SINKS AND SOURCES

A STRATEGY TO INVOLVE FOREST COMMUNITIES IN TANZANIA IN GLOBAL CLIMATE POLICY

DISSERTATION

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List of Abbreviations

BVEK	German Emissions Trading Association
CATIE	Tropical Agricultural and Higher Education Centre
CBFM	Community Based Forest Management
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CFM	Collaborative Forest Management
CHAPOSA	Charcoal Potential in Southern Africa
CO_2	Carbon dioxide gas
CoP	Conference of the Parties
DANIDA	Danish International Development Agency
EB	Executive Board
EU	European Union
EUTCO	East Usambara Tea Company
FAO	Food and Agriculture Organization (of the United Nations)
FBD	Forest and Beekeeping Division (Tanzania)
FINNIDA	Finnish International Development Agency
FR	Forest Reserve
FRA	Forest Resources Assessment
GEF	Global Environment Facility
GHGs	Green House Gases
GIS	Geographical Information System
GPS	Global Positioning System
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (German society for technical cooperation)
IDA	International Development Agency
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JFM	Joint Forest Management
K:TGAL	Kyoto: Think Global Act Local
KSUATFR	Kitulangalo Sokoine University of Agriculture Training Forest Reserve
LAMP	Land Management Programme
LULUCF	Land Use, Land Use Change and Forestry
MAI	Mean Annual Increment
MEMA-Iringa	Matumizi Endelevu ya Misitu ya Asili i.e Sustainable Management of Natural Forests-Iringa
MFA Finland	Ministry of Foreign Affairs Finland
MNRT	Ministry of Natural Resources and Tourism, Tanzania
NGO	Non-Governmental Organization
NORAD	Norwegian Agency for Development Cooperation
PFM	Participatory Forest Management
PNG	Papua New Guinea
PRA	Participatory Rural Appraisal
REDD	Reduced Emissions from Deforestation and forest Degradation
RS	Remote Sensing
SBSTA	The Subsidiary Body of Science and Technology Advice
SIDA	Swedish International Development Agency
SPSS	Statistical Package for Social Science
SUA	Sokoine University of Agriculture

TAFORI	Tanzania Forest Research Institute
TFCG	Tanzania Forest Conservation Group
TROFIDA	Tropical Forest Inventory Data Analysis package
TShs	Tanzanian Shillings (In 2008; on average TShs 1,200 = $ 1)
UCLAS	University Collage of Lands
UDSM	University of Dar es Salaam
UMBCP	Uluguru Mountains Biodiversity Conservation Project
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
VEO	Village Executive Officer
VFCs	Village Forest Committees
VFR	Village forest Reserve
WCST	Wildlife Conservation Society of Tanzania
WWF	World Wildlife Fund

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Chapter 1

Outline of the Problem

1.1 Extent and status of forest resources in Tanzania

Tanzania has a total area of about 94.5 million hectares out of which 88.6 million hectares are covered by landmass and the rest is inland water. 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 much as possible of those catchment forests, which still existed. This brought about reservation of a chain of mountain areas in the northern and southern parts of the country with a total of 0.5 million hectares (Hermansen *et al.,* 1985). The British administration (1920-1961) followed up by protecting the catchment forests and reservation of more catchment and other forests, bringing the total reserved areas into 1.3 million hectares. After independence in 1961, efforts were made to re-survey and demarcate old forest reserves while new ones were created. Current statistics show that the country has a total of 34 million hectares of forestland[1] out of which 16 million hectares comprise of reserved forests[2], 2 million hectares are forests in national parks and the rest, 16 million hectares (47% of all forestland), are unprotected forests in General Land[3] (URT, 1998; Malimbwi, 2002; URT, 2006).

Forests in General Land are 'open access', characterized by insecure land tenure, shifting cultivation, annual wild fires, harvesting of wood fuel, poles and timber, and heavy pressure for conversion to other competing land uses, such as agriculture, livestock grazing, settlements and industrial development. The rate of deforestation in Tanzania, which is estimated at between 130,000 to 500,000 hectares per annum (see Box 1), is mostly in the General Land forests (URT, 1998; FAO, 2006). Efforts towards forest reservation aim at reversing this trend. However, assessments of different forests conditions have revealed a lot

[1] "Forestland" means an area of land covered with trees, grass and other vegetation but dominated by trees.
[2] According to the Forest Act (URT, 2002) "forest" means an area of land with at least 10% tree crown cover, naturally grown or planted, and or 50% or more shrub and tree regeneration cover; and, includes all forest reserves of whatever kind declared or gazetted under this Act and all plantations. "Forest reserve" means a forest area, either for production of timber and other forest produce or protective for the protection of forests and important water catchments, controlled under the Forests Ordinance and declared by the Minister. In addition, declared forests under village managements are also recognized as forest reserves.
[3] General Land as used here means all public land which is not reserved or village land (URT, 1999) including unoccupied or unused village land.

of human disturbances also inside forest reserves including encroachment on forest areas, illegal mining, pit-sawing, illegal harvesting for building materials, firewood collection and medicinal activities (Frontier-Tanzania, 2005; Malimbwi *et al.*, 2005a; Forestry and Beekeeping Division, 2005). Therefore not only forests in General Land are diminishing but also the condition of reserved forests is deteriorating.

1.2 Emergence of Collaborative Forest Management (CFM)

As pointed out above, forests in Tanzania are threatened by the prevailing high rate of deforestation. In the past both the government and the international community joined hands in addressing this problem of deforestation through forest resources management aiming at conservation (Kajembe, 1994). It is presently realized that the continuing deforestation is due to the failure of the past conservation approaches that aimed to bring more forests under state tenure and protection as reserves or parks (Kiss, 2004). That approach excluded local communities from forest management, the consequence of which was increasing deforestation (Wiersum, 2004). Realization of this, together with limited financial and human resources for the forest sector have led to the emergence of a new policy: Collaborative Forest Management (CFM) also termed Participatory Forest Management (PFM). CFM, in its varying facets, reflects different degrees of involvement of local communities in the management of forest resources.

Involvement of local communities in natural forest management in Tanzania started in the mid 1990’s with a number of pilot activities in the north and western parts of the country (Wily, 1997). These experiments demonstrated a viable engagement of local communities in forest management and triggered their inclusion in the forest policy and legislation in the late 1990’s (URT, 2006). Both the current National Forest Policy of 1998 and its subsequent Forest Act of 2002 recognise the role of community involvement on sustainable forest management and utilization (URT, 1998; 2002). This is demonstrated by the three policy objectives of PFM which put emphasis on: i) improved forest quality through sustainable management practices, ii) improved livelihoods through increased forest revenues and secure supply of subsistence forest products, and iii) improved forest governance at village and district levels through effective and accountable natural resource management institutions (URT, 2003a).

CFM in the country is undertaken in two different styles. These are: Joint Forest Management (JFM) and Community Based Forest Management (CBFM). As described by Wily (2001), under JFM, forest ownership remains with the government while local communities are duty bearers and in turn get user rights and access to some forest products and services. On the other hand, with CBFM the local communities are the owners as well as rights holders and duty bearers. Most of the CBFM areas are demarcated in village General Land. Thus, they are also called Village Forest Reserves (VFRs). Since the establishment of self-reliant village-based governments in Tanzania in 1974, most of the land area of rural Tanzania is currently divided into more than 14,000 villages (Ministry of Lands and Human Settlements, 2007); each with land area encompassing homesteads, private farms and General Land. Each village is governed through an elected government responsible to oversee executive and legislative issues in the village community. Through donor and government support some of the General Land in these villages is now reserved as VFRs.

1.3 Extent of CFM activities in Tanzania

Current statistics shows that in 2006 CFM is operational in over 1,800 villages and on over 3.6 million hectares of forestland (UTR, 2006). These statistics further reveal that there are 382 VFRs under CBFM with a total area of 2.06 million hectares in 1,102 villages. According to Malimbwi (2002), in 2001 there were only 78 village forest reserves under CBFM with a total of 186,292 hectares. Comparing these statistics, it can be deduced that between 2001 and 2006 CBFM activities have increased by 304 forests with about 1.9 million hectares in 1,024 villages. This increase, observed within a span of five years, was fuelled by the change of forest policy and legislation. The contribution of both local and international NGOs, local governments and bilateral development partners was also very crucial in the spread of CBFM in the country (Blomley, 2006). With this emerging trend of CBFM, the unprotected forestland in General Land was reduced to about 16 million hectares from 18 million hectares in a span of about 5 years. The speed under which CBFM are established is low due to, among other factors, limited financial and human resources, as detailed in Chapter 7, Section 7.5. If the same trend continues it will take 40 years for the entire unprotected forestlands to be reserved under CBFM. There is therefore a need to develop strategies to speed up the process. Accessing global carbon financing mechanisms could potentially facilitate the process by providing the needed financial resources to allow CFM projects to be set up at an accelerated rate.

CFM provides for a promising forest management strategy to curb deforestation and forest degradation in the country. Through CFM many of these forests are reported to recover under the management of the village governments, since encroachment is decreased, unregulated activities such as charcoal burning and timber harvesting decline, and game numbers increase (URT, 2006; Zahabu, 2006; Blomley *et al.*, 2008). CFM shifts the common pool management regime of General Land forests to the control of villagers for better conservation.

However, as experiences with CFM accumulate, it is understood that they do not currently provide for cash benefits to the local communities (URT, 2006). Most of the forests under CBFM do not have potential timber to merit harvesting as they are in the recovery stage, while JFM forest strategy (in more valuable forests) restricts local use to a few non-wood forest products such as medicinal plants, thatching grass and honey (Blomley and Ramadhani; 2006; Meshack *et al.*, 2006). For effective participation of local communities in CFM activities on a large scale, they need to be provided with tangible incentives (Kiss, 2004; URT, 2006), and preferably with cash benefits.

Sound forest management practices like those under CFM generate a number of environmental services such as water catchment, scenic beauty, biodiversity, and carbon sequestration, which in principle could be valued and paid for by various consumers. Financial resources from environmental services payment systems is one option for provision of the required tangible economic benefits and hence incentives to local people participating in CFM. Management of water catchment and landscapes can benefit from compensation schemes arranged through governments and NGOs at a local or national level. On the other hand, biodiversity conservation and carbon sequestration activities can benefit from international mechanisms since these provide benefits at global scale. Biodiversity conservation compensation mechanisms are based on payment for foregone activities such as timber extraction, in forests with high species diversity (Rice, 2002). The determination of the biodiversity compensations based on foregone timber sales is relatively easy. However, there are not many such biodiversity compensation schemes yet operating. There is, however, a growing market for forest carbon due to the increasing recognition of the importance of forest management in reducing emissions and storage of carbon dioxide gas (CO_2).

Forests play an important role in the global carbon cycle. Forest biomass acts as a source of carbon when burned or when it decays. Also when soil is disturbed it releases CO_2 and other greenhouse gases into the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) estimates that 20-25% of current global annual carbon emissions are the result of loss of tropical forest (IPCC, 2000). On the other hand, forests also act as carbon sinks when their area or productivity increases, resulting in an increased uptake of CO_2 from the atmosphere. This is known as carbon sequestration. They absorb CO_2 and release oxygen into the atmosphere through the natural process of photosynthesis in which CO_2 is converted to carbon and stored in the woody tissue (biomass) of the plant. It is because of this that some forms of forestry activities are used as valid means for atmospheric CO_2 reduction as they contribute significantly to climate change mitigation.

1.4 Forest carbon trading mechanisms

At present, forest carbon trading is possible through the Clean Development Mechanism (CDM) of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). Under the Kyoto Protocol, developed countries (called Annex 1 countries) are required to reduce their emissions of greenhouse gases by about 5% of their 1990 levels by the years 2008 – 2012. These countries can meet their reduction targets for CO_2 emissions in a variety of ways: through improved energy efficiency, by substituting fuels that produce less CO_2, and by using renewable energy sources. Investment in certain kinds of tropical forestry is also a possibility as shown in Sub-Section 1.4.1, through CDM, which enables them to invest also in projects in developing countries (non-Annex 1 countries) and to use these to offset their reduction commitments. The CDM essentially provides a market mechanism for the sale of carbon credits, called Certified Emission Reductions (CERs), from developing countries.

1.4.1 Permitted tropical forestry activities under the CDM

The terminology used to describe all activities involving bio-carbon under the Kyoto Protocol is '*Land Use, Land Use Change and Forestry'* (LULUCF). It has been agreed that in the first commitment period (2008-2012), eligible LULUCF under CDM will be limited to *afforestation* and *reforestation* projects only. These activities result in new, additional sinks through sequestration, in areas where there has been no forest in living memory or no forest since 31 December 1989, respectively. The option of reducing the rate of carbon emissions by improved forest management and by avoided deforestation, *i.e*. the kinds of activities currently carried out under CFM in Tanzania is not eligible under CDM at present.

1.4.2 Why only *afforestation* and *reforestation* projects under the CDM?

Other forms of LULUCF were excluded in the first CDM commitment period partly on the grounds that it might be so cheap to do, so that Annex 1 countries would meet a large reduction target in this way and thus continue 'business as usual' at home. This is related to the fact that the reduction targets (5% on average) were negotiated before the idea of LULUCF as an option was introduced. Further, some non-Annex 1 countries wish to continue to develop their lands economically and as a means of food production just as Annex 1 countries historically have done. However, most objections relate to methodological problems that were foreseen. It was argued that the *avoidance of deforestation* is problematic because it may be difficult to prove whether forests are at risk from deforestation (additionality), and deforestation may simply be displaced to another area of forest (leakage); also, monitoring and measuring sequestration is difficult in natural mixed forests making verification problematic; moreover, there are difficulties in defining sustainable forest management and certifying activities.

On the other hand there is a growing criticism on the way LULUCF is handled under CDM. First, biodiversity is a very important element of forest management and is best assured through management of existing natural forest The inclusion of *afforestation* and *reforestation* projects under CDM, as allowed at present, favours plantation forestry at the expense of natural forestry since their sequestration rates are higher, management cheaper and monitoring easier, although plantations have detrimental impacts on biodiversity and ecology in general (Brown, 2003). More important from the social point of view, however, is that smallholder farmers, peasants and forest users without secure land tenure may have difficulties in meeting the contractual and negotiating requirements and may even find themselves pushed off land in favour of large-scale forest carbon enterprises.

The Marrakech Accords[4] consider emissions from forestry sector resulting from deforestation. Deforestation was defined as “the direct human-induced conversion of forested land to non-forested land” (UNFCCC, 2001). However, there are other activities that are responsible for emissions from forest land use without entirely removing of the forest cover. Through forest disturbances from fires, selective logging, shifting cultivation and the like, a considerable amount of forest carbon is removed from the forest (degradation), but in most cases this will not lead to reduced forest area. As such, quantification of emissions from forest land use should also include reduced emissions from degradation. It is clear that degradation and deforestation are a result of powerful economic drivers and are directly related to economic development but they involve different processes. While a large part of deforestation is ‘governed’ i.e. the result of deliberate national policy and choices by government (e.g. expansion of agriculture, commercial logging and infrastructure extension), degradation is ‘ungoverned’ as a result of failure to enforce law and forestry regulations (illegal pit sawing and shifting cultivation). It is clear that complete prevention of deforestation (*avoidance of deforestation*) (Brown, 1999; Pagiola *et al.*, 2002) and degradation is unrealistic but slowing them down through sustainable forest management provides a very useful carbon sink (*i.e. Reduced Emissions from Deforestation and Degradation* - REDD) and protects biodiversity.

In the light of these arguments there is already a joint proposal by Papua New Guinea and Costa Rica, and proposals by several other rainforest nations, to include REDD in future climate agreements (UNFCCC, 2005). Negotiations started at the Eleventh Conference of the Parties (CoP 11) session in Montreal, Canada, in 2005 where a two year process to review relevant scientific, technical, and methodological issues and positive incentives for reducing emissions from deforestation in developing countries, was established. Following this process, the Subsidiary Body of Science and Technology Advice (SBSTA) of the UNFCCC on its 25th session (Nairobi, 2006) invited views on among others the potential policy approaches and positive incentives mechanisms for REDD. Already a number of proposals such as by the Tropical Agricultural and Higher Education Center (CATIE) and German

[4] The Kyoto Protocol sketched out basic rules, but did not specify in detail how they were to be applied. As such, since its adoption in 1997, several Conferences of the Parties (CoP) meetings discussed and set up rules for the implementation of the Protocol. In 2001, the CoP 7 meeting held in Marrakech, Morocco spelt out more detailed rules for the Protocol (Marrakech Accords) as well as advanced prescriptions for implementing the Convention and its rules.

Emissions Trading Association (BVEK) and Costa Rica in association with other Latin America countries have been presented. The debate is still going on as detailed in Chapter 2.

1.5 Prospect of REDD as a national forest carbon trading option for Tanzania

The proposed mechanism involves international payments for REDD that would be made to countries or perhaps provinces/regions, on the basis of their average or net achievements in driving down loss of carbon from forests (see Chapter 2). A key aspect of determining the carbon benefit of any forest carbon project is to accurately quantify the levels of carbon changes to known levels of precision. The main focus is to determine the net differences between carbon pools or stock for the managed forest, and the projected unmanaged forest conditions on the same piece of land over a specified time period. At a national level this requires among other things reliable data from national forest inventory. However, as is the case with most developing countries, Tanzania has no reliable data on forest extent, characteristics, growth and yield (Box 1) because national forest inventory has not been carried out (FAO, 2006; 2007) due to limited capacity in terms of number of staff and finance.

Box 1. Example of poor quality forest data available

For its reporting to FAO: Global Forest Resources Assessment (FRA) of 2005, Tanzania used satellite imagery interpreted data of 1984 (Millington and Towsend, 1989) and compared these with 1995 data by Hunting Technical Services (1997) for the determination of land cover changes in the country. The annual deforestation was 412,279 hectares for the forest land use cover, while that of Other Woodlands (OWL) was 1,174,538 and the remaining Other Land (OL) area increased by 1,586,817 hectares annually. The deforestation in the forest category is within the range of the common quoted annual rate of deforestation in Tanzania of between 130,000 and 500,000 hectares but that of OWL seems to be unrealistically very high. This could be explained by an oversight on the analysis of the two data sets.

Also in this reporting, a default value derived from data obtained from the Centre for Energy, Environment, Science and Technology, (1999) was used to estimate stocking levels in observed forests. From that study five ecotypes were distinguished: tropical closed forest (185 m^3/ha), mangrove forests (120 m^3/ha), miombo woodlands (32 m^3/ha), wooded grassland (32 m^3/ha), and thicket and shrubs (10 m^3/ha). This gave rise to a weighted standing volume value of 36 m^3/ha which was applied as an average stocking for all the forest types. This value was also used to estimate the standing forest biomass. These standing volume figures and the resulting default value used were very low compared to different studies in Tanzania which show for example that miombo woodlands have 39 to >120 m^3/ha (Temu, 1979; Kielland-Lund, 1990; Malimbwi *et al*., 1994; Malimbwi, 2000) while montane forests have 500 to 2600 m^3/ha (Zahabu and Malimbwi, 1998; Malimbwi and Mugasha, 2001; Maliondo, *et al*., 2000; Munishi and Shear, 2004).

