europe, the U.S., and Australia (Hamilton *et al.*, 2008). Prices vary greatly, from US$5-$35 or more per tCO_2 e, depending on the quality and location of the project, and the price is set by the retailer. The market is wholly unregulated, as the credits are not being used to meet legally binding targets, though project developers may choose to follow CDM standards and verification methods, or may develop their own methods to ensure the integrity of the offsets sold (Hamilton *et al.*, 2008).

The voluntary market represents a promising complement to the compliance market as it covers many project types that are otherwise excluded from regulatory markets. While projects generating less than 50 000 tCO_2e annually are typically considered unattractive in the regulatory CDM market, such projects make up approximately 86% of the voluntary market (Butzengeiger, 2005; Taiyab, 2006). The voluntary market therefore effectively creates market opportunities for small-scale projects that would otherwise not exist. In addition, forestry projects that are for the most part excluded from compliance markets make up 56% of the voluntary market (Hamilton *et al.*, 2008). Table 5 provides a summary of these markets.

Table 5: Carbon markets.Transaction volumes and values, 2006 and 2007

Markets	Volume (MtCO2e)		Value (USDmillion)	
	2006	2007	2006	2007
Voluntary OTC Market	14.3	42.1	58.5	258.4
CCX	10.3	22.9	38.3	72.4
Total Voluntary Markets	**24.6**	**65**	**96.7**	**330.8**
EU ETS	1.1044	2.061	24.436	50.097
Primary CDM	537	551	6.887	6.887
Secondary CDM	25	240	8.384	8.384
Joint Implementation	16	41	141	495
New South Wales	20	25	225	224
Total Regulated Markets	**1.702**	**2918**	**40.072**	**66.087**
Total Global Markets	**1727**	**2983**	**40.169**	**66.417**

Source: Ecosystem Marketplace. New Carbon Finance. World Bank

2.16.2 Markets for Non Timber Forest Products

Since early 1990s, the role of Non-timber Forest Products (NTFPs) for sustainable forest management and poverty reduction has received increased attention (Arnold, 2002). NTFPs are fundamental for development and sustainable forest management and conservation strategies. They play an important part in supporting household livelihoods and therefore can be used to raise the perceived value of forest resources. They act as incentives for more sustainable use of forest and woodland resources (Arnold, 2002). In Tanzania, majority of rural household and a large proportion of urban household depend on NTFPs to meet some parts of their nutritional, health, construction material and income when selling these products.

Beekeeping as one of the major Non timber forest activity in Tanzania plays a major role in socio-economic development and environmental conservation. It is a source of food (e.g. honey, pollen and brood). raw materials for various industries (e.g. beeswax candles, lubricants). medicine (honey, propolis, beeswax bee venom) and source of income for beekeepers. It is an important income generating activity with high potential for improving incomes, especially for communities leaving close to forests and woodlands and employs about 2 million rural people. Beekeeping also plays a major role in improving biodiversity and increasing crop production through pollination. In Tanzania, beekeeping is carried out using traditional methods that account for 99% of the total production of honey and beeswax in the country. Approximately 95% of all hives are traditional including log and bark hives (Mwakatobe, 2001). Besides playing wider domestic roles in the bees and bee-products industry in Tanzania, beekeeping is also a good source of foreign exchange earnings (Table 6).

According to Mapolu (2005), the internal markets for honey and beeswax are not well established. Demand for honey as food and as an authentic ingredient in various foods and as a product with healing qualities is increasing. About 50% of honey produced is sold locally for beer and wine production and about 10% of honey produced is consumed locally as industrial honey in confectioneries and pharmaceutical industries. At the beekeepers gate 1 kg of honey is sold between TZS 3000 and TZS 5000 while in cities like Dar-es salaam, Arusha, Moshi and Morogoro, the price of honey is between TZS 8000 and TZS 12 000 per kg. One USD is equivalent to 1600 TZS.

Demand for honey and beeswax in the world market is very high and the demand for Tanzania honey and beeswax exceeds supply. In 1991, Tanzania honey won by 100% the quality test for "organic honey" in UK. However, quality control in terms of other factors such as colour, taste, viscosity and aroma, needs legal directives that will have to be adhered by all people handling the honey before it reaches the consumer (URT, 1998). The main buyers of Tanzania honey are the European Union member countries especially UK, Germany and The Netherlands. Other countries are United Arab Emirates, Oman and Kenya. The main importers of Tanzanian beeswax are Japan, USA and European Union member countries. Regarding international market prices. the quality table honey price was 1 200 US$/tonne. while industrial honey was only about 1 000 US$/t in 2009. The price of beeswax was USD 5 000/t. Table 6 sumarizes export data for honey and beewax from 2005 to 2009.

Table 6: Honey and beeswax exports for the period 2005-2009 from Tanzania

Product	2005	2006	2007	2008	2009
Natural honey (Tonnes)	43.67	325.73	156.01	612.96	485.84
Value/Year (TZS)	14 969 588	538 102 710	218 348 125	1 199 283 500	1 097 642 183
Beeswax (Tonnes)	481.71	364.53	320.66	580.15	556.00
Value / Year (TZS)	2 000 566 333	2 036 643 69	1 909 188 517	3 653 036 682	3 525 245 806
TOTAL (TZS)	**2 015 535 921**	**2 574 746 401**	**2 127 536 642**	**4 852 320 182**	**4 622 887 989**

Source: Beekeeping in Tanzania. Country position paper (Undated).

2.17 The Concept of Optimisation and Optimisation Models

2.17.1 Optimisation

Modelling forest management activities has been tackled by scientists over the last two decades. Both simulation and optimisation techniques have been used in solving forest management planning problems. With the introduction of ecosystems management (EM) that focuses on sustainable production and maintenance of ecological, social and economical values, neither approach provided a credible solution to help design the complex structure of forest management activities (Baskent, 2001). Alternative to these is a group of meta-heuristic or combinatorial optimisation techniques which have just gained the attention of forest modellers. Quantitative modelling of forest management incentives has been a challenging research endeavour within a planning process. Perhaps the most significant aspect of that challenge is developing a sound forest modelling approach that accommodates requirements with often conflicting management objectives such as wood supply, wildlife habitat, water quality, carbon sequestration and biodiversity. Multiple forest objectives are difficult to integrate in a forest management model. When two or more objectives are not completely complementary, mathematical programming models can help quantify tradeoffs between competing objectives (Schulte *et al.*, 1999).

2.17.2 Optimisation models

Since prehistoric times, humans have had an abiding interest in optimising the performance of systems that they use. Now-days all the decisions that we make at work, and those affecting our personal lives, usually have the goal of optimising some desirable characteristic. If there are some objective functions to optimise in addition to satisfying the requirements on the decision variables, the resulting model is known as an optimisation model (Baskent and Jordan, 2002). Each of the objectives to optimise is typically a measure of effectiveness of performance of the relevant system, and should be expressed as a mathematical function of the decision variables. If higher values of a measure of performance are more desirable (such a measure could be considered as a profit measure) we seek to attain the maximum or highest possible value for it. If lower values of a measure of performance are more desirable (such a measure could be interpreted as a cost measure) we seek to attain the minimum or the lowest possible value for it. The various measures of performance are usually called the objective function(s) in the mathematical model. To optimise an objective function means to either maximize or minimize it as desired (Murty, 2003).

In optimisation models, the requirements come from the relationships that must hold among the decision variables and the various static or dynamic structural elements by the nature of the system. Each requirement leads to a constraint on the decision variables that will be expressed as a mathematical equation or inequality in the model for the problem. The model also includes any bounds (lower and/or upper) that the decision variables or some functions of them must satisfy in order to account for the physical limitations under which the system must operate (Murty, 2003).

According to Baskent and Jordan (2002) if an objective function is a cost function we would like to minimize and if a profit functions to maximize it. Fortunately, it is not necessary to consider minimization and maximization problems separately, since any minimization problem can be transformed directly into a maximization problem and vice versa.

2.17.3 Types of Optimisation Models

2.17.3.1 Single versus multiobjective models

If there is only one measure of performance (such as yearly total profit, or production cost per unit) the model will be a single objective model. When there are several measures of performance, we get a multiobjective model in which two or more objective functions are required to be optimised simultaneously (Sadeghi *et al.*, 2008).

Mathematical theory of single objective models is well developed while for multiobjective optimisation models, we do not even have the concept of an optimum solution. Often, the various objective functions conflict with each other (i.e. optimising one of them usually tends to move the other towards undesirable values), for solving such models one needs to know how many units of one function can be sacrificed to gain one unit of the other, but this trade-off information is not available (Steuer, 1995b). In other words, one is forced to determine the best compromise that can be achieved. Since trade-off information among the various objective functions is not given, multi-objective optimisation problems are not precisely stated mathematical problems. Techniques for handling them usually involve iteration using several degrees of compromises among the various objective functions until a consensus is reached that the present solution looks reasonable from the point of view of all the objective functions (Xevi and Khan, 2005).

2.17.3.2 Static versus dynamic models

Models that deal with a one-shot situation are known as static models. These include models which involve determining an optimum solution for a one period problem. For example, consider the production planning problem in a company making a variety of products. To determine the optimum quantities of each product that this company should produce in a single year, leads to a static model. However, according to Murty (2003), planning does involve the time element, and if an application is concerned with a situation that lasts over several years, the same types of decisions may have to be made in each year. In the production planning problem discussed above, if a planning horizon of 5 years is being considered, it is necessary to determine the optimum quantities of each product to produce, in each year of the planning horizon. Models that involve a sequence of such decisions over multiple periods are called multi-period or dynamic models (Denardo, 1982).

When planning for a multi-period horizon, if there is no change in the data at all from one period to the next, then the optimum solution for the first period determined from a static model for that period, will continue to be optimal for every period of the planning horizon. Thus multi-period problems in which the changes in the data over the various periods are small, can be handled through a static one period model, by repeating the same optimum solution in every period. Even when changes in the data from one period to the next are significant, many companies find it convenient to construct a static single period model for their production planning decisions, which they solve at the beginning of every period with the most current estimates of data for the optimum plan for that period. This points out the importance of static models, even though most real world problems are dynamic (Denardo, 1982; Spring *et al.*, 2005).

2.17.3.3 Stochastic versus deterministic models

An optimisation model in which there is no uncertainty (i.e. all the data elements are known with certainty) is known as a deterministic optimisation model. In a single objective static optimisation model, the objective function can be interpreted as the yield or profit that is required to be maximized. The objective function expresses the yield as a function of the various decision variables. In real world applications, the yield is almost never known with certainty; typically it is a random variable subject to many random fluctuations that are not under our control. For example the yield may depend on the unit profit coefficients of the various goods manufactured by the company (these are the data elements in the model) and these things fluctuate randomly. To analyze the problem treating the yield as a random variable requires the use of complicated stochastic optimisation (programming) models (Spring *et al.*, 2005). Instead, one normally analyses the problem using a deterministic model in which the random variables in the yield function are replaced by either their most likely values, or expected values etc. The solution of the deterministic approximation often gives the decision maker an excellent insight for making the best choice.

It is also possible to perform sensitivity analysis on the deterministic model. This involves a study of how the optimum solution varies as the data elements in the model vary within a small neighborhood of their current values. Decision makers combine all this information with their human judgement to come up with the best decision to implement. Some people may feel that even though it is more complicated, a stochastic programming model treating the data elements as random variables (which they are), leads to more accurate solutions than a deterministic approximation obtained by substituting expected values and the like for the data elements. In most cases this is not true. To analyze the stochastic model one needs the probability distributions of the random data elements. Usually, this information is not available. Therefore most real world optimisation applications are based on deterministic models (Falcao and Borges, 2002; Spring *et al.*, 2005).

2.17.4 Use of linear programming in modeling

Despite the vast literature that exists in the optimisation field, frequent application of the applied mathematical approach in the management of ecosystem goods and services in the developing world is minimal (Sadeghi *et al.*, 2008). Linear programming (LP) is the most widely used mathematical programming method and it has been the most broadly applied of all management science techniques in natural resource management and related disciplines (Holmes, 1976; Martin and Sendak, 1993). Some of its application in forest management include planning of logging operations, product optimisation in a log concentration yard (Little and Wooten, 1972), optimising timber production and carbon sequestration (Keles, 2010), land use optimisation in watershed (Sadeghi *et al.*, 2008) and analysis of internal transfer pricing policies for logs and reforestation planning (Buongiorno and Teeguarden, 1973). The bibliography compiled by Martin and Sendak (1973) lists more than 400 publications related to the application of the management science in forestry and forest products, with more than 200 devoted to linear programming.

There are many efficient techniques for optimisation of ecosystem goods and services out of which linear programming is a basic method (Jianbo *et al.*, 2002; Gabriel *et al.*, 2006). Compared to goal programming, the impossibility of weighing relative importance to different objectives required for goal programming owing to inaccessibility of reliable data, linear programming is more preferred for application due to its simplicity and availability (Chang *et al.*, 1995; Amir and Fisher, 1999; Benli and Kodal, 2003). The most popular software packages which are used to solve linear programmes (LPs) and other types of mathematical programmes include LINDO, GAMS, LPWYE and XPRESS-MP. However, all these packages tend to be DOS based and are intended for a specialist market which requires tools dedicated to solving LPs (Dykstra, 1980).

The planning models of the 1970s and 1980s used linear programming techniques such as FORPLAN (Johnson and Scheurman, 1977) to identify efficient land allocations on national forests. Linear programming generally replaced more simplistic cost-benefit analysis but still used simple linear approximations to represent resource interactions. In fact, spatial considerations along with the inclusion of multiple forest values have given birth to Ecosystem Management (EM). Essentially, it works on the premise that a sustainable flow of various resource values can be achieved by managing forests as ecosystems (Grumbine, 1994; Baskent and Jordan, 1995; Baskerville, 1997).

2.17.5 Application of optimisation models in Tanzania

Optimisation models in Tanzania have been applied in few cases. However, the application has been in the form of academic pursuits rather than being tailored toward practical application (Kaoneka, 1993). Even with limited scope, models in Tanzania could be useful and have considerable prospects for increasing the scope of application. Their usefulness is attributed to the fact that they provide management with options and criteria for evaluating alternatives. Options are based on the premise that, in a given situation, resources are limited, thus it is important to develop a portifolio of options based on preferences by decision makers. The choice of an alternative is always based on evaluative procedures. Evaluative procedures vary according to scope and stated intent of decision maker. In most cases, a conceptual framework is designed as a starting point. This is followed by operationalization of the conceptual framework in order to generate quantitative information. At this stage, modeling is of interest. Models generate quantitative data which can aid the decision maker to select the best among the evaluated alternatives. This background gives one of the reason to believe that by increasing the scope of model application in Tanzania, one may enhance and improve decisions related to forest governance and planning. The trade-offs generated by models can be used as the basis in the decision making process.

In Tanzania. Linear Programming (LP) has been applied in planning forest plantation management regimes at the project level (Mgeni, 1986). It was developed and applied to Sao Hill Forest Project located in Iringa Region, southern highlands of Tanzania. The LP was applied specifically to problems related to determining optimal planting regimes (how many hectares of land should be planted with a particular tree species each year) which could satisfy the wood demand while observing certain technical constraints (Kaoneka, 1993). LP model was also developed and applied to a forest-based (wood) processing factory in Arusha, northern Tanzania. The objective function was to maximize profits from the different units of the factory with the limitations of the production capacities of the units, wood raw material supply and market restrictions. Another LP model in analysing agroforestry farming systems in Mbeya Region, southern highlands was based on the work by Dykstra (1980). LP model was developed to minimize the total land under cultivation while assuring adequate production of food and fuelwood with assumption that peasants are averse to the strenuous work of tilling land using handtools.

CHAPTER THREE

3. 0 STUDY AREA AND RESEARCH METHODS

3.1 Study Area

This study was conducted in two different regions/districts within the Uluguru Mountains in Morogoro and Udzungwa Mountains in Iringa which are part of the Eastern Arc Mountains, Tanzania. The two sites were selected based on the abundance of CFRs with JFM projects where communities and central government have signed JMAs. Fig. 7 shows a map of the Eastern Arc Mountains.

3.1.1 Location, access and topography

Uluguru Mountains are located in Morogoro region, approximately 200 km west of Dar es Salaam City. The mountains are situated within Morogoro rural and Mvomero districts. In the foothills of these mountains, there are a number of lowland forests including Kimboza and Ruvu FRs. These two FRs were sampled for ecological data collection. Kimboza and Ruvu are gazzeted CFRs with areas of 405 ha and 2 983 ha respectively. Kimboza FR is located at 6° 59' 7'' 02' South and 37° 47' 37'' 49' East (Rodgers *et al.*, 1983) and Ruvu FR is at 6° 53' 7'' 02' South 37° 49' 37'' 54' East (Lovett and Pocs, 1993). Kimboza and Ruvu FRs which are approximayely 50 km from Morogoro town can be accessed through the Morogoro to Kisaki road. They are situated in Mkuyuni and Matombo divisions respectively. Kimboza is in the eastern foothills of Uluguru covering a karstic plateau south of Kibungo Mission at 300 to 400 m.a.s.l. Ruvu FR covers a plateau on either sides of the Ruvu River gorge at 200 to 480 m.a.s.l. (Lovett and Pocs, 1993).

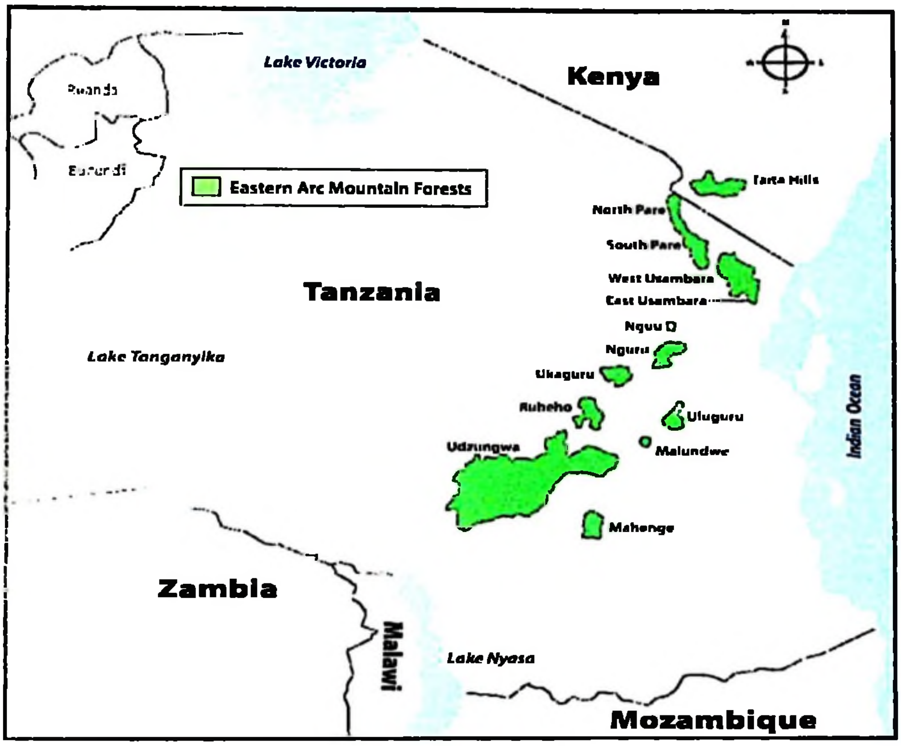

Figure 7: A map showing Eastern Arc Mountains including Uluguru and Udzungwa blocks in Tanzania.

Kimboza FR has been under JFM regime between Central government and four villages of Kibangile, Mwalazi, Changa and Kilemela since 2000. Ruvu FR is under the central government management with no community participation. Fig. 8 is a map showing the study sites (the forests) in Morogoro, Tanzania.

Udzungwa Mountain forests constituted the other study site. The forests are the largest in the Eastern Arc blocks stretching across four districts in the southern highlands of Tanzania. The major part is found in Kilolo and Mufindi districts within Iringa region. The Udzungwa Mountains rise to 2332 m a.s.l. and there is a large plateau area above 1500 m altitude (Lovett and Pocs, 1993). These mountains contain a number of forest reserves in different categories of management including Kilombero Nature Reserve. Two FRs including New Dabaga Ulongambi (NDU) and Kisinga Lugalo (KL) were used in this study. All the two forests are located in Kilolo district.

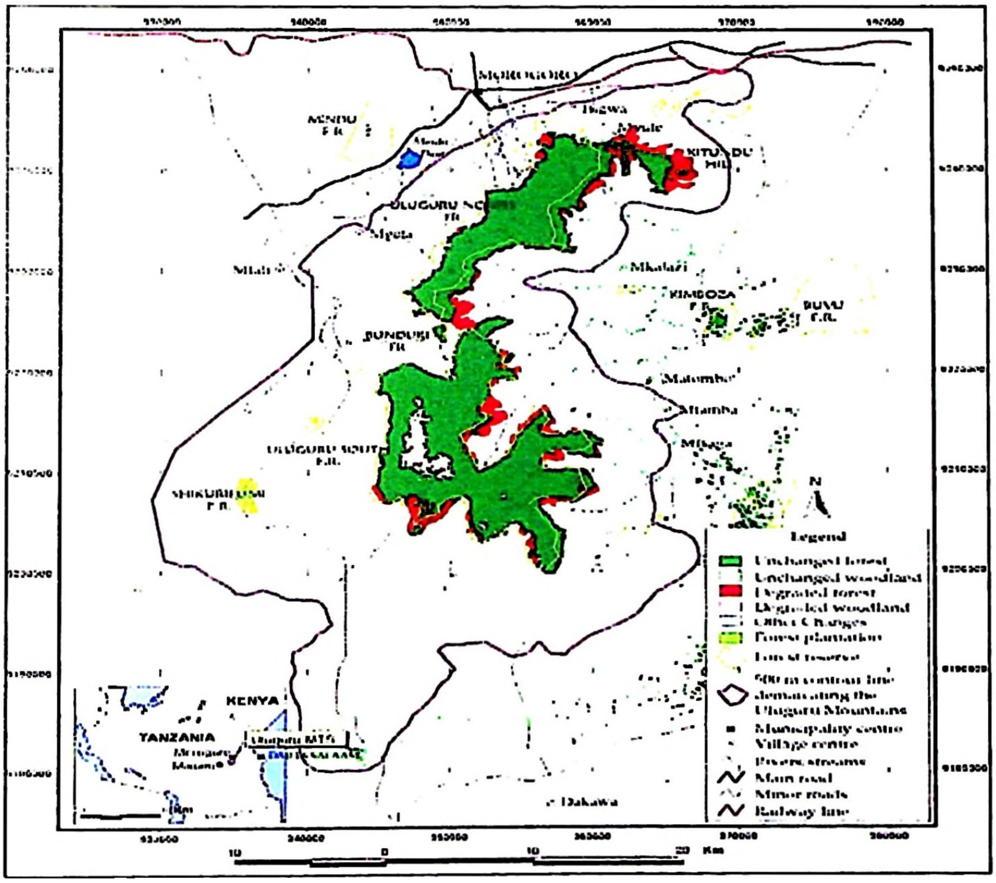

Figure 8: A map showing study sites, Kimboza and Ruvu FRs in Morogoro, Tanzania.