Usually national forest inventory utilizes remote sensing technology for the determination of the extent of forest resources in the country. Apart from forest extent, there are also more advanced technologies on assessing and monitoring forest characteristics and stocking based on remote sensing, such as the use of radar imagery (Lefsky *et al.*, 2005). However, these advanced technologies are currently very expensive especially when a high level of accuracy has to be met and require highly skilled human resources. Alternatively, low resolution remote sensing technologies can be used, which provide data on forest extent. This has to be supported by field observations of parameters such as species composition, age/size distribution, and disturbances levels.

Instead of using the combination of the remote sensing data with field observations, it is also possible for UNFCCC purposes to use default values of standing stock for different vegetation types. However, their universal application is unsound (de Gier, 1999; Brown 2003). Also these values are set at very low conservative (unfavourable) levels. Currently, Tanzania is bound to use default values due to absence of reliable forest data. Due to lack of forest data to determine carbon stock change, when REDD policy comes into force, the country might not be able to access the mechanism at all, or would benefit unfavourably through the use of default values.

From a forest management point of view, the lack of forest data leads to poor forest management because of lack of information for making informed management decisions. The Tanzania Forest Policy (URT, 1998) and its Forest Act (URT, 2002) clearly stipulate the need for proper forest management based on specific forest management plans, but to date there is hardly a forest reserve with a proper management plan, owing to lack of data. Due to this shortfall in the forestry sector and given the shift toward involvement of communities in forest management, it is logical that participatory forest assessment methodologies be carried out by communities themselves. Community methods could be developed to ensure sustainable availability of forest data. The carbon assessment methodology developed in this study will generate data both for the determination of carbon benefits of forest projects and for forest management planning.

1.6 General objectives and aim of the research

With relevance to REDD forest carbon trading, this research is aimed (a) at exploring the potential for greater protection of forest through global carbon trading mechanisms and (b) at giving local people more control and benefit over their forest by (c) developing a valid, easy to implement and cost-effective estimation technique for assessment and monitoring forest carbon by local communities. It is expected that this might pave the way for CFM under REDD as a valid mechanism in the mitigation of global warming in the future since this type of forest management brings with it many other benefits including poverty alleviation in isolated rural communities as well as biodiversity and water conservation. Should this type of forest management be accepted for climate mitigation by the international community and if funds become available among stakeholders through the cost effective carbon measurement by local communities, this could motivate communities to participate in forest management at a much larger scale than that of today.

1.7 Study hypothesis and approach

CFM projects involve management of natural forests that would otherwise degrade or be deforested and result in carbon emissions. As pointed out in Sub-Section 1.4.1, this type of forest management is not credited under the current carbon payment mechanisms. The alternative mechanism that is still under discussion (REDD) could potentially allow CFM to be credited on the basis of overall national efforts to slow down loss of carbon from forests. With this mechanism, CFM projects could be aggregated under the forestry sector to form a country level REDD approach. However, as pointed out also in Section 1.3, the current speed under which CFM are established is very low. Accessing carbon finances from REDD could potentially accelerate the process by providing the required financial resources. However, participation in REDD implies additional transaction costs that could be costly for the participating communities. In order to minimize the transaction costs, local communities could be trained and equipped to use reliable, valid, easy to implement and cost effective techniques to carry out some of the activities that would be required, particularly as regards mapping the forest and carrying out annual carbon stock measurements by themselves. The central hypothesis tested by the research was, *local communities can be trained to carry out forest measurements, and as a result benefit and participate more in forest management, if carbon saved through CFM could be credited.* The REDD policy for crediting forest carbon is still being debated, thus the second part of this hypothesis is still pending. The thesis therefore, also informs the policy debate on the possible strategy of involving CFM projects in the REDD policy.

A fundamental component of project assessment for carbon credit is the determination of the extent to which project interventions lead to carbon benefit that are additional to ‘business as usual' (IPCC, 2000). Quantification of the additional carbon benefits requires the elaboration of a without-project baseline scenario against which changes in carbon stocks occurring in the project can be compared. There is no standard approach currently existing to establish baseline scenarios for LULUCF activities that are not *afforestation* and *reforestation* in nature since these are the only permitted activities at present in the current CDM carbon credit trading in developing countries. A literature review on how deforestation, degradation and forest enhancement would be included under the REDD policy and on the existing knowledge on how their baselines can be determined is therefore presented in Chapter 2. After ascertaining the baseline approach, we then need to prove that CFM projects themselves are additional to 'business as usual' i.e. result to reduced carbon emissions and increased sequestration compared to unmanaged forests. The first research question is therefore: *how effective are CFM projects in carbon storage and sequestration compared to unmanaged forest?*

It has also already been stated in Section 1.6 that currently there are no reliable data on forest stocking and characteristics because forest inventories are not done due to limited skilled human and financial resources. This lack of forest data for the determination of carbon benefits will limit not only the individual projects but also the country's participation in the REDD mechanism. Forest inventory involves measuring and assessing forest resources to provide information about the quantity and quality of the forest, and monitoring their changes over time. There are commonly accepted principles of forest inventory following standard procedures on sampling determination, sample plot layout, tree measurement techniques and data analysis (Philip, 1983, Malimbwi, 1997, MacDicken, 1997). Most forest inventories have been done by professionals because this is regarded as a professional activity which requires highly specialized skills and education. In Tanzania forest inventories have been carried out by specialized technical staff from the Forest and Beekeeping Division, Sokoine University of Agriculture and the Tanzania Forest Research Institute. No one can deny the fact that the number of forest inventory staff from these organizations is far too limited to fulfil the inventory need for the whole country. This together with lack of financial resources from limited government budget for the forestry sector has contributed to the continuing lack of forest data.

As a forester who has worked on forest inventories of both natural forests and plantations in Tanzania, I feel that there is a need to develop an alternative approach that will ensure sustainable availability of forest data. In keeping with the current forest policy, this alternative approach should take aboard the local communities in order to involve them in forest management. The innovative aspect of this research is therefore the development of a valid, easy to implement, cost-effective estimation technique for assessment and monitoring forests and hence carbon stocks by local communities. This is built on the current forest management approach that has put much emphasis on the involvement of local communities in forest management. It is also build on existing (scientific/professional) carbon estimation and monitoring methodology for sink projects (MacDicken 1997; Weyerhaeuser 2000; de Gier, 1999; Intergovernmental Panel on Climate Change (IPCC, 2003). The experiences of participatory use of Geographical Information System (GIS) by local communities (Theocharopoulos, *et al.*, 1995; McCall, 2003; Zurayk, 2003) including the use of indigenous knowledge in the classification of forest types and species identification were also sourced.

Among few examples in which local communities are involved in forest measurements is the project Scolel Te Forestry and Land-use in Chiapas Mexico (de Jong *et al.*, 1997 & Cacho *et al.*, 2003). The project involves individual farmers and forest user groups who are practising agroforestry and avoided deforestation of shifting cultivation, in carbon assessment and monitoring. The farmers are trained and tasked to carry out measurements for estimation of carbon in their farms. Farmers report on the progress of their measurements that are periodically checked by technicians. The data is reviewed by an internal evaluation team composed of researchers who develop a carbon-flux model for each system category and ecological region. Technical and research teams verify the quality of data through random checks.

This project shows that it is possible for the local communities to carry out forest carbon assessment and monitoring. For their active participation in forest management, local communities may be trained to carry out forest inventories at a much lower cost than professionals, while at the same time ensuring reliable estimations and presentation in a format that is acceptable to the professionals. The project also shows that the local people have the ability to utilise their indigenous knowledge to collect required forest inventory data, instead of using professionals for this task. For Tanzania therefore, an alternative approach involving local communities managing CFM projects that will provide forest data which is acceptable to the professionals, has been developed and tested in this thesis. The second research question is therefore: *to what extent local communities can provide data to substitute* *for professionally gathered data of forest inventory*?

Further, CFM projects are normally managed for other purposes such as environmental protection and sustainable production of timber, firewood and building materials. The effects of the inclusion of carbon production on costs and benefits of CFM, if these projects become carbon projects are not known. The third research question is therefore that *to what extent will communities' costs and benefits be altered by inclusion of carbon production in CFM projects?* From this costs and benefit analysis, and the carbon stocks of the CFM projects, an estimate of the expected net revenues from the sale of carbon and the extent to which these could potentially motivate more communities to participate in CFM, is done. This is guided by research question four: *to what extent could sale of carbon credits potentially motivate more communities to participate in CFM*.

The thesis therefore explores the possibility of speeding up CFM establishment in Tanzania through the anticipated global carbon payment mechanisms under REDD policy. The flow of research questions helped structuring the thesis as outlined below in Section 1.9.

1.8 Structure of the thesis

This thesis consists of eight chapters and is structured as follows:

Chapter 1: *An outline of the problem*, contains background information on extent and status of forest resources in Tanzania; emergence of CFM; extent of CFM activities in Tanzania, forest carbon trading mechanisms; prospect of REDD as a national forest carbon trading option for Tanzania; general objectives and aim of the research; study hypothesis and approach, and structure of the thesis.

Chapter 2: *Baselines for REDD in developing countries*, considers the importance of including emissions from degradation and carbon stock enhancement in the REDD policy. It then examines the data requirements for baseline determination and propose how baselines for crediting CFM under REDD policy could be developed.

Chapter 3: *Methodological approach of the research*, contains operationalization of research questions, and outlines the field methods used for data collection, analysis and testing of the developed field forest inventory guide. The field sites where the research was carried out were also briefly described.

Chapter 4: *Carbon storage and sequestration in community managed and un-managed forests*, provides evidence that CFM projects result in carbon storage and sequestration compared to unmanaged forests.

Chapter 5: *Carbon assessment and monitoring by local communities*, determines to what extent local communities can use the developed field forest inventory guide to assess and monitor carbon in their forests.

Chapter 6: *Costs and benefits of CFM projects and the likely changes if they become carbon projects*, determines the current costs and benefits of CFM projects and examine how these will be affected by the introduction of carbon production.

Chapter 7: *Estimates of communities gain from forest carbon trading*, estimates the expected net revenues from the sale of carbon credits and examines the extent to which these could potentially motivate more communities to participate in CFM.

Chapter 8: *Conclusions and recommendations*, answers the hypothesis and the research questions, and gives policy and further studies recommendations.

Chapter 2

Baselines for Reduced Emissions from Deforestation and Forest Degradation (REDD) in Developing Countries

2.1 Introduction

In most systems that credit carbon emissions reductions, a baseline is required against which the savings can be compared. However, the nature of the baseline depends on the accounting rules about what, exactly, can be credited. There is considerable uncertainty at the moment about how baselines may be determined for operationalisation of UNFCCC policy on Reduced Emissions from Deforestation and Degradation (REDD), since it is not yet decided what will be included. The first point that needs to be noted is that as REDD is usually conceived, baselines will not be at project level as in CDM, but at national level, reflecting activity across the whole forest estate, and average gains and losses throughout this whole area over a given commitment period[5]. The rewards (carbon credits) would also be issued centrally. The possible options include crediting: (a) reduction in emissions from deforestation i.e. based on comparisons of rates of change of forest area over time (and here the question also arises of whether, and how, to include new areas planted e.g. through CDM projects), (b) reductions in emissions from degradation, that is to say reductions in biomass/carbon stock in the forest without loss of forest area based on comparisons of rates of loss over time (in practice these rates could be reduced for example by introduction of sustainable forest management practices in logging and other extraction processes), (c) enhancement or increases of forest biomass within areas of existing forest (sometimes referred to as forest restoration), (d) conservation (in this context this usually means crediting for maintenance of a steady level of forest area and biomass density i.e. not just for improvements in these values), and (e) carbon stock, under which all forest carbon stock receives some sort of credit. These five options are not mutually exclusive, and the eventual REDD agreement will probably include provision for several of them, which will require several different approaches to baseline construction.

The last two options relate to forests that are already properly managed, although not necessarily for carbon production. This applies mostly to countries that have being

[5] There has been some discussion about sub-national baselines e.g. for a province (for the case of Colombia, whose government has almost no control of forest activity in some provinces due to internal political problems, or for an island (e.g. for the case of Indonesia), but in any case REDD baselines will cover very large land areas and are not related to individual projects.

implementing forest protection for many years in the past, and which may not be able to profit from REDD if this is limited to reductions in rates of emission. These forests with long protection status could for example be credited based on the maintenance of carbon stock which could be rewarded through a special "conservation" fund that could be included under REDD. The other three options relate to forests that are used for different wood products such as those under CFM. They require either historical baselines or assessment of carbon stock change over a given time interval.

This Chapter will, therefore, deal with the latter to explore the problems and opportunities for baselines for crediting REDD including degradation and forest enhancement in the accounting system. It starts by outlining the policies currently under discussion at UNFCCC level regarding REDD, and pointing out the importance of including emissions from degradation and the effects of forest enhancement. It then examines briefly the principle of baseline construction including the technical and political problems related to developing baselines for deforestation, and extends this discussion to the particular case of degradation and forest enhancement, showing that different approaches as regard data sources are essential. Finally, this chapter proposes how baselines for crediting CFM under REDD could be determined.

2.2 The REDD policy context

As already pointed out in Chapter 1 (Section 1.4), at present forest carbon trading is only possible through the Clean Development Mechanism (CDM) of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). CDM, as adopted in the first commitment period (2008-2012), however, is limited to *afforestation* and *reforestation* projects only. This is despite the fact that deforestation, particularly in the tropics, has been estimated by the IPCC to result in annual emissions of around 8 Gtons CO_2, which represents almost 20% of anthropogenic greenhouse gas emissions (IPCC 2000; Gullison *et al.*, 2007). Deforestation, as defined under the Kyoto Protocol, means permanent change of land use from forest to non-forest and, therefore, involves, and is measured by, a loss in forest area. Forest is defined in terms of canopy cover (10-30% cover), tree height (2-5 m at maturity of the trees) and area (minimum patches 0.1 ha). Increasing evidence of the contribution of tropical deforestation to global carbon emissions has prompted re-negotiation of climate change policy for the post-2012 period to include REDD. This new policy is currently under discussion by Parties to the UNFCCC regarding crediting or otherwise rewarding reductions in carbon emission by reducing rates of deforestation and forest degradation. Under REDD, non-Annex 1 countries would, on a voluntary basis, aim to reduce the rate at which their forests are being lost, and receive compensation in proportion to the carbon emissions saved compared to a baseline which would represent the ‘without intervention’ case or some other agreed target (Moutinho and Schwartzman, 2005). The policy, unlike CDM, would operate at a national or possibly regional level, so that average reductions in deforestation over very large areas would be assessed, meaning that ‘leakage’, at least within the area, would be accounted for.

As also pointed out in Chapter 1, REDD policy negotiations started at CoP 11 in Montreal, Canada in 2005, and continued at CoP 12 in Nairobi in 2006. During the CoP 13 in Bali in 2007 major advances were made, and there was a clear commitment of Parties to deal with this issue in the context of an overall package for a post-2012 regime. A time span of 2 years was set for negotiations which should culminate in agreement on this post-2012 regime at CoP 15 in Copenhagen (December, 2009). It was also agreed to start demonstration activities to support REDD as a climate mitigation measure. The Decision (CoP 2.13) expressly focuses on reduced emissions from deforestation and degradation. Other possible options mentioned are ‘sustainable forest management’, ‘forest enhancement’ and ‘conservation’. The Decision also explicitly recognizes that the needs of local and indigenous communities should be addressed when action is taken to reduce emissions from deforestation and degradation. However, technical issues with respect to baseline determination for crediting REDD were left for further study.

2.2.1 The importance of including emissions from forest degradation

Degradation has generally been underestimated as an emission source, owing to the difficult in detecting it from remote sensing combined with poor statistics on national forest inventory in most developing countries. Forest degradation in the context of climate change refers to the loss of carbon from within a forest due to thinning out of the biomass stock, without loss of forest area. This is widely acknowledged to occur in tropical forests of all types, although data on rates of loss are hardly available. If anti-degradation measures to reduce emissions from this source are to be included within crediting options under national or international climate policy, the question of baselines for degradation arises.

Degradation has been defined in various ways, for example by the US Forest Service as "a loss of a desired level of maintenance over time of biological diversity, biotic integrity and ecological processes", and by Singh (1998) as "chronic disturbances; removal of only a fraction of forest biomass at a given time". An official UNFCCC definition has yet to be coined (Penman *et al.,* 2003), but most Parties consider degradation of forest to mean thinning out of biomass, and hence loss of carbon stock, from within a forest, without loss of forest area or land use change (UNFCCC, 2006).

There is in fact considerable confusion in the literature regarding forest degradation, as the term is often incorrectly used synonymously with deforestation. Studies that have investigated the underlying causes and drivers of deforestation have unfortunately not clearly distinguished between deforestation and degradation (Arildsen and Kaimowitz, 2001, Geist and Lambin, 2002). There is often an implicit assumption that forest degradation is a first step on the slippery slope to deforestation. While it may seem logical to argue that gradual reduction of forest biomass will eventually lead to complete loss of forest cover – a much cited example involves agricultural settlers colonizing and converting forest land after timber concerns have cut roads through the forest and extracted the few most valuable species, e.g. in the Mato Grosso in the Amazon - in most cases deforestation and degradation are caused by completely different social and economic processes and are not necessarily linked at all. There may also be considerable differences between degradation in rainforest, which is often the result of timber extraction by outside concerns (and may in some cases be followed by agricultural colonization), and degradation in dry forest areas, where it more often occurs as a result of local people's survival activities including burning for low intensity shifting cultivation, and charcoal production. A large amount of the deforestation that takes place in most countries is in any case the result of formal decisions to make land use changes ('governed deforestation'), although part may be 'ungoverned' – the result of informal, illegal or semi-legal, and corrupt practices. Degradation on the other hand is almost always 'ungoverned' (Table 1).

There are two major reasons for including degradation in the REDD agreement. The first relates to the integrity of the mechanism, the second relates to the importance of degradation emissions in overall forest emissions, which has been underestimated in the past.

Table 1. Activities resulting in deforestation and degradation

Forest type	Activities leading to deforestation	Activities leading to forest degradation
Rainforest	*Governed processes* • Infrastructure development • Urban expansion, settlement schemes • Commercial agriculture • Commercial ranching • Timber concessions for clear felling	*Governed/ungoverned* • Selective felling at unsustainable rates
	Ungoverned processes • Illegal clear felling • Agriculture following legal/illegal selective timber felling • Uncontrolled fires	*Ungoverned processes* • Non-timber forest products harvesting at unsustainable rates
Dry forest	*Governed processes* • Infrastructure development • Urban expansion • Commercial agriculture/ranching *Ungoverned processes* • Uncontrolled fires	*Ungoverned* • Selective, low-level timber extraction • Shifting agriculture • Charcoal production • Commercial firewood extraction • Grazing in forest

2.2.1.1 Integrity of the mechanism

Since the Kyoto Protocol definition of forest as laid out in the Marrakech Accords includes lands with canopy cover down to 10-30%, any forest which is depleted from its original state down to this level will not be considered deforested. It is quite possible, however, for countries with low deforestation rates to be harbouring high degradation rates (and thus high forest carbon emissions), and indeed measures taken for further lower deforestation rates could result in greatly increased degradation rates. In theory, a country could halt all deforestation (loss of forest area) and instead thin out its forests until they were all just above their lower threshold level. It could then claim large numbers of deforestation credits simply by shifting the location of the emissions. This situation may be viewed as ‘leakage’ from deforestation into degradation. From the point of view of mitigating climate change therefore it is essential that good estimates are made of the extent of areas that are being degraded, and the losses of carbon that are associated with this, to prevent false claims being made which would undermine the integrity of the agreement.

2.2.1.2 The relative contribution of degradation to carbon emissions

The IPCC estimates of emissions from deforestation are based mainly on research at Woods Hole by Houghton and others (Houghton, 1999; Ramankutty, *et al.*, 2007). They include human-induced land-use changes, data which has been derived from remote sensing combined with calculations from secondary statistical data at national level on wood extraction. The data includes emissions from clearing forest areas entirely (deforestation) and shifting cultivation and selective logging in rainforest areas for which data is available. Achard, *et al.,* (2004) and Asner, *et al.,* (2005) have estimated that typical cases of disturbance and logging in rainforest result in 25 to 60 tons of carbon emissions per hectare. Schoene, *et al.,* (2007) estimated that 5-8 hectares of degradation emit as much as one hectare of deforestation; these are not insignificant quantities. The IPCC estimates however, exclude many of the small scale degradation processes common in dry forests for example in Africa (Houghton, 1999). Here, the original carbon density per hectare is much lower, but such forests are much more widespread than rainforest. Moreover, they are more under threat of degradation because they are easier to penetrate, and are often closer to human populations.

Based on off-take rates and Mean Annual Increments (MAI) observed in this study (Chapter 4) and a study by Millington's and Townsend's (1989), carbon loss due to degradation for seven largely dry forest countries in sub-Saharan Africa, none of which have any primary or undisturbed forest remaining, were quantified (Table 1). Observed rates of biomass extraction are in the range of 1 to 3.5 tons/ha/year, and we estimated the loss of biomass over and above the MAI of forest to be typically in the range of 0.5 to 1.3 tons/ha/year, meaning that the carbon dioxide loss due to degradation would be 0.9 to 2.3 tons/ha/year, depending on the mix of extractive activities involved and the local MAI. Even under a conservative value of 2 tons biomass per hectare per year for total extraction, the net CO_2 emissions would be 178 million tons/year for the seven countries, which is more than the estimate of emissions resulting from deforestation (154 million tons/year) in these countries taken together. Although 178 million tons/year is not a large quantity in comparison with emissions from countries with huge rainforests and steep deforestation curves (e.g. Brazil, around 1500 million tons/year; Houghton, 2003), it is roughly equivalent to the deforestation emissions from Peru and double to those of Bolivia, Colombia and Cameroon. However the main point here is that, in dry forest countries, degradation may be a larger part of the problem than deforestation, although these estimates are rough and more research would be needed to establish accuracy.

Table 2 Estimated emissions due to degradation for 7 sub-Saharan countries with dry forest

Country	1. Forest Area[1] (ha)	Deforestation: 2. Average Growing Biomass Stock [1] t/ha	3. Growing Biomass Stock[1] (t)	4. Annual rate of Deforestation[1] (ha/yr)	5. Annual CO_2 Emission due to Deforestation (t)	Degradation: 6. Biomass Growth Rate (MAI)[2] t/ha/yr	7. Annual Growing Biomass Increment (t)	8. Scenario: Annual Biomass offtake of 2 t/ha/yr (t)	9. Net Loss of Biomass = Degradation (t)	10. Annual CO_2 Emission due to Degradation (t)	11. Total annual CO_2 Emission from Deforestation & Degradation (t)
Botswana	11,943,000	19	228,000,000	118000	4,130,326	0.7	8,	23,886,000	15,510,566	28,438,622	32,568,948
Malawi	3,402,000	76	260,000,000	33000	4,624,171	1.2	3,940,652	6,804,000	2,863,348	5,249,948	9,874,119
Mozambique	19,262,000	51	978,000,000	50000	4,654,665	1.4	27,445,543	38,524,000	11,078,457	20,312,351	24,967,016
Swaziland	541,000	70	38,000,000	5000	643,928	0.6	348,831	1,082,000	733,169	1,344,265	1,988,193
Tanzania	35,257,000	103	3,636,000,000	412000	77,903,442	1.2	44,066,004	70,514,000	26,447,996	48,492,401	126,395,843
Zambia	42,452,000	43	1,821,000,000	445000	34,998,765	1.2	52,506,498	84,904,000	32,397,502	59,400,820	94,399,585
Zimbabwe	17,540,000	48	843,000,000	313000	27,581,840	1.5	27,104,783	35,080,000	7,975,217	14,622,560	42,204,400
Total	**130,397,000**		**7,804,000,000**		**154,537,137**		**163,787,746**	**260,794,000**	**97,006,254**	**177,860,966**	**332,398,103**

1. Data from global Forest Resources Assessment (FRA) of 2005 (FAO, 2006)
2. Data from this study & Millington and Townsend 1989

NB: Base data is from recent FAO sources. None of these countries reported any changes since 1990 in stocking/carbon density within forests. The reliability of some of the estimates, particularly of annual rates of deforestation, is dubious, for example for the case of Tanzania it was based on two independent studies from 1989 and 1997 which used different methodologies and forest classifications, with a straight line through these two points to extrapolate current rates of deforestation. The result is almost certainly a gross overestimation. If this is the case, then the relative importance of degradation becomes even stronger. The scenario for degradation (column 8) is demonstrative only: the rate of 2 tons/ha is selected from the low end of estimates made in individual case studies. We recognise that this rate may be an overestimation for countries with low population densities (particularly Botswana), and that it will vary from place to place within the other countries. The purpose of this calculation is simply to put the probable relative contribution of degradation, which has been ignored in national statistics in the past, more clearly in focus.

2.2.2 The importance of including carbon sequestration due to forest enhancement

Most proposals under REDD are geared to the crediting of reductions in emissions, thus in reductions in the annual rates of deforestation and degradation. However, measures taken to reduce deforestation and forest degradation such as CFM, will generally not only halt the degradation, but also increase the level of woody biomass in the area and result in forest enhancement, potentially until the ecological maximum for that ecotype is reached. If the management includes controlled off-take of some forest products, as is usually the case in CFM and sustainable forest management, a high rate of carbon sequestration may be maintained for a very long period. Forest enhancement (sometime referred to as "forest restoration") is thus the other side of the degradation coin, and if avoided degradation is measured and credited, then it would seem logical that enhanced carbon stocks are also included. Introducing forest enhancement under REDD, however, implies a conceptual shift, since it means crediting increased sequestration (increased sinks), as well as decreased emissions, and it implies a move to something approaching full carbon accounting, at least in the forest sector, in a manner similar to that currently required of Annex 1 countries when reporting on their national emissions from forestry. It makes sense from the point of view of rationalising forest management and reducing atmospheric carbon dioxide, since the carbon sequestration may be larger than the component of degradation avoided, as shown in Figure 1. Moreover the assessment of forest recovery does not require historical baselines but only measurement of the carbon stock at point zero, or when the intervention starts (gross-net accounting). Figure 1 illustrates this. The pale area above the horizontal line can easily be measured and credited, although the actual savings in carbon include the dark area below the line, which is essentially an unknown quantity.

In the Noel Kampff project in Bolivia (Brown *et al.*, 2000), detailed data were continuously taken in permanent sample plots to monitor changes in different carbon pools of the forest. Since this project area is large (ca 600,000 ha), it was also possible to integrate this data with remotely sensed data on land use change to develop a spatial model that predicts carbon stock changes over time (Paladino and Pontius, 2004). Measurements made in this study show that CFM projects are increasing their CO_2 storage at rates between 3.2 to 9.8 tCO_2/ha/year. This is on top of the avoided degradation, for which very rough estimates at different sites vary between 1.8 and 6.5 tCO_2/ha/year.

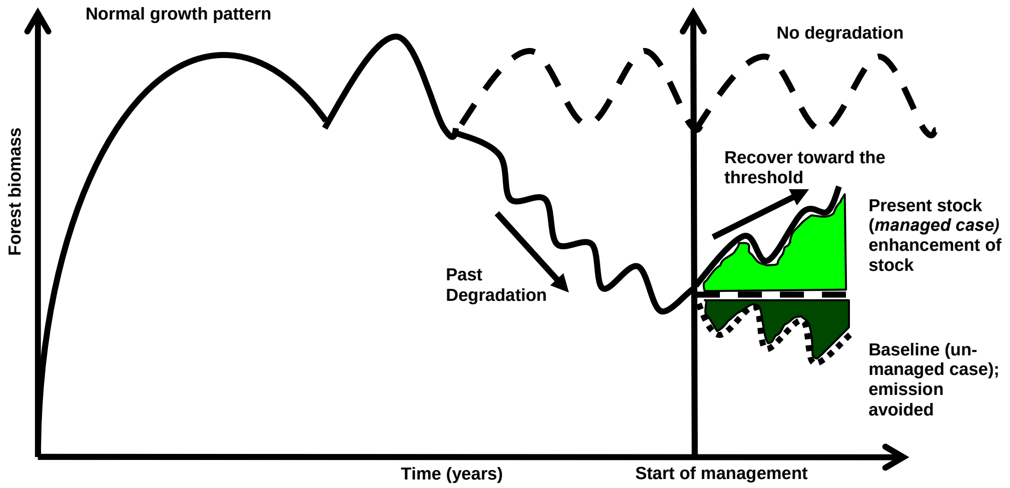


Figure 1. Forest recovery and sequestration resulting from management of a typical degraded forest

2.3. Principles of baseline construction

Carbon credits can currently be earned though CDM LULUCF projects for *afforestation* and *reforestation* projects. To be eligible, these projects have to demonstrate 'additionality' i.e. human induced activities (e.g. through planting and seeding) that would have not happened in absence of CDM involving planting trees on land that has never been forest (using the host country national threshold for the forest definition), or has not been under forest since 1990. After the proof of eligibility, project developers shall either use baseline and monitoring methodologies previously approved by the CDM Executive Board (EB) or propose a new methodology to the EB for consideration and approval. So far, the EB has accepted a number of approved baseline methodologies for LULUCF CDM projects (UNFCCC, 2008a). Appendix 1 summarizes the baseline principles associated with various mitigation mechanisms, including those already agreed (emissions and removals in Annex 1 countries, and *afforestation* and *reforestation* under CDM) and a variety of instruments proposed for REDD. These include both: net-net and gross-net accounting systems.

Net-net accounting compares emissions or removal in the commitment period to those of a reference scenario, such as a historical base year (e.g. 1990) or base period (e.g. 1990-2000), or to a projected baseline constructed to represent the 'business as usual' situation throughout the commitment period (Appendix 1, No. 2, 4, 5, 6, 7, and 9). This is different from gross-net accounting where emissions and removals during the commitment period are not compared with those in base year or base period but measurements of change of carbon stock are compared only over the commitment period itself (Appendix 1, No. 3). Although the latter is used under the current CDM for LULUCF projects (Trines *et al.*, 2006), the former has an advantage of avoiding natural forest cover and stock variations over time. Forests as ecological communities have different stages of growth and as they approach maturity, the rate of sequestration decreases. Therefore baselines that consider only shorter intervals of time are likely to be affected by these variations and the only way of avoiding them is to have baselines observed over long time.

Annex 1 countries that ratified the Kyoto Protocol, have to report to the UNFCCC on their annual inventories of emissions and removals of Green House Gases (GHGs) to demonstrate compliance with the Protocol's commitments. A full account model is used for national GHGs inventories of anthropogenic emissions by sources and removals by sinks of GHGs. This model implies that once the mitigation benefits of an LULUCF activity decline, the increase in emissions or decrease in sequestration will have to be compensated by measures in other sectors. Therefore these parties have to report all carbon stock changes per year in all forests which they have decided to include. However, they are not under any obligation to include all of their forests. Finland for example does not include LULUCF activities in their annual submissions (UNFCCC, 2008b) because most of its forests are in private ownership with no publicly available data. So the main difference, if such an accounting system were to be adopted under REDD, would be that the participating countries would be required to include all their forest areas.

As noted in the introduction to this chapter, the nature of a baseline depends on what, in principle, may be claimed as regard carbon ‘savings’, and five different options were presented. A fundamental problem with most baselines, and one that is causing a great deal of controversy in the current discussions, is the fact that countries which have had high rates of loss of forest area in the recent past perversely stand to gain most from REDD policies while countries that have implemented forest protection for many years may not be able to profit from it. Political sensitivities of this kind mean that policy compromises, such as the creation of a ‘stabilisation’ or ‘conservation’ fund for countries which have managed to retain their forest, may have to be included if REDD policy is to be ratified internationally. This is therefore another reason why different types of baselines may be required, rather than a ‘one-size-fits-all’ approach. The detailed theoretical possibility for baselines for deforestation, degradation and forest enhancement are discussed in the following sections.

2.3.1 Baselines for deforestation

Most approaches relating to reduced emissions from deforestation, such as variations on the Compensated Reduction model first proposed by Santilli *et al.*, (2005), are founded on the principle of a reference scenario from a historical period and net-net accounting (Appendix 1, No. 2, 4, 5, 6, 7, and 9). There are a number of technical difficulties associated with establishing such a reference scenario, which are summarized in Box 2. These relate essentially to four sets of problems.

The first of these is the fact that the global forest area varies annually due to natural causes, particularly forest fires, with these variations balancing themselves out over many years. However, since the variations can be on the same order of magnitude as annual losses due to human activities, long reference periods would be needed to ensure that human-induced trends are correctly estimated. Selecting a standard set of years for this is complicated by the fact that each country would prefer to have those years represented which demonstrate its own highest deforestation rates, so as to maximize the amount of savings it can declare during the crediting period.

The second problem relates to the difficulty of obtaining accurate data on forest area in past periods. Remote sensing is the only practical means of covering large areas over long periods of time. Fortunately medium resolution images e.g. from Landsat are widely available and cheap. Nevertheless, there are margins of uncertainty in reading forest area from satellite images which mean that crediting will be based on the most conservative estimates (Figure 2).

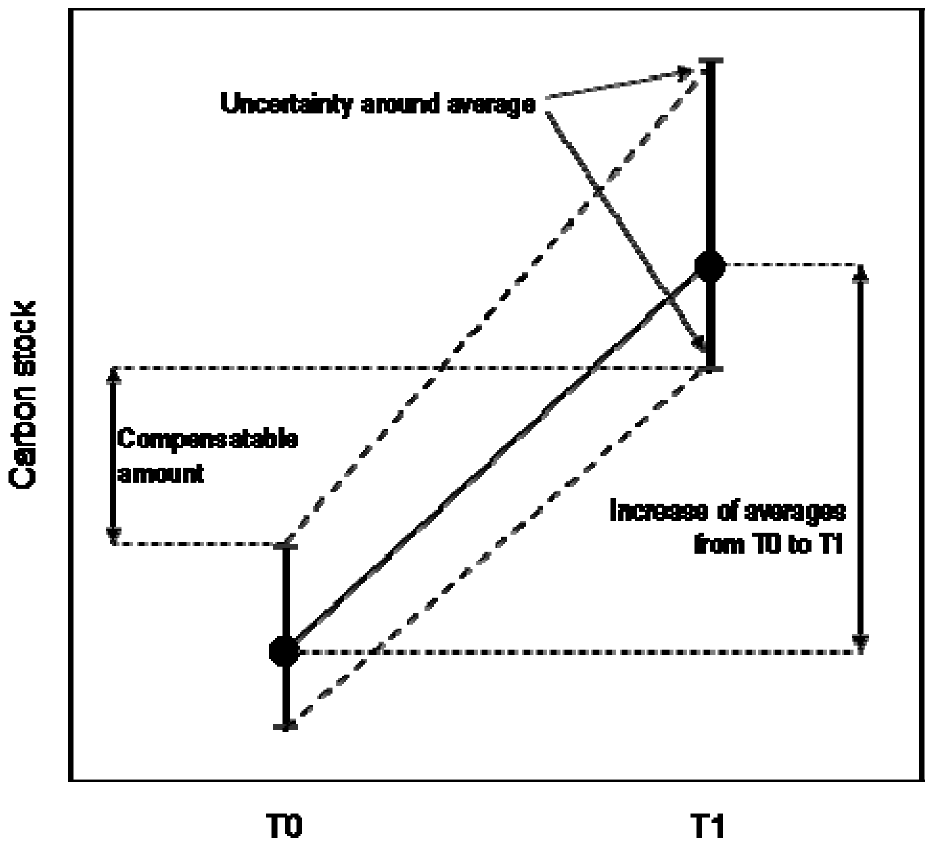
The third relates to the difficulty of projecting past observations to the future, to provide a baseline.

Box 2. Overview of problems associated with developing baselines for deforestation

- Measuring past rate of changes in forest area requires an accurate and reliable statistic representing average long term change, taken over very large land. In establishing such a statistic there may arise some problems:
    - Problem of cyclic fluctuations in forest area due to natural causes (e.g. die-back and fire) which may distort the picture if too short a historical period is used for reference.
    - Problem of cyclical fluctuations in forest area due to manmade change (e.g. rotational harvesting) which may distort the picture if too short a historical period is used for reference.
    - Problem of distinguishing natural from manmade changes (only manmade changes should count in the baseline).
- Accuracy in the measurement of area change
        - resolution of commonly available remote sensing images (Landsat: officially 30m, in practice minimum patch size 2ha); high resolution images very expensive (de Fries *et al.,* 2005);
        - cloud cover and need for same season images for comparison;
        - difficult of correctly distinguishing different land uses (forest/non-forest), resting partly on skill level of RS technicians; and
        - sampling system (with associated lower accuracy) or wall-to-wall measurement (expensive, needs greater capacity)
    - Non-availability of ground level measurements (forest inventory data) in the past to check the RS data over the time frame in question.