NDU and KL FRs (Fig. 9) are found in the upper slopes of Udzungwa. NDU FR is located at 08°03'15" - 08°06'46" South; 35°54'07" - 35°56'52" East and KL FR is located at 07°44'25" - 07°53'00" South; 35°53'52" - 36°03'40" East. NDU FR covers an area of 3 700 ha and it is 50 km away from Iringa town adjacent to Kidabaga village (Lovett and Pocs, 1993).

The reserve is on the Uhehe plateau 25 km west of the Udzungwa escarpment. Access is by road from Kidabaga to the southern side and from Lulanzi/Luhindo villages to the western side and northern side. The reserve range from 1 760-2 060 m. a.s.l. KL FR covers an area of 14 164 ha and it is 40 km from Iringa town through Kisinga village from the south (Lovett and Pocs, 1993). Access to the south-west corner is through Lundamatwe village, 12 km East of Iringa on the main Iringa - Morogoro road. Access from the North is through the Imalutwa village.

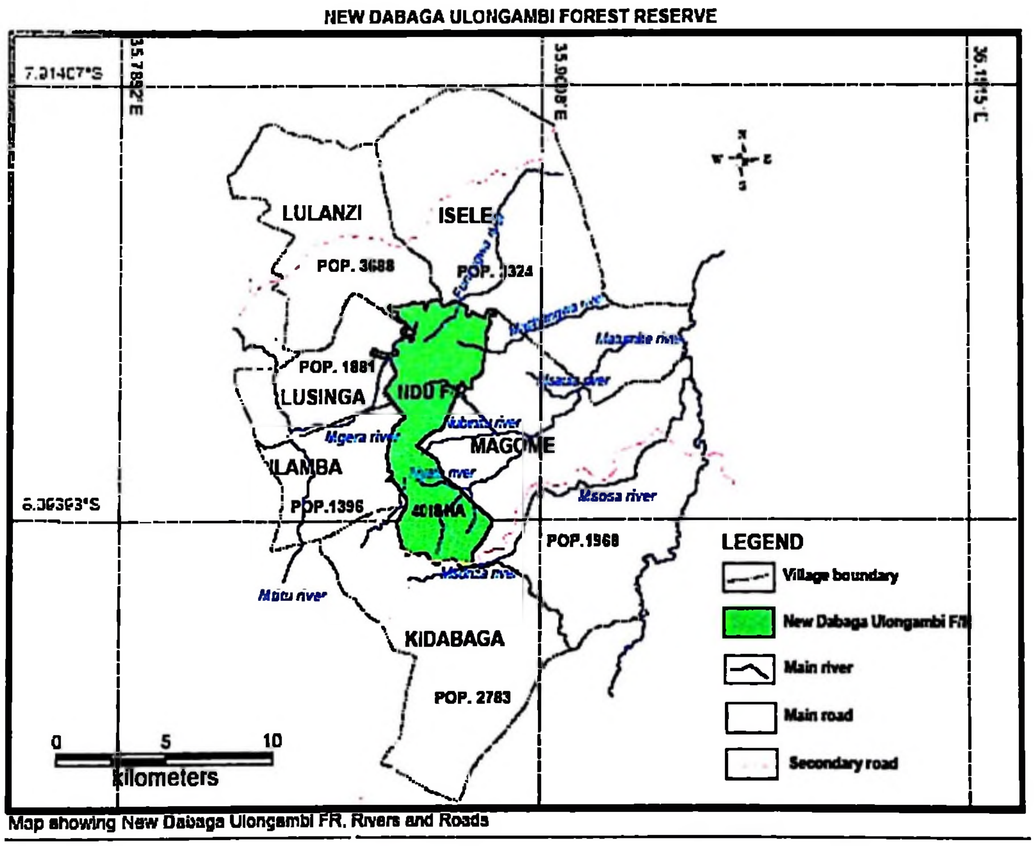

Figure 9: A map showing study site, NDU FR and the adjacent villages in Iringa, Tanzania.

The reserve covers an extensive area of undulating plateau with a range of 1 700 - 2 332 m.a.s.l. NDU FR is owned by the central government and managed jointly with communities of six villages of Magome, Kidabaga, Ilamba, Lusinga, Luhindo and Isele. KL FR is owned by the central government with no JFM.

Kimboza and NDU FRs were selected for this study based on their long history of JFM implementation for about two decades. Furthermore, they represent important water catchment areas (CFRs) in the country. Four villages were randomly selected for socio-economic study around forests with JFM regime. These were Kibangile and Changa for Kimboza FR and Kidabaga and Luhindo for NDU FR.

3.1.2 Geology and soils

Kimboza soils are of tropical rendzina on Precambrian dolomitic marble base rocks which is the same as that of Ruvu FR especially on its western half (Rodgers *et al.*, 1983). In the eastern side, Ruvu FR is mainly covered by red ferralitic latosols on Precambrian granulite and gneiss. Protruding metamorphosed limestone Kants are prominent across all the two reserves (Lovett and Pócs, 1993; Doggart *et al.*, 2000). NDU and KL FRs are characterized by brown sandy loams over crystalline gneiss with areas of clay with stones and seasonally inundated grassland (Lovett and Pocs, 1993).

3.1.3 Climate

Kimboza and Ruvu FRs receive oceanic rainfall with oceanic temperatures (Rodgers *et al.*, 1983). The rainfall pattern is bimodal with short rains from October to December, and long rains from February to May. Estimated rainfall is up to 1 800 mm/yr with groundwater. Dry season is from June to September. Maximum and minimum temperatures are 28°C and 23°C in December and July respectively (Rodgers *et al.*, 1983). Both NDU and KL have oceanic rainfall with oceanic/continental temperatures. Estimated rainfall is between 1 500 to 2 000 mm/yr. Dry season is between June to November. Mean maximum and minimum temperatures are estimated to be 20°C in December and 15°C in July respectively (Lovett and Pocs, 1993).

3.1.4 Vegetation

The predominant natural vegetation type in Kimboza and Ruvu FRs is lowland forest with average of 30 m high canopy of trees (Rodgers *et al.*, 1983). Another type of vegetation is open woodland tree species decribed by Malimbwi *et al.* (2005). In Kimboza FR there are areas dominated by *Cedrella odorata* plantations and few areas with planted teak (*Tectona grandis*). Teak plots are along the road and *Cedrella* is extensively distributed almost everywhere in the forest to the extent of dominating the lowland tree species (Personal observation, 2010). Therefore, in this study, four vegetation types were used to differentiate four different tree groups present in Kimboza FR, (the lowland, woodland, *cedrella* and teak vegetations). In the lowland vegetation, large trees include: *Antiaris toxicaria*, *Aningeria pseudoracemosa*, *Bombax rhodognaphalon*. *Cordyla africana*, *Elaeis guineensis*, *Parkia filicoides*, *Ricinodendron heudelotii and Sterculia appendiculata*. Tree species including *Milicia excelsa*, *Khaya anthotheca*, *Isoberlinia scheffleri*, *Lettowianthus stellatu and Newtonia paucijuga* that existed earlier are almost exploited (Malimbwi *et al.*, 2002; Personal observation, 2010). In some parts of the reserves, dry semi-deciduous tree species also occur (Lovett and Pocs, 1993).

The predominant vegetation in NDU and KL is the montane forest with some few patches of bamboo (Lovett and Pocs, 1993). Black wattle (*Acacia mearnsii*) has invaded open areas near the forest edges following disturbances in some parts of the forests. Due to forest logging in the past, many areas of the forests had broken canopies, often with climber tangles (FBD, 2005). Tree species in montane forest on steep slopes include *Albizia gummifera, Agauria salicifolia, Aphloia theiformis, Bersama abyssinica, Diospyros whyteana, Kiggelia africana, Macaranga kilimandscharica, Myrica* and *Prunus Africana* (Lovett and Pocs, 1993). Species more typical for montane forest occur in the valleys. These trees include: *Albizia gummifera, Bersama abyssinica, Bridelia brideliifolia, Bridelia micrantha, Canthium oligocarpum, Casearia battiscombei, Cassipourea gummifera, Chrysophyllum gorungosanum, Cussonia spicata, Ixora scheffleri, Macaranga kilimandscharica, Maesa lanceolata, Maytenus acuminata, Myrianthus holstii, Nuxia congesta, Ochna holstii, Ocotea usambarensis, Phoenix, Polyscias fulva, Rapanea, Rawsonia reticulata, Schrebera alata, Strombosia scheffleri, Syzygium guineense, Syzygium masukuense, Vepris stolzii,* and *Zanthoxylon gilletii* to mention a few.

3.1.5 Biodiversity

Kimboza and Ruvu FRs have a mixture of both the Eastern Arc and coastal forest types, and so, are rich in biodiversity. As part of the Uluguru Mountains they are one of the ten most important tropical forest sites for conservation in Africa (Frontier-Tanzania, 2005). The mountains are recognized as one of the 34 globally important "hot spots" for biodiversity according to Conservation International (Mittermeier *et al.*, 2004). For example, the blue dwarf gecko (*Lygodactylus williamsi*) is an endemic lizard species found only on Pandanus stems in Kimboza FR (Lovett and Pocs, 1993). Endemic plant species in Kimboza FR include two *Asystasia* species, *Baphia pauloi*, *Chassalia discolor* var. *grandifolia*, *Cynometra ulugurensis* (a tall tree), *Garcinia bifasciculata* (tree), *Impatiens cinnabarina*, *Pavetta crebrifolia* var. *kimbozensis*, *Streptocarpus kimbozana*, and an epiphyllous liverwort, *Cololejeunea jonesii* (Rodgers *et al.*, 1983). An Eastern Arc endemic species found in Ruvu FR is *Pycnocoma macrantha*. *Rawsonia reticulata* also occurs although it is below its normal altitudinal range (Lovett and Pocs, 1993).

A number of species occur in Udzungwa Mountain ranges including NDU and KL FRs with restricted distribution, notably *Psydrax uzungwensis*. Endemic species in this range include seventeen strict endemic vertebrate species, twenty seven Eastern Arc endemic vertebrate species and thirty six Eastern Arc endemic trees. NDU and KL FRs contain varieties of animals which include. Black and White Colobus (*Mbega*). Vervet monkey (*Tumbili*), Eastern Tree Hyrax (*Pimbi*), Iringa Red Colobus (*Ng'uluba*). Red Duiker (*Nfuno*), Abbot's Duiker (*Vinde*). Sykes Monkey (*Nyabu*). Sanje crested Mangabey (*Ngologa or Babaoto*) Livingstone's Suni (*Swangala*), *Neotragus moschatus* (*Digidigi*) Bushbuck and Bushpig (*Ngubi*). Buffalo occur in low numbers in the Western parts of KL forest reserve. Birds available include, *Stephanoaetus coronatus* (Ng'ungule, or Kiwikiwi), *Accipiter tachiro, Francolinus afer* (Kware). *Tauraco livingstonii, Apaloderma vittatum, Smithornis capensis. Cercococcyx montanus, Psalidoprocne pristoptera, Dicrurus ludwigii, Alcippe abyssinica, Andropadus masukuensis. Andropadus milanjensis, Andropadus tephrolaemus, Andropadus virens, Phyllastrephus placidis, Cossypha anomala, Apalis alticola, Apalis melanocephala, Apalis chapini, Apalis thoracica, Bradypterus mariae, B. cinnamomeus, Orthotomus metopias, Muscicapa adusta, Trochocercus albonotatus, Malaconotus multicolor, Laniarius fuelleborni, Nectarinia mediocris, Zosterops senegalensis, Ploceus bicolor* and *Cryptospiza reichenovii* (Lovett and Pocs, 1993).

3.1.6 Hydrology and water catchment values

The Uluguru Mountains form the main water catchment area of the Wami Ruvu Basin which drain into Indian Ocean and receive one of the highest rainfalls (> 1 700 mm/year in

Tanzania (Burgess *et al.*, 2010). The importance of the Uluguru catchments to water supply was recognized as early as 1906 by the German colonialists (Munishi and Shear, 2005). The Ruvu River, which originates from these mountain blocks and passes through Kimboza and Ruvu FRs is the single major source of water for some parts of Morogoro region, Coastal region and Dar es Salaam. Kimboza and Ruvu FRs have several springs producing water all year round supplying several streamlets carrying water to the Ruvu River (Lovett and Pocs, 1993). These forests together with the Ulugurus represent a cloud forest ecosystem which performs important functions in terms of water catchment. A reduction in cloud forest cover is thus generally considered to lead to less cloud capture, and reduced stream flows particularly in the dry season when there is little rainfall (Bruijnzeel and Hamilton, 2000). There are no major rivers originating from NDU and KL FRs. However, there are 13 small rivers and streams which are used locally for small scale irrigation and general water supply and there are probably twice of these originating from KL (Lovett and Pocs, 1993).

3.1.7 Human Population and Ethnography

The people around Kimboza and Ruvu FRs are of Waluguru ethinic group of matrilineal system of inheritance. There are few immigrants including Pare, Sambaa, Nyakyusa, Haa, Hehe and Kutu. Currently, pastoral and agro-pastolarists including the Maasai, Wasukuma and Wamang'ati are also found. According to the population census of 2002 (URT, 2002), the population of the four villages and six villages adjacent to Kimboza and Ruvu FRs was 7 304 and 11 507 respectively. The growth rate for Morogoro rural district was 2% annually (URT, 2002). There were approximately 150 villages in the Udzungwa Mountains, containing at least 700 000 people. Some areas have high population density, but there are also large areas with sparse population and few villages, particularly in the higher areas close to the Udzungwa National Park and Kilombero Nature Reserve. The main inhabitants were the Wahehe, Wabena and Wakinga. During 2002 census, the population of 6 villages adjacent to NDU FR was 14 340 and the 9 villages adjacent to KL FR were 21 196 people (URT, 2002). The current population size of the study villages and the ratio between male and female is shown in Table 7.

3.1.8 Land use and socio-economic activities

Land transfer in the Ulugurus used to be matrelineral although it is now changing to patrimonial system (Bangati, H.N. personal communication, 2010). Many farmlands are customarily owned by men and there are joint decisions on the use of family land.

Table 7: Population distribution and ethnicity in the study villages

		Population		Total
Village	**Ethnicity**	**Male**	**Female**	
Morogoro Rural District		**2 251**	**2 544**	**4 795**
Kibangile	Dominated by Waluguru	792	883	1 675
Changa	Dominated by Waluguru	1 459	1 661	3 120
Kilolo District (Iringa)		**1 317**	**1 465**	**2 782**
Kidabaga	Wahehe, Wabena and Wangindo	716	847	1 563
Luhindo	Wahehe, Wabena and Wadzungwa	601	618	1 219
Grand Total		**3 568**	**4 009**	**7 577**

Source: Village Executive Officers' Data, 2010

The village leadership administers some of the village land adjacent to the forest reserves but some land remains under clans (Bangati, H.N. personal communication, 2010). The main land use systems include farming, mining, livestock keeping, agro forestry and collection of forest products. Also forests provide favorable climate for crop production (e.g. spices), water and good habitat for wildlife. In all the study sites, communities range from very poor people depending on subsistence farming to relatively rich people that have developed intensive farming. Their land-use choices and economic livelihood depend on a range of factors such as climate, location, type of food or cash crops and access to markets. Farmers often own scattered pieces of land, usually less than 5 acres per parcel (Hymas, 2000).

In some cases however, farmers rent land where landowners determine what they should grow. Farming is the main economic activity for the forest adjacent communities and therefore the main source of income. Main crops include maize, beans, rice, banana, vegetables, fruits, potatoes, simsim, sorghum, black pepper, groundnuts, coconuts, sugarcane, sunflower, and cassava. However, the communities adjacent to the forest reserve are engaged in beekeeping, lumbering, carpentry, mining, livestock keeping, small business, brick making and fuel wood selling, formal employment and provision of casual labour. In Morogoro sites, mining is the second economic activity after farming (Shila, 2004) of which ruby mining is the most serious problem in Ruvu FR with people coming from all over Tanzania to dig holes looking for the stones and hence destroying the vegetation (Lovett and Pócs, 1993; Bhatia and Ringia, 1996; Doggart *et al.*, 2000; Rwamgira, 2007). There are also gold miners who camp on the banks of the Ruvu River within the reserve (Field surveys, 2009).

The villages are connected to the market centers by earth roads, which is passable throughout the year. For Morogoro rural district, Matombo, Mkuyuni and Morogoro town are the nearest active markets. For Kilolo, local markets are at Kidabaga, Lulanzi and Iringa town. The markets at regional town centres are connected to other cities like Dar es

Salaam and Dodoma through major highways. The transport is almost reliable through out the year, thus easy transportation of crops, commonly done by middlemen.

3.2 Research Methods

3.2.1 Research design

This study applied cross-sectional design which studied a cross-section of the population at a single point in time and data collection was done once. This type of research is quick, cheap and it is one of the best ways to determine prevalence and useful at identifying associations that can then be more rigorously studied using a randomised controlled study (Bailey, 1995). As there is no follow up, fewer resources are required to undertake the study. This design was adopted for both socio-economic and ecological surveys.

3.2.2 Sampling procedure

Purposive and stratified random sampling procedures were used in selecting study areas. A purposive procedure was employed in selecting regions and districts which suits the conditions for the study including catchments with long history of JFM. The study areas were selected accordingly in two major ecological zones; the lowlands in Morogoro and the highlands in Iringa. Stratified random sampling (SRS) was used to select heads of households (for interview) following the wealth ranking as identified prior the interviews. SRS was chosen because it enhances getting representative samples from various wealth categories within the sampling frame. Social scholars have reported that SRS produces better results than simple random and systematic sampling (de Vaus, 1993; Bailey, 1995).

3.2.3 Sampling frame and sample size

The sampling unit in socio-economic data was a household while for ecological data was a plot. The sampling frame for socio-economic data was the list of all households in the village register while for ecological data it comprised of the entire FR. The average sampling intensity of 9.5% of the population was maintained during the survey. This sampling intensity was considered enough to represent the population to be studied as it was above 5% and it refelected the available research budget. Sample size and intensity for socio-economic data is shown in Table 8.

Table 8: Proportional sample size of the study villages in Morogoro and Iringa, Tanzania

Location	Number of Households	Sample size	Sampling Intensity (%)
Morogoro Rural			8
District	970	80	
Kibangile	367	44	
Changa	603	36	
Kilolo District	828	84	10
Kidabaga	488	46	
Luhindo	340	38	
Grand Total	1 725	164	Mean = 9

3.2.4 Primary data collection

This study used two main types of data sets; ecological and socio-economic data. These were collected in three different phases. Phase one involved reconnaissance survey carried out prior to actual data collection. The second phase involved collection of ecological data where forest inventory for stocking parameters and disturbance levels was done. The third phase was collection of socio-economic data which involved PRA, Key Informant

Interviews, Focus Group Discussions (FGDs), Household Questionnaires and Direct Observation (Appendices 2-4). This combination of techniques helped to complement limitations that could be contributed by one technique, therefore allowed cross checking and verification, commonly known as triangulation (Singleton *et al.*, 1993; Mikkelsen, 1995).

3.2.4.1 Reconnaissance survey

This phase aimed at familiarising the researcher with the social settings of the study areas, selection of study sites (villages and FRs), pre-testing of data collection tools and pilot survey before actual forest inventory. The reconnaissance exercise was carried out in Kimboza and NDU FRs and questionnares were pre-tested at Kibangile and Kidabaga villages for Morogoro and Iringa sites respectively. Households that were used in pre-testing were excluded from the main survey.The reconnaissance survey also enlightened the researcher on other logistical issues that would contribute to the success of the study.

The first days of the pilot survey were used to familiarize with the forest, tree species, forest boundaries, terrain and all other issues in the sampled forest. Determination of basal area per ha (G) was done by using a relascope. A total of 15 points were selected randomly to cover all possible variations in the forest. The objective of doing this was to allow estimation of number of sample plots needed for forest measurements based on observed tree population variation. A relascope of basal area factor of 1 cm was used to determine 'in', 'out' and 'half' or 'boarder' trees in these 15 selected points. Standard deviation (SD) and G were calculated (Table 8). The number of sampling plots (n) required to attain a desired precision at specified sampling error (E) was given using equation 2:

$$n = CV^2 t^2 / E^2 \qquad (2)$$

Where:

CV = coefficient of variation

t = value of t obtained from the student's t-distribution table at n-1 degree of freedom of the pilot study with 95% confidence. For 15 plots t value is 1.761

E = allowable sampling error

A range of 5% to 10% sampling error was used depending on the size of the forest. IPCC (2003) recommends adopting a sampling error of 5% which gives estimates within the precision of ±10% of the mean with 95% confidence. However, Zahabu (2008) argued that given the nature of Tanzania's natural forests with fragmented, degraded and intact patches, sampling error of up to 10% is acceptable. This is because increasing the sampling error reduces the number of plots required, but this means compromising the level of precision (Brown, 2002). The level of precision required has direct effect on inventory cost. With 5% sampling error considerably more plots would be required and that implies more time needed for the inventory, which of course greatly increases the costs (Zahabu, 2008). In this study, a compromise therefore had to be made between the precision desired and the costs where sampling error varied from 5% to 9% depending on the size of the forest.

Taking NDU FR as an example, using sampling error of 5% needed 98 sample plots which would be very costly but sampling error of 8% instead needed only 38 plots that are justifiable in terms of costs (Fig. 10). Firstly, it is statistically acceptable since the sampling units are more than 30 (Bailey, 1995). Secondly, if a curved line is drawn to connect the points in Fig. 10, its slope would be drastically reduced from this point implying that additional error has less effect on precision. Thirdly, it was the practical compromise given the available time and financial resources.

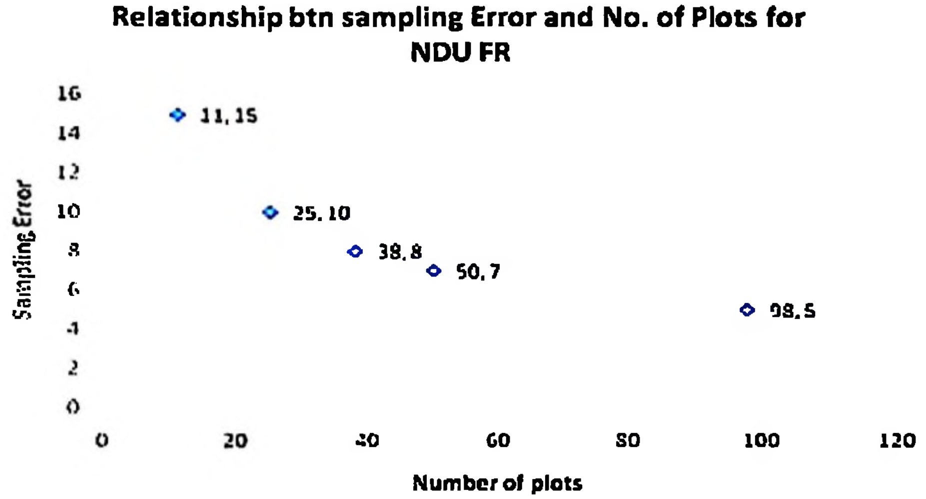

Figure 10: Number of plots versus sampling error for NDU FR in Iringa, Tanzania.