:

- Forward projection of rate of deforestation: (how can one know what the future would be if no intervention were to take place?), through:
        - simple statistical projections;
        - straight line or curve: what rationale is there for either of these?
        - rates of deforestation in any one specific area tend to peak over a short period and then halt (because forest cover is more or less all removed);
        - the need (for practical reasons) to predict which particular geographical areas are likely to be most subject to deforestation.
    - The alternative method for projecting would be modelling based on cause and effect relationships in deforestation processes:
        - explanatory value varies with different models (Brown *et al.*, 2000) and may be low 60% (de Jong *et al.,* (1997); stratified regional baselines may be more appropriate;
        - needs major data gathering and analysis exercise.
- Accuracy in conversion of area to tons carbon
    - lack of accurate volume/ha data for large areas;
    - lack of adequate allometric equations for mixed stands and naturally occurring trees;
    - lack of information on some pools (particularly soil carbon); and
    - other (non-carbon) GHGs: how to incorporate assessments?



Source: K:TGAL, 2008

True values are indicated by the dots; the vertical lines through these give the range of uncertainty owning to measurement error. The conservative rule will be to claim only that portion of carbon which is secure, i.e. between the upper estimate of the first observation and the lower estimate of the second.

Figure 2. The margins of uncertainty around estimated rates of deforestation.

The fourth set of problem concerns converting area estimates into ton carbon estimates, since carbon density in forests is by nature highly variable (due to for example different ecotypes and different rainfall belts). Forest inventory work is necessary to establish what the natural biomass stock in different ecotypes is. In some countries there may be sufficient data on this to be multiplied by forest areas of different types to obtain the total carbon stock at any one point in time[6]. But these figures may not take into account that forests have been degraded in places and have lost stock since the estimates were made. Most countries have no data on this at all. Ninety three out of 147 countries reporting to FAO in 2005 register no change in biomass density of their standing forest from 1990 to 2005, although it is well known that all but the most remote tropical forests have been partly to severely degraded during this period (FAO, 2006). Achard *et al.*, (2004) have proposed an accounting system in which only three

[6] Carbon is essentially equivalent to half the dry biomass of woody material.

categories of land cover are recognized and shifts between this would be measured: intact forest (no degradation); non-intact forest (with human disturbance, i.e. degraded forest, for which they estimate carbon stock is 50% compared to intact forest), and non-forest. Though simple, the use of this kind of system will give only a very sketchy account of the true carbon quantities involved.

2.3.2 Baselines for degradation

A baseline for degradation has to look at rates of biomass loss within the forest rather than at loss of forest area, and as such is a much bigger challenge from a technical point of view. Although it is safe to assume that natural variations will not affect degradation estimates nearly as much as deforestation estimates, one is faced with the fact that degradation is more difficult, if not impossible, to identify, let alone quantify, from remote sensing images. Degradation is not generally visible in medium resolution satellite images because much of it occurs below the canopy or in small patches which cannot be picked up at this resolution (Pfaff *et al.,* 2002; de Fries *et al.,* 2007). High resolution images such as IKONOS may be able to detect clearings down to ten meters square, for example Souza and Roberts (2005) and Asner *et al.,* (2005) have been able to identify larger disturbances such as logging in rainforests using this system, but apart from the fact that they are extremely expensive to purchase, the manpower involved in analyzing images at this level of spatial detail would be prohibitively costly, if available at all. Besides, the earliest IKONOS images were taken in 1999, which means that they cannot be used for reference periods earlier than that. This type of technology can only really be applied for random spot-checking, or for zooming in on particular areas which have been brought under special management. Lidar (laser based) imagery may in the future prove useful to estimate degradation levels but is also expensive and capacity to use it is very low in most developing countries. And, as noted above, ground level forest inventory data on biomass stocking rates is not available at all in most developing countries for the historical period that would be relevant for constructing baselines or reference scenarios, even if they were to be pursued with vigour from now on. From a practical point of view, the almost total lack of historical data on degradation rates means that net-net accounting cannot be applied, and that a quite different approach may be needed than for deforestation.

2.4 Setting-up baselines for deforestation, degradation and forest enhancement in practice

After the review of principles and problems underlying the different baselines constructions in Section 2.3, this section is about the kinds of data needed for baseline construction. Deforestation and degradation reference scenarios would have to be established using two quite different methodologies because of the inherent differences in the data required and available. Forest enhancement baselines would require different kinds of data from deforestation and degradation baselines too. For each of the processes i.e. deforestation, degradation and forest enhancement, a description of the kind of data required for baseline determination is given and how it could be obtained is presented in the following sections.

2.4.1 Data for baselines on deforestation

A deforestation reference scenario can be based on remotely sensed data over a historical period which shows change in area covered by forest. Then statistical (secondary) data on carbon stock in different types of forest are used to calculate the change in terms of tons of carbon. This is similar to the previous experiences as shown in Appendix 1 (No. 2, 4, 5, 6, 7, and 9). The reference scenario may be projected into the future either by using very simple assumptions (linear continuation of past patterns) or more sophisticated approaches (relating the past changes to particular drivers, and using predictions of these drivers to forecast forest areas likely to be lost in the future under 'business as usual' conditions). This reference scenario is then used to credit the additional mitigation benefit of the project under net-net accounting as described in Section 2.3.

2.4.2 Data for baselines on forest degradation

A degradation reference scenario on the other hand is much more difficult to establish because most degradation cannot be detected from remote sensing imagery. There is therefore no historical record of the spatial pattern of degradation (which areas are being degraded), and because of lack of forest inventory data in most developing countries, there is no detailed information on the rate at which carbon stock is being lost in the areas that are subject to degradation.

Degradation is caused by a variety of activities as shown in Table 1 in Sub-Section 2.2.1. These include: selective logging; unsustainable rates of extraction of timber and non-timber products by local communities, mainly for their own use, with possibly some minor commercial benefit (sale of firewood or charcoal to cities); and slash and burn agriculture, of a nature which exceeds the natural regeneration capacity of the areas concerned. Also fire, in regions in which it is not a natural occurrence.

With no previous data on the intensities of these activities, it is possible to use one of the following techniques: advanced remote sensing techniques, harvesting estimates from the local people, harvesting estimates from stumps counts, default values (rule of thumb), modelling using estimated rate of off-take, or harvesting estimates from control sites. These techniques are shortly described below.

2.4.2.1 The use of advanced remote sensing techniques

As pointed out in Sub-Section 2.3.2 it is possible to use advanced high resolution imagery such as IKONOS to detect forest degradation. However, these new technologies are limited in their application due to the fact that the imageries are available only since 1999, and in developing countries, moreover, due to high costs and low human capacity. In the future however, these technologies might be readily available and therefore useful for forest degradation studies in developing countries.

2.4.2.2 The use of harvesting estimates from the local people

The processes responsible for degradation are strongly correlated with population dynamics. At low levels of population density, neither off-take of forest and non-forest products, nor shifting cultivation in the forest will result in long term loss of carbon stock, as the forest can regenerate naturally. It is only when the population density per hectare of available forest rises that the effects will be seen. Given that the per capita volumes of extraction of forest and non-forest products, and the per capita areas taken for shifting cultivation have probably not changed over the last 20-25 years, it might be possible, for rural populations in forest areas, to make an estimate of the current per capita impact of these activities (in terms of tons forest carbon per capita per year), and using census data, back-cast to estimate absolute loss rates of carbon in the past, and project forwards given, a reasonable assumption about future population growth. Using mean annual increment rates of forest, it might be possible to establish a reference scenario, although clearly it would be a rather rough estimate.

However such estimations of losses due to forest use by local people rest on the assumption that per capita extent of forest use and shifting cultivation have not changed over 20-25 years which is not the case for a country like Tanzania which has experienced a lot of macro-economic policy changes over this period[7]. Secondly this option requires the use of mean annual increment rates of forests which are in general not available. These shortfalls together with the fact that most of the activities that cause degradations are carried out illegally (see Sub-Section 2.2.1) means that it is very difficult to get utilization data from local people.

2.4.2.3 The use of harvesting estimates from stump counts

With no record of harvested wood it is also possible to estimate degradation by a count of stumps in a given forest. Luoga *et al.,* 2002 was able to estimate wood volume of 'newly' harvested (stumps harvested within the last year) and 'old' harvested stumps (stumps harvested more than a year previously) for the miombo woodlands of eastern Tanzania. Such extraction rates can be modelled for the estimation of the degradation patterns. However, the procedure fall short in determining the actual time and purposes at which the trees were harvested, and moreover, it does not take into account lopping of branches. This makes it difficult to estimate the annual off-takes.

2.4.2.4 The use of default values and modelling

Default values are crude estimates based on broader generalization and expert judgements. They are therefore not much accurate. Because of this inaccuracy, conservative lower end values of confidence limits are estimated to allow for the uncertainty. The use of default value therefore means less carbon benefits.

[7] Since 1980's, Tanzania has been implementing policy reforms such as Structural Adjustment Programme in order to attain macroeconomic balance by bringing national expenditure in line with national income. In order to realise this, the government has been controlling credit and has removed subsidies on food items and agricultural inputs; liberalised trade; and has reduced government expenditure by retrenching employees and by introducing cost sharing measures in the education and health sector. As a coupling mechanism most of the people who lost their jobs in towns went to rural areas and the result of this was increased forest extraction and expanded subsistence agriculture (Monela *et al.,* 2001).

Modelling utilize default values, previous data or just one point measurements to predicts carbon stock changes over time. However, this requires a well elaborated study on the forest stand growth habit that can only be obtained from continuous monitoring from permanent sample plots. The use of default values estimated from expert judgement will always result to conservative estimates.

2.4.2.5 The use of harvesting estimates from control sites

Control sites are unmanaged forests with conditions similar to those of managed forests. Permanent sample plots could be established in the control sites to determine the 'business as usual' scenario in which degradation could be captured. Countries that wish to access REDD funding will need to carry out periodic forest inventories in order to get detailed information on the rate at which carbon stock is being lost in the areas that are subject to degradation. This should in fact be a major activity under the so-called 'readiness' mechanisms that are being proposed, e.g. by the World Bank under the new Forest Carbon Partnership Facility, as well as in demonstration activities for REDD that may be carried out between 2008 and 2012. With such data, at any accounting time the difference between the carbon emissions or removals of the control site and the carbon emissions or removals of managed forests at the start of project represent the carbon benefit (Figure 3).

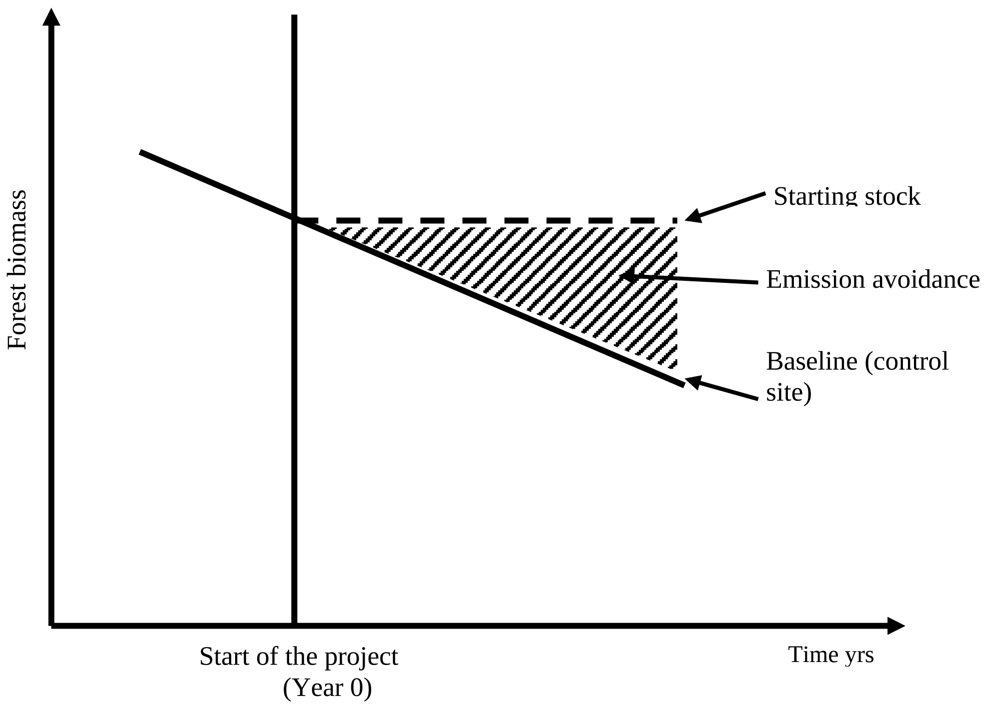


Figure 3. **Reference scenario for avoidance of forest degradation.**

2.4.3 Data for baselines on forest enhancement

As pointed out in Sub-Section 2.2.2 and illustrated in Figure 1, forests which have been subject to degradation in the past but in which the rate of degradation has been reduced following management intervention, may eventually reach the point at which biomass actually increases in an absolute sense. Data for this does not require historical baselines but measurements are taken at point zero or when the intervention starts and monitoring done at definite interval of time, say annually. This will generate data on forest enhancement as a result of checked degradation. Figure 4 illustrates this, where right from the beginning of the management intervention the starting forest stock is determined and through annual measurements the enhanced stocks in the managed forests are recorded.

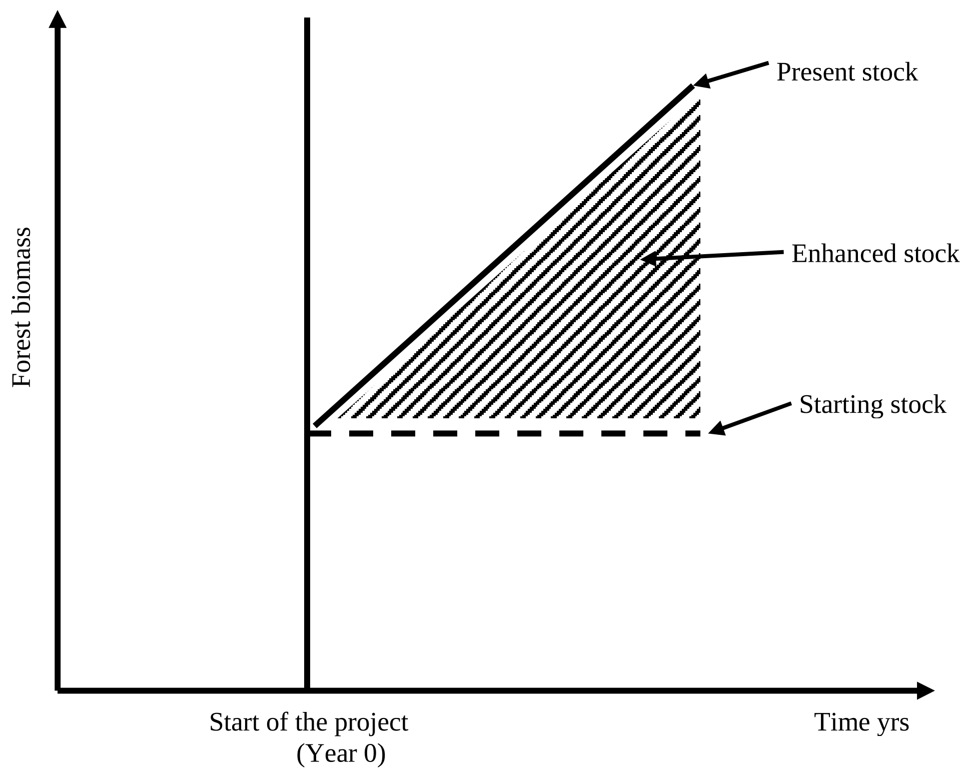


Figure 4. Reference scenario for forest enhancement.

2.5 'Nested baselines'

The proposed REDD policy has been seen as addressing the question at national level with the advantage that 'leakage' will be avoided through balancing out of gains and loses internally. Also it is likely that under REDD, the scrutinizing of emission reductions of participating stakeholders will also be done internally in order to avoid the bureaucracy that has dogged CDM projects (Trines *et al*., 2006). But there has been a lot of controversy on this, with for example, a counter proposals for so-called ‘nested baselines’ which would allow for individual projects to be included as long as they take proper account of ‘leakage’, as proposed by Chile (UNFCCC, 2007). However, whatever will be agreed on this, the idea of ‘nested baselines’ is introduced in this thesis as meaning something different i.e. *an interlocking set of baselines that covers the whole country and sums to the national baseline*.

These ‘nested baselines’ are therefore specifically tailored to different geographic regions and also account for different forest regimes e.g. national parks, forest reserves, community forests, and private forests. This system of ‘nested baselines’ will be needed in order to provide incentives to stakeholders within the country; in other words, to enable the state to account in a fair way for gains and losses and to reward stakeholders who are responsible for reductions in carbon losses.

With this system the individual baselines from different regions and different regimes will add up to the national reference scenario. The government can identify and prioritize high degradation areas and/or specific forest regimes with the assistance of ‘nested baselines’.

‘Nested baselines’ for different regimes can be approached using a gross-net accounting system (as shown under Section 2.3) where individual management regimes are credited depending on their mitigation levels in the commitment period without comparison with the base year. This is similar to the CDM approach where the individual project is responsible for accounting for its own carbon benefits. From the start of a carbon project, monitoring is done to determine the standing stock in both managed project area and unmanaged forests with similar conditions. At any accounting time the difference between the carbon emissions or removals of the without-project activities and the carbon emissions or removals for with-project activities represent the carbon value. However, this does not distinguish the process of avoidance of forest degradation from forest enhancement. As illustrated in Figure 5 these can be distinguished by determining the starting forest stock at the beginning of the management intervention and thereafter taking annual measurements of both the lost stock in unmanaged forest and enhanced stock in the managed forest. When the stock increases in managed forests, there would be grounds for rewarding the local stakeholders whose actions have led to these improvements. Similarly, when the stock decreases in unmanaged forests, the management gets credit which is the difference between the stock at the beginning of management intervention and the control site stock. In this way both avoidance of degradation and forest enhancement can be distinguished and credited.