Note: In the points, the first number represents the number of sample plots and the second number the sampling error in (%)

3.2.4.2 Ecological data

Payments for carbon sequestration is one of the potential incentives for people owning or managing forest resources with assumption that REDD+ policy will be passed after the Kyoto protocol in 2012. With this knowledge, forest inventory was carried out to estimate biomass and carbon storage for FRs under study. Apart from estimation of carbon, forest inventory also assessed levels and spatial distribution of human disturbances in the FRs. A comparison of these disturbances was made between forests under JFM and those with no JFM arrangements based on the fact that they were nearby and had similar ecological conditions. The assumption made was that more human disturbances reflect low compliance to rules which means high level of un-satisfaction to communities, which would be a result of poor incentives. Disturbance level was also used as a constraint in the optimisation model.

Forest stratification

According to MacDicken (1997); Brown (2003) and IPCC (2003), it is often useful to do forest stratification before biomass and carbon estimation. In this study, stratification was done in Kimboza FR because the forest was made up of four distinct vegetation types composed of *Cedrella odorata*, *Tectona grandis*, "lowland vegetation" and Woodland. The forest was therefore divided into four vegetation strata and sampling was done from each stratum. In the other three FRs (NDU, KL and Ruvu), each forest was treated as one continuous stratum because it was observed during the pilot survey that the vegetation types were more or less homogeneous.

Locating sample plots on the ground

All sample plots were marked on map before laying them on the ground. Depending on the size of a particular forest and number of plots, the number of transects were decided to sample the forest systematically. All transects started from the forest edge towards inside the forest at a distance of 900 m. Sample plots were located at a distance of 200 m from each other for all the FRs except in NDU FR (where the distance was 250 m). Each first plot was located at half the distance between plots. In this case, GPS coordinates of the start and the end of all transects and plot centres and their associated location names and landmarks were recorded.

Parameters measured from sample plots

Stand parameters measured were Diameter at Breast Height (DBH) of all trees, height and basal diameter of three sample trees in a plot. All trees and poles were measured for DBH at 1.3 m above the ground. Since there were no records of illegally harvested trees, basal diameters of stumps for harvested trees were measured to estimate removals from the forest. Stumps of harvested trees were described as "new" if the stumps were fresh (harvested within that year) and "old" if there was blackening on the stump (harvested in the previous year or more). Based on the experience of local plant identifiers, the old stumps were described to be harvested more than one year ago and the new cut, within that year (2009) as data were collected towards the end of 2009. This determination of old and new cuts was also used in previous disturbance studies in Tanzania (Luoga *et al.*, 2002; FBD, 2005; Frontier Tanzania, 2005; Bracebridge, 2006). Local names of all trees were recorded. Botanical names were filled by using a checklist and by a help of a botanist. Other types of human disturbances such as mining, hunting, charcoal making, forest fires and grazing were recorded through casual and opportunistic observations throughout the survey. All these data were recorded in a form (Appendix 1).

For the woodland vegetation in Kimboza and Ruvu FRs, individual tree heights were not required because the volume equation used DBH variable only (Zahabu, 2008). Trees were recorded clockwise from the direction of transect and from the plot centre. Measurements were taken as follows:

- Within 2 m radius: trees >1 cm to 5 cm DBH were measured
- Within 5 m radius: trees > 5 cm to 20 cm DBH were measured
- Within 15 m radius: trees > 20 cm DBH were measured

3.2.4.3 Socio-economic data

Participatory Rural Appraisal

A number of different Participatory Rural Appraisal (PRA) tools ranging from field based visualization to interviewing and group discussions were used in the field to gather and analyse information. These were pair wise ranking, wealth ranking, and resource use matrix. A sample of village government leaders and village natural resources committee members, men and women were involved. PRA offered a creative approach to information sharing and a challenge to prevailing biases and preconceptions about rural people's knowledge (Mikkelsen, 1995). According to Mikkelsen (1995), also cited by Mbeyale (2009), with PRA, villagers with minimum level of formal education can comfortably participate during the exercises with the assurance of getting useful information in a relaxed conversation. These tools promoted interactive learning, sharing of knowledge and flexible structured analysis.

Pair wise ranking

In pair wise ranking, existing and potential incentives in JFM were identified. These were paired and compared against each other by asking which incentive was given a priority over the other. This was done through discussion, consensus and sometimes voting where priorities differed among the PRA team members. Afterwards, they were sieved and ranked according to their relative importance as perceived by members (Appendix 5a-c).

Wealth ranking

Wealth ranking was a tool which helped to better understand well being categories within each village. It was used to explore differences in how people used resources and their role in forest governance. In this exercise, individuals were not asked about their wealth, but rather the exercise helped to assign households to different groups in the village that were then ranked according to their relative wealth. It was then possible to ask about how the different groups used forest resources or participated in forest governance (Appendix 6a-d).

Resource Use Matrix

Resource use matrix was used to analyse two sets of variables in order to explore institutional issues more systematically. In this exercise, a set of ten sweets were used to indicate ranking. The matrix was used to identify the principle users of various forest products and explore how these groups use the products and their importance. Forest products exploited by villagers were placed in vertical axis. Different factors affecting resource use (e.g. gender, wealth, villager, or outsider) were put along the horizontal axis. PRA members were asked to divide the ten sweets into the boxes to indicate the relative importance of the product to each factor (Appendix 7a-d).

Focus Group Discussions

Focus Group Discussions (FGDs) on general issues on JFM and its operationalization in the village were done. Group members were asked questions on rules and regulations with regards to JFM and whether they were accruing benefits or incurring costs in implementation. Members were also questioned to know if there were issues hindering implementation or issues enabling smooth running of JFM and associated incentives. In these discussions, members were free to discuss and follow up questions were asked immediately as an interesting point was mentioned. The discussions were conducted in a group of not more than ten people guided by the researcher with a standardized checklist (Appendix 4). Four groups were used for discussion in each village; these were members of a village government, village natural resources committee (VNRC), women group and elders group. This method was used as triangulation to acquire important qualitative information to complement those obtained through other methods. It was very useful in gaining a deeper understanding, crosschecking and supplementing information for important issues raised in PRA.

Structured Questionnaire

Structured questionnaires were used to collect quantitative and qualitative data from households. It comprised both closed and open-ended questions and it was administered to the head of the household or the spouse. In the first part of the questionnaire respondents were asked about general issues, demographic and income sources. Information collected in the subsequent sections included benefits currently accrued under JFM arrangements, incentives which are perceived to be potential, motivation for participation and various institutional arrangements with regard to accessing the forest reserves. This information helped to answer research question 2 and 3. The questionnaire (Appendix 2) also comprised general questions on JFM and effectiveness of JMAs.

Key informant Interviews

Key informants including local leaders, influential people in the villages, central, local government staff working in the study areas and scientists (academicians) were interviewed. Some of these key informants were pre-determined but some came to light during PRA exercises and in informal discussions. A checklist was made to guide the interview in semi structured interviews (Appendix 3). However, the interview was kept flexible in order to discuss matters of most concern to the villagers and a follow up on the unexpected was done. This interview was done with a single participant. Some unstructured interviews involved casual talks with key informants on a particular issue without prior appointment or telling them the purpose of the conversation. In these kinds of free chats, neither notebook nor pen was used to record the conversation, but important issues were memorized and immediately written down after the talk.

Direct Observation

Direct observation was a method that encouraged the researcher to observe the villagers day to day activities. While implementing other research activities, the researcher observed and recorded different community and household activities relevant to the research. These included collection and use of forest products and other general activities. It was to a great extent used to crosscheck validity of the research results from other methods as the researcher had a better understanding of the situation by own observations without asking any respondent. Direct observation helped the researcher to understand better the communities' attitudes and perceptions, motives and constraints on issues related to the research. The method helped to learn peoples' behaviour, people-resource interaction, rules, and norms that operate within the respective villages.

3.2.5 Secondary data

Collection of secondary data was a continous process that was carried out during the entire study period. Relevant information about the study were collected from various libraries including the Sokoine National Agricultural Library (SNAL). University of Life Sciences in Norway. University of Dar es salaam. Government offices including Iringa and Morogoro Catchment forest offices, Tanzania Forestry Research Institute (TAFORI). NGOs such as CARE International, and from other various sources including websites. Some published and unpublished literature were also obtained from the local government offices in Iringa and Morogoro including the village offices.

3.2.5 Data Analysis

3.2.5.1 Ecological data

The stocking parameters (number of stems. basal area and volume per ha) were calculated using the standard formulae adopted from Philip (1983).

Number of stems per ha (N)

$N = \sum(n_i/a_i)/n$ ....(1)

Where

N = number of stems per ha

n_i = tree counts in the ith plot

a_i = area of the ith plot in ha

n = total number of sampled plots

Basal area per ha (G)

$$G = \sum^{n} \sum^{m} n_{ij} g_{ij} / \sum^{n} a \quad (m^2/ha) \qquad (3.2)$$

Where

G = average basal area per ha

n_{ij} = number of trees in jth diameter class on the ith plot,

g_{ij} = basal area of average tree in jth diameter class of the ith plot, m^2

m = number of diameter classes in the ith plot, 1 ...i...n

n = number of plots 1....i....n

a = area of each sample plot, ha

Volume per ha (V)

$$V = \frac{\sum^{n}\sum^{m_i} v_{ij}}{na} (m^3/ha) \qquad (3.3)$$

Where

V= average volume per ha estimated from n samples each of a ha

v_{ij} = volume of jth tree estimated on the ith plot

m_i = total number of trees in the ith plot, 1 .....i....n

Average volume of removed trees was calculated to reflect level of disturbances. Since tree growth is logarithmic in nature, a natural logarithm transformation of sample heights and harvested tree stumps were done for each vegetation type. Height equations were used to estimate the height of trees that were not measured. DBH equations were used to estimate DBH of harvested trees. Regression analysis was run and various equations with coefficients of determination (R^2) were developed as shown in Table 9.

Table 9: Allometric equations used to estimate height of unmeasured trees and DBH for stumps of harvested trees in the study area

Forest Reserve	Vegetation type	Regression Equation (Ht)	R^2	SE	Regression Equation (DBH)	R^2	SE
NDU	Montane	Ln (Ht) =0.59+0.63ln(DBH)	86	0.2	Ln (DBH) =-0.28+1.05ln(Bd)	99	0.1
KL	Montane	Ln (Ht) =0.49+0.59ln(DBH)	67	0.3	Ln (DBH) =-0.23+1.04ln(Bd)	99	0.1
Kimboza	Lowland	Ln (Ht) =0.36+0.70ln(DBH)	86	0.2	Ln (DBH) =-0.13+1.01ln(Bd)	99	0.1
	Cedrella	Ln (Ht) =1.03+0.53ln(DBH)	86	0.2	Ln (DBH) =-0.94+1.23ln(Bd)	98	0.1
	Teak	Ln (Ht) =1.45+0.40ln(DBH)	90	0.1	Ln (DBH) =-0.06+0.98ln(Bd)	99	0.1
Ruvu	Lowland	Ln (Ht) =0.78+0.57ln(DBH)	87	0.2	Ln (DBH) =-0.41+1.09ln(Bd)	99	0.1

Source: Field data. (2010).

The appropriate single tree volumes for montane and lowland forests were calculated using a general tree volume formula in equation 3.4:

$$V_i = 0.5\, gh_i \qquad (4)$$

Where;

V_i = the volume of the ith tree (m^3)

h_i = the total height of the ith tree (m)

g = the tree basal area (m^2)

0.5 = the tree form factor.

Tree form factor of 0.5 was recommended to be used for natural forests in Tanzania without distinction of the vegetation type involved (Haule and Munyuki, 1994; Luoga *et al.*, 2005). Volume of standing and harvested trees in the Woodland vegetation were calculated using equation (3.5) developed by Malimbwi *et al.* (2005b).

$V_i = 0.000011972d_i^{3.1917}$ .... (5)

Where;

V_i = the volume of the i^{th} tree (m^3),

d_i =DBH (1.3 m) for the i^{th} tree (m) with (R^2 =98)

Mean volume of harvested trees from both montane and lowland forests was calculated as average of sums of individual plots. Volume of individual tree in each plot was computed by using equation (3.4).

The relative sampling error *(SE %)* of the stocking parameters was calculated using equation 3.7:

$SE(\%) = t * CV / \sqrt{n}$ ....(6)

Where:

t = obtained from the student's t-distribution (n-1 degrees of freedom. p = 0.05)

CV = the coefficient of variation between plots within sites and

n = the number of sample plots within sites.

The confidence interval *(CI)* of the stocking parameters was calculated using equation 3.7:

$CI = \bar{x} \pm S_x = \bar{x} \pm \frac{s}{\sqrt{n}} t$ ....(7)

Where;

$\bar{x}$ = the mean value of the stocking parameter

S_x = the standard error of the mean

s = the standard deviation between plots within sites,

n and t as above.

Above ground biomass was computed as a product of total tree volume and wood basic density. Since basic density of these tree species were unknown, the assumption made by Brown (1997) of average wood density for unmeasured African tropical trees of 0.58 g/ cm^3 was used for both montane and lowland forests (see also MacDicken, 1997). Above ground biomass was converted to carbon stock based on a biomass carbon ratio of 0.49 (MacDicken, 1997; Brown, 1997; Brown, 2003). Finally, carbon was multiplied by 3.67, the ratio of the molecular weight of carbon dioxide to carbon. Tropical Forest Inventory Data Analysis (TROFIDA) software was used for the computation of forest stand parameters (N, G and V) by species and size classes. The data inputs required were tree species, DBH and height. TROFIDA is user friendly and its applicability was successful tested by Zahabu (2008). The database was designed in such a way that the user needs to replace default tree species checklist and trees data tables. All other computation procedures are already included. The stand parameters were separated for each species into diameter classes for convenience. The diameter classes used in this study are given in Table 10.

Table 10: Distribution of diameter classes

DBH class	1	2	3	4	5	6	7	8
DBH range (cm)	<10	11-20	21-30	31-40	41-50	51-60	61-70	>70

Statistical analysis was done using two-tailed *t*-tests (*α=0.05*) to compare stocking parameters (N, G and V) between FRs with and without JFM for similar vegetation types. Comparison was done between NDU and KL FRs in montane sites, Kimboza and Ruvu FRs in lowland and Woodland vegetations.

3.2.5.2 Socio-economic data

PRA data were analyzed thematically at the point of collection in participatory way with local communities. In pair wise ranking of incentives. communities were guided to sieve a larger list of incentives to get the most important ones through scoring. Data collected through semi-structured interviews and FGDs were organized and summarized to ensure that they are in a suitable form for addressing the relevant research questions. The categorization of collected information based on the research questions was done. According to Silverman (1993), categorization helps to understand social phenomenon observed during field work.

Content analysis was used to analyse qualitative information from interviews and discussions. The analysis aimed to isolate themes and tendencies portrayed in the content of recorded conversations and observations made in the field. Content analysis helped to reduce the volume of recorded information to a set of categories that represent some characteristics of the research. Both conceptual analysis (establishing the occurrence and importance of concepts and phenomenon in a text) and relational analysis which examines the relationships among concepts and situations were applied. Quantitative data were coded and fed into Statistical Package for Social Sciences (SPSS) software (Version 16) for analysis. Descriptive statistical analysis was used to summarize information and explore the data for the distribution of responses.

3.2.6 Optimisation model

The objective function of the model was made up of two variables; carbon and honey. Carbon payment is a potential source of income that is expected to benefit communities protecting CFRs in Tanzania while honey is among the tangible existing forest product currently used as source of income by local communities.

It was considered worth choosing carbon rather than biodiversity or water (for example) because large sums of money have already been spent on carbon in Tanzania by the international community, particularly Norway and the fact that payment for water services in Tanzania is not yet well developed. The country is piloting REDD+ where national REDD+ framework and strategy have been developed and nine REDD+ piloting projects are carried out to generate experience and lessons.

For the past three decades, there has been a growing awareness of the importance of honey for food and medicinal uses. This growing awareness is not only for the role it plays in the subsistence economy, but also for its potential and contribution to the economy of the country. Among the list of NTFPs, honey is the most commercialized in the study sites due to development of beekeeping sector in the country. It is because of these reasons that carbon and honey were chosen to be included in the optimisation model.

3.2.7 The Emperical model

The general benefit maximization model was formulated as below:

$$Maximize\ f(x) = \sum_{i=1}^{n} wiXi$$

$$Max\ Z = w_1X_1 + w_2X_2$$

Assuming the current price of Certified Emission Reductions (CERs) is USD 20 per tonne of CO_2e and the price of honey is USD 5 per kg then the objective function becomes

$$Max\ Z = 20X_1+5X_2$$

Subject to:

Labour:	$10X_1+5X_2 \leq 3,072$	(hrs)
Capital:	$2X_1+X_2 \leq 7,400$	(US$)

Forest area: $5X_1 + X_2 \leq 3{,}700$ (ha)

Disturbance: $X_2 \leq 0.5$ (m^3/yr)

$X_1 \geq 0$ Non-negativity constraint for X_1

$X_2 \geq 0$ Non-negativity constraint for X_2

Where:

Z= Value of the objective function (net returns per year)

w_1= Current price of carbon per tonne in the international market (USD 20)

w_2= Average price of honey (USD 5 per kg)

X_1= Amount of carbon credits to be produced (tonnes/yr)

X_2= Amount of honey to be collected (kg)

The LP problem is summarized in a tabular format known as detached coefficient matrix. Table 11 illustrates the detached coefficient matrix for the carbon and honey introduced above.

Table 11: The coefficient matrix of the model

Columns				1	2
Activities				Carbon	Honey
	Entity	Unit	Right Hand Side (RHS) value		
0	Objective function	USS	Maximize	20	5
1	Labour	Hrs	≤ 3,072	10	5
2	Capital	USS	≤ 7400/810	2	1
3	Forest area	Ha	≤ 3,700/405	5	1
4	Disturbance	m^3	≤ 0.5/2.7	0	1

Source: Field data (2009, 2010) and Zahabu (2008)

3.2.8 Model constraints

3.2.8.1 Labour availability

In villages adjacent to CFRs, VNRCs have other livelihood activities to perform apart from forest conservation and beekeeping. That means, labour is limited. On average, in both sites (Iringa and Morogoro), VNRC worked for eight hours per week for forest conservation activities. A group of eight VNRC members (8 hrs*8 persons*48 weeks) is equivalent to 3072 man hours. Management activities included forest patrols, protection against fire and boundary maintenance. The 3072 hours per year were applied for both NDU and Kimboza FR independent of the forest area. It has also been assumed that 10 hours are required for each tonne of CO_2e produced. Furthermore, it has been assumed that the production of one kg of honey requires 5 hours work.

3.2.8.2 Capital/investment

In any production system, inputs such as capital are needed before profit is realized. Carbon storage in the study forests is a result of established JFM regime (Lugandu, 2010). Therefore it has little investment as all the necessary start up and implementation activities have been carried out through JFM. Zahabu and Malimbwi (2008), estimated costs related to measuring and monitoring of carbon by local communities in a forest area more than 150 ha to be less than USD 2 per ha per year. Based on this data, NDU FR with 3 700 ha, requires a maximum of USD 7 400 per year while Kimboza FR (405 ha) required not more than USD 810 per year for measurement and monitoring of carbon. It has been therefore assumed that one tonne of CO_2e produced (sold) requires a cash input of USD 2, and that the production of one kg of honey requires USD 1.

3.2.8.3 Land availability (forest size)

Kimboza FR is small in size compared to NDU FR. It is assumed that the smaller the forest the lower the carbon credits and honey produced. The variables to be maximized are assumed to be limited to gazzeted area of the FR. Therefore, land constraint for Kimboza FR was determined as 405 ha and that of NDU at 3 700 ha. These figures reflected forest size constraint for the optimisation model. The study also assumed that the production (sale) of one tonne of CO_2e requires a minimum of 5 ha of forest, and that the production of one kg of honey requires a minimum of one ha.

3.2.8.4 Forest disturbance

Forest disturbances have negative impacts to potential forest in carbon storage (Munishi *et al.*, 2010). Unlike mortality, the human induced causes usually involve complete removal of forest biomass and thus causing carbon emissions and therefore a constraint in maximizing carbon and honey benefits. It was assumed that carbon storage does not lead to any disturbances while the production of one kg of honey results in the removal of one m^3 of wood for beehives construction.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Existing and Potential Incentives for Communities Implementing JFM in CFRs

4.1.1 Existing incentives

Results revealed that, in both lowland villages (Changa and Kibangile in Morogoro) and highland villages (Kidabaga and Luhindo in Iringa), there were several existing incentives perceived by local communities as Table 12 shows. Existing incentives refers to those incentives which were enjoyed by communities living adjacent to the CFRs. These were incentives motivated them to participate in forest conservation and management.

Table 12: Existing incentives in JFM as perceived by local communities in Iringa and Morogoro, Tanzania

Region	Village	Existing Incentives
IRINGA	Kidabaga	Presidential environmental award
		Income from beekeeping and other NTFPs
		Income from visitors (in and outside the country)
		Payment to patrol team
	Luhindo	Weather regulation (rainfall)
		Income from visitors, tourists and researches
		Availability of basic needs from the forest (e.g. NTFPs, firewood, water)
MOROGORO	Kibangile	Income from visitors and tourists (camping) and researchers
		Training on forest conservation
		Income from fines and sale of confiscated equipments
	Changa	Water for domestic use
		Rainfall due to presence of the FR
		Income from visitors, tourists and researchers

Source: PRA data (2010).

Existing incentives in Table 12 were further categorized into four main groups including:

(i) Incentives due to income paid by various visitors such as tourists and researchers. These can be regarded as direct cash incentives because the income is paid directly to the community organizations like VNRCs. According to FAO (1987), such payments act as an incentive to compasate individual's time spent in conservation activities.

(ii) Incentives due to availability of basic needs obtained by conserving the forest including water, NTFPs and other climate regulation services. These can be classified as direct (in kind) incentives. They are in kind because they take the form of material goods and services. According to Gregersen (1978), such types of incentives are usually most effective in poor communities because they are straightforward and meet immediate social and productive needs.

(iii) Incentives obtained through various environmental awards, fines and sales of confiscated forest products and equipments of forest offenders/culprits. This is a direct cash incentive. This type of incentive also relates to subsidie as defined in chapter two (sums of money given to individual or community by the state to encourage works in the public interest, Garcia-Pelayo, (1981). Subsidie also include prizes, bonuses, fellowships and other forms of assistance.

(iv) Incentives obtained through individual gain (e.g. income from daily wage payments from forest patrols, firebreak clearing, commercial tree nurseries and various trainings) are also direct incentives. This is in line with results reported by Vihemaki (2009), that payment for forest patrols, firebreak cleaning and training were among the important incentives, motivating communities to conserve East Usambara Mountain forests.

In Same district, Butuyuyu (2003) found that prizes, study visits and material support including provision of tree seedlings were the mojor economic incentives that motivated communities to conserve forests. In Usambara Mountains, Malundo (2008) reported that capacity building in altenative income generating activities motivated communities in East Usambara to sustainably conserve catchment forest reserves. The author further argued that both forest products and ecosystem services from the forests were perceived as incentives for conservation. Incentives due to income obtained from researchers, tourists and visitors has been the main stable source of income in both NDU and Kimboza FRs as Table 13 shows.

Table 13: Entrance fees for various activities in NDU and Kimboza FRs, Tanzania

	Research entrance fee (TZS/head)	Study visitors (TZS/day/group)	Tourists (TZS/head/day)
NDU FR	5 000	20 000	10 000
Kimboza FR	3 000	15 000	5 000

According to Lugandu (2010), revenues for NDU FR from these sources have been increasing from TZS. 953 505 in 2003 to 2 600 000 in 2008. Increased income helps to maintain a positive motivational environment for individuals, communities and conservation organizations to conserve forests (Emerton, 1998). However, Emerton further argues that incentives due to income, encourage compliance rather than risk taking because most rewards are based only on performance, as a result, the sustainability of conservation activities ceases once funding is withdrawn.

Incentives perceived due to availability of water, firewood and rainfall was a major concern of most respondents in the study villages. In their local context, communities perceived a direct and a positive relationship between reduced forest cover and rainfall. This perception was also felt by communities in East Usambara as reported by Vihemaki (2009). In her study, she reported that the assumption of connection between rainfall and the existence of the forest was evident. She argued that rainfall was conceived as important because availability of rain was key condition for agriculture. It was further emphased that conservation of CFR during the German and British era had strenthernced the idea of connection between forest and water. Communities around NDU FR had a perception that the increased amount of rainfall in recent years is due to the improved forest cover as a result of enhanced forest protection.

JFM led to the recovery of degraded forest cover in NDU FR (Lugandu, 2010). He further argued that improved forest cover was a result of compliance by local communities, control and management of fire incidences, control of tree damaging, control of encroachment and reduction of dependence on NDU FR for wood based needs. However, communities adjacent to Kimboza FR presented a different scenario. They complained with regard to drying up of their water sources which are just adjacent to Kimboza FR, a situation that necessitated them to start collecting water from sources inside Kimboza FR as it is shown in Plate 1.

Plate 1: Photos showing women from Changa village washing clothes and collecting water for domestic use inside Kimboza FR in Morogoro, Tanzania

In Iringa, communities were proud of winning the Presidential Award on conservation of water sources and tree planting awarded to their village in 2010. In Morogoro, communities claimed that benefits obtained through payment of fines and confiscated products were small compared to the actual offences and disturbances observed in Kimboza FR. While the plan in Iringa was to plant more trees and enhance protection of natural forests, in Morogoro the plan was to enhance law enforcement as local communities were sure that more illegal harvesting would happen in Kimboza FR. These differences in perception on income sources were interesting because as others thought of getting income through enhancement of conservation, others thought getting the same through fines for continued illegal activities. The differing perceptions on conservation between communities in Udzungwa and those of Uluguru Mountains can be traced back from the colonial time.

During the British rule in 1914, communities along the eastern side of Uluguru slopes refused to adopt conservation interventions such as terraces (Kajembe and Mbeyale, 2010). The protest resulted into several deaths including that of John Mahenge, where one street in Morogoro municipality is named after him as a hero. Since then, farmers resisted terraces in the area (Mkindi. H.A. personal communication, 2010). They were reluctant to adopt externally introduced conservation measures. something that led to major conflicts of which its impacts are observable until today. Community reluctance to adopt new introduced interventions was also reported in East Usambara Mountains (Conte, 2004), also occurred in the Peruvian and Bolivian highlands, where communities viewed terrace construction as an outmodeled solution (FAO, 1987). Under Equitable Payment of Water Services (EPWS) project in the Uluguru, the number of people who were early adopters of improved agricultural practises were more than 200 but only 144 performed well (Kajembe and Mbeyale, 2010). The low number of early adoption in this project may also indicate the protest syndrome.

The study further revealed that income generating projects including camping site and fish farming through NORAD support, introduced along with JFM, had collapsed in villages adjacent to Kimboza FR. In contrast with Udzungwa Mountains in Iringa, there were evidences that communities were willing to adopt new technologies introduced during and post colonial time including conservation of natural forests, soil conservation measures along mountain slopes and planting of trees outside the protected areas. In Kidabaga village, there was a village bylaw clause that requires every household to plant and manage two acres of trees in their farmlands. Communities complied with this rule as a result Kidabaga village won the 2010 Presidential Award on conservation of environment and water sources at the country level.

The present study also showed that communities in Iringa, managed to build stronger institutional structures including village natural resources committees, village leadership and their active participation in various community fora including MVIWATA (*Mtandao* *wa Vikundi vya Wakulima Tanzania* meaning Farmers Groups network of Tanzania) and MJUMITA (*"Mtandao wa Jamii wa Usimamizi wa Misitu Tanzania"* meaning Community Forest Conservation Network of Tanzania). These observations are in line with what has been reported in East Usambara Mountains that, income generating activities, capacity building and institutional arrangements were among the key incentives for communities to conserve CFRs (Malundo, 2008).

The above mentioned institutions exist in the regions (Iringa and Tanga) working on community capacity building activities. MJUMITA has managed to create awareness of its members on good forest governance and issues in climate change including adaptation and mitigation measures through its REDD+ pilot project.

Results on individual income as incentives for forest conservation differed between the sites. In Iringa, patrol teams were paid some allowances for the patrolling work, in Morogoro, payments to patrol teams had never been effected and therefore the teams worked free of charge. Unpaid labour for forest patrol was also reported in East Usambara (Vehemaki, 2009). According to FGDs in Kibangile and Changa villages in Morogoro, one of the main sources of income was from a camping site which operated for five years (2004 to 2008). Also, while communities in Morogoro were paid for boundary cleaning work, in Iringa this activity was shared equally between communities and the central government (Massao, T. personal communication, 2010).

Monetary rewards are good but may in certain situations result in reduced effort (Gneezy and Rustichini, 2000; Fehr and Falk, 2002). This is because introducing monetary payments to communities seems to shift the logic from "moral obligation" to "individual gain" and hence may reduce effort. As soon as the shift in motivation is made, paying more seems to work (Vatn, 2008). Therefore, money can represent at least three different logics. It can be seen as a measure of value, a creator of incentives and finally as a pure compensation. In this study, the focus in payments relies on the second logic (money as a creator of incentives).

4.1.2 Potential incentives

The study revealed a number of potential incentives in JFM across the four study villages. Community perception on potential incentives was different among the sites as shown in Table 14.

Table 14: Potential incentives in JFM as perceived by local communities in Iringa and Morogoro, Tanzania

Region	Villages	Potential Incentives
IRINGA	Kidabaga	Income from REDD+ payments. Payment from water services (TANESCO, Mtera and Kidatu Dams, water departments, Industries), Alternative income generating projects for households
	Luhindo	Income from REDD+ payments, Income from cleaning forest boundaries (fire lines), Provision of working gears and transport for the patrol team, Provision of permits for hunting in the FR
MOROGORO	Kibangile	Working equipments (e.g. uniforms, boots, identity cards and pangas), Presence of a forester at Kimboza forest station, Study tours for VNRC members and village leaders, Income from ecosystem services (e.g. water and carbon)
	Changa	Working equipments (gears) including transport and uniforms Training for VNRC members in forest protection, Wood products utilization (e.g. permits to use naturally fallen trees), Rights in JFM (decision, income from camping site and responsibility), Payments to VNRC members

Source: PRA data (2010)

Potential incentives were also re-categorized into four main groups across the study villages including:

i. Incentives related to working gears for the patrol teams or VNRC members. The working gears included transport facilities such as bicycles or motorcycles. uniforms, gum boots and rain coats, identity cards. pangas. touches and communication facilities like mobile phones or walk talkies.

ii. Incentives related to wage payment for patrol teams and training for the VNRC members and village government leaders including study tours to areas with success stories in JFM.

iii. Incentives related to rights for communities expecting to receive payments for carbon credits and water services. permits for collecting and utilizing naturally fallen trees and hunting or trapping crop damaging animals.

iv. Incentives related to presence of a government staff (extension officers/foresters) to work in collabouration with the VNRC members on full time basis.

While communities in Iringa needed motivation through carbon payments. their counter parts in Morogoro requested working gears and training as motivation for conservation. The demand for REDD+ payments in Iringa could be due to sensitisation done through extension service. Lalika (2006) reported that availability of extension officers, education and training (study tours and short courses) were regarded as important incentives for communities to conserve biodiversity in the forests in Uluguru Mountain forests.

During NORAD and DANIDA support in the last fifteen years, working gears were supplied to serve as motivation for forest patrol teams to work effectively. VNRC members and village leaders were provided with training and necessary office facilities.

Since these are not provided currently in the study area, as also noted in East Usambara Mountains (Vihemaki, 2009), provision of such facilities are potential incentives.

In Iringa, (Luhindo village in particular) it was revealed that patrol teams used eight hours per day. The same number of hours was also recorded by Zahabu (2008) in four villages of Tanzania (Gwata-Ujembe, Mgambo-Miembeni, Ayasanda and Ludewa). For Luhindo village, five hours among eight were lost on the way walking to and from NDU FR and the other three hours were used for actual patroling inside the forest. In that regard, forest patrol members argued that motorcycles would easen the work. In Morogoro villages, elders argued that mobile phones were important for forest patrol teams to easen communication. However, a counter argument was given that whenever patrols are organized, thereafter no culprits were caught because as the patrol team entered into the forest, information leaked to forest offenders through mobile phones.

As noted in Table 14, payments for environmental services including trading of carbon credits through REDD+ and payments for water services were considered as potential incentives that could motivate communities to enhance conservation. The prospect of carbon credits is considered as an additional "non timber forest product" which could be exploited by local communities (Skutsch and McCall, 2011). In principle, payments for REDD+ to forest adjacent communities will give them an additional source of income and hence an additional reason to manage the forest sustainably. Such payments could provide new funding and incentive to promote JFM in areas with high biodiversity value.

If at all the Tanzanian government has ever felt guilty of using communities as cheap labour to manage catchments which had minimal direct benefits from harvestable wood, it is now time to compensate communities through REDD+ to reach a "win win" situation.

Because catchment forests are just a small proportion (only 8%) of Tanzania forests. every possible income from REDD+ in CFRs would be left to local communities as incentive for them to continue conserving these "delicate" and valuable but currently "unprofitable" ecosystems (MNRT, 2009). REDD+ programmes in Tanzania may increase incentives for local people to self-enforce resource use restrictions and eventually help to overcome a lack of state enforcement and business as usual scenarios (Engel and Palmer, 2008).

Key informants and FGD members argued that their forests have been a major source of water feeding *Mtitu* and *Gonza* Rivers. These Rivers are contributors of small Ruaha River that flows into Mtera Dam for hydroelectric power production. However, the village had never been considered for electricity supply or any other return for their conservation efforts. Discussion with Environmental Manager of Tanzania Electrical Supply Company (TANESCO) in Dar es Salaam revealed that the company is paying tax to central government via offices of water basins but there has no working mechanism to channel some of these funds back to the community members who are directly involved in the conservation of water sources (Hamdun, M. personal communication, 2011).

There has been a long complain that communities had no financial structures to manage such funds but in all the study sites (Iringa and Morogoro) it was observed that communities through their zonal environmental committees were well organized in terms of management of forest resources and finances where they had operational bank accounts. The accounts were managed by the zonal leadership in close supervision of District Catchment Forest Manager (DCFM). In Iringa for example, the bank account book is kept by the DCFM who approved transactions done by zonal leaders (Lugandu, 2010). Another formal opportunity that TANESCO could channel back funds is through Tanzania Forest Fund or through the Eastern Arc Mountain Conservation Endowment Fund (EAMCEF).

The EAMCEF could be appropriate institution because it is specific to Eastern Arc Mountain forests. Furthermore it is a Trust Fund that was established as a mechanism to provide long-term and reliable funding to support Community Development. Biodiversity Conservation and Applied Research Projects. which promote biological diversity. ecological functions and sustainable use of natural resources in the Eastern Arc Mountains of Tanzania. In its fundraising strategy. it allows government bodies and other stakeholders to channel conservation funds back to communities through small development projects (EAMCEF. 2011).

New Dabaga Ulongambi (NDU) FR was degraded before JFM as it was one of the main targets for harvesting East African camphor tree (*Ocotea usambarensis)* in the region. According to Lugandu (2010). there has been positive improvement of forest cover between 1990 and 2006 mainly due to implemention of JFM. Lugandu reported that bushed grassland. dense bush land and grassland with scattered cultivation in NDU FR were reduced by 100% while open grassland was reduced by 95%. Within ten years. bushland with scattered cultivation-land cover in NDU FR increased by 513%. His study also showed that in 1990 mixed cropland, closed forest, wooded grassland and open grassland seasonally inundated were non existence but appeared in 2000. The emergency of closed forest as a result of high protection could be associated with increased biomass and carbon stock. For that matter, the conservation efforts in NDU FR could be compensated through REDD+ payments as also suggested by Skutsch and McCall (2011).

The present study revealed that hunting rights in NDU FR were important (Table 14). Hunting was proposed to reduce problem of vermin including wild pigs, monkeys and wild rats which raide crops in farms. Several studies in the Earstern Arc Mountains including Lalika (2006) and Vihemaki (2009) reported presence of vermin as a result of improved conservation in CFRs. Presence of wild animals in NDU FR was observed during forest inventory. Number of animal traps, animal droppings (Plate 2 and 3) and animal footsteps seen were indicators of presence of these animals in the FR and probably a result of strict protection through JFM. Personal observation revealed several farms growing sweet potatoes and maize near NDU FR destroyed by wild pigs and monkeys.

Plate 2: Wild animal droppings indicating presence of large mammals in NDU FR, Iringa, Tanzania

Plate 3: Steel trap for large mammals found along the boundaries of NDU FR, Iringa, Tanzania

According to Frontier Tanzania (2001), animals in NDU FR were subjected to a severe hunting in the past (before JFM), with a minimum of 33 set traps per km^2. As a result many of the larger mammals were rather low in numbers, some even threatened to extinction. Discussion with elders in Luhindo village revealed that monkeys and wild pigs were hunted freely before JFM and they did not threaten their croplands. Nielsen (2006) also found that large mammals like wild pigs and Abbott's duiker were depleted in NDU FR. He also noted that the number of hunters positively correlated with village population. Nielsen (2006) found that groups of *Procolobus badius* were less than ten individuals and speculated that it was likely that the few individuals observed were due to high hunting pressure. It was found difficult to determine the relative effects of hunting and habitat degradation but finally it was concluded that low red colobus group sizes appear to be related to human activity rather than elevation (Marshall *et al.*, 2004). The author also revealed high level of hunting where the population density of Blue and Harvey's duikers in NDU FR was reduced by 10% when compared to their density in Kilombero Nature Reserve, which is subject to low hunting pressure.

According to the Forest Act, number 14 of 2002, hunting and trapping activities are forbidden inside FRs (URT, 2002; URT, 2009). Possession or using of any trap, snare, net, bow and arrow, gun, poison or explosive substance for the purpose of hunting inside FR without a permit is prohibited (URT, 2002). Even if a person has a hunting license or permit from the Director of Wildlife for the purpose of hunting in a FR, the person must seek and obtain a permit from the Director of Forest and Beekeeping Division to enter the specified FR (Forest Act, 2002 Sections 49(1)(j) and 68(a). Furthermore, the Wildlife Conservation Act, number 5 of 2009 prohibits hunting by use of poison or poisoned bait, use of traps, snares, pits, spears, bows and arrows and use of fire to surround or drive an animal. It also prohibits hunting at night by means of a torch, spotlight or other artificial light and use of dogs. Observations made in NDU FR revealed some hunting by use of snares. The study by Nielsen (2004) in NDU FR also revealed a more serious hunting in the FR by use of snares, noose traps, pit fall traps, log-fall traps, spike trap, guns, spears and dogs (Plates 4 and 5).

Plate 4: A Blue Duicker illegally hunted by use of manila snare in Iringa, Tanzania

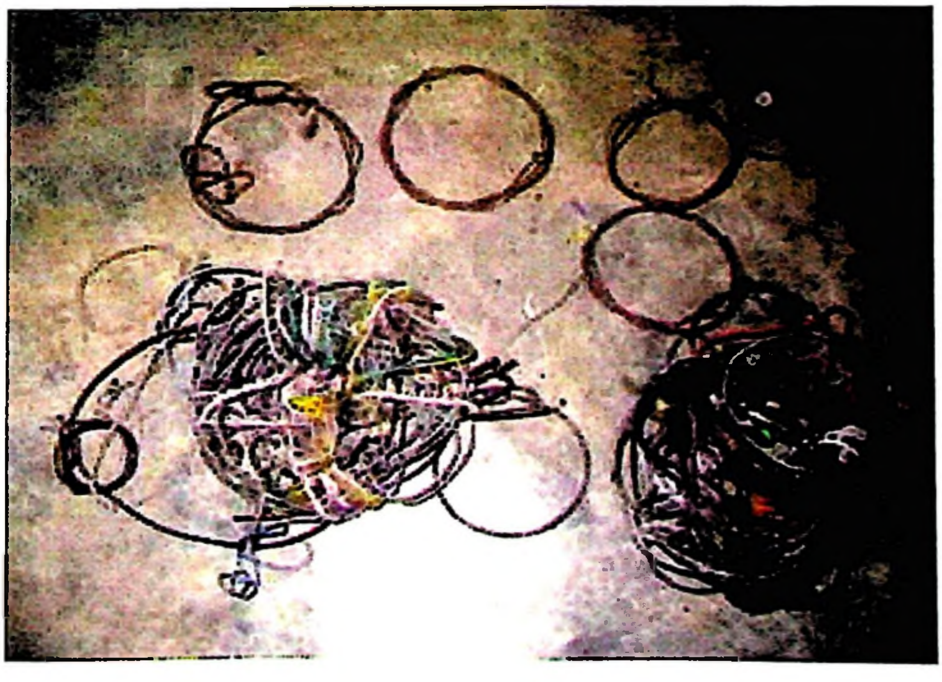

Plate 5: Manila snares used for trapping wild animals in Iringa, Tanzania

Table 14 also showed that rights to collect and utilize naturally fallen trees from Kimboza FR were regarded as motivation to communities in JFM. This was because there were insufficient sources of fuelwood in Uluguru Mountains due to land scarcity. In this regard, respondents had a feeling that, rights to collect naturally fallen trees was a potential incentive for their protection efforts. A short story in Box 1 gives highlights on bureaucracy in JFM for communities to use naturally fallen trees from Kimboza FR.

Box 1: Bureaucracy in JFM for communities to use forest products

Mr. Hatibu Ali Mkindi (53 years), a member of Kibangile village council was quoted during FGD arguing, "*In 2006, a big tree in Kimboza FR fell into Ruvu River near the bridge. The tree was valuable for timber. The village government requested a permission to use this tree to make desks for Kibangile primary school. The Regional Catchment Forest Manager (who signed the JMAs on behalf of Director of Forestry and Beekeeping Division) refused as he said, had no mandate to give such permission. The tree overstayed there until when a Regional Commissioner by then (Mr. Mashishanga) crossed over the bridge as he saw the tree, he ordered the village leaders to remove the tree and use it*".

According to key informant (forest officer), giving communities such rights (access to naturally fallen wood whether green or dead) would be good. However, he was worried that villages around Kimboza FR have weak institutional structures to govern forest utilization. Therefore, giving them such rights would need supervision of forest officers otherwise it would jeopardize other standing trees. That means, the partnership between communities and central government in JFM in this case did not represent a win-win scenario.

Under JFM, presence of a forester to represent central government was potential incentive (Table 14). FGDs revealed that the absence of officer in charge in Kimboza station was used as opportunity for illegal tree harvesting in the FR. Again, most of illegal activities were conducted at night. Village patrol teams themselves without a forester could not do patrols at night. Even during the day, the patrol teams could not manage to stop and inspect suspected vehicles carrying illegal logs as they are not respected the same way as foresters. Box 2 gives a short account that reveals importance of foresters for strentherning governance in forest issues in villages around Kimboza FR.

Box 2: Importance of foresters for strentherning governance in JFM

In changa village, an interviewee Mr. Lawrence Paulo (63 years old) narrated that "*One day a researcher from University of Dar es Salaam was working in Kimboza FR. He was accompanied by the VNRC chairman, VNRC member and a local plant identifier. While in the forest, they heard a group of people pit-sawing in a short distance. Amazingly as they approached them, the wrong doers were not scared as they saw the VNRC members. After a little moment when they saw the researcher, they all ran away thinking he was a forester from the District Forest Department*".

Such a scenario (presented in Box 2) reveals the importance of foresters to represent the government but it also gives some signals that VNRC powers were rather weak. The weakness could be due to corruption, low capacity in terms of working facilities and elite capture. According to Hamisi Nimbwa Bangati (key informant) in Changa village, Kimboza FR was without a forester due to various reasons including insufficient staff in the Forestry and Beekeeping Division of the Ministry of Natural Resources and Tourism.

4.1.3 Communities' Perception on Incentives before and after JFM

About 57% of the respondents (n=164) in the study villages agreed that incentives were better under JFM regime as compared to time before JFM. However, 19% of the respondents had a perception that incentives under JFM regime were insufficient compared to those before JFM and about 23% were indifferent. Tables 15, 16 and 17 show number and percentage of respondents who compared incentives, level of happiness and willingness to participate in JFM before and after its introduction in the study area.

Table 15: Number of respondents comparing incentives before and after JFM in the study villages in Morogoro and Iringa, Tanzania

Forest Reserve	Village	Bad now	The same	Good now	Not sure	Total (n)
Kimboza	Kibangile	5	2	20	17	44
	Changa	5	3	18	10	36
NDU	Kidabaga	11	1	34	0	46
	Luhindo	11	4	22	1	38
Total		32(19)	10(6)	94(57)	28(17)	164

Table 16: Number of respondents comparing level of happiness before and after JFM in the study villages in Morogoro and Iringa, Tanzania

Forest Reserve	Village	Bad now	The same	Good now	Not sure	Total (n)
Kimboza	Kibangile	1	1	37	5	44
	Changa	2	3	27	4	36
NDU	Kidabaga	1	0	45	0	46
	Luhindo	3	1	32	2	38
Total		7(4)	5(3)	140(85)	11(7)	164

Table 17: Number of respondents willing to participate and cooperate in JFM in the study villages in Morogoro and Iringa, Tanzania

Forest Reserve	Village	Bad now	The Same	Good now	Not sure	Total (n)
Kimboza	Kibangile	1	1	36	6	44
	Changa	3	2	25	5	35
NDU	Kidabaga	0	0	45	1	46
	Luhindo	1	0	36	2	39
Total		5(3)	3(2)	139(85)	14(9)	164

Note: Numbers in paranthesis are the corresponding percentages of the total

Plausible reasons as to why many respondents thought that JFM had better incentives. is the fact that JFM probably leads to sustainable use of forest resources. That is, there are bylaws that regulate access and in a way the bylaws were prepared and administered by communities themselves. Through JMAs, communities had some rights and responsibilities in the management and utilization of natural forests.