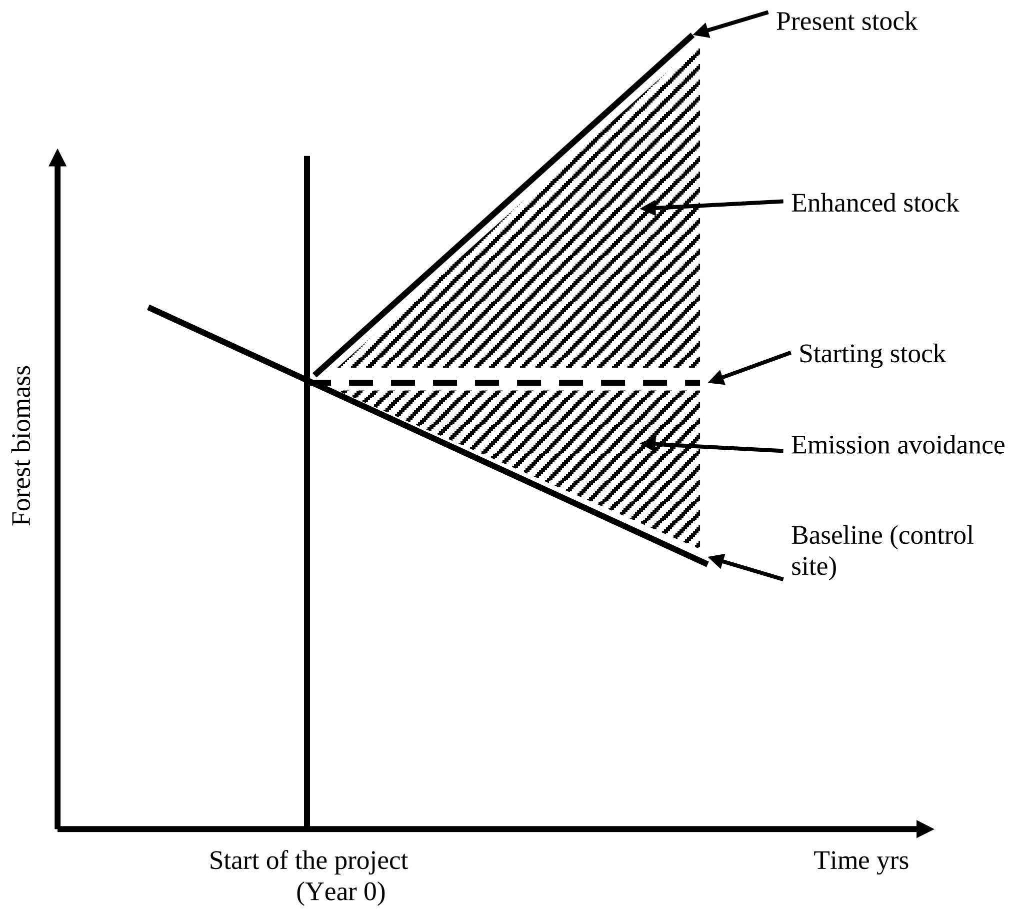


Figure 5. Reference scenario for degradation and forest enhancement for individual management regimes.

2.6 Summary

Under REDD, the reference scenario will be the baseline against which achievements made by a country can be measured and credited. However, there is considerable uncertainty at the moment about how baselines may be determined for operationalisation of REDD policy, since it is not yet decided what will be included. The possible options include crediting: reduction in emissions from deforestation; reduction in emissions from degradation; enhancement; forest conservation; and carbon stock. The last two options relate to forests with long protection status which would be credited based on the maintenance of carbon stock which would be compensated through a “conservation” fund that would be included under REDD. The other three options relate to forests that are used for different wood products such as those under CFM. They require either historical baselines or assessment of stock change over time interval.

In this chapter, it has been demonstrated that since the REDD policy is likely to be undertaken nationally, the country deforestation baseline would be determined by depicting historical land use changes from satellite imageries and typical carbon stock data for different types of forests to calculate the changes in terms of tons of carbon. After developing national level reference scenarios for the whole country, the system of 'nested baselines' is proposed to operationalize REDD internally for the different geographic regions and to account for different forest regimes e.g. national parks, forest reserves, community forests, and private forests. This system is needed in order to provide incentives to stakeholders who are responsible for reductions in carbon losses within the country. The sum of the 'nested baselines' for deforestation from different regions, and degradation and forest enhancement from different regimes will add up to the national reference scenario.

With 'nested baselines', individual management regimes would then be credited depending on their mitigation levels in the commitment period. From the start of the project, monitoring is done to determine the standing stock in both managed project area and unmanaged forests with similar conditions. At any accounting time the difference between the carbon emissions or removals from the without-project activities and the carbon emissions or removals for with-project activities represent the carbon value to be credited.

With these ideas in mind, the carbon benefits of CFM forests will be determined by assessing and monitoring carbon stock changes from CFM managed forests and unmanaged forests in their vicinity. From these measurements, the rate of forest degradation and enhancement may be established from which the carbon benefits will be computed. How this could be put into practice is outlined in Chapter 3.

Chapter 3
Methodological Approach of the Research

3.1 Introduction

This Chapter presents the methodological approach of the research. It begins with a description on the operationalization of the research questions by presenting the field methods for the collection of relevant data and testing of the methodology that was developed for forest community carbon assessment. This is then followed by a short account of field sites where the research was carried out.

3.2 Operationalization of research questions

As pointed out in Chapter 1 this thesis explores the possibility of speeding up CFM establishment in Tanzania through the anticipated global carbon payment mechanisms under REDD policy. The REDD policy is still being debated but the likely approach for baselines determination for crediting CFM under REDD policy is given in Chapter 2. Based on the likely REDD policy, the operationalization of the research questions are elaborated in the following sections.

3.2.1 Determination of forest carbon stock in managed and unmanaged forests

As stated in Chapter 2, individual CFM projects will need to determine their own baselines. For their participation in the REDD policy they have to prove that their forest management activities result in halted deforestation and reduced levels of degradation and thus carbon storage and enhancement. In order to provide evidence for these, carbon stock changes both from managed and unmanaged forests in the proximity were determined for 6 CFM forests, in 4 different villages (see the details of the study sites in Section 3.3). This has been done by local communities themselves using the specially developed field forest inventory guide on procedures and techniques for carbon assessment and monitoring after basic training (see the details in Sub-Section 3.2.2 and Appendix 2). The results for the forests measurements are presented in Chapter 4. The first research question, *How effective are CFM projects in carbon storage and sequestration?,* is subdivided in the following specific research questions:

- What are the levels of carbon stock in CFM projects compared to unmanaged forests?

- What are the growth rates in CFM and in unmanaged forests?
- What are the differences in terms of species composition between CFM and unmanaged forests? and,
- How much carbon per ha per year is sequestered (under CFM) and lost (in the unmanaged forests, through forest degradation)?

3.2.2 Forest carbon assessment and monitoring by local communities

As pointed out earlier in Chapter 1, most studies that involve carbon assessment in forest employ professionals who are few and the financial resources for this are also limited. This study intended to examine whether local communities, i.e. villagers and their local supporting organizations, may be able to assess and monitor carbon sequestered in their forests more cheaply than professionals. To test this, a field forest inventory guide on procedures and techniques for carbon assessment and monitoring by local communities was developed and tested (see Appendix 2). This experimentation is presented in Chapter 5 and was guided by the second research question: *To what extent can local communities provide data to substitute for professionally gathered data of forest inventory?* The specific research questions were:

- Are local communities able to assess and monitor carbon sequestered in their forests?
- Does carbon assessment and monitoring by local communities result in accurate and reliable estimates compared to professionally gathered data? and,
- What is the relative cost of community gathered data compared to professionally gathered data?

The experimentation with the field guide was done for the selected local communities in four locations who are already managing six different CFM forests in Tanzania. The following sections provide details about the field forest inventory guide, its experimentation and the data handling.

3.2.2.1 The developed field forest inventory guide

The techniques developed utilises handheld computer with ArcPad™ 6.0 software and Global Positioning System (GPS). The software provides the user with the ability to bring geo-referenced maps and images into the field with the possibility to add and change the attributes attached to the maps and images during the actual observations. It offers users the ability to connect a GPS to the handheld computer. The field handheld computers are manufactured to accommodate jacket GPS mounted directly on them so that a position on ground in real time can be shown on the handheld computer screen map. With this system it is possible very simply to locate forestry boundary, sample plots and record measurement data for further processing. The data processing can also be done by way of fitted computation procedures in a spreadsheet/database computer programme such as MS Access.

In this study, a system including Ipaq handheld computer with ArcPad™ 6.0 software, and Navman jacket GPS was developed. All steps on how to operate the system are provided in a field user manual (Appendix 3). To facilitate easy follow-up, a *Kiswahili* version of the manual was also prepared (Appendix 4).

The main field forest inventory guide provides a protocol on how carbon can be measured in any given piece of forest (Appendix 2). This field forest inventory guide gives step-by-step techniques and procedures that need to be undertaken at field level, the idea being that similar standard procedure are used for each site. The procedure draws heavily on MacDicken (1997), Weyerhaeuser (2000) and on *Good Practice Guidance for Land Use*, *Land-Use Changes and Forestry* by the Intergovernmental Panel on Climate Change (IPCC), (2003). It is based on commonly accepted principles of forest inventory, soil sampling and ecological surveys that provide methods for sampling design and for accurately and precise measuring individual carbon pools in forests. The IPCC procedures are currently the official procedures under the UNFCCC.

As pointed out above (Sub-Section 3.2.1), using this system, data for forest carbon changes were collected from both community managed and unmanaged forests in their proximity. This enabled the comparison of these forest management regimes in terms of tree species composition, growth rates and carbon storage and sequestration. This was done by the local communities after practical training (as detailed in Chapter 5, Section 5.3). In order to facilitate checks on precision of the data collected, the researcher was part of the field team in each site as an observer especially in the first year during the training sessions.

3.2.2.2 Forest inventory data analysis

From the data collected, forest parameters were computed. Tropical natural mixed forests are complex ecosystems characterised by high number of different species of different age and sizes (Zahabu and Malimbwi, 1998; Maliondo *et al.,* 2000; Malimbwi and Mugasha, 2001; and Munishi and Shear, 2004**)**. In order to determine forest stocking (volume, biomass and carbon), tree species composition, structures and diversity of these complex forest ecosystems, it was logical to express the forest stocking by sizes for each species. To facilitate this, the procedures for data analysis are described hereunder. But first, an explanation concerning the selection of appropriate allometric equations for different ecotypes is given.

Selection of appropriate allometric equations

Local allometric equations were used to compute stand biomass as average sums of trees biomass in the plots. The use of local allometric equations for areas with similar geographical and vegetation type is recommended in the literature (de Gier, 1999; Brown, 2003; IPCC, 2003). For woodland forests, an allometic equation developed by Chamshama *et al*., (2004) for woodland areas was used. This equation includes trees greater than 1 cm diameter at breast height (dbh) and it has the advantage of requiring only dbh as a variable. It also had R^2 of 97% making it reliable for the estimation of biomass. The equation is:

$$\textbf{\textit{Biomass}} = 0.0625\boldsymbol{D}^{2.553}$$

Where $\textbf{\textit{Biomass}}$ = total tree biomass (kg/ha) and

$\boldsymbol{D}$ = tree dbh (cm)

($R^2 = 0.97$)

For the montane and lowland forests, tree biomass was computed as a product of total tree volume and wood basic density. Average wood density of 0.58 g cm^{-3} for montane high forest of Tanzania observed by Munishi and Shear (2004) was used.

The appropriate single tree volumes for montane and lowland forests were calculated using a general tree volume formula i.e.:

$$\boldsymbol{V_i = 0.5\ g\ h_i}$$

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

h_i = the total height of the i^{th} tree (m) and

g = the tree basal area (m^2)

0.5 = the tree form factor. Tree form factor of 0.5 is recommended to be used for natural forests in Tanzania without distinction of the vegetation type involved (Haule and Munyuki 1994).

The biomass from these different forest types were then converted to carbon using a biomass-carbon ratio of 0.49 (MacDicken, 1997; Brown, 1997; Brown, 2003).

For the woodland forests, the total tree volume was calculated from the allometric equation developed by Malimbwi *et al.,* (2005b). The equation was:

$$\boldsymbol{V} = 0.000011972\boldsymbol{D}^{3.191672}$$

Where $\boldsymbol{V}$ = tree volume (m^3) and

$\boldsymbol{D}$ = tree dbh (cm)

(R^2 = 0.98)

From the collected data it was also possible to compute some other forest stand parameters such as: density, i.e. the number of stems per ha (N) and basal area per hectare (G). These parameters are very important in forest management as they provide useful information on forest stocking levels.

Data analysis procedures

Normally inventory data analysis is done by the use of computer spreadsheets, but this is very cumbersome and liable to errors. For consistency, accuracy and ease of computations, all computations were fitted on Microsoft Access data base file to enable computation as fast as data were entered. This data base was used for the computation of important forest stand parameters such as number of stems, basal area, volume, biomass and carbon by species and size classes. The data inputs required were: tree species and tree data from plots.

A tree species checklist was prepared for each forest by compiling a list of all local names of all deferent tree species encountered in all the measured plots. This was then followed by matching the local names to their appropriate botanical names using locally available tree species checklists. The two columns of names were then sorted alphabetically by either local names or botanical names, and assigned species identification codes. These are used for convenient species identification during the computation process.

The tree data from each plot then need to be prepared for analysis. This was done first by writing the species identification code against each tree on the field plots forms. Then the species identification code, tree dbh and height for each measured tree are entered into pre-designed forms into a computer spreadsheet for each plot. Having entered all the data on the spreadsheet, the data is saved to the computer ready for analysis.

If allometric functions for estimation of trees biomass/volume/carbon require height measurements, a few trees (sample trees) in each plot are measured for height. Using the sample trees whose heights were measured, a height diameter equation was developed for each forest (vegetation type). The equation is used to estimate the height of trees that were measured for dbh only.

The pre-designed Microsoft Access database

For simplicity of use, the database is designed in such a way that the user needs to replace default tree species checklist and trees data tables only. All other computation procedures are already included. As soon as data for a particular forest are loaded onto the database, the forest stand parameters are outright obtained. The stand parameters are separated for each species into diameter classes of convenience. The default diameter classes used in this case are:

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

This database is now called the Tropical Forest Inventory Data Analysis package (TROFIDA). It is user friendly and its applicability has been tested in this study. It has facilitated data analysis by the staff from the local supporting organizations for immediate sharing of the results with the villagers.

3.2.3 Costs and benefits of CFM projects and the likely changes if they become carbon projects

At present CFM forests are managed for environmental protection and sustainable utilization of products and services and the effect of the inclusion of carbon production into the general costs and benefits need to be understood. In order to determine the likely changes if CFM were to include carbon trading, an estimation of the costs and benefits of CFM projects is required. Social studies were therefore carried out in the 4 locations selected for this study to determine the current costs and benefits of the CFM project and the likely changes if they become carbon projects. These answer the third research question and are dealt with in Chapter 6. The question; *To what extent will community costs and benefits be altered by the inclusion of carbon trading in CFM projects?* is sub-divided into the following specific research questions:

- What sorts of management activities are supposed to be used by communities under CFM projects and what activities are in practice used?
- What are the current forest products and services generated by CFM projects?
- What changes in management will be associated with carbon management? and,
- Will there be losses of other benefits if CFM projects are turned to carbon projects?

In order to answer these questions, multiple methods of data collection such as Participatory Rural Appraisal (PRA), interviews with stakeholders and participant observation methods were used. The use of these multiple methods was necessary for the validation of data and to bring out more details from the viewpoint of the communities studied.

3.2.3.1 Participatory Rural Appraisal (PRA)

This method was used at the beginning of the research as it was necessary to build rapport and obtain general information on communities involved. In each village a village government chairperson or village executive officer was approached before hand and requested to call a meeting of about 30 villagers including the village forest committee members. At the beginning of the PRA meeting the aim of the meeting was explained to the villagers and they were requested to participate. Then various PRA techniques such as timelines, resource mapping, matrix scoring, and venn diagrams were used to extract relevant information as shown in Table 3. This exercise formed a basis for communities' stratification based on wealth categories as defined by the villagers themselves. The community stratification was later on used in household questionnaire sampling.

Table 3. Information generated during community profiling

Information type	Purpose
Background information	Get information on land use history, economic activities, land/forest ownership, identification of actors and their involvement in different CFM activities.
Socio-economic status	Stratification of the communities into wealth categories using own communities criteria e.g. amount of land owned, number of livestock owned, number of main meals per day and nature of their houses.
Spatial information	Get community's perceived distinction of major zones of land use and topography. Community forests zones if any can also be distinguished.
Forest products	List of all forest benefits and all species used for subsistence and commercial use, classified according to importance.
Forest products sources, availability and sustainability	Identification of where a particular forest product is collected from and its availability in the past, present and future alternative source. A perceived state of sustainable availability will also be explored.
Communities and facilitating organizations Costs in CFM	Costs of CFM in terms of: time spent in meetings for planning, by-law formulation and awareness creation. Also the costs for actual CFM implementation in activities such as patrolling, forest boundary clearing, gap planting, and fire lines clearing and maintenance.

3.2.3.2 Interviews

Households formed the sampling units for structured questionnaire interviews. A household in this case is defined as a group of people living together and sharing the same kitchen. The same definition of a household was also adopted by Kajembe (1994) and Monela *et al.*, (2001) for questionnaire interviews in Tanzania. The household questionnaires (Appendix 5) were administered to 5% of the heads of households in each wealth group for each site/village. As far as possible female headed households were included in order to get gender balanced information since in the communities studied males are the heads of households. The aim of administering questionnaires was to quantify issues resulting from the PRA with special ties to the research question. Information on socio-economic activities, forest products used, their sources and availability, and costs of CFM by the local communities were investigated. Statistical Package for Social Sciences (SPSS) was used to analyze the data from the household questionnaires.

Open-ended interviews were also done with key informants such as village leaders and officials from the local supporting organizations. These interviews were guided by way of checklists (Appendix 6) to corroborate evidence obtained from PRA and structured questionnaire exercises together with broader information on CFM projects. The results were also cross-checked in separate meetings with each wealth group. In addition to individual households' costs and benefits determination, the CFM costs by the facilitating organizations were also explored.

3.2.3.3 Participant observations

Participant observation method that encourages researchers to immerse themselves in the day to day activities of the people whom they are attempting to study was also used. This research involved at least a visit of about 7 days by the researcher to the study villages for each of the 4 years of the research. While in the villages implementing other research activities, the researcher observed and recorded different community and household activities relevant to the research such as socio-economic activities, forest products used and their availability, and costs of CFM. This 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 from this technique.

3.2.4 Estimates of communities gain from forest carbon trading

The approach for the determination of carbon benefits of CFM projects are described in Sections 3.2.1 and 3.2.2. The way in which the costs of CFM facilitation and implementation are estimated is detailed in Sub-Section 3.2.3. Having determined the carbon benefits and costs of CFM projects, the net gains from the sale of carbon were estimated and the probable responses of communities examined. This is done in Chapter 7 using the fourth research question: *To what extent could sale of carbon credits potentially motivate more communities to participate in CFM?* The specific research questions for this were:

- What are the management (in financial and time terms), transaction (verification and marketing) and opportunity costs of CFM with a carbon management activity included?
- What is the likely overall financial benefit to the community per ton of carbon?
- How much the rate of deforestation and degradation could be driven down if a payment system for carbon were set up for CFM in Tanzania, and how much carbon will be saved? What will the country earn as a result? and,

- What stops communities from taking up CFM today and to what extent could payments under REDD remove these barriers?

These questions were answered using both forest carbon and socio-economic data collected as detailed in Sub-Sections 3.2.1, 3.2.2 and 3.2.3.

3.3 Study sites

Four sites in which CFM has already been operating for some time were selected. They represent both JFM and CBFM projects. They also represent a range of ecological conditions, including woodlands, lowland and montane forests ecosystems. Woodlands are the most widespread forests types in the country constituting 96% of all forests, the rest being lowland and montane forests (3%), and mangroves and plantations (1%) (URT, 1998). The locations of the selected sites are shown in Figure 6 while their attributes are shown in Table 4 and described in detail in Chapter 6.

Table 4. Attributes of the selected forests sites

Forest attributes	Handei	Kitulangalo		Mangala	Ayasanda (Warib & Haitemba)
		KSUATFR	Kiminyu		
Location	Mgambo - Miembeni village about 45 km from Muheza township, Tanga Region, North-eastern Tanzania	Kitulangalo area 50 km east of Morogoro municipality, Eastern, Tanzania	14 km from KSUATFR, Eastern, Tanzania	Ludewa village, Mkuyuni division, 45 km from Morogoro municipality, Eastern Tanzania	Duru-Haitemba, 20 km South of Babati township, Manyara, Region, Northern, Tanzania
Accessibility	Gravelled road from Muheza township	Along Dar – Moro highway	Earth road from KSUATFR	Gravelled road from Morogoro	Gravelled road from Babati township
Area (ha)	156	600	420	28.5	550
Rainfall (mm)	1,500	700 - 1,000		1,000 – 3,000	500 - 1200
Forest type	Sub-mountane evergreen forest	Miombo woodlands	Miombo woodlands	Lowland forest	Miombo woodlands
Management purposes	Protective and production	Protective and research	Protective and production	Protective and production	Protective and production
Forest ownership	Village government	Central government	Village government	Village government	Village government
Management type	CBFM	JFM	CBFM	CBFM	CBFM
Start of management	1996	1995	2000	2004	1994

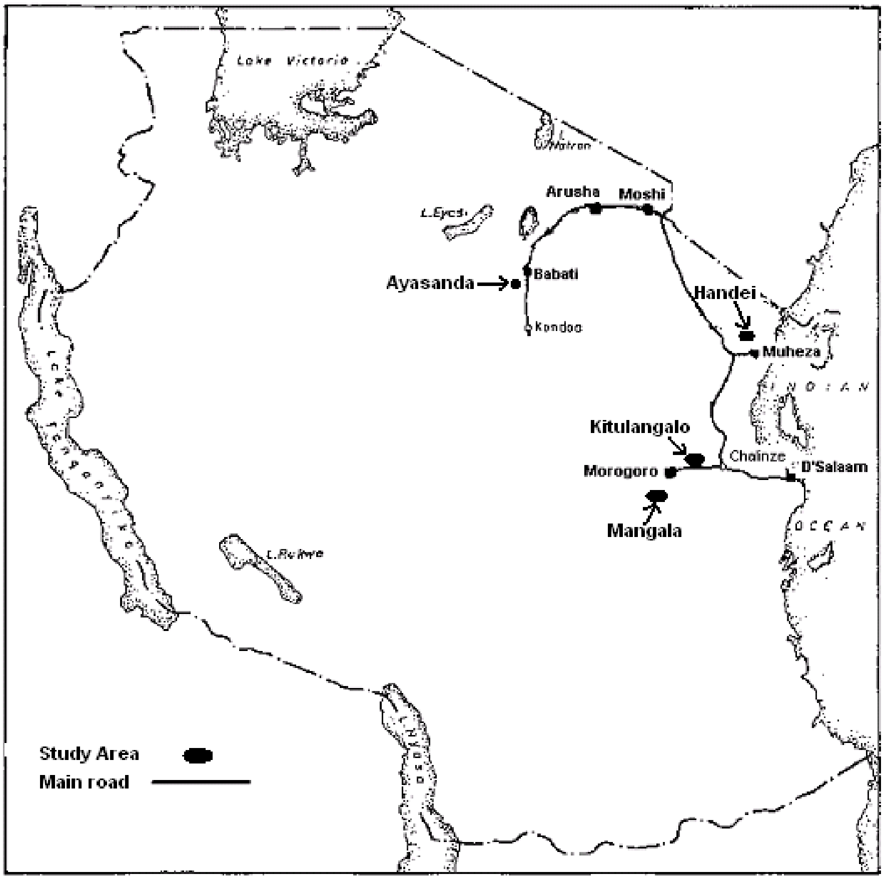


Figure 6. **Map of Tanzania showing the location of the study areas**

3.4 Summary

This chapter provided a detailed description on the methodological approach of the research. Four sites with a total of 6 forests one under JFM and 5 CBFM were selected. Of the selected forests, four comprised miombo woodlands from both eastern and inland parts of the country, and the rest comprised lowland and montane forest types. Woodland forests occupy 96% while lowland and montane forests cover only 3% of the total forest land. . These study sites therefore allowed a comparison between the forests in terms of management types as well as the main vegetation types in the country. In each site, social and forest resources assessment and monitoring studies were done. Social study was done to address socio-economic profiles of the villages, costs and benefits of CFM projects, and general CFM management issues. The forest resource assessment included carbon assessments in the field by the trained local communities. Using these methods, the following chapters present the results from the field.

Chapter 4
Carbon Storage and Sequestration in Community Managed and Un-managed Forests

4.1 Introduction

As shown in Chapter 2, for their participation in a national REDD programme under the international REDD policy, individual CFM projects would have to prove that their forest management activities results in reduced levels of degradation and increased sequestration, compared to unmanaged forests. Though increased sequestration can be measured directly in terms of increased biomass in the forest, to determine how much degradation has been reduced will require a ‘business as usual’ scenario that would show what would have happened with the managed forest in the absence of the management. For the purposes of this thesis, control sites were used to determine ‘business as usual’. These measurements address the first research question that determine the effectiveness of CFM projects in carbon storage and sequestration compared to unmanaged forests. This Chapter therefore, presents results on carbon stock changes observed for community managed forests and compares these with data from control sites in unmanaged forests. First, the levels of carbon stocks, biomass growth rate (tons/ha/year), carbon sequestration rates (tCO_2/ha/year) and other forest parameters observed in community managed forests are presented. This is then followed by a comparison of forest stocking and tree species composition between the managed and unmanaged forests. Then the degradation rates (i.e. loss of biomass tons/ha/year and CO_2 emissions tCO_2/ha/year) of the unmanaged forests are presented. Finally, the issue of ‘leakage’ (i.e. displaced activities as a result of management) is raised as a potential challenge, since it may not be fully clear whether what was measured from unmanaged forest represents ‘business as usual’ scenario or ‘leakage’.

4.2 Stand parameters in community managed forests

The stand parameters in terms of number of stems, basal area, volume, biomass and carbon per hectare for the studied CFM forests are shown in Table 5. The following sub-sections describe the observed trends in these forest stand parameters.

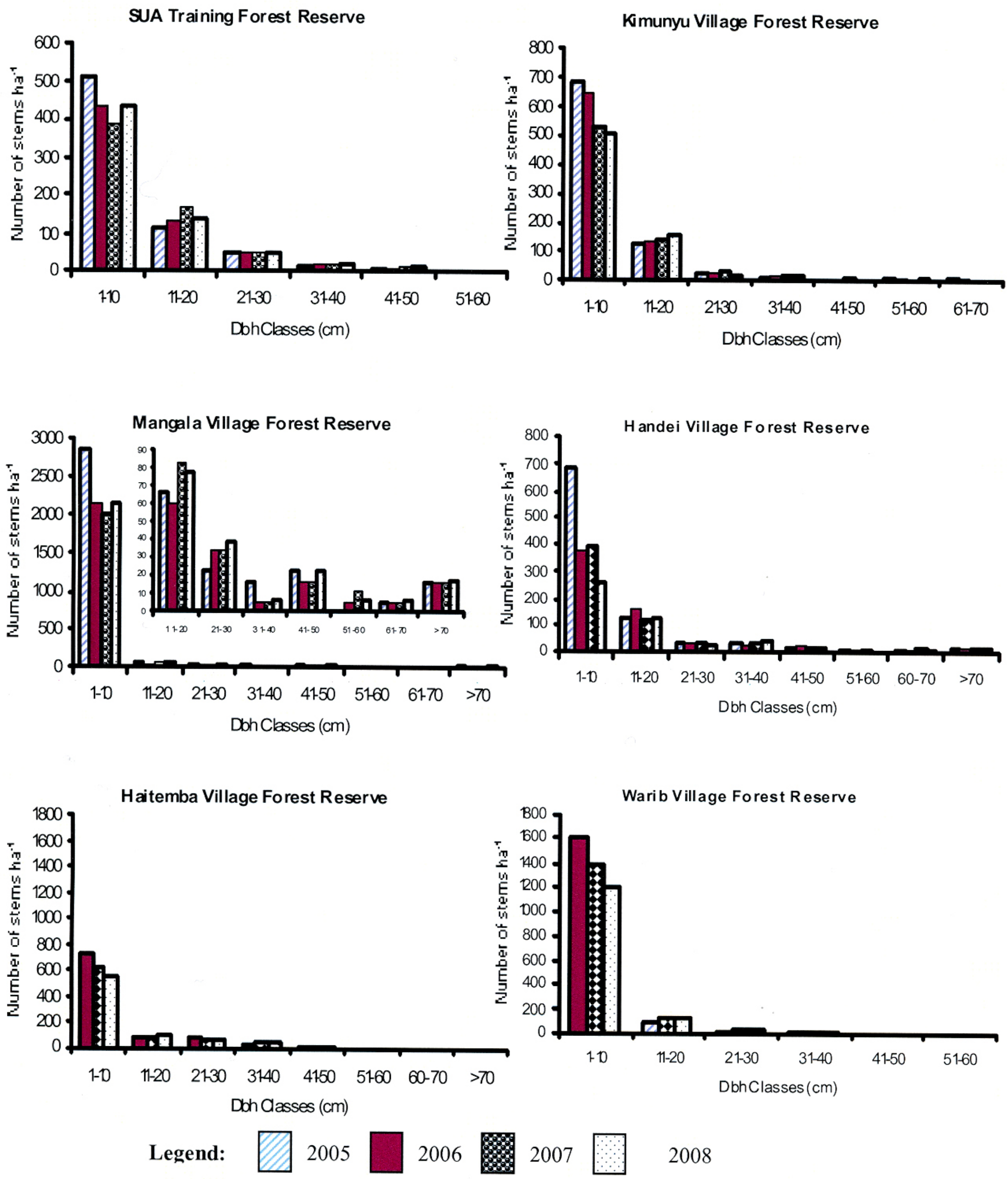
Table 5. Stand parameters for the studied forests (at p=0.10)

Forest Name	Vegetation type	Year	N	G (m^2/ha)	V (m^3/ha)	Biomass (t/ha)	Carbon (t/ha)
KSUATFR	Miombo woodland	2005	694.9±82 (12)	7.9±1.4 (17.5)	55.3±14.8 (26.9)	35.2±7.7 (21.8)	17,6±3.8 (21.8)
		2006	638.9±79.8 (12)	8.6±1.5 (17.3)	63.0±16.9 (28.8)	39.3±8.5 (21.6)	19,7±4.2 (21.6)
		2007	628.7±79 (13)	9.9±1.6 (16)	74.8±19.4 (26)	45.9±9.5 (21)	22.96±4.7 (21)
		2008	653±83 (13)	9.2±1.5 (17)	68,12 ±16.9 (26)	42.2±8.7 (20)	21.1±4.3 (20)
Kimunyu		2005	845,5±153.9 (18)	7,9±3.0 (37.7)	78,9±51.1 (64.7)	40,5±20.8 (51.3)	20.24±10.4 (51.3)
		2006	817,2±151.2 (19)	8,8±3.2 (35.9)	88,2±56.1 (63.5)	45,0±22.4 (49.8)	22,52±11 (49.8)
		2007	720±156 (22)	8.4±3 (36)	72.4±51.8(72)	39.8±20.6 (51.8)	19.91±10 (51.8)
		2008	701±160 (23)	8.2±2.7 (33)	73.5±45.8(62)	39.7±18.4 (46)	19.86±9 (46)
Mangala	Lowland forest	2005	2987.3±1331.2 (45)	21.7±15.2 (69.8)	260.5±121 (84.8)	151.1±128 (84.8)	75.55±64 (84.8)
		2006	2285.1±1328.5 (58)	21.7±15.7 (72.6)	263±227.0 (86.3)	152.6±131.7 (86.3)	76.3±66 (86.3)
		2007	2180±1492 (68)	23.2±15.8 (68)	275.8±230.8 (83)	159.9±133.9 (83)	79.95±65.6 (83)
		2008	2307±1264(55)	25±17 (69)	306.7±252.9 (82)	177.9±147 (82)	88.9±73 (82)
Handei	Sub-montane	2005	926.0±457 (49)	22.6±13.3 (59)	261.2±182.4 (69.8)	151.5±105.8 (69.8)	75.76±52.9 (69.8)
		2006	643.1±364.4 (57)	23.3±13.8 (59)	272.3±188.5 (69.2)	157.9±109.3 (69.2)	78.95±54.7 (69.2)
		2007	615±369(60)	23.3±13.8 (59)	279.2±192 (69)	161.9±111 (69)	80.96±55.6 (69)
		2008	488±239(49)	24.56±14.3 (58)	299.9±202(68)	173.9±117 (68)	86.96±58.7 (68)
Haitemba	Old grown miombo	2006	915.5±115.9 (13)	13.2±3.0 (23)	153.5±72.8 (47.4)	73.4±24.2 (33)	36.68±12.1 (33)
		2007	811±99 (12)	13.4±2.9 (22)	155.9±72.4 (46)	74.7±23.9 (32)	37.34±11.9 (32)
		2008	744±88 (12)	13.5±2.9 (22)	156.7±70.3 (45)	75.4±23.6 (31)	37.7±11.8 (31)
Warib	Re-growth miombo	2006	1742.7±325.6 (19)	8.2±2.3 (28.6)	45.4±24.2 (53.8)	31.7±13.1 (41.4)	15.83±6.6 (41.4)
		2007	1555.8±285 (18)	8.4±2.6 (31)	47.5±25.4 (54)	32.9±13.9 (42)	16.46±7 (42)
		2008	1479±258 (17)	8.8±2.8 (32)	55.1±34.3 (62)	36±16.7 (46)	17.99±8.3 (46)

The figures in brackets indicate precision levels of estimates i.e. confidence intervals as percentage of the mean value.

4.2.1 Number of stems per hectare

At Kitulangalo area (i.e. KSUATFR and Kimunyu VFR) where the dominant vegetation type is miombo woodland, the observed stems numbers per hectare (Table 5) is consistent with earlier studies done at the area (Nduwamungu, 1996; Zahabu, 2001; Chamshama *et al.*, 2004) as shown in Table 6, and other dry miombo woodlands (Frost, 1996; Malimbwi, *et al.*, 1994, Malimbwi, 1999). Also the distribution of stem numbers per hectare in both forests follows the usual expected reversed J-shaped trend (Figure 7). This is an indication of good forest regeneration and a recruitment trend which depicts presence of many small size trees and fewer large size trees, a common feature in naturally grown forests.



NB: For Mangala VFR a separate graph on top was used for the distribution of trees with more than 10 cm dbh since these were very few and masked by many small trees of less than 10 cm dbh

Figure 7. Distribution of number of stems per hectare for the studied forest.

Table 6. Observed stand parameters for similar forests

Forest name and location	**Vegetation type**	**N**	**G (m^2/ha)**	**V (m^3/ha)**	**Source**
Chome F.R, South Pare Mountains.	Montane / Lowaland	2040	44	658	Malimbwi and Mugasha, 2001
Shume-Magamba, West Usambara		1000	36	413	Maliondo *et al.*, 2000
Kwamkoro, East Usambara		468	58.9	655	Zahabu and Malimbwi, 1998
Kimboza, Uluguru		717	18	231	Malimbwi, *et al.*, 2005a
KSUATFR	Miombo	691	10.3	71	Nguwamungu, 1999
		619	10.2	78	Zahabu, 2001
Kitulangalo Gov. FR		1085	9	76	Chamshama *et al.*, 2004

Mangala VFR has more than 2,200 stems per hectare, which is greater than expected for a lowland forest (Zahabu and Malimbwi, 1998; Maliondo *et al.,* 2000; Malimbwi and Mugasha, 2001) as also shown in Table 6. The distribution of stem numbers per hectare observed for this forest also suggests that there are many small diameter trees of less than 10 cm dbh (Figure 7). In Figure 7, a separate graph on top for Mangala VFR was made to show the distribution of trees of greater than 10 cm dbh since these were masked by many (about 2000 stems per hectare) that are below 10 cm dbh. Presence of high regeneration is likely the result of past disturbances such as harvesting, wild fires and small scale agricultural encroachment into the forest area. During the fieldwork these sorts of disturbances were witnessed to have taken place in the past. The observed high regeneration is attributed to the fact that germination and recruitment of young forest is enhanced through increase of gaps, light, raised soil temperature, and reduced nutrient competition (Augspurger, 1984; Chadzdon and Robert, 1991). This indicates that the forest is recovering following management change from the district government to the villagers (as will be explained in Chapter 6).

Observed stem numbers in Handei VFR are comparable to other forests in similar site conditions as shown in Table 6. Their distribution also follows the usual expected reversed J-shaped trend (Figure 7), an indication of good forest regeneration and recruitment trend.

In Ayasanda village, Warib forest, which is composed of re-growth miombo woodland, has many stems per hectare compared to Haitemba old-grown miombo forest, as expected (Table 5). Presence of many small trees compared to few large trees in both forests also suggests active regeneration following disturbances (Figure 7).

Figure 7 also shows that there is noticeable sharp decrease of stem numbers for trees of less than 10 cm dbh between 2005 and 2006 compared to the decrease between 2006 and 2007 for the forests of KSUATFR, Mangala and Handei. This may be attributed to the occurrence of prolonged drought in the year 2005/6 that caused mortality of a lot of small trees in many of Tanzanian forests. The general conclusion is that in all these community managed forests, there is considerable regeneration going on following past disturbances. The general trend suggests good recruitment of trees from lower to higher diameter classes between successive years.

4.2.2 Stand volume, basal area, biomass and carbon

The average stand basal area, volume, biomass and carbon per hectare are given in Table 5. For the miombo woodland forests at Kitulangalo area the observed parameters are consistent with those obtained in earlier studies as shown in Table 6 (Nduwamungu, 1996; Zahabu, 2001; Chamshama *et al.,* 2004,) and other dry miombo woodlands (Frost, 1996; Malimbwi, *et al.,* 1994, Malimbwi, 1999).

The distribution of biomass by dbh classes shown in Figure 8, suggests that the structure of KSUATFR is good compared to that of Kimunyu VFR. While the regeneration and recruitment trend of the former between successive years shows that the forest is recovering following firm management, the harvesting in the village forest especially for trees of 41 cm dbh and above seems to have disturbed the forest recruitment trend. The harvesting happened illegally as detailed in Chapter 6. However the regeneration and recruitment trend for trees below 40 cm dbh in this forest is good.