Most respondents (85%) were happier with JFM than non JFM regime (Table 16). Seven percent of respondents (7%) were indifferent, (4%) were generally unhappy with JFM while (3%) felt no difference. Similar trend was observed for respondents who showed willingness to participate and cooperate in JFM (Table 17).

Generally, the perceptions of local communities on incentives were positive because high percent (Tables 15 to 17) agreed that there were more incentives in JFM regime and they were happier with JFM than the centralized management regime. Most of them were also willing to participate in various JFM activities.

4.1.4 Forest Products and Ecosystem Services

As described in chapter two, local communities may also be motivated in conservation if forests provide goods and services important for their livelihood. The current study showed that, a number of forest products and ecosystem services were enjoyed by local communities in the study villages as indicated in Table 18. FGDs showed that climate regulation, water and tourism services were the most direct and positive ecosystem services perceived by the local communities.

Table 18: Forest products and ecosystem services available in NDU and Kimboza FRs in Iringa and Morogoro, Tanzania

Region	Village	Forest products	Ecosystem services
Iringa	Kidabaga	Vegetables (mushrooms) Firewood Ropes Grasses for thatching Medicinal plants Fruits Wild meat	Good weather condition (micro climate) Biodiversity conservation Climate change mitigation Water
	Luhindo	Honey Vegetables Grasses for thatching Ropes Fruits Weaving materials for mats and baskets(*milulu*) Medicinal plants Wild meat Mushrooms	Biodiversity conservation Research and tourism Climate change mitigation Water
Morogoro	Kibangile	Medicinal plants Fire wood Large and small animals and reptiles Vegetables Poles and withies Strings and ropes for building Timber (logs) Weaving materials for making mats –(*nemvu*) Wild potatoes for food in dry season	Climate regulation service (micro-climate) Water for domestic use and irrigation Biodiversity conservation Research and tourism

	Wild fruits Minerals (alluvial gold- mined in FR)	
Changa	Honey Medicinal plants Wild fruits Timber (logs) Wild meat Poles and withies Fire wood Weaving materials for making mats Strings and ropes for building Stones for building (extracted in FR)	Water for domestic use and irrigation Research and tourism Wind and soil erosion control

Forest products obtained for use from the study forests include honey, firewood and vegetables. Others were medicinal plants for treating various diseases, grasses were used for thatching houses and as fodder. Stones, timber, poles, withies and ropes were used for house construction. Wild meat, fruits and mushrooms were for food and weaving materials ("*Miludu*" in Iringa and "*Nemvu*" in Morogoro) were used for mats and baskets making. Illegal business of trapping and selling of blue lizard dwarf gecko (*Lygodactylus williamsi*) was observed in villages adjacent to Kimboza FR. Mining of alluvial gold along Ruvu River was also observed. In *de jure*, these activities were illegal in the FR but in *de facto*, they were important sources of income especially for young men as also noted by Rwamugira (2007) in the same area and Newmark *et al.* (2003) in East Usambara.

In order to know which forest product was more important to communities, pairwise ranking was done in all four villages. Table 19 shows result of a pairwise ranking of different forest products in Luhindo village in Iringa, tables for other villages are shown in appendix 5(a)-(c). Medicinal plants and honey were among the prioritized products in the study sites but honey was the most commercialized forest product.

Table 19: Pairwise ranking of NTFPs by communities in Luhindo village, Iringa, Tanzania

	Honey	Vegetable	Grasses	Ropes	Fruits	*Milulu*	Medicine	Wildmeat	Rank
Honey		honey	honey	honey	honey	Honey	Medicine	honey	02
Vegetable			vegetable	ropes	vegetable	vegetable	Medicine	vegetable	03
Grasses				grasses	fruits	*Milulu*	Medicine	wildmeat	04
Ropes					ropes	Ropes	Medicine	ropes	03
Fruits						*Milulu*	Medicine	wildmeat	05
Milulu							Medicine	wildmeat	04
Medicine								medicine	01
Wildmeat									05
Total Score	06	04	02	04	01	02	07	03	

Source: PRA data (2010).

4.2 Stocking and Forest Disturbance levels in Forests with and without JFM

4.2.1 An overview

Tables 15 to 17 and 25 report villagers perception on the performance of the JFM using a likert scale. However, this study did also not rely only on people's perceptions but some physical indicators in the field were measured to show the condition of the forests studied. One may judge the performance of the agreements on the basis of how well CFRs are concerved, or how badly they are disturbed. It is for this reason that the study compared stocking levels between FRs with and without JFM regimes.

4.2.2 Number of stems, basal area and volume

Stand parameters in terms of stems per ha (N) and basal area per ha (G) determined the regeneration potential and structure of the forest. Number of stems per ha were higher in

FRs under JFM regime than those without JFM and the difference was statistically significant across all the vegetation types except in woodland ($p = 0.9049$). In lowland vegetation, the average number of stems per ha in Kimboza FR was twice as high as that in Ruvu FR (Table 20). Generally in all vegetation types, many trees were found in the smallest diameter class (1-10 cm, removed in Figure 11 to improve scale).

Table 20: Comparison of stocking parameters (number of stems, basal area and volume; mean ± standard error) in FRs with and without JFM in Iringa and Morogoro regions, Tanzania

Forest Reserve	Management regime	Vegetation type	N±SE (Stems/ha)	G±SE (m^2/ha)	V±SE (m^3/ha)
NDU	JFM	Montane	1581±195	21.5±2.9	170.5±31.5
KL	Without JFM	Montane	1018±183	15.8±3.3	108.0±28.1
Kimboza	JFM	Lowland	1117±254	22.6±4.8	225.4±64.2
		Woodland	363±323	10.7±1.3	100.5±36.4
		Cedrella	1091±286	42.6±20.0	455.9±383.7
		Teak	564±475	27.8±18.4	232.0±169.6
Ruvu	Without JFM	Lowland	561±176	9.8±3.4	81.6±37.7
		Woodland	344±107	10.1±2.1	127.9±43.1

Source: Forest Inventory data (2009).

The overall distribution of number of stems (Fig.11 to 14) by DBH classes indicated a normal reversed 'J' shape trend in all four FRs. However, diameter class 21-30 cm had slightly more stems per hectare than expected for a normal reversed 'J' shape for both NDU and Kimboza FRs. This might be due to effect of introducing JFM where communities were restricted to harvest poles in these forests in last 15 to 20 years. It is assumed that during that time this diameter class (21-30 cm) was of a pole size suitable for construction. It can also be observed that Kimboza do not have Woodland tree species in higher diameter classes above 61 cm (Fig. 12).

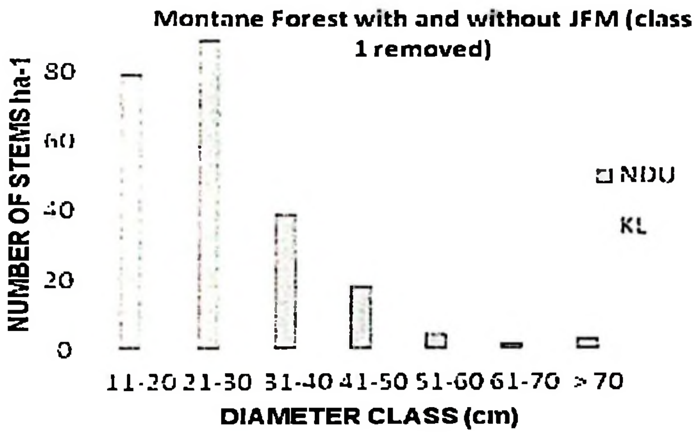

Figure 11: Distribution of stems per ha compared between FRs with and without JFM regime in Iringa region, Tanzania.

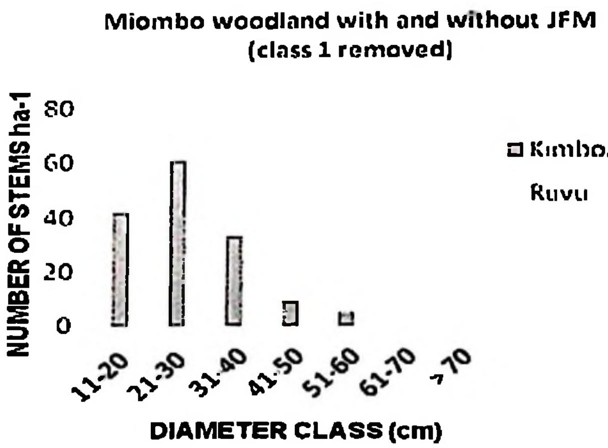

Figure 12: Distribution of stems per ha compared between FRs with and without JFM regime in Morogoro region, Tanzania.

Note: Black bars in figure 11 to 14 represent forest "with JFM" and Gray bars "without JFM"

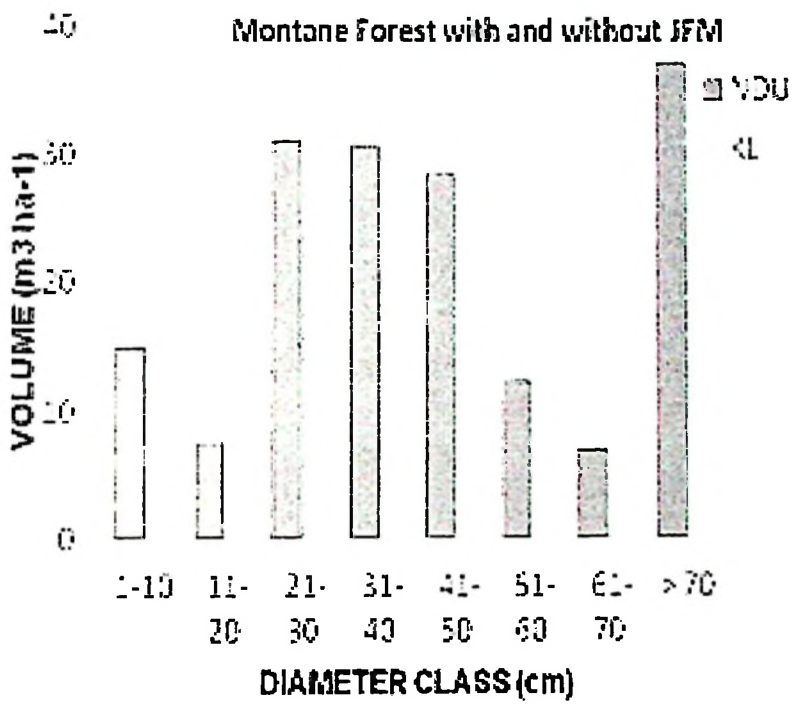

Figure 13: Distribution of volume per ha by DBH classes compared between FRs with and without JFM regime in Iringa region, Tanzania.

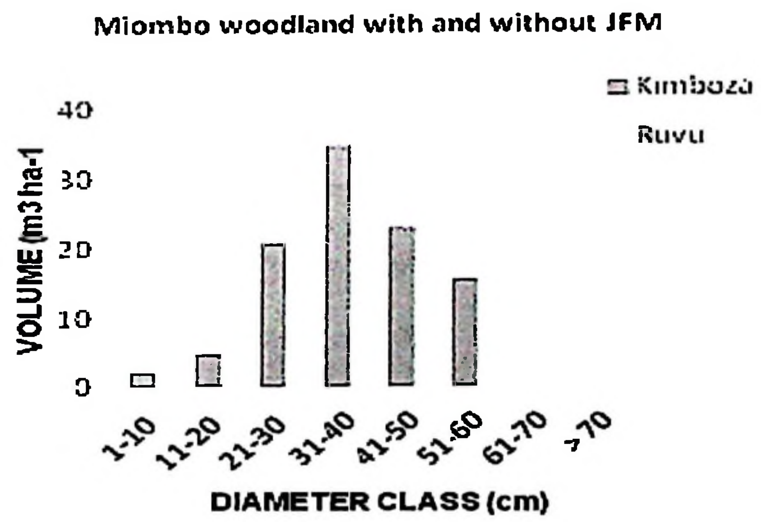

Figure 14: Distribution of volume per ha by DBH classes compared between FRs with and without JFM regime in Morogoro region, Tanzania.

This could be due to the fact that Kimboza is composed of small size re-growth woodland trees of less than 61 cm diameter. It is also shown that, there are on average more stems per hectare in forests with JFM than in those without. This tendency can also be generalized as the effect of strict rules in JFM that limit access of extraction in forests. This trend is common in most forests in Tanzania as it has also been depicted by Zahabu (2008) in forests with similar ecological characteristics.

In general, the average stand basal area and volume per ha were higher in FRs with JFM than in those without. The difference was statistically significant for both basal area (p= 0.0151) and volume (p= 0.0046) between NDU and KL FRs. For the Morogoro sites, basal area and volume were also higher in Kimboza FR than in Ruvu FR and the difference was also statistically significant (p= 0.0009) and (p= 0.0037) for basal area and volume respectively. However, in patches of woodland the difference was not statistically significant. It was also revealed that basal area and volume in Kimboza FR were twice as much as those in Ruvu FR. The highest values were recorded in *Cedrella odorata* vegetation within Kimboza FR. Fig. 13 and 14 show distribution of volume per ha for FRs with JFM regime and those without.

Presence of many regenerants in all the study FRs revealed a good recruitment of young trees. As most tree species are light demanders, many regenerants might be due to the presence of disturbances (Wright *et al.*, 2003). Disturbed forests have increased gaps, light, increased soil temperature and reduced nutrient competition (Augspurger, 1984). This can also be a manifestation of the ecosystems resilience and an indication of healthy forest as stated by the intermediate disturbance theory (Hobbie *et al.*, 1993; Philip, 1994). The reversed 'J shape' of the diameter distribution is interpreted as an indication of vibrant regeneration and recruitment (Huston, 1979; Condit *et al.*, 1998; Wright *et al.*, 2003) which generates a balance between recruitment and mortality of individual species (Connell, 1978). A reversed 'J' shape distribution (Fig. 11 and 12) explains presence of many small sized trees and fewer big ones as expected in tropical natural forests (Philip, 1983; Gwali *et al.*, 2009).

Comparing stocking levels in this study with Malimbwi *et al.* (2002) for Kimboza FR, both stem density and timber volume were found to be lower by 90 stems/ha and 16.7 m^3 ha^{-1}, respectively. The difference could be due to illegal harvesting. This study also showed higher stocking levels in Ruvu FR than that shown by Rwamugira (2007). The difference could be explained by sampling techniquecs used or it is an evidence of a shift of illegal loggers towards *Cedrella* trees in Kimboza FR as alternative to the disappearing Miombo woodland tree species in Ruvu FR. Ecologically. *Cedrella odorata* is fast growing but for good reasons, could not be promoted in woodlots due to its invasive nature to the native tree species (Malimbwi *et al.*, 2002; Madoffe *et al.*, 2006).

4.2.3 Above-ground Tree Biomass

In general, FRs without JFM regime showed lower values in above ground biomass compared to those with JFM as also observed earlier in other stocking parameters (Table 21). Since the tree biomass was estimated based on volume data (Brown and Lugo, 1982) and the fact that carbon stock and carbon dioxide are all associated with biomass (MacDicken, 1997; Brown 1997), the parameters in Table 21 follow the volume trend, the higher the volume the higher the biomass. Using the inventory data, the above ground biomass was estimated according to vegetation types within FRs. As Table 21 indicates, it was observed that the exotic tree species in Kimboza FR (*Cedrella odorata* and *Tectona grandis*) had the highest biomass compared to the natural forests in lowland vegetation.

Table 21: Biomass, Carbon and Carbon dioxide distribution in the studied FRs in Morogoro and Iringa regions, Tanzania

Forest Name	Management	Vegetation Type	Biomass (t/ha)	Carbon (t/ha)	Carbon dioxide (tCO_2/ha)
NDU FR	JFM	Montane	98.9±18.3	48.5±8.9	177.9±32.8
KI. FR	Non JFM	Montane	62.6±16.3	30.7±7.9	112.6±29.3
Ruvu	Non JFM	Lowland	47.3±21.8	23.2±10.7	85.1±39.3
FR		Woodland	74.2±25.0	36.4±12.3	133.4±44.9
Kimboza	JFM	Lowland	131±37.2	64.1±18.3	235.1±66.9
FR		Woodland	58.3±21.1	28.6±10.3	104.8±37.9
		Cedrella	264.4±222.6	129.6±109.1	475.5±400.2
		Teak	134.6±98.3	65.9±48.2	242±176.8

Source: Forest Inventory data (2009).

These findings were expected due to higher basal area for fast growing exotic tree species compared to natural forest trees. However, for the natural forests, this study reports comparatively lower biomass values for montane vegetations but higher values for woodlands compared to those reported by Zahabu (2008) in forests with equivalent ecological characteristics. Zahabu reported above ground biomass of 160 t/ha in montane vegetation and 40 t/ha in woodland. These variations might be due to edaphic factors and sampling. Furthermore, Munishi *et al.* (2010) found an average above ground carbon density of 19.2 t/ha in woodland in local authority forest reserve in the Southern Highlands, which are comparable to those estimated by Zahabu (2008) in Kimunyu and Kitulangalo-SUA Training FRs, in Morogoro. Results of the current study for carbon density fited well with both the Edinburgh Center for Carbon Management (ECCM, 2007) and Shirima (2009) who reported carbon storage potential of between 25 and 80 t/ha for the Eastern woodlands in Tanzania. Munishi and Shear (2004) found an average above ground tree biomass density of 872 t/ha in the afromontane rain forest of the Usambara and 648 t/ha in the Uluguru with carbon densities of 427 and 318 t/ha, respectively, which are higher as compared to those estimated in NDU and KL Mountain forests. These differences might be due to varying degree of exposure to human disturbances, differences in age of the tree species and the type of Woodland species involved. Furthermore, the huge differences with Munishi and Shear (2004) were expected because the authors estimated below ground biomass and soil carbon in addition.

These biomass estimates are considerably lower than those from studies of mature tropical forests elsewhere based on direct measurement. Brown and Lugo (1982) compiled direct-estimate data to calculate mean above ground biomass for mature tropical humid forests in Asia (350 t/ha) and for all mature tropical forests of the world (300 t/ha). Kira *et al.* (1967) conducted a study in Khao Chong (Thailand) using direct measurement of undisturbed tropical rain forest in experimental plots and obtained above ground biomass of 331 t/ha. Two years later, using the same methods, Kira *et al.* (1967) conducted a study on evergreen seasonal forests in Cambodia, and obtained above ground biomass of 321 t/ha. Brown *et al.* (1989) and Clark *et al.* (2001) argued that direct biomass determination from a few small plots usually results in over estimates due to plot biases (probably because plots are not randomly selected, or are not sampled from the population of interest, or have a small sample size) and the influence of large trees.

Furthermore, Brown *et al.* (1989) estimated biomass for tropical forests and obtained a weighted average of 215 t/ha for undisturbed tropical forests of Asia. In 1999, she suggested that biases associated with biomass estimates using data from forest inventory are less than those of direct measurement because generally more data are used, and the data are collected from a large sample area using sampling methods that are statistically valid. However, it has been argued that undisturbed tropical forests would have biomass of more than 350 t/ha, while the disturbed forests would have less than 270 t/ha (Brown *et al*., 1991). However, the current study estimated tree biomass only, leaving away liter and herbs which are also components of above ground biomass. Apart from that, most forests in Asia and other parts of the tropics are both denser and taller than those sampled in the current study in Tanzania.

4.2.4 Tree species dominance

There were many common tree species found in the study forests. More tree species were found in Kimboza FR (106 species in 33 sample plots) followed by KL FR (101 species in 46 sample plots). Ruvu FR had 83 species in 35 sample plots and lastly NDU FR had 75 species in 38 sample plots (Fig. 15).

However, the dominant tree species by volume in NDU FR (Fig.16) were *Macaranga kilimandscharica* (Mpalapala), *Ficus capensis* (Mdaamba), *Cassipourea malosana* (Msengela), *Pittosporum viridiflorum* (Mpeta) *Chionanthus battiscombei* (Mgiiwe) *and Ixora narcissidora* (Mmemena). In KL FR the dominant tree species (Fig. 17) were *Albizia gummifera* (Mtanga) *Chrysophyllum gorongosanum* (Mlembelembe), *Macaranga kilimandscharica* (Mpalapala), *Vitex species* (Mhongola), *Catha edulis* (Mhulo\Mrungi), *Polyscias fulva* (Mdeke) and *Nuxia floribunda* (Mngogo). These tree species were normally found in high altitudes and they are typical of montane vegetation.

In the lowland sites in Morogoro (Fig. 18-21), the FRs were stratified into Woodland and Lowland vegetation. In Kimboza FR, other vegetations of *Cedrella odorata* and *Tectona grandis* existed. The dominant tree species in Kimboza FR were *Parkia filcoides* (Mkundi), *Bombax rodognofalon* (Msufipori), *Sterculia appendiculata* (Mgude) *and*

Cynometria ulugulensis (Mhengele) for Lowland vegetation (Fig.19). Others are *Combretum molle* (Mlamamweusi). *Acacia polyacantha* (Muwindi). *Annona senegalensis* (Mtomokwe/Mtopetope) and *Piliostigma thorningii* (Msegese) for Woodland vegetation (Fig.21)

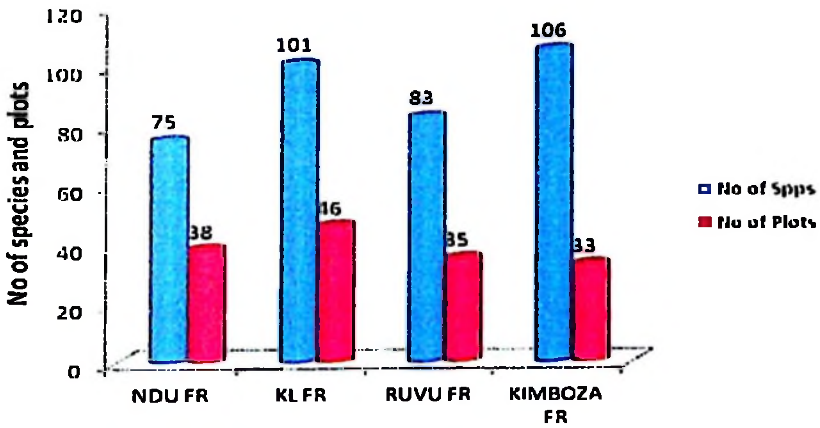

Figure 15: Species abundance for the four FRs in Iringa and Morogoro regions, Tanzania.

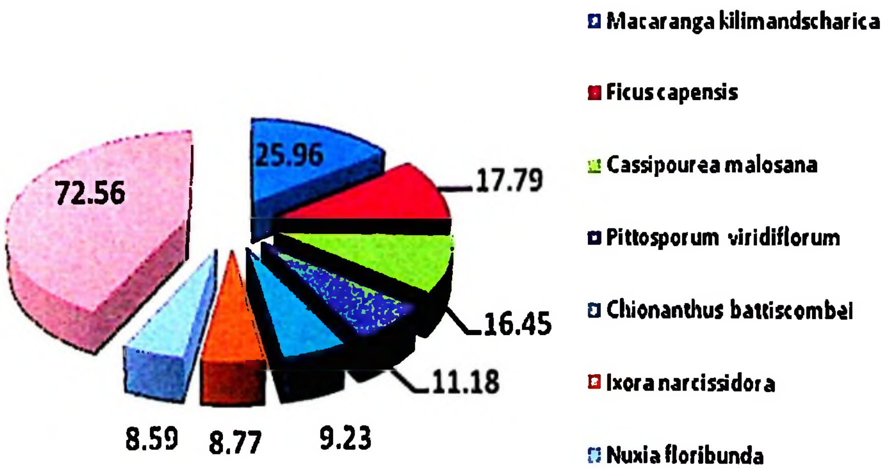

Figure 16: Tree species dominance for NDU FR in Iringa region, Tanzania.

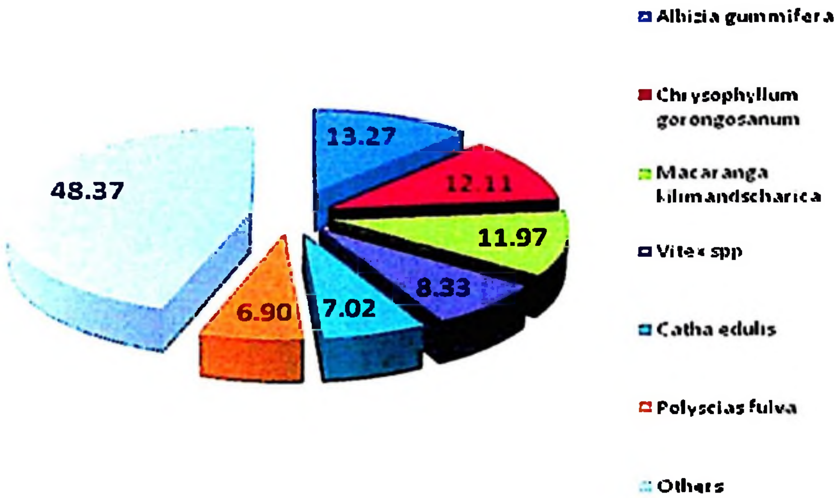

Figure 17: Tree species dominance for KL FR in Iringa region, Tanzania.

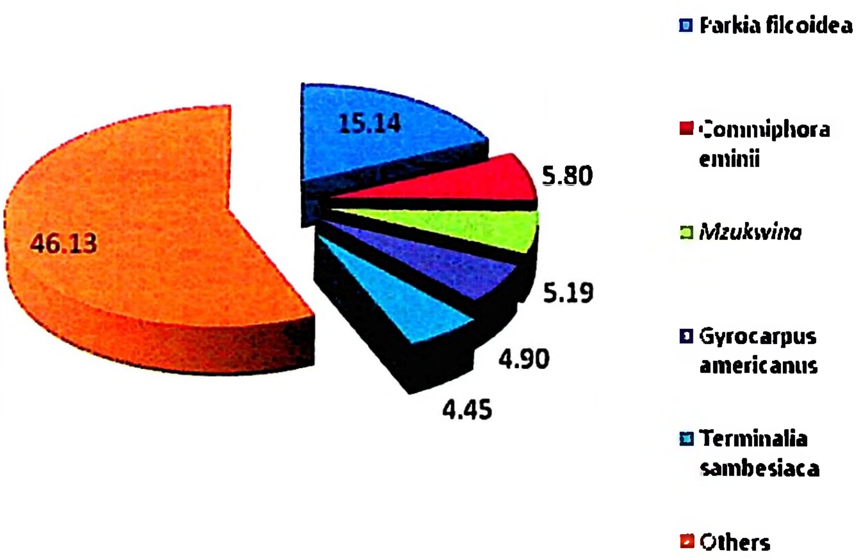

Figure 18: Tree species dominance for lowland vegetation in Ruvu FR, Morogoro region, Tanzania.

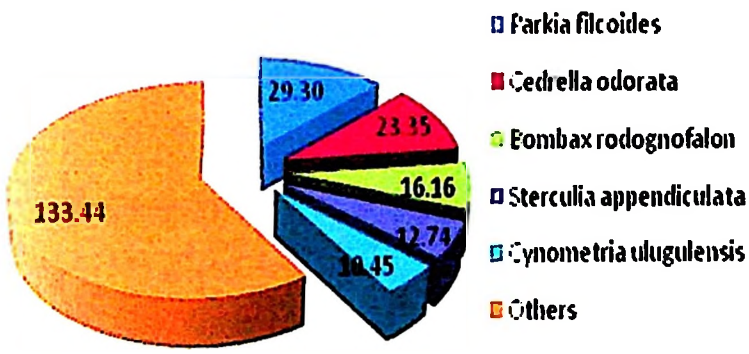

Figure 19: Tree species dominance for lowland vegetation in Kimboza FR.

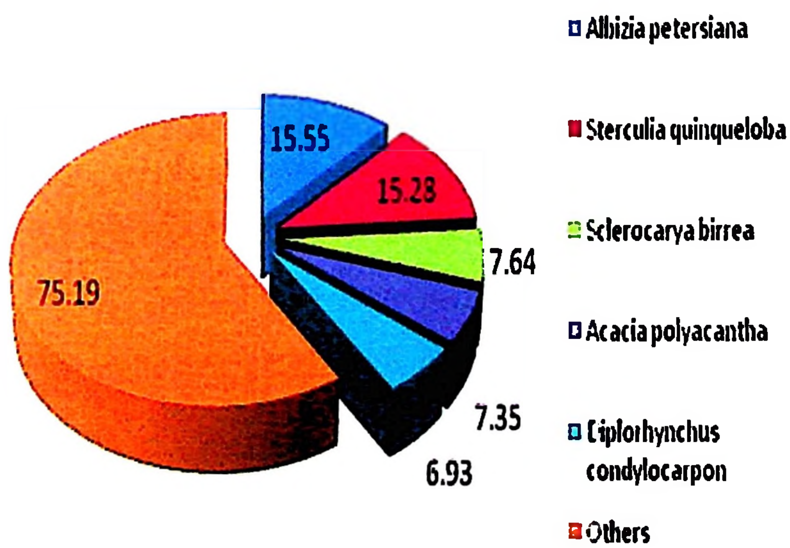

Figure 20: Tree species dominance for Woodland in Ruvu FR.

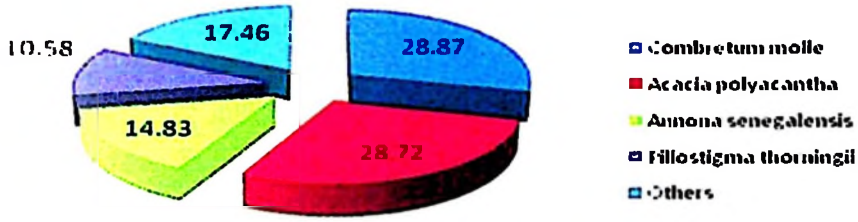

Figure 21: Tree species dominance for Woodland in Kimboza FR.

For Ruvu FR, dominant tree species were *Parkia filcoides* (Mkundi), *Commiphora eminii* (Mbani), "Mzukwina", *Gyrocarpus americanus* (Bwendele) and *Terminalia sambesiaca* (Mpululu) in Lowland vegetation (Fig. 18).

In Woodland, tree species were *Albizia petersiana* (Mkenge), *Sterculia quinqueloba* (Mhembeti), *Sclerocarya birrea* (Mng'ongo), *Acacia polyacantha* (Muwindi) and *Diplorhynchus condylocarpon* (Mtogo) (Fig. 20).

4.2.5 Forest disturbances in FRs with and without JFM regime

4.2.5.1 Disturbances as depicted through cut tree stumps

Table 22 shows that FRs with JFM regime had slightly higher removal (volumes per ha) than those without JFM but their difference was not statistically significant (p=0.4752) and (p=0.4879) for Kimboza/Ruvu and NDU/KL FRs respectively. Removed volume for both new and old cut trees were also not statistically significant. The most harvested tree species in NDU and KL FRs was *Ocotea usambarensis* that was used for timber while in Kimboza and Ruvu FRs were *Cedrella odorata*, *Milicia excelsa*, *Combretum molle* and

Albizia petersiana which were also used as timber and poles. *Combretum molle* was also among the tree species with largest volume of illegally harvested trees in Kitulangalo FR and nearby general lands in Morogoro (Luoga *et al*., 2002).

The results revealed that, although forests under JFM regime had by-laws to control access, they were not effectively conserved because illegal harvesting continued. A similar observation was recorded by Luoga *et al*. (2002) where illegal harvesting was common in both reserved and public lands around Kitulangalo FR in Morogoro. In their study, they estimated a total removal volume of 7.1 m^3 ha^{-1} in reserved forest and 19.62 m^3 ha^{-1} in nearby public lands. However, their figures are in the lower side compared to those reported in this study probably due to difference in tree species and age between the forest reserves.

Table 22: Comparison of forest disturbances (number of stumps and volume; mean ± S.E.) between FRs with and without JFM in Iringa and Morogoro region, Tanzania

Forest Reserves	Regime	New stumps		Old stumps		All stumps	
		No. (stems ha^{-1})	Volume (m^3ha^{-1})	No. (stems ha^{-1})	Volume (m^3ha^{-1})	No. (stems ha^{-1})	Volume (m^3ha^{-1})
Iringa region							
NDU (n=38)	JFM	1.0±1.22	0.5±0.06	5.0±2.18	127.1±9.14	6.0±2.18	127.6±6.89
KL (n=46)	Non JFM	1.0±0.43	0.2±0.03	6.0±3.28	126.4±5.64	7.0±3.28	126.6±4.91
Morogoro region							
Kimboza (n=33)	JFM	4.0±1.64	2.7±0.21	34.0±14.55	49.4±1.69	38.0±14.36	52.1±1.19
Ruvu (n=35)	Non JFM	2.0±1.46	2.5±0.61	2.0±0.76	13.2±2.12	4.0±1.58	15.7±1.26

Source: Forest Inventory data (2009).

Table 23 represent removal/standing stock ratios (new removals only) which reflect the extent of disturbance in comparison with the remaining standing stock of a particular FR. The higher the ratio, the higher are the disturbances and therefore the less sustainable is the forest reserve. Generally, new removal in all the four FRs were not alarming (Table 23). Based on new removals, it was shown that there were more harvested trees in Ruvu FR compared to its standing stock and least in KL FR. As described above however, differences were statistically not significant.

Table 23: Annual removal/standing (R/S) ratio for the four FRs in Iringa and Morogoro, Tanzania

Forest Reserve	Annual Removal (m^3/ha/yr)	Standing volume (m^3/ha)	Annual R/S ratio
NDU	0.48	170.5	0.003
KL	0.19	108.0	0.002
Kimboza	2.68	225 .4	0.012
Ruvu	2.49	81.6	0.031

Source: Forest Inventory data (2009).

The forest inventory also revealed that forest boundaries of all FRs were not clearly demarcated (Table 24). Most portions with unclear boundaries were encroached for agriculture. Livestock grazing was common in the northern part of Ruvu and KL FRs. Old and new signs of fire damage were observed in many parts of Kimboza and Ruvu FRs. Fire incidences were however, not observed in any of the Iringa sites. Table 24 shows some disturbances that were recorded through opportunistic observations.

Table 24: Other types of disturbances recorded in the study sites in Iringa and Morogoro, Tanzania

Forest Reserve	Regime	Grazing (sites)	Encroachment Agriculture (sites)	Charcoal making (sites)	Burned (sites)	Mining (pits)	Hunting (snares/traps)
NDU	JFM	02	04	00	00	00	13
KL	Non JFM	04	06	00	00	00	09
Kimboza	JFM	02	02	00	06	11	03
Ruvu	Non JFM	06	05	03	08	87	05

Source: Forest Inventory data (2009).

Based on opportunistic observations. Morogoro sites were more disturbed compared to Iringa sites. Charcoal making sites targeting *Combretum molle*, mining pits mainly for alluvial gold and forest fires were all recorded in Kimboza and Ruvu FRs. Both illegal and licensed small artisans were found mining in the reserves. Hunting was observed in almost all the FRs, but snares were more recorded in NDU and KL FRs. One steel snare for trapping large mammals was recorded along the boundary of NDU FR (Plate 6-11).

Iringa forests had fewer disturbances than Morogoro probably because most households in Iringa owned private woodlots to cater for their domestic needs as well as commercial supply of timber, building poles and firewood. That means, sale of wood increased household income which eventually reduced pressure on FRs. Furthermore, Iringa FRs are situated in mountains with difficult terrain and they are far from commercial centres. Higher fines charged between TZS 15 000 to 50 000 for offenders and responsive village leadership were restrictive to illegal timber dealers. Photos in Plate 6 to 11 show some disturbances in the study sites.

Plate 6: Extraction of tree bark for medicinal use in KL FR, Iringa

Plate 7: Illegally harvested Milicia excelsa in Kimboza FR, Morogoro

Plate 8: Cedrella odorata planks illegally extracted in Kimboza FR, Morogoro

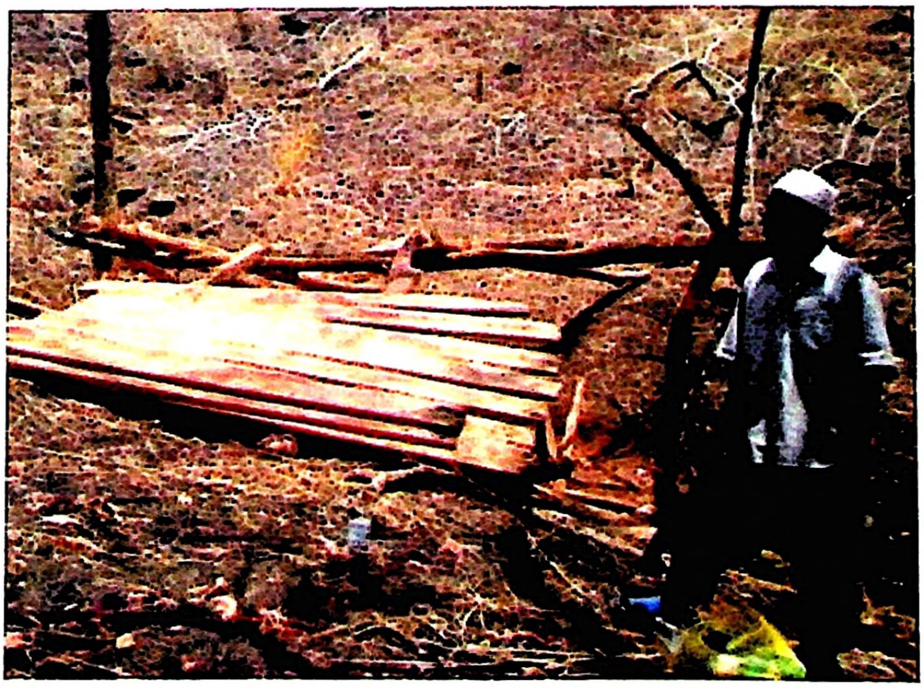

Plate 9: Illegal timber harvesting in Ruvu FR, Morogoro

Plate 10: Illegal charcoal making in Ruvu FR, Morogoro

Plate 11: Gold mining in Ruvu River inside Ruvu FR, Morogoro

In Morogoro, woodlots were not a common phenomenon and forests were easily accessed by road due to its flat terrain. Kimboza and Ruvu FRs are very close to the main roads and also closer to Dar es Salaam city (250 km) which is a major commercial center in the country. The small fines (TZS 3 000 to 30 000) charged for offenders in Morogoro could be another factor that hastened illegal harvesting (1 USD was equivalent to 1 300 TZS in May 2010).

4.2.5.2 Disturbances as perceived by local communities before and after JFM

Respondents were asked whether they thought CFRs were more disturbed during JFM regime or before. About 68% of respondents mentioned that FRs were less disturbed during JFM regime than the time before JFM. However, 23% of respondents (all from Morogoro sites) perceived more disturbances during JFM (Table 25).

Table 25: Comparison of perceived forest disturbances before and after JFM for the study villages in Iringa and Morogoro, Tanzania

Forest Reserve	Village Name	Bad now	The same	Good now	Not sure	Total (n)
NDU	Kidabaga	0	0	46	0	46
	Luhindo	0	0	34	2	36
Kimboza	Kibangile	15	3	24	4	44
	Changa	22	2	08	4	36
Total		37(23)	5(3)	112(68)	10(6)	164

Note: Numbers in paranthesis are the corresponding percentages of the total

While some communities in Morogoro perceived some level of disturbance under JFM regime, communities in Iringa sites perceived a different situation. There were no respondent who acknowledged presence of forest disturbances in JFM regime. These results from household questionnaires correspond with results obtained through forest inventory.

During forest inventory in Kimboza FR, some *Cedrella odorata* trees were found drying up. Discussion with authorities revealed that they were research plots to test ways of eliminating the species due to their invasive nature. The research was not in the interest of communities and it led to increased illegal harvesting in the FR. Box 3 illustrates this scenario as recorded in one of the FGDs in Kibangile village.

Box 3: Effects of research on elimination of *Cedrella odorata* in Kimboza FR

During the discussion, Mr. Jonas Msumi (40 years) explained "A *group of people from SUA and TAFORI made research on ways to eliminate Cedrella odorata (invasive tree species) in Kimboza FR. When they came to our village for a meeting they informed the villagers that in Mexico where Cedrella trees originate, the trees have been eliminated due to their harmful invasive effects. They informed us that they are investigating better ways to eliminate Cedrella in Kimboza FR; their trials involved injecting Cedrella trees with chemicals and ring-barking.*

When community members heard that Cedrella are no longer required, they requested a permit to harvest all Cedrella trees so that they can benefit financially through sale of timber. Their request was rejected. As a consequence rampant illegal harvesting by local communities was witnessed (see Plate 8).

4.3 Institutional Arrangements under JFM Regime

In principle, all FRs in Tanzania are governed by formal rules as stipulated in the Forest Act No. 14 of 2002. In addition, reserves under JFM regime are governed by village by-laws. The study revealed that all four villages had by-laws and Joint Forest Management Agreements (JMAs) with Central Government. About 96% of respondents (n=164) were aware of existence of by-laws which were used in their villages. However, during FGDs, respondents complaints were raised (Morogoro) that the by-laws were outdated because since their formulation in 2000, they were not revised. For Iringa sites, at least they were revised once but were not approved by the Ministry of Natural Resources and Tourism due to the unsolved issues of benefit sharing with communities (MNRT, 2009). FGDs with elders revealed that, communities did not have informal or traditional rules used to regulate access in the CFRs during the survey time. Under JFM, law enforcement was vested on the village through village natural resource committees (VNRC). The committees controlled access and utilization of forest resources with some technical backstopping from foresters.

However, some key informants in all the study sites complained about the problem of elite capture within VNRCs. Elite capture was one of the main problems leading to forest disturbances and one of the main causes of persistent poverty. This problem (elite capture) is not new in Tanzania and other parts of the world. For example, MNRT (2008) and Global Forest Coalition paper (undated) reported a wrong representation and elite resource appropriation in VNRCs in Eastern Arc Mountains, Tanzania and Asia respectively.

By-laws stipulated fines/penalties for forest offences (Tables 26 and 27). Culprits were sanctioned by village council for offences within its jurisdiction and primary courts for offences above the capacity of village by-laws. However, the later was not preferred because it was expensive for villagers to run cases and all the fines charged thereafter were remitted to the central government with no retention scheme.

Table 26: Recorded cases of forest offenses and action taken by village administration in Kibangile village adjacent to Kimboza FR in Morogoro region, Tanzania

Date	Offense	Fine/action taken
25/5/2003	Harvesting poles, ropes and caught with several animal traps	Products confiscated and auctioned, traps destroyed
4/6/2004	Harvesting Bamboo and caught with several animal traps	Products confiscated and auctioned, traps destroyed
17/6/2004	Harvesting 30 pieces of timber	Fined TZS 25 000 and all timber confiscated
12/1/2006	Harvesting Bamboo	Fined TZS 15 000 and Bamboo confiscated
19/10/2006	Harvesting 25 pieces of timber	Fined TZS 55 000 and timber confiscated
25/11/2007	Killed a wild animal	Fined TZS 20 000
28/09/2008	Caught with 34 bamboo baskets	Fined TZS 15 000
27/08/2008	Caught with poles	Fined TZS 3 000 and poles confiscated
23/09/2008	Harvesting 5 bamboo	Fined TZS 15 000 and bamboo confiscated
22/10/2008	Harvesting 1 bamboo	Fined TZS 3 000 and bamboo confiscated
8/4/2010	Harvesting Timber	Fined TZS 50 000 and timber confiscated

Note: 1 USD was equivalent to 1 500 TSZ.

Table 27: Recorded cases of forest offenses and action taken by village administration in Changa village adjacent to Kimboza FR in Morogoro region, Tanzania

Date	Offense	Fine/action taken
8/11/2001	Causing forest fire in Kimboza FR	Fire was extinguished but offender was not known
19/09/2002	Causing forest fire in Kimboza FR	Fire was extinguished but offender was not known
16/10 /2002	Causing forest fire in Kimboza FR	Fire was extinguished but offender was not known
20/09/2003	Charcoal making inside Kimboza FR	The offender was sent to court and jailed for 7 years.
13/10/2004	Causing forest fire in Kimboza FR	Offender was caught but action taken was not recorded
26/09/2005	Causing forest fire near Sanali sub village	Fire could not be extinguished as it was so large.
03/10/2005	Causing forest fire near Kimboza FR	Fire was extinguished but offender was not known
16/2/2006	Possession of 22 pieces of timber	All 22 pieces were taken to the village office and used for making school desks
05/08/2006	Illegal making of tree planks in the FR	All planks were auctioned and funds used for conservation activities
26/03/2007	Harvesting *Cedrella* timber in Kimboza FR	Fined TZS 30 000/= and timber confiscated
12/09/2007	Caused forest fire in Kimboza FR	Fire was extinguished but offender was not known
23/08/ 2010	Lorry with *Cedrella* logs caught	Fined TZS 1million and logs confiscated

Note: These were the only cases that were managed to be recorded in the VNRC monitoring books. According to village leaders, there could be several of such cases that were not recorded in the books as culprits were not caught or if patrol team members were bribed.