Observed average stand basal area, volume, biomass and carbon per hectare for Mangala VFR are comparable to those observed for Kimboza forest (Malimbwi, *et al.,* 2005a) while those for Handei VFR are rather low compared to other forests in similar site conditions. For example, Zahabu and Malimbwi (1998), Maliondo *et al.,* (2000) and Malimbwi and Mugasha (2001) observed the volume per hectare of similar forest types ranging from 413 to 658 m^3/ha (Table 6). This indicates that the Handei forest was over exploited in the past. Although the distribution of these parameters by dbh classes generally shows J-shaped trend a normal feature for naturally grown forests (Figure 8), there are obvious discontinuities between classes also signifying over-exploitation of some preferred tree sizes in the past. However, the general trend between successive years shows that both Mangala and Handei forests are now growing with good recruitment trend between classes. This indicates the effectiveness of the current management.

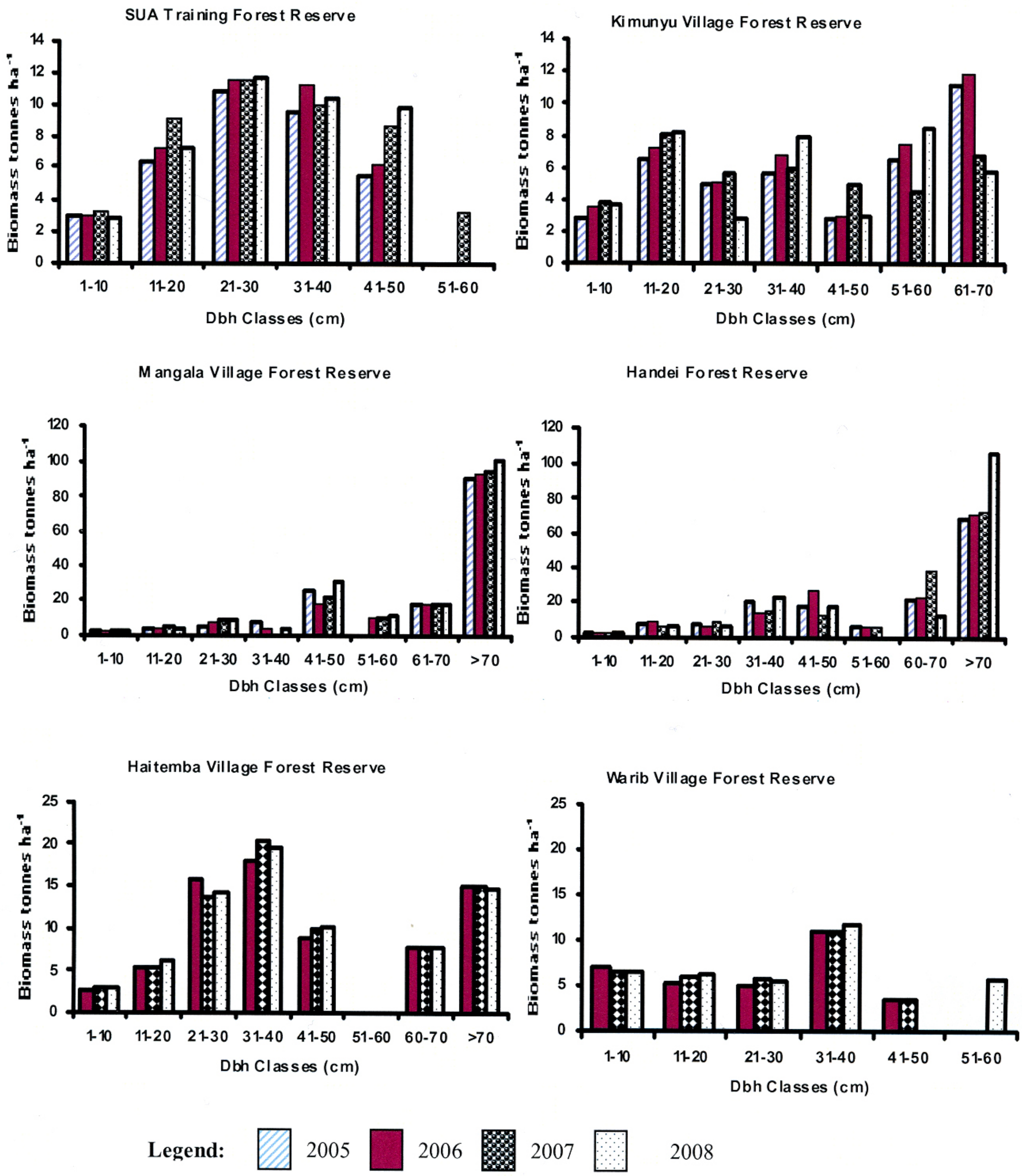


Figure 8. **Distribution of biomass per hectare by Dbh classes for the studied forests.**

As was the case for the stem numbers, other stand parameters for Haitemba and Warib forests in Ayasanda show significant differences between the two forests. Haitemba forest has almost twice as much standing volume, biomass and carbon compared to Warib forest. This was expected due to the fact that Warib forest is composed of small size re-growth miombo trees of mostly less than 40 cm dbh while Haitemba is dominated by old grown miombo with some large sized trees above 40 cm dbh (Figure 8). Figure 8 also shows that both of these forests have good stocking and recruitment for trees of less than 40 cm dbh indicating recovery.

The overall observation from the forests studied is therefore that there is considerable forest biomass and carbon stock in community managed forests. These stocks also increase between successive years indicating the effectiveness of the current management in protecting the forests.

4.2.3 Growth rates and carbon sequestration

In all forests except Kimunyu VFR at Kitulangalo there are annual increases in tree stocking levels and therefore carbon sequestration (Table 7). There is limited and contradicting literature on forest growth studies in Tanzania to offer comparison with the current study. For example, for the miombo woodland at Kitulangalo area, Ek (1994) reported a volume increment of 4.35 m^3/ha/year while Malimbwi *et al.,* (1994) estimated an annual growth rate of 7.4 m^3/ha/year. For the same area also, Malimbwi *et al.,* 2005c estimated the Mean Annual Increment (MAI) for the period of three years (1996-1999) to be 2.4 m^3/ha/year. A similar rate was found by Nilsson (1986) and Temu (1979) who estimated an annual growth rate of 1-2 m^3/ha/year for disturbed woodlands in Tanzania. Chidumayo (1988) reported a mean annual fuelwood increment of 1.96 m^3/ha/year for the dry miombo of Zambia. These studies reflect the fact that conditions vary greatly from place to place, and provide a realistic picture of the range of annual growth rates in the area. As shown in Table 7, the volume increments measured by this study for the KSUATFR between 2005 and 2008 were 7.7, 11.8 and 2.56 m^3/ha/year. Therefore at least the first and the last incremental rates are in line with findings of other studies although the middle value is on the high side. In view of the corroborating evidence from other studies, it was decided that this high value would not be used in the current study in the estimation of annual growth rate for this forest. Similar decisions were made regarding data for the other studied forests, as indicated in the remark column in Table

7. These inconsistencies in the observed growth rates in individual forests in the subsequent years may possibly be explained by human errors during dbh measurements but in this study checks for consistency were done when measurements were retaken in the following year of field assessment. Many years of systematic measurement would be needed to establish certainty on these growth rates.

Table 7. Carbon sequestration rate of studies CFM projects

Forest Name	Year	Volume Increment (m^3/ha/yr)	Biomass Increment (t/ha/yr)	Carbon Increment (t/ha/yr)	Remarks	Average Annual Increment	
						Biomass (t/ha/yr)	CO_2 sequestration (tCO_2/ha/yr)
KSUATFR	2005					2.8	5.3
	2006	7.7	4.1	2.1	√		
	2007	11.8	6.6	3.3	**		
	2008	2.56	1.5	0.7	√		
Kimunyu	2005						
	2006	9.3	4.5	2.3	√		
	2007	-15.8	-5.2	-2.6	***		
	2008	1.1	-0.1	-0.05	***		
Mangala	2005					4.4	8.3
	2006	2.5	1.5	0.75	√		
	2007	12.8	7.3	3.65	√		
	2008	30.9	18	8.95	****		
Handei	2005					5.2	9.8
	2006	11.1	6.4	3.2	√		
	2007	6.9	4	2.0	√		
	2008	20.7	12	6	****		
Haitemba	2006					1.7	3.2
	2007	2.4	1.3	0.7	√		
	2008	0.8	0.5	0.2	√		
Warib	2006						
	2007	2.1	1.2	0.6	√		
	2008	7.6	3.1	1.5	√		

Key on Remarks:
√ The measurements were okay
** There was something wrong with measurements for this year, data checked against measurements in the following year.
*** Illegal harvesting as explained in Chapter 6 Sub-Section 6.3.1.
**** There is something wrong with measurements for this year and data will be checked against measurements in the following year.

After the necessary data checks, Table 7 also shows that the low end value of MAI is typically 0.5 tons of biomass/ha/year. On average the rate of biomass increment is 2.8 tons/ha/year for the miombo woodland forest of KSUATFR which is equivalent to CO_2 sequestration of 5.3 tCO_2/ha/year. Biomass increment for Warib and Haitemba woodlands is 1.7 tons/ha/year, equivalent to CO_2 sequestration of 3.2 tCO_2/ha/year. For Mangala (lowland forest) and Handei (montane forest) the biomass increment rates are 4.4 and 5.2 tons/ha/year and the equivalent CO_2 sequestration rates are 8.3 and 9.8 tCO_2/ha/year. The variation in these sequestration rates among the different forest is due to tree growth differences influenced by soil type, climate, species composition and age of the stands.

For the Kimunyu Forest there was significant increment of forest biomass of 4.5 tons/ha/year, between 2005 and 2006 (Table 7). In the following year of assessment there was a loss of biomass of 5.2 tons/ha/year through uncontrolled harvesting. Management was therefore advised to review its forest protection strategies to prevent this over extraction, as detailed in Chapter 6.

From these findings, the main conclusion is that although there is enough evidence to support the statement that there is significant carbon sequestration in community managed forests, long time accurate observations are needed to substantiate actual amounts sequestered. Similarly it is observed that growth rates in natural forests are site specific with variations depending on soil, weather, species composition and age of the forest stands.

4.3 Current carbon stocks in unmanaged forests

In order to compare carbon stocks between managed and unmanaged forests, carbon assessment was also carried out in unmanaged forests. These unmanaged forests are forestlands in the immediate proximity of the managed forests that are assumed to have similar conditions. These are considered to be control sites where ‘business as usual’ scenario of the extent of forest degradation is determined to portray the situation that would have happened in the managed forests had they not been managed. This was possible for Kitulangalo area, Mangala and Handei forests. At Ayasanda there are no unreserved forests in the village and therefore no data was taken for comparison with Haitemba and Warib VFRs. The observed forest stand parameters for the unmanaged forestlands studied are shown in Table 8 and described in the following sections.

4.3.1 Unmanaged forests around Kitulangalo area

In the Kitulangalo area, a study carried out in the General Land by the Charcoal Potential in Southern Africa (CHAPOSA) research project (Malimbwi, *et al.,* 2005c) had investigated how the richness and wood stocking of preferred tree species for charcoal varied with proximity from the highway. The same lay out of plots was adopted in this study for the determination of annual rate of forest stock changes in the General Land. The results also enable comparison of the current carbon stocks between the General Land and the reserved forests.

Table 8. Current forest stands parameters for unmanaged forests in the studied sites

Name of the site	Year	Standing V (m^3ha^{-1})	Standing biomass (t/ha)	Annual biomass change (t/ha/yr)	Average biomass change (t/ha/yr)	Equivalent CO_2 emitted (t/ha/yr)
Kitulangalo area	2000*	46.2	23.1			
	2005	16.97	8.5	-2.9		
	2006	11.14	5.6	-2.9		
	2007	15.73	7.9	2.3		
	2008	14.06	7	-0.8	-1	1.8
	2006	2.03	1			
	2007	2.07	1	0		
Mangala	2008	2.04	1	0	0	0
	2006	243.8	121.9			
	2007	231.8	115.9	-6		
Handei	2008	230	121.7	-1	-3.5	6.5

*Source: Malimbwi *et al.*, 2005.

It has been observed that in a span of 5 years between 2000 and 2005 there was considerable decline of standing volume amounting to a biomass loss of 2.9 tons/ha/year (Table 8). A similar rate was also observed between 2005 and 2006. This may be explained by continuing harvesting for charcoal in the area. Some areas of the General Land had also been placed under shifting agriculture and during the process most of the trees were cleared and used for charcoal making. However, the situation changed in the following years when the stock was increasing, which could be due to depletion of preferred species and rampant regeneration following harvesting.

Supporting data from satellite imagery interpretation and a socio-economic study was available for both the supply and consumption sides, and CHAPOSA (2002) established that charcoal production and shifting cultivation in this area has been responsible for the degradation of the woodlands. However, the study showed that regeneration had occurred in areas previously cut provided they had not been converted to farmland. Therefore it was cautioned that in the face of increasing population and the demand for agricultural land, such areas are often not given enough time to regenerate and as such proper woodland management strategies were needed.

The present study observed exactly what had been predicted to happen in the area five years after the CHAPOSA study. Most of the woodlands have already been converted to farmlands because no appropriate management strategies were put in place in areas where trees were cut. This implies that the remaining woodland continued to be thinned for charcoal. Areas which have been harvested for charcoal production are easily converted to farmland for the shifting agriculture since large trees have already been cleared.

Table 8 also shows that the average stand values for unmanaged forest are low compared to those of managed forests (Table 5). This may be explained by the impact of continuing charcoal extraction as explained above. Apart from low stocking levels, tree species composition and abundance is also different. While there are a total of 56 and 47 different tree species for KSUATFR and Kimunyu VFR respectively, the total number of species in the unmanaged General Land is only 21. Further, *Xeroderris stuhlmannii* tree species contributes about 66% of the biomass in the unmanaged General Land (Figure 9). This species is not suitable for charcoal making but is a good timber species, so probably was intentionally left for future timber harvesting. The over dominance of a single species in a forest stand indicates degradation and loss of biodiversity.

These woodlands however, have high *in situ* regeneration potential. The data shows that a change in forest management from open access to a village reserve has to a great extent succeeded to curb degradation in the area. The Kimunyu VFR that was once a General Land forest is now being managed by local communities and shows significant recovery.

4.3.2 Unmanaged forests around Handei and Mangala Village Forest Reserves

Table 8 shows the standing volume and biomass for the unmanaged forests around Handei and Mangala forests. While the standing forest stock in unmanaged forest at Handei is almost equal to that of reserved forest, the biomass stocking in unmanaged forests around Mangala is very low. This is because the General Land around Handei forest is in a similar condition to the reserved forest, while in the Mangala area the unmanaged forest around is frequently interrupted by agroforestry systems in which some subsistence agriculture is done, a practice which has been carried out for many years now. These farms, of course, include some trees as part of the local agroforestry practice. They therefore form alternative sources of woodfuel and timber for construction, probably reducing pressure on the forest a bit.

There is also a clear indication of high tree species diversity in managed compared to unmanaged forests in these sites (Figure 9). Only 7 different tree species were encountered for the unmanaged forest at Mangala while the reserved forest had 35 species. At Handei 41 different tree species were found in the forest reserves and 26 species in the unmanaged forest. Figure 9 also shows that in unmanaged forests at these sites *Ficus sp* (47%) and *Annona sp* (78 %) over-dominate the General Land at Handei and Mangala respectively. This also signifies the low diversity in these forests compared to reserved forests and the effectiveness of forest management when placed under local communities compared to open access situation.

4.4 Degradation rates on unmanaged forests

Table 8 shows the forest standing volume and biomass for the unmanaged forests observed in different years up to 2008. The trend of the data shows that the stocking levels are in fluctuation with an average net biomass loss of 1 and 3.5 tons/ha/year equivalent to CO_2 emission of 1.8 and 6.5 tons/ha/year for the woodland forests at Kitulangalo and the Lowland and montane forests of Handei. The unmanaged forests at Mangala show almost no change in terms of stocking levels.

As pointed out in Sub-Section 4.3.1, the rate of annual biomass loss for the unmanaged woodlands at Kitulangalo area between 2005 and 2006 was found to be 2.9 tons/ha/year (Table 8). This is equivalent to a stand volume loss of 5.83 m^3/ha/year which is also similar to the rate obtained for the six years period between 2000 and 2005. However thereafter, there is an increase in stand biomass of 2.3 tons/ha/year which was again followed by a decline of 0.8 tons/ha/year. The first trend is explained by the depletion of trees of harvestable sizes towards the end of 2006 and subsequent high regeneration of trees. The fact that there was subsequently a decline indicates that, there are a lot of dynamics happening in these unmanaged forests. Long time observations are therefore needed in order to draw up firm conclusions on the observed trend.