In all the study sites, 50% of the charged fines were used for conservation activities including establishment of tree nurseries, boundary cleaning and fire control. The remaining 50% was used for community development activities by the village council including building crassrooms and health services as also reported from East Usambara Mountains by Vehemaki (2009). Confiscated equipments are normally sold in auction and funds obtained are also used for conservation.

Weak village leadership which failed to conduct quarterly meetings and increased forest boundary conflicts between Kibangile and Mwalazi villages around Kimboza FR weakened conservation efforts. This weakness can also be traced in Tables 26 and 27 where enforcement of rules was weak between 2008 and 2009. Forest inventory also revealed that there were trees cut within these years and FGDs also confirmed that VNRCs were not doing forest patrols as required due to absence of a forester who used to motivate them. Personal observations revealed that the protection by VNRC was just *de jure* but in reality the power of VNRCs was negligible because they were not respected by other villagers (as described earlier in Box 2). Discussion with VNRCs revealed that by-law enforcement was not properly done due to lack of motivation (incentives). According to Ostrom (1990), most rules work when they are enforced or there is motivation. Therefore, the forest disturbances in Kimboza FR may be interpreted as an indication of institutional failure, as a result of weak protection by both villagers and less motivation from central government (Acheson, 2006).

In India and Nepal for example, restricted access to catchment forests has been reported to affect forest users and there was evidence that JFM in India had not been successful (Malla, 2000). It is reported that the FRs became more accessible after management responsibility was handed over to local communities (Poffenberger and McGean, 1998).

Adhikari *et al.* (2005) reported that when forests were under a strict protection, disturbance was reduced and it increased as it became more accessible. In Tanzania, JFM was expected to reduce disturbance and hence ensure sustainable forest management. However, despite all the regulations, illegal harvesting continued indicating that JMAs are not effective measures to reduce or stop illegality.

4.4 Incentive Optimisation Model for Communities Implementing JFM in CFRs

4.4.1 The Model outputs

The optimal solution for NDU FR gave a value of USD 6 144 per year (Table 28).

Table 28: Optimal solution for NDU FR in Iringa, Tanzania

Return	Value	Status	Slack
Objective function value (US$)	6 144		
Decision Variable			
Carbon dioxide stored (tCO_2e)	307.2		
Honey produced (kg)	0		
Constraint			
Labour (Hrs)	3 072	Binding	0
Capital (US$)	6 144	Not Binding	1 256
Forest area (ha)	1 536	Not Binding	2 164
Disturbance ($m^3 yr^{-1}$)	0	Not Binding	0.5

Source: Survey data, (2009/2010)

In order to achieve this optimal solution, a combination of 307.2 tonnes of carbon and non optimal amount of honey (kg) were produced. The number of hours that were required (labour) for management of the forest was found to be binding with slack value of 0 (Table 28). This is true because NDU FR is a big forest (3700 ha) and is surrounded by six villages. That means 3072 hours of work (patrols, boundary maintenance, fire prevention and monitoring for carbon and beekeeping) were not sufficient for such a big FR.

The optimal values obtained for both sites are comparable to findings of other studies. For example. Walker *et al.* (2008) suggested a financial gain of between USD 1 650 to $ 250 for every hectare of natural forest protected from deforestation and degradation in Africa. Laurence (2007) further reported that at the market value of carbon, a hectare of rainforest if left intact, could worth from USD 400 to more than USD 8 000. Juma (2012, unpublished) reported a potential earning of about USD 3 700 per year for Kwevumo FR and USD 3 900 per year for Derema FR in Eastern Arc sites, Tanga region, Tanzania. However, figures from the latter are relatively small because the study used small prices of carbon at the rate of USD 5 per tonne. A study by Strassburg *et al.* (2009) which modelled the effects of reduced emissions from 20 most forested developing countries (Tanzania inclusive) concluded that the price of USD 8 per tCO_2 was on the very low side of the UNFCCC estimates of mitigation options.

Sensitivity analysis in Table 29 suggests that 628 hours could be increased at optimal solution. However, all other constraints were in excess with positive slack values. That means, they were in adequate and reducing their amount by the value shown as slack would not affect the optimum solution. Practically, this suggests that capital can be reduced by USD 1 256 given the same conditions and assumptions. Forest area cannot be reduced because the forest is already gazzeted. Table 29 shows sensitivity analysis which is a measure of confidence in the results presented in Table 28.

Table 29: Sensitivity analysis for NDU FR in Iringa, Tanzania

		Reduced	Objective	Allowable	Allowable
Decision Variable	**Value**	**Cost**	**Coefficient**	**Increase**	**Decrease**
Carbon stored per ha (tCO_2e)	307.2	0	20	1E+30	10
Honey produced per ha (kg)	0	0	5	5	1E+30
		Shadow	**Constraint**	**Allowable**	**Allowable**
Constraint	**Value**	**Price**	**R.H. Side**	**Increase**	**Decrease**
Labour (Hrs)	3 072	2	3 072	628	3 072
Capital(US$)	6 144	0	7 400	1E+30	1 256
Forest area(ha)	1 536	0	3 700	1E+30	2 164
Disturbance ($m^3 yr^{-1}$)	0	0	0.5	1E+30	0.5

Sensitivity analysis suggests that, one may increase labour up to 628 hours from the existing 3 072 hours per year to satisfy the objective function. It also shows that for every additional unit of labour, there is additional profit of USD 2 (the value of shadow price in Table 29). For other constraints, there was a shadow price of zero showing that increasing the constraint value to any amount will never add any profit because they are already in excess.

The optimal solution for Kimboza FRs was USD 2 025 per year. According to the model, this optimum level was contributed mainly by the amount of honey produced from the FR. In this case, forest area was small for optimal production of carbon credits. This is true because the model suggests that labour and capital were in excess but forest area is binding with a slack value of zero (Table 30).

Table 30: Optimal solution for Kimboza FR in Morogoro, Tanzania

Return	Value	Status	Slack
Objective function value (US$)	2 025		
Decision variable			
Carbon stored per year (tCO_2e)	0		
Honey produced per year (kg)	405		
Constraint			
Labour (Hrs)	2 025	Not Binding	1 047
Capital (US$)	4 050	Not Binding	3 350
Forest area (ha)	405	Binding	0
Disturbance ($m^3 yr^{-1}$)	0	Not Binding	2.7

According to the model, Kimboza FR would qualify for optimal carbon credits with additional area of 209.4 ha (Table 31). However, the forest is surrounded by private farm lands and it can be very expensive for the Government to have these additional hectares.

Table 31: Sensitivity analysis for Kimboza FR in Morogoro, Tanzania

Decision Variable	Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Carbon stored per year (tCO_2e)	0	0	20	5	1E+30
Honey produced per year (kg)	405	0	5	1E+30	1
Constraint	**Value**	**Shadow Price**	**Constraint R.H. Side**	**Allowable Increase**	**Allowable Decrease**
Labour (Hrs)	2 025	0	3 072	1E+30	1 047
Capital (US$)	4 050	0	7 400	1E+30	3 350
Forest area (ha)	405	5	405	209.4	405
Disturbance ($m^3 yr^{-1}$)	0	0	2.7	1E+30	2.7

If that could be possible, the model simulates additional profit of USD 5 per every ha that could be added to the FR (value of shadow price). This finding is also supported by Chhatre and Agrawal, (2009) who also found that the area of the forest commons and the degree of rule-making autonomy are both positively associated with win–win outcomes for high carbon storage and livelihood benefits. It was further argued that when local users perceive insecurity in their rights (because the central government owns the forest land), they extract high levels of livelihood benefits from them, and when their tenure rights are safe, they conserve the biomass and carbon in such forests. Therefore, to maximize profit based on carbon stock, forest size is one important factor and forestland tenure is another.

It has to be noted that the prices for a tonne of carbon and a kg of honey is subject to market forces hence may change. There are few chances that these prices may decrease due to rising of important products in the world market. It was estimated for example that, carbon prices may rise up to USD 100 by 2 030 (Strassburg *et al.*, 2009). The model suggests that, any price increase of carbon and honey will automatically increase the profit. In next two years, the price of one tonne of carbon would reach USD 30 and a kilo of honey would be sold at USD 10 (Keles, 2010). According to the model, this increase would generate up to USD 9 215 and USD 4 050 per year for NDU and Kimboza FRs respectively.

In order to explore more incentive opportunities for communities, further options were explored in the optimisation model to include an extra variable (sustainable wood production for charcoal making). The additional variable was considered with assumption that wood being removed illegally could be legally used for charcoal making. The price of wood was calculated as 12 US$/bag of charcoal (60 kg) requiring 0.42 m^3 of wood. One m^3 of wood harvested was equal to one m^3 of disturbance. There were 170 m^3/ha available in NDU FR, so only 0.006 ha was required for each m^3 removed. It was assumed that 3 hours were required to produce one m^3 of wood for sale. It was also assumed that a cash outlay of half a dollar was required for each m^3 of wood harvested. Table 32 gives improved model output.

Table 32: Optimal solution and sensitivity analysis results for NDU FR, when wood production is included in the model

Decision variable	CO_2	Honey	Wood	Limit	Usage	Status
Object function value US$/yr)						29 286
Income (US$)	20	5	28.6			
Decision variable values	0	0	1 024			
Labour (hrs)	10	5	3	3 072	3 072	Binding
Capital (US$)	2	1	0.5	7 400	512	Not binding
Disturbance (m^3/yr)	0	1	1	1 850	1 024	Not binding
Area (ha)	5	1	0.006	3 700	6	Not binding

The optimal solution for NDU FR with sustainable wood harvesting was USD 29 286 per year. Only 1 024 m^3 of wood was produced although no production of CO_2 or honey was optimal. Results also showed that labour limitation was again binding but the total income to communities has significantly improved.

In Table 33, the requirements of labour for CO_2 storage has been drastically reduced. As a result less wood was removed and considerable amount of CO_2 storage was payed for. Although both labour and land restrictions were binding, the total income was higher than before.

Table 33: Optimal solution and sensitivity analysis results for NDU FR, when labour for CO2 storage is reduced in the model

Decision variable	CO_2	Honey	Wood	Limit	Usage	Status
Object function value (US$/yr)					37 022	
Income (US$)	20	5	28.6			
Decision variable values	739	0	778			
Labour (hrs)	1	5	3	3 072	3 072	Binding
Capital (US$)	2	1	0.5	7 400	1 867	Not binding
Disturbance (m3/yr)	0	1	1	1 850	778	Not binding
Area (ha)	5	1	0.006	3 700	3 700	Binding

This study suggests that wood products were more valuable than carbon and honey. These findings are in line with MNRT (2003a) that wood related products rank high in total economic value. Wood production is still an important activity for income generation as shown earlier in chapter two where it was reposted that wood products are more valuable than NTFPs and carbon.

Table 33 also shows that the model outputs were quite sensitive to labour. Decreasing labour from 10 to one unit led to optimal production of CO_2 and significantly increased the total income around NDU FR from USD 6 144 to 37 022 per year. Diaz- Balteiro and Rodrigez (2006) and Yousefpour and Hanewinkel (2009) studied the impact of different carbon prices on the net present values of timber and carbon and forest ecosystem structure. They found that the unit carbon price might be very important in multiple-use management of forest resources. Backeus *et al.* (2005) and Baskent and Keles (2009) indicated that assigning carbon sequestration a monetary value increased carbon sequestration in the forest and decreased harvest levels. Therefore, sustainable wood harvesting could increase incentives for communities in the expence of the central government to prevent illegal harvesting. This would be possible through enforcing rules. assuming that young trees are growing and ensuring that the sustainable removal is less than the expected disturbance.

When putting incentives in a broader perspective, we should go further to analyse whether village council or VNRC should receive carbon funds or it should be distributed to individuals within the target village. Whatever decision made, it could be complex. A common approach in Tanzania has been to pay communities through their existing formal institutions like village council (Zahabu, 2008). However, TFCG and MJUMITA have piloted payment to individuals at Dodoma-Isanga and Chabima villages in Kilosa district, Morogoro region. A total of TZS 36.5 million were paid to 2 581 individuals in the two villages and the total funds were distributed as shown in Fig. 22.

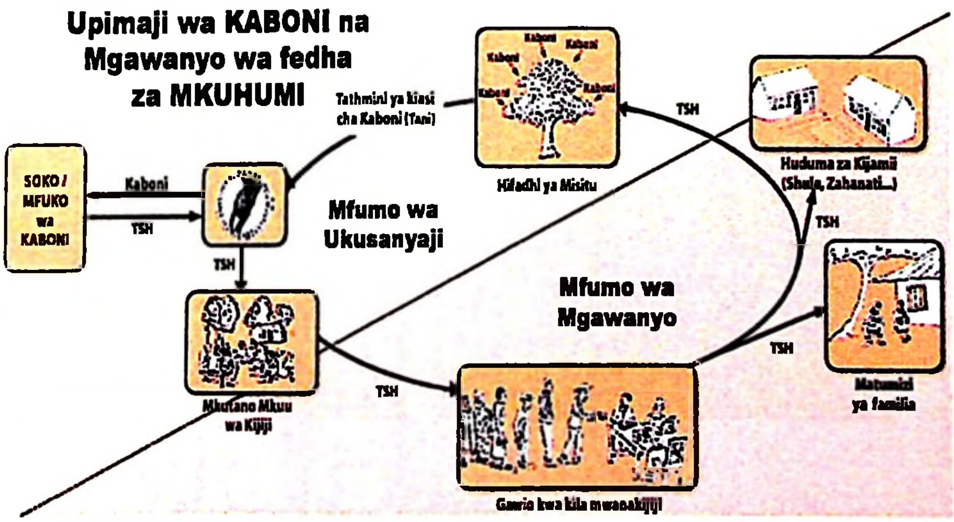

Figure 22: REDD+ revenue distribution model (in Swahili)

Source: TFCG and MJUMITA (2012).

Payment to village council is good if the funds are efficiently used for community development activities which are for everyone. However. most village leaders have been criticized due to poor governance and mis management of public funds. Paying individuals leads to direct incentives but does not guarantee wise use of funds. It depends on who receives the funds (mother. father or child). A key informant in Iringa sites argued that most women in Iringa were not involved in making decisions on household income: it is decided rather by the father-head of the household. REDD+ money could also fall in the same trap. However. TFCG and MJUMITA trial payment model for REDD+ looks to be fairly good because the funds are channelled to all levels (individuals. community services and some to conservation activities). According the REDD+ payment bylaws (developed in Kilosa). individuals could be a father. mother or a child within household. Normally each household agrees to register one of them to participate in the trial payment for REDD+ on behalf of the household. This was witnessed during the trial payment event that some households were represented by pupils as Plate 12 shows.

(a) (b)

Plate 12(a and b): show Kilosa villagers assembling and signing trial payment for REDD+

4.4.2 The Model limitations

4.4.2.1 Unsufficient resources for determination of constraint coefficients

Time and financial resources were not enough to determine all the coefficients of the constraints in the optimisation model empirically. It was necessary to review relevant literature to determine coefficients for labour and capital. Therefore, the estimates carried uncertainties of the studies used as sources of information.

4.4.2.2 Few number of decision variables

The model considered only two important forest values, honey and carbon where honey was a direct use value and carbon had indirect use value. Total economic value of forests includes also non use values like option values and existence values which were not considered in this modeling. As harvesting is currently not allowed in all CFRs in Tanzania, wood production has been included just to show its influence as the most profitable forest product.

4.4.3 Policy implications from the model outputs

4.4.3.1 Size of the forest

Size of the forest is an important determinant in carbon storage and honey production. Forest size has also been an important factor when wood production was included in the model. According to the model, forest size below 615 ha has its optimal solution when only honey is paid for (Table 34). Also, any forest size above 1536 ha has optimal solution when only carbon stored is payed for. Therefore, the model estimates that smaller forests would not be suitable/effective for carbon storage/sequestration or they have insignificant contribution in sequestering carbon and hence insignificant payments. This is in line with what was reported by Zahabu (2008) and Mustalahti (2012). Increasing forest size above 1536 ha has no effect in the amount of honey produced if other factors are held constant.

This implies that, communities around Kimboza FR (405 ha) should not expect to benefit from carbon trade but rather they may concentrate on beekeeping and maximize its potential. Table 34 is an illustration of the sensitivity of the model parameters in the forest area.

Table 34: Model sensitivity to forest area

Forest Area (ha)	**3 700**	**1 530**	**1 500**	**1 250**	**700**	**600**	**405**
Carbon stored (tCO_2e)	307	305	295	212	29	0	0
Honey produced (kg)	0	4	24	191	557	600	614
Objective function value (US$/year)	**6 144**	**6 124**	**6 024**	**5 191**	**3 357**	**3 000**	**2 025**

From Table 34, it is observed that when the forest size changes, optimal levels for carbon and honey changes too. Decreasing forest size decreases profit due to decrease of amount of carbon stored in the forest. The model further suggests that, communities around NDU FR can generate up to USD 6 144 per year in their 3 700 ha forest even if honey production is not at optimal level. Combination of carbon and honey to optimal solution happens only when forest area is between 1536 and 615 ha. However, any combination of these products leads to a profit slightly below USD 6 144. For example, when forest size is 1250 ha, about 212 tCO_2 and 191 kg of honey are produced at optimal solution with a profit of USD 5 191 per year. Therefore, for maximum profit, a CFR above 1500 ha should be recommended for JFM if carbon storage/sequestration services and honey production need to be explored.

4.4.3.2 Forest fragmentation

In Tanzania, several small FRs below 1 500 ha are managed under JFM regime and would wish to benefit from carbon trade. To solve this "size" problem, several nearby FRs may be aggregated in terms of forest management and later in assessment and payments (forest networks). This strategy is not new in Tanzania as it is being practised by Tanzania Forest Conservation Group (TFCG) in management of small community based forests for carbon offsetting under the project "Making REDD+ work for Communities and Forest Conservation in Tanzania." Nearby villages form networks aiming at conserving their forests to avoid leakage and reduce transaction costs (Mustalahti *et al.*, 2012).

It is also reported that formation of community networks is essential for the success of the project to meet minimum transaction costs, even for small-scale activities including projects developed or implemented by low-income communities (Thomas *et al.*, 2010). In the network, every village measures its forest and manages it in the agreed standards. Monitoring is done to check the agreed standards and later assessment is done for several forests under one network where they are considered as one forest ecosystem and therefore paid as one forest. Later, the funds are distributed to villages based on the forest size or other criteria. These networks in Tanzania and even in Brazil are implemented through cooperatives (Mustalahti, 2012). In the study sites, this strategy can easily be implemented due to the existing institutional structures such as MJUMITA or through the Tanzania Farmers Group Network (MVIWATA).

4.4.3.3 Product prices in the markets

As with any tradable commodity, the price of carbon credits and honey are determined by supply and demand. Keeping the price at an adequate but reasonable level means striking the balance between the needs of carbon credit producers (developing countries) and consumers (industrial nations). If the later would agree to substantiate emission reductions, then demand for carbon credits could be very high, creating greater incentives in forest conservation (Laurence. 2007).

It was estimated (for example) that carbon prices may range from USD 40 to 110 per ton by 2030 (Strassburg *et al.*, 2009). Any increase of these prices will also increase the profit. Backeus *et al.* (2005) and Baskent and Keles (2009) argued that the unit carbon price might be very important in multiple-use management of forest resources. In next decade, the price of one tonne of carbon would reach USD 30 and a kilo of honey would be sold at USD 10. According to the model, this increase would generate up to USD 9 215 for NDU FR and USD 4 050 for Kimboza FR per year.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Incentives for community participation in conservation of CFRs

The government of Tanzania is still in view that community participation in conservation of CFRs under JFM regime is a plausible approach due to limited financial and human resources it faces. However, weak incentives for conservation have given rise to an increasing concern by researchers and communities on how to give value to ecosystem goods and services especially in areas with high biodiversity potential. Though incentives for communities in conservation are site specific but in general there are fewer incentives at present in all the study sites. The study also revealed a number of potential incentives in all the study sites which can be explored and used to motivate communities in their conservation efforts. Some of these include PES schemes (carbon, water and biodiversity), sustainable utilization (wild animals, timber and non timber forest products), working equipments, rights and various payments from forest related work.

Sustainable utilization arrangements for natural resources are not new in Tanzania. They are common in village land forest reserves, wildlife management areas, game controlled areas, game reserves and national parks. In a long run, there should be possibilities for sustainable use of resources in CFRs, other wise communities have a perception that the beautiful terminologies such as "participatory" or "empowernment" are misleading and not applied in the practical sense because they are not beneficial to them.

5.1.2 Stocking and forest disturbance

Based on the results, forests with JFM regimes have shown better stocking levels compared to those without. Forest reserves with JFM regime had significantly higher stocking in terms of species number, basal area, volume and biomass compared to those without JFM. Therefore, in terms of forest resource base, this study concludes that JFM is important in CFRs. Higher stocking also means higher carbon sequestration that will in turn reflect higher incentives through carbon payments. Differences in forest disturbance between reserves with JFM regime and those without was very small and insiginificant meaning that more incentives are required in JFM regime. This can also be a site specific issue as Iringa sites were much better than Morogoro sites. Therefore in some sites, JFM has not much reduced illegal activities as expected.

5.1.3 Institutional arrangement issues underlying JFM

Generally, unresolved issues of cost-benefit sharing with local communities, increased income-poverty, emerging timber markets and weakening of traditional rules are some of the reasons for communities not to comply with formal rules. Specifically, enforcing rules was cumbersome in the study areas due to lack of motivation for VNRCs, high dependence on FRs due to lack of alternatives, weak leadership, poor forest governance and insecure boundaries. It can therefore be generalized that the cause of prevalent disturbance in JFM is both from internal (institutional failure) and external forces.

JFM has not been effective in stoping illegal activities. In contrast, the high level of rules compliance in villages surrounding NDU FR in Iringa reflected the viability of local institution structures. Therefore, effectiveness of JFM is site specific and in this study JFM has shown good performance in Iringa and poor in Morogoro.

5.1.4 Optimal levels of incentives in the study areas

Most principal-agent models predicted that increasing incentives has a higher performance, and therefore leads to sustainable management of forest reserves. The optimal solutions given in this study suggest a reasonable return to communities based on forest values from honey and carbon, notwithstanding the importance of other potential benefits including water, eco-tourism and biodiversity. It can therefore be concluded that a range of USD 2 025 to 6 144 per year is a potential incentive for communities who are jointly managing CFRs with Government in hope that the latter will be willing to let carbon finances flow down to communities in post kyoto protocol. Futhermore, there are possibilities of increasing this income to USD 29 286 per year for NDU FR when sustainable harvesting of wood (that is currently considered as disturbance) is considered. When the cost of labour is reduced, the total income may further increase to USD 37 022 per year.

5.3 Recommendations

5.3.1. The need to explore potential incentives for forest adjacent communities

As long as the Government of Tanzania is still in favour of JFM, there is a need to look into possible ways to accommodate all potential ecosystem values (goods and services) of CFRs and other incentives that can be beneficial to the communities managing these reserves. Some of the potential incentives (e.g. payment for water services) may require review of existing Forest Policy and Act and others do not. The government should have an equitable distribution of income from PES schemes including carbon, water and eco-tourism with communities adjacent to forest reserves to ensure sustainability of resource base and livelihoods. An effective scheme to reward forest adjacent communities for conserving forests, especially if it ensures that a sizeable fraction of the benefits reach poor communities, could radically alter the flawed economic logic and perverse incentives that are driving forest disturbances. When forest adjacent communities are assured with income from the existence of a particular FR, they will devote their time and energy to protect it. This will also reduce cost of enforcement as there will be reduced illegal activities/disturbances in the forests. That means, forest adjacent communities should receive tangible benefits that exceed the opportunity costs of not clearing forests. Perfomance based payments to communities will create direct incentives to reduce forest disturbances along with promoting rural development. While economic incentives can often play a complementary and supporting role, they should be carefully targeted so as to strengthen and encourage existing social and cultural incentives for forest conservation.

Given the importance of timber values and their potential contribution to local communities, JFM efforts should investigate the potential for limited harvesting and processing by local communities. Controlled harvesting, if properly supervised, would be more sustainable than the illegal harvesting carried out today by a small group of people.

5.3.2 Critical size of forest to be included in JFM regime

The optimisation model suggested that not all forests are effective with regard to carbon sequestration. Small forests are less effective and therefore should not be included in JFM. First, they have small produce compared to the number of surrounding communities and secondly their management lead to higher transaction costs. It is therefore recommended that practitioners in JFM (especially with carbon sequestration objectives) should select forests above 615 ha to initiate JFM. In situations where there are forests less than 615 ha, several nearby forests should form a network (for assessment and monitoring) and therefore be regarded as one (a landscape approach). In terms of institutional failure, appropriate training on governance approaches need to be done.

5.3.3 The need for a more comprehensive model and optimisation techniquees

The current optimisation model has just considered carbon storage and honey among many ecosystem goods and services. It is therefore recommended to carry out further studies with a more comprehensive model(s) that will accommodate all possible ecosystem goods and services. It is also recommended to try using different programming and optimisation techniquecs including goal programming, dynamic programming, parametric optimisation and non-linear optimisation to assess their viability in formulating and solving incentive problems in JFM for CFRs of Tanzania. For future studies, it is recommended to combine optimisation techniquecs with other tools including geographical information systems (GIS), cost benefit analysis and applying different analytical softwares to solve forest management problems.

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APPENDICES

Appendix 1: Forest Inventory Field Form

Date:……………….. Recorder:…………………………..
Forest Name: ……………………………Plot No: …….. Transect No. ……
Location: ……:…………..Landmarks…………………………..
Topography…………………..Altitude …… ..(m asl) Slope …………
Eastings ……..……. Northings ……..…………….
Vegetation type:……………………

A: Plot Measurements

Spp code	Local Name	Botanical name	DBH (cm)	Plot Remarks

B: Sample Trees

Spp code	Local (tribe) / Botanical Name	BD (cm) at stump height	DBH (cm)	Height (m)

C: Disturbance (Old or New Cut and Naturally Dead trees)

Local name	NC/OC/ND	BD (cm) stump	Reasons for cutting	Remarks

D: Other Human Disturbances

Disturbance type	New or Old signs	Extent	Comments
Fire damage			
Timber harvesting			
Pole cutting			
Charcoal production			
Cultivation			
Animal grazing			
Human settlement			
Mining activities			
Animal traps (hunting)			
Medicinal plants collection			
Bamboo cutting			
Others			

General Remarks on Forest Health and Human Interferences

....

....

E: Regenerants (Talling within 2 m plot radius)

Tree local/species name	Regenerants tally	Remarks (associated grass type)

F: Tree Species and their Uses

Vegetation type	Local Name	Uses

Appendix 2: Household Questionnaire

Questionnaire No. ______Village_______________ Ward____________ Division ________________

District _______________ Name of Enumerator: _______________________Date: __________

SECTION A: DEMOGRAPHIC INFORMATION

1. Are you the head of the household/ the spouse of the head of the household?

_____ (01) Yes_____ (02) No

2. How many persons are there in your household (i.e. persons that live here with you and share this house/room)?______ Number of Household members

3. How old are you (i.e. age of the respondent): _________ years.

4. Where were you born?

01 Same village

02 Same ward different village

03 Same district different ward

04 Same region different district

05 Other regions

5. If not born in this village when did you start living in this village? (Year)_________

6. Which factors influenced your movement to this village?

01 search for work

02 Search for farm land

03 Search for grazing land

04 Followed family

05 Other specify---

7. Please help us fill this table about your household

	7A Name	7B Sex	7C Relationship with head of household	7D Age	7E Education	7F Occupational status (select only one)
No	*Start with respondent*	Male ....01 Female ...02	Head of household..01 Spouse....02 Son......03 Daughter......04 Brother........05 Sister...........06 Father..........07 Mother.........08 Other Family...09 Housemate (not family).10 Other (not family)...11	Adult (18 years old or more......01, Less than 18 years of age 02	None..... 01 Primary complete..... 02 Primary incomplete... 03 Secondary complete... 04 Secondary incomplete... 05 University complete.... 06 University incomplete... 07 Postgraduate ....08 Other 09	Farming......01 Fisher folk.... 02 Employed/Have permanent work ....03 Retired.... 04 Unemployed ...05 Casual worker... 06 Livestock keeper... 07 Pri school pupil.. 08 Sec school student ...09 Other 10
1						
2						
3						
4						
5						

8. Give reasons for the mentioned Primary and Secondary incomplete members of the household

SECTION B: ECONOMIC ACTIVITIES

9. What is your household member's main economic activities? Tick for the appropriate answers

Activity	Tick	Activity	Tick
01 Crop Farming -cash crops,- food crops		09 Livestock Keeping -Dairy cattle, Local cattle, Sheep/Goat, Poultry	
02 Mining		10 Firewood selling	
03 Making Charcoal		11 Logging timber	
04 Business/Shop		12 Tailoring	
05 Pole cutting		13 Fishing	
06 Hunting		14 Tourism	
07 Paid Employee -Government, Parastatal, NGO		15 Not active -Too old/retire, Disabled, -Sick	
08 Plant Products harvesting -palms, reeds, grasses, wild food plants, medical plants		16. Others Specify	

SECTION C: HOUSEHOLD SOURCE OF INCOME

10. Which is the household main source of cash income per year? What is the amount on average per year?

1. Sales of Cash crops ( )
   TZS.__________________
2. Sales of livestock ( )
   TZS.__________________
3. Sales of Food crops ( )
   TZS.__________________
4. Sales of vegetables ( )
   TZS.__________________
5. Sales of Livestock products ( )
   TZS.__________________
6. Sales of timber/Poles ( )
   TZS.__________________
7. Sales of Non Timber Forest products ( )
   TZS.__________________
8. Sales of Firewood ( )
   TZS.__________________
9. Sales of furniture/crafts ( )
   TZS.__________________
10. Business income ( )
    TZS.__________________
11. Wage or salaries ( )
    TZS.__________________
12. Other casual cash earning ( )
    TZS.__________________
13. Cash remittances ( )
    TZS.__________________

SECTION D: JOINT FOREST MANAGEMENT AND INCENTIVES

15. Is this village involved in Joint Forest Management? _____ (01) Yes_____ (02) No

16. Is there a member of your household participating in JFM activities in the village? _____ (01) Yes_____ (02) No

17. Without fear, which of the following disturbances are currently carried out in the Forest reserve?

Activity	Tick	Activity	Tick
01 Crop farming		09 Livestock Keeping	
02 Mining		10 Firewood cutting (green wood)	
03 Making Charcoal		11 Fishing	
04 Livestock grazing		12 Bush firing	
05 Pole cutting		13 Others Specify	
06 Hunting			
07 Pit sawing			
08 Plant products harvesting -fodder, grasses, food plants, fruits, medical plants, bamboo, palms, mushrooms etc			

18. (a) Is there any restriction with regard to the access and use of the forest resources _____ (01) Yes_____ (02) No

18. (b) If Yes, what are restrictions?

____

19a. What do you think are the current benefits that motivate people to participate in forest conservation?

a) _______________________________________
b) _______________________________________
c) _______________________________________

19b. Do you have an idea of any potential incentives that can be provided to motivate participation of villages in forest conservation? If Yes mention them

a) _______________________________________
b) _______________________________________

For JFM Villages

20a. How do you compare flow of benefits before and after JFM in your village/household?

Much worse now..........................1
A little worse now........................2
The same, no difference..................3
A little better now.........................4
Much better now...........................5
Don't know.................................6

20b. How do you rate happiness of the villagers in JFM as compared to the situation before JFM?
Much worse now..........................1
A little worse now........................2
The same, no difference..................3
A little better now.........................4
Much better now...........................5
Don't know................................6
20c. How do you rate the levels of disturbance in the forest today as compared to time before JFM?
Much worse now..........................1
A little worse now.........................2
The same, no difference..................3
A little better now.........................4
Much better now...........................5
Don't know................................6
20d. How do you rate the willingness of people to participate in forest protection now
Much worse now...........................1
A little worse now.........................2
The same, no difference..................3
A little better now.........................4
Much better now...........................5
Don't know................................6
21.a What are the costs or cost activities incurred by JFM practitioners currently

22a. How do you rate the costs and benefits in JFM?
01 _____Costs are higher than benefits
02_____Benefits are higher than the costs
22b. In your opinion, do you think something can be done to make sure that benefits in JFM are higher than the costs in your village?
a____
b____

Appendix 3: Checklist for Key Informants Interview

Name of related Forest Reserve_______________________

Village/Institution_______________________Date________

Name of Key informant_______________________

Type of Job_______________________

1. Why do you think JFM was initiated/important for........FR?
2. Are people happy to participate in JFM now? Why?
3. In your opinion, are there any direct or indirect costs incurred by local communities in the process and implementation of JMA? If Yes what are they?
4. Which are the current disturbances in the JFM Forest?
5. How do you compare disturbances (pit sawing, pole cutting, grazing, farming etc) in the forest now and the time before JFM?
6. Are there any rules (formal or informal) regulating access to the Forest? Which are they?
7. Are there any cases of illegal harvesting reported since JFM started? Which are they?
8. Which incentives do you think may add value in JFM and motivate more people to actively engage in JFM activities? Please mention
9. For the (JMA) signed between villagers and Government, Is it implementable? Reviewed?
10. What should the Government of Tanzania through Forestry and Beekeeping Division do to improve smooth running of JFM especially in Protected Forests?
11. *If not mentioned at all*, do you think Payment for Environmental Service (PES) schemes can add value in JFM? Why do you think so?
12. What is your general view on JFM implementation in Catchment FRs of Tanzania?

Appendix 4: Checklist for Focus Group Discussion

Focus Group Discussions in ____________________(Name of related Forest Reserve) The type of group_____________Village ______________

Date ______________

1. Can any one of you start our discussion by giving a brief history of how PFM and specifically JFM came into being in this village? Please give the background and the process briefly. Explain how JFM works in this village in practise. Eg. How the village council monitors VNRC members. which rules are working and which are not. Your relationship with the Forester from forest department, how do you handle offences, how do you share costs and revenues, which are the cost activities and which are the revenue generating activities etc.
2. What kind of forest produce (goods and services) do villagers get from this forest? How is the access regulated locally? (*de facto* access)
3. Can you discuss generally, how does JFM constrain or enables provision of various benefits that can be enjoyed by local people adjacent to the Forest Reserve? *In here, we may need to discuss incentives and disincentives as a result of JFM*
    a. *Costs activities of JFM*
    b. *Benefits*
    c. *Incentives lacking*
    d. *Disincentives*
4. What kind of forest disturbances can be observed currently? What need to be done to control disturbances locally?
5. Pair wise ranking of Forest products and services in Kibangile village

Appendix 5a: Pair wise ranking of Forest products and services in Kibangile village

	Med. Plants	Climate	Wild Food	Poles	Firewood	W. animals	Minerals	"Nemvu"	Freq	Rank
Med Plants		Climate	Med plants	Poles	Firewood	Med Plants	Minerals	Med Plants	3	04
Climate			Climate	Climate	Climate	Climate	Climate	Climate	7	01
Wild Food				Poles	Firewood	W. animals	Minerals	Nemvu	0	06
Poles					Poles	Poles	Minerals	Poles	5	03
Firewood						W animals	Minerals	Firewood	3	04
W animals							Minerals	W animals	3	04
Minerals								Minerals	6	02
"Nemvu"									1	05

Appendix 5b: Pair wise ranking of Forest products and services in Changa village

	Mplant	Fruits	Water	Timber	animals	Poles	Fwood	"Nemvu"	Ropes	Stones	Freq	Rank
Mplant		Mplant	water	timber	Mplant	poles	Fwood	nemvu	Ropes	stones	2	08
Fruits			water	timber	animal	poles	Fwood	nemvu	Ropes	stones	0	10
Water				water	water	water	water	water	Water	water	9	01
Timber					timber	poles	timber	timber	Timber	timber	7	03
Animals						poles	Fwood	nemvu	Ropes	stones	1	09
Poles							poles	poles	Poles	poles	8	02
Fwood								Fwood	Fwood	Fwood	6	04
"Nemvu"									Ropes	stones	3	07
Ropes										ropes	5	05
Stones											4	06

Appendix 5c: Pair wise ranking of Forest products and services in Kidabaga village

	Water	Vegetables	Firewood	Ropes	Grasses	Med. Plants	Fruits	W. animals	Freq	Rank
Water		Water	Water	Water	Water	Water	Water	Water	7	01
Vegetables			Firewood	Ropes	Grasses	Mplants	Vegetable	Wanimals	1	07
Firewood				Ropes	Grasses	Mplants	Firewood	Wanimals	2	06
Ropes					Water	Mplants	Ropes	Wanimals	4	04
Grasses						Mplants	Grasses	Wanimals	3	05
Med. Plants							Mplants	Mplants	6	02
Fruits								Wanimals	0	08
W. animals									5	03

Appendix 6a: Wealth ranking in Kibangile village

Wealth K's	Poor (66.6%)	Middle (26.7%)	Rich (6.7%)
Housing quality -Const.materials -Roofing -Flooring	Poor House -wood (poles and planks) -thatched grasses -dusty flow	Poor house -un burnt mad bricks -iron sheets -graved flow	Good house -burnt mad bricks -iron sheets -cemented floor
Meals	Single and poor meal per day (in the evening)	Affords two meals per day	Is sure of three good meals per day
Farm land	Posses less than 1 acre (all farms)	Has medium size farms up to 1 acre	Posses more than 1 acre inside and outside the village
Main source of income	Casual labour	Peasantry	Business(shops), salary, farming
Use of forest resources	Use more: construction and selling	Average use: roofing and furniture	Use more: roofing and more furniture
Source of fuel	Firewood	Firewood	Charcoal, Kerosine
Source of light	Kerosine	Kerosine	Kerosine, battery lights, generator
Secondary School fees	Not able to pay	Able to pay fees for ward sec. schools	Able to pay fees even for private sec. schools
Means of communication	Have no Radio and no mobile phones	Have Radio and few have bicycles but no mobile phones	Posses Radio, TV, mobile phones and motorbikes
Participation in village meetings	Many do attend but they are shy to speak their views	Many do attend and speak a little bit	Few do attend but they speak more to influence decisions

Appendix 6b: Wealth ranking in Changa village

Wealth K's	Poor (50%)	Middle (33.3%)	Rich (16.7%)
Housing quality -Const.materials -Roofing -Flooring	Poor House -wood (poles and planks) -thatched grasses -dusty flow	Poor house -un burnt mad bricks -iron sheets -graved flow	Good house -burnt mad bricks -iron sheets -cemented floor
Meals	Single and poor meal per day (in the evening)	Affords two meals per day	Is sure of three good meals per day
Farm land	Farming in less than 1 acre in one season	Farming up to 2 acres in one season	Farming more than 3 acres in one season
Main source of income	Casual labour	Peasantry, small business (genge)	Business(shops), salary, farming
Use of forest resources	Use more: construction and selling	Average use: roofing and furniture	Use more: roofing and more furniture
Source of fuel	Firewood	Firewood	Charcoal, Kerosine
Source of light	Kerosine	Kerosine	Kerosine, battery lights, generator
Beddings	No bed/sisal fiber bed, no mattress. Use Nemvu mats	Posses a bed with local made mattress	Posses a good bed with good mattress 6*6
Secondary School fees	Not able to pay (assisted by relatives or other family members)	Able to pay fees for ward sec. schools (with some difficulties)	Able to pay fees even for private sec. schools
Means of communication	Have no Radio and no mobile phones	Have Radio and few have bicycles but no mobile phones	Posses Radio, TV, mobile phones and motorbikes
Participation in village meetings	Many do attend but they are shy to speak their views	Many do attend and speak a little bit	Few do attend but they speak more to influence decisions

Appendix 6c: Wealth ranking in Kidabaga village

Wealth K's	Poor (33.3%)	Middle (50 %)	Rich (16.7%)
Housing quality -Const.materials -Roofing -Flooring	Poor House -wood (poles and planks) -thatched grasses -dusty flow	Poor house -un burnt mad bricks -iron sheets -graved flow	Good house -burnt mad bricks -iron sheets -cemented floor
Education level	Did not attend school or has attended few classes	Many have completed STD VII and few secondary education	Some STD VII and some secondary education
Meals	Single and poor meal per day	Affords two meals per day	Is sure of three good meals per day
Farm land	Posses about 1 acre (all farms) per season	Has medium size farms up to 3 acres	Posses more than 5 acres inside and outside the village
Agricultural inputs	Cannot afford to buy fertilizer	Affords to use fertilizer in some seasons	Uses fertilizer always in all the seasons
Main source of income	Casual labour	Selling agricultural crops and livestock	Business (shops, café, bar, timber), farming
Use of forest resources	Use more: construction and selling	Average use: roofing and furniture	Use more: roofing and more furniture
Source of fuel	Firewood	Firewood	Charcoal, Kerosine
Source of light	Kerosine/Firewood stick	Kerosine	Kerosine, battery lights, generator or electricity
Beddings	Simple bed made of bamboo and a mat	Bed made up of timber with mattress	6*6 bed with a good mattress
Secondary School fees	Not able to pay	Able to pay fees for ward sec. schools	Able to pay fees even for private sec. schools
Means of communication	Few have Radio but no mobile phones	Have Radio, bicycles, mobile phones and few have motorcycles	Posses Radio Cassettes, TV, mobile phones, motorbikes and some have cars
Participation in village meetings	Many do attend but they are shy to speak their views	Many do attend and speak a little bit	Few do attend but they speak more to influence decisions

Appendix 6d: Wealth ranking in Luhindo village

Wealth K's	Poor (20 %)	Middle (60 %)	Rich (20 %)
Housing quality -Const.materials -Roofing -Flooring	Poor House -wood (poles and planks) -thatched grasses -dusty flow	Poor house -un burnt mad bricks -iron sheets -graved flow	Good house -burnt mad bricks -iron sheets -cemented floor
Education level	Did not attend school or has attended few classes	Many have completed STD VII and few secondary education	Some STD VII and some secondary education
Meals	Single and poor meal per day	Affords two meals per day	Is sure of three good meals per day
Farm land	Posses about 1 acre (all farms) per season	Has medium size farms, 2 to 3 acres per season	Posses 5 to 10 acres inside and outside the village
Agricultural inputs	Cannot afford to buy fertilizer	Affords to use fertilizer in some seasons	Uses fertilizer always in all the seasons
Main source of income	Casual labour	Selling agricultural crops and livestock	Business (shops, café, bar, timber), farming
Use of forest resources	Use more: construction and selling	Average use: roofing and furniture	Use more: roofing and more furniture
Source of fuel	Firewood	Firewood and charcoal	Charcoal and Kerosine
Source of light	Kerosine /Firewood stick	Kerosine	Kerosine, battery lights, generator or electricity
Beddings	No mattress, use animal skins and mats	Bed made up of timber with mattress	Good bed with a good mattress
Secondary School fees	Not able to pay	Able to pay fees for ward sec. schools	Able to pay fees even for private sec. schools
Means of communication	Few have Radio, bicycles and mobile phones	Have Radio, bicycles, mobile phones and few have motorcycles	Posses TV, shops, motorbikes, grinding mills and cars
Participation in village meetings	Many do attend but they are shy to speak their views	Many do attend and speak a little bit	Few do attend but they speak more to influence decisions

Appendix 7a: Resource Use Matrix in Kibangile Village

	Wealth			Gender		Provenance of user		
	poor	middle	rich	M	F	villager	nearby village	stranger
Med Plants	6	3	1	7	3	3	1	6
Climate	5	3	2	5	5	6	2	2
Wild Food	7	3	0	7	3	8	1	1
Poles	4	2	4	8	2	6	3	1
Firewood	6	3	1	3	7	9	0	1
W animals	6	4	0	10	0	8	2	0
Minerals	5	3	2	9	1	4	3	3
Weaving Materials	6	3	1	0	10	2	1	7

Appendix 7b: Resource Use Matrix in Changa Village

	Wealth			Gender		Provenance of user		
	poor	middle	rich	M	F	villager	nearby village	stranger
Mplant	6	3	1	8	2	5	3	2
Fruits	6	3	1	7	3	6	3	1
Water	2	3	5	3	7	10	0	0
Timber	5	3	2	7	3	5	2	3
Animals	6	3	1	10	0	6	2	2
Poles	5	3	2	7	3	6	3	1
Fwood	5	3	2	3	7	7	2	1
Weaving Materials	5	4	1	0	10	7	3	0
Ropes	5	4	1	7	3	7	3	0
Stones	5	3	2	7	3	6	2	2

Appendix 7c: Resource Use Matrix in Kidabaga Village

	Wealth			Gender		Provenance of user		
	poor	middle	rich	M	F	villager	nearby village	stranger
Water	2	3	5	3	7	10	0	0
Vegetables	6	3	1	2	8	10	0	0
Firewood	6	3	1	3	7	10	0	0
Ropes	6	4	0	8	2	8	2	0
Grasses	7	3	0	2	8	10	0	0
Med. Plants	4	3	3	6	4	9	1	0
W. animals	6	4	0	10	0	8	2	0
Fruits	0	0	0	0	0	0	0	0

Appendix 7d: Resource Use Matrix in Luhindo Village

	Wealth			Gender		Provenance of user		
	poor	middle	rich	M	F	villager	nearby village	stranger
Honey	10	0	0	10	0	8	2	0
Vegetable	10	0	0	4	6	8	2	0
Grasses	6	4	0	4	6	10	0	0
Fruits	5	5	0	5	5	4	3	3
Ropes	5	5	0	6	4	10	0	0
Weaving Materials	4	4	2	5	5	10	0	0
Wanimal	10	0	0	10	0	10	0	0
MPlant	3	4	3	9	1	4	3	3
Water	3	3	4	5	5	3	2	5