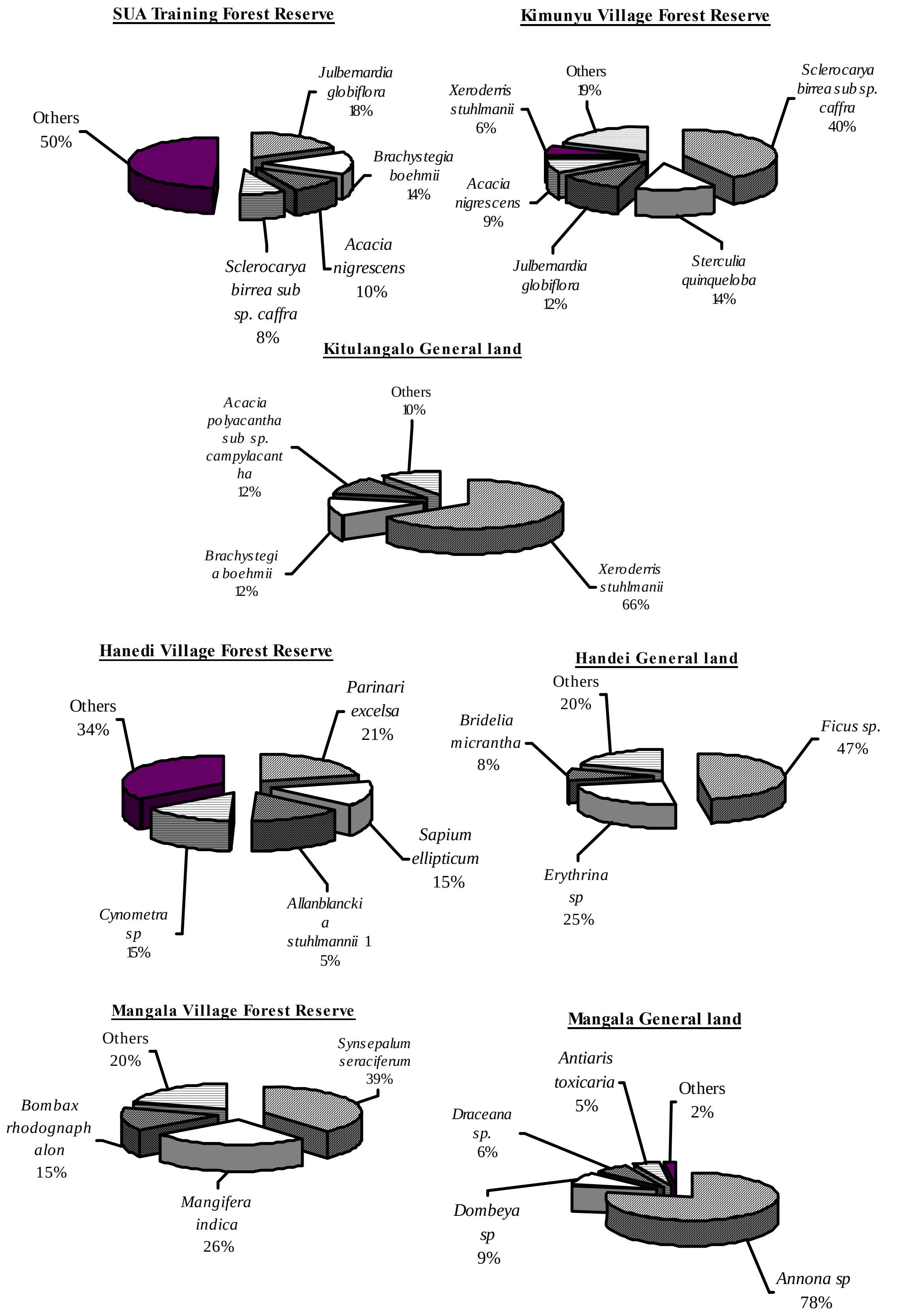


Figure 9 Tree species dominance in terms of biomass content for the studied forests.

Luoga *et al*., (2002) in a one time study estimated a slightly higher rate of annual removal of about 6.38 m^3/ha/year from the General Land in this area using a method involving counting of cut stumps. However, growth monitoring studies are usually based on data from continuous measurements in permanent sample plots (MacDicken, 1997; Weyerhaeuser, 2000; IPCC, 2003; Brown, 2003). Observations from only one point in time may be biased by some specific driving factors that may not necessarily be representative.

Based on forest area change, FAO in their Global Forest Resources Assessment report of 2005 estimated an annual forest loss for the entire country of 1.1% (equivalent to the volume loss of -0.04 m^3/ha/year) between 2000 and 2005 (FAO, 2006). This rate is very low as it considers only deforestation and not degradation which also contributes significantly to loss of forest stock. Also since it considers only the change in forest area, it does not take into account the recovery potential of the forests following disturbances. The rate of forest loss from selective harvesting that is the main cause of forest degradation as well as the forests' growth potential can only be accurately assessed from continuous forest assessment. This information is lacking for natural forests of different species and mixed ages because continuous forests assessments are usually not carried out in Tanzania, as in most developing countries.

4.5 Leakage

One of the important observations from this study is the clear trend of higher stocks and positive sequestration in managed forests as compared to unmanaged forests. The unmanaged forests in this case are considered as control sites that portray a 'business as usual' situation i.e. what would have happened in the managed forests in the absence of management. However, the question is whether they are real control sites or whether what is measured is in fact 'leakage'. It is possible that a village might have improved the status of its managed forest because it has shifted the harvesting to other areas outside the project area, a phenomenon known in climate research as 'leakage'. Much depends on what constitutes the project area and where the boundaries of the system are. For the CBFM forests that are under village management, if the harvesting is shifted from the reserved forest to the unmanaged forestland within the village, then rates of off-take in the unmanaged forestland within the village would increase. If the entire village is treated as one project and carbon stock were measured in all its forests, both managed and unmanaged, this shift will not be treated as ‘leakage’ as the effects would be balanced out in the full village carbon accounts. ‘Real leakage’ is therefore when the harvesting shifts outside the village boundaries, and is therefore not measured. This is likely to happen if the neighbouring villages have no proper land use management plans including forest management through CBFM. There is also a possibility for the harvesting to be shifted to the government forest reserves that are not under JFM. In order to control ‘leakage’ therefore, it is important for the entire country to practice CFM. This is happening for example in the mid-hills in Nepal, where all the forests are under sustainable management by local communities with no area available for ‘leakage’ (Karky, 2008).

The CBFM situation is however different from what might happen if a private forest is established within the village where the shift of activities as a result of project management is considered as ‘leakage’ just outside the boundaries of the forest. With such a situation it is difficult to account for and to control ‘leakage’. This underlines one of the strengths of a country approach for REDD policy under which the problem of ‘leakage’ is eliminated since a whole country is considered as a single project. But even with this country approach, ‘leakage’ control and accounting for individual private projects is still controversial. The CBFM approach for REDD therefore, makes a lot of sense since it provides, in principle at least, a mechanism for internal ‘leakage’ control. However, the overall assumption with this national approach is that forest management will result in overall higher productivity and be able to supply enough wood products internally.

4.6 Summary

The findings of this study show that forests under CFM projects have considerably greater carbon stocks than unmanaged forests. For example, while the biomass stock in 2008 for KSUATFR was 42.2 tons/ha, that of unmanaged forest in its proximity was only 7 tons/ha. The reason for higher stocking in CFM is that these were much degraded a few years ago and were therefore handed over for village management. As a result they are now beginning to recover.

The observed low end value of biomass increment is typically 0.5 tons of biomass/ha/year in managed forests. On average the rate of biomass increment is 2.8 tons/ha/year for the miombo woodland forest of KSUATFR which is equivalent to the sequestration of 5.3 tCO_2/ha/year.

Biomass increment for Warib and Haitemba woodlands is 1.7 tons/ha/year equivalent to sequestration of 3.2 tCO_2/ha/year. For Mangala (lowland forest) and Handei (montane forest) the biomass increment rates are 4.4 and 5.2 tons/ha/year and their equivalent CO_2 sequestration rates are 8.3 and 9.8 tCO_2/ha/year. The variation in these sequestration rates among the different forests is due to tree growth differences among them which are influenced by soil type, climate, species composition and age of the stands. For unmanaged forests the trend of the data shows that the stocking levels are fluctuating with an average net biomass loss of 1 and 3.5 tons/ha/year (equivalent to CO_2 emission of 1.8 and 6.5 tCO_2/ha/year) for the woodland forests at Kitulangalo and the lowland and montane forests around Mangala and Handei VFRs. The number of individual tree species in managed forests is also higher compared to unmanaged forests, further indicating over-utilization in unmanaged forests.

The implication of these results is that if ‘business as usual’ had been allowed, the managed forests would have acquired the status observed in the unmanaged forests. That is to say, due to competing uses such as shifting cultivation and harvesting for firewood and charcoal, carbon emissions would have been much higher. However, it must be said that it is difficult to distinguish to what extent the situation in the unmanaged forest reflects the real ‘business as usual’ or ‘leakage’. This is because some of the activities formerly carried out in the now-managed areas might have been displaced to these unmanaged sites. The research was not able fully to separate out these facts, and this merits further study.

Another important observation from this study is that although general trends are clear, differences in rates of increase or of loss between years was observed, and it is not entirely clear whether these are due to real variations in stock change rate or measurement error. Long term observations therefore would assist in developing a stronger trend line.

Chapter 5
Carbon Assessment and Monitoring by Local Communities

5.1 Introduction

As pointed out in Chapter 1, most studies that involve carbon assessment in forest, employ professionals to carry out measurements because this is considered to be a professional activity which requires highly specialized skills and education. This Chapter addresses research question two to examine whether local communities i.e. villagers and their local supporting organizations may be able to assess and monitor carbon sequestered in their forests at a much lower cost compared to the professionals. Local communities in 4 locations in Tanzania were selected to carry out carbon assessment and monitoring. A field forest inventory guide on procedures and techniques for carbon assessment and monitoring by local communities was developed (see Chapter 3 on the description of this field forest inventory guide, also Appendix 2). The techniques utilise mobile GIS technology on handheld computers. Experimentation with the field forest inventory guide was done in the different case studies to determine to what extent villagers can, after a short training accurately map the forest area, stratify the forest by ecotype, accurately locate permanent sample plots using GPS, measure parameters relating to forest biomass in the field using standardized procedures, reliably record all this data, and retrieve the permanent sample plots for future assessment. Another aim was to find out to what extent and for what tasks additional (external) support is needed for these tasks. Further the study determined the reliability of estimated forest parameters and the costs for forest carbon assessment by local communities compared to professionals.

5.2 Selection of the trainees

The selected case study villages were approached using contact persons who were working for local organizations fostering CFM activities in the areas. These contact persons together with a team of 4 to 7 villagers participated in the training on carbon assessment with the use of the handheld computers (Table 9). The trainees from the villages were selected by the village environmental committees mostly from among themselves. Only three of them had secondary school education (Halima Kipande in Ludewa, Shabani Chamuungwana in Mgambo and Ally Juma at Ayasanda), the rest had either primary school education or had never had opportunity to attend formal education at all. Shabani Chamuungwana in Mgambo village has a certificate in forestry in addition to secondary school education. Involvement of women was also given priority since if not emphasised they are not given chance to participate. Efforts were therefore purposely made to have a good number of women in each group. About one third of all the trainees were women. Further, the trainees from the villages were all subsistence farmers based permanently at their villages. Permanent residence at the village is very important so that the same team can be used each year for monitoring the forest carbon.

Table 9. List of trainees for forest carbon assessment and monitoring in the studied villages

Forest Name	Village Name	Contact person (s)	No.	Village trainee name	Age
KSUATFR and Kimunyu VFR	Gwata-Ujembe	Mr. Hassan Mwendua & Juma Athumani Forest Guards for the KSUATFR	1	Sarah Amani (F)	29
			2	Pili Joseph (F)	38
			3	Mwajuma Mrisho (F)	30
			4	Juma Athumani	24
			5	Adamu Shomary	38
			6	Fatuma Hemedi (F)	25
			7	Jackson Milambo	35
Mangala VFR	Ludewa	Mr. Enos Eliakimu Field Forest Officer for Uluguru Mountains Biodiversity Conservation Project (UMBCP) under Wildlife Conservation Society of Tanzania (WCST)	1	Mgoa O. Kipande	40
			2	Yusufu Digaru	22
			3	Halima A. Kipande (F)	33
			4	Mrisho Saidi	38
Handei VFR	Mgambo	Mr. Shabani Chamuungwana A forester with a certificate in forestry and a resident at the village	1	Omary Maneno	49
			2	Shabani Chamuungwana	35
			3	Jestina Joseph (F)	28
			4	Hamisi Ally	33
			5	Mama Teresia (F)	52
Haitemba & Warib VFR	Ayasanda	Mr. Maanga, J.K & Mr. Eward, E of LAMP and Mr. Slaa, a division catchment forester	1	Sarah Nante (F)	65
			2	Ayubu Sani	35
			3	Juma Taliyani	23
			4	Daniel Cosmas	31
			5	Ally Juma	25

5.3 The training

For the planning of forest inventory, forest maps formed one of the basic requirements. In villages with no forest maps, these had to be drawn. Therefore, the first part of the training was on the use of handheld computers for mapping. This was then followed by the training on basic forest mensuration techniques and data recording.

The entry point was introducing the trainees to the project activities and the whole idea of forest assessment and monitoring. This introductory part was attended also by other members of the village, mostly the village leaders and other village environmental committee members. In all such meetings the idea was welcomed as villagers appreciated the need to have scientific data on the growing trees stocks of their village forests. They were also told about the prospects of getting financial income from the carbon stored and sequestered by their forests, although it was stressed that this was a future opportunity and not yet certain. Thus one of the purposes of the research is to examine if the local communities can provide forest carbon data that is of sufficient quality to enable them to participate in the carbon trading in the future, should CFM be credited.

5.3.1 Training on the use of handheld computers

The handheld computers basically work in the same way as normal desktop or laptop computers. None of the village trainees had ever come across a computer, let alone used one before. As such the first step was to introduce them to basics; how it works (e.g. on-off button). They were then introduced to ArcPad GIS computer program and the Global Positioning System (GPS). The trainees were then taught how the system could be used in carbon assessment and monitoring by marking of the forest reserve boundaries and delineation of different vegetation zones, locating permanent sample plots, and recording measurement data on trees, regeneration, herbs/grasses and litter in the plots. They also had opportunity to practise how to operate the system. This introductory training took one day in each village.

Thereafter, for seven consecutive days for each village, the trainees were taught and had opportunities to practice the use of the system using user manuals in Kiswahili language (Appendix 4). The manual outlined all the steps to be done, from the switching on of the handheld computer, to the carrying out of the different applications.

The trainees were very cooperative and keen to learn on how to operate the system. To them operating a computer for the first time was very exciting and they felt privileged to be selected to do this from among the fellow members of the village. They were also supplied with training material such as handbooks, pens and coloured printed manuals. The village trainees were paid about $ 5 as their daily wage which was also very much appreciated. In Tanzania normally a wage is paid on per day basis. The official government rate paid as a daily wage for hiring local labourers in the village areas is currently about $ 2.5.

Although there were cases of late coming and absenteeism during the training, the trainees, even the ladies, who had family obligations such as house keeping and cooking for their families, were able to cope very well. Just within the 7 days of the training, the trainees were able to use the user manuals and performed different activities for themselves.

However, the following difficulties were observed:

- the manual outlined different activities as if they were done separately in the field. As such the trainees faced difficulties to sequentially switching between different forms in the handheld computer system;
- tree data were entered separately for every tree, this was a very tiresome work for the trainees who had to log in data for all trees in a plot; and,
- entering alphabetical data to the computer was also difficult as the trainees were using the computer for typing for the first time. They had difficult navigating a qwerty keyboard.
- trainees were also helpless when something went wrong with the system. Common troubles were:
    - tapping a wrong button;
    - poor GPS signals;
    - alarm alerts especially for GPS poor signal reception; also when a value was not entered in the form; and,
    - on screen keyboard hiding some boxes or forms for filling the data.

In the light of these difficulties some remedies were made. These included modification of the user manuals to include more detailed steps on switching between different forms on the system. A trouble-shooting section was also included to provide solutions to the common problems encountered. However, it was found that the practice of logging in all the data to the handheld computer in the field environment was the most difficult task. Therefore only a plot form which records the location of a plot on a map, together with its details was filled into the database in the computer in the field. The rest of the data was recorded in pre-prepared paper field forms and later logged into the computer database at home by the staff from the supporting organizations.

5.3.2 Training on basic forest mensuration[8] techniques

Commonly accepted principles of forest inventory, soil sampling and ecological survey and in particular those that follow IPCC Good Practice Guideline (IPCC, 2003) were used. These included standard sampling procedures and techniques to measure different forest stand variables in the field. Although the technical staff from local supporting organizations might have knowledge of most of these, it was necessary to share experiences and follow common procedures. As such, all participating technical staff first practiced the basic forest mensuration techniques to measure diameter at breast height (dbh), total tree height (h) and distance on sloping terrain. During that practical exercise the trainees from the villages were taken aboard. The field forest inventory guide that outlines all the procedures for carbon assessment and techniques to be employed was followed. Using the standard procedures detailed in the field forest inventory guide, measurements were taken for both managed and unmanaged forests.

5.4 Steps for carbon assessment in managed forests

As stated above, the field forest inventory guide provides the procedures to be used for forest carbon assessment. These are organized in steps. The first step is to divide the forest area into strata of areas that are distinctly different from each other in type and which will almost certainly have different amounts of carbon stored. Then in each stratum, a pilot survey is made to estimate the variance in the tree stocking. This will allow an estimate to be made of how many sample plots are required for each stratum based on the observed variance. The number of sample plots needed per stratum to obtain a particular level of certainty in the results is then calculated and allocated systematically within each of the stratum, on the geo-referenced base map.

The actual field work will then start by laying down the sample plots on the ground using compass and tape measure. Data should be recorded that allows for the plot to be found again

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[8] The science of forest measurement is also commonly referred to as forest mensuration

at a later date. This is done by way of the handheld computer system or a stand alone GPS receiver as well as a description of characteristics of the plot and any available landmark. From these plots tree measurements are then carried out and recorded. It may also be important that weight measurement of shrub, herb and litter samples from subplots are also taken and recorded. Finally, soil samples can also be taken randomly within the plot, bagged and labelled. A record of the total time taken including the travel time to the plot is also made.

The experience with the implementation of these procedures from the villages studied is given below. As it will be shown in Section 5.6 the trainees were not able to perform all of these different activities. Therefore, alternative ways for carrying out a number of tasks were devised.

5.4.1 Forest stratification

It is required that the project area should be stratified into sub-populations or strata that form relatively homogeneous units, if the forest area is not homogeneous. Stratification can increase the accuracy and precision of the measuring and monitoring in a cost-effective manner through diminishing the sampling effort necessary to achieve a given level of confidence (MacDicken, 1997; Brown, 2003; IPCC, 2003). The community measurement teams in the villages involved in this study were asked if they could stratify each of their forests based on vegetation differences and stocking levels. In all cases they agreed that their forests are homogeneous in terms of vegetation types and there is no need to have different stocking levels stratification. However, field observations later revealed that those forests were not homogeneous because some parts were open while others were completely covered by trees. What made the local communities fail to stratify them is probably the discontinuity of the strata, as they occur in patches.

History reveals that the VFRs studied were delineated from the villages' General Lands. The forests in those General Lands were disturbed through exploitation of various forest products, shifting agriculture, and establishment of settlements. These activities were halted when the forests came under CFM although evidence of their existence in the past is still found inside the forests (Figure 10). The general pattern of the forest is fragmentation of degraded and intact patches which are too small to delineate on a map or to stratify. This results in a high variance in the biomass data collected and hence generally low precision of stand parameters as shown in Section 5.7.

If different vegetation strata were identified, it was also required to include them on the forests boundary maps. The maps are also important for the smooth running of the day to day forest management activities. Forest boundary maps for Handei, Mangala, Warib and Haitemba VFRs were recently prepared through the support of Amani Nature Reserve, Uluguru Biodiversity Conservation Project and LAMP Babati respectively. In Gwata-Ujembe village, all trainees acknowledged that the forest map for KSUATFR was outdated and that they had no map at all for Kimunyu VFR. They therefore recognised that they can use the handheld computer system to get more updated boundary maps of both forests. The mapping exercise was then done separately for KSUATFR and Kimunyu VFR before the pilot carbon assessment began. One day was enough to walk around the boundary of each forest to map its extent.

Figure 10. A portion of Handei VFR that was once a farm, and still has some un-attended banana trees.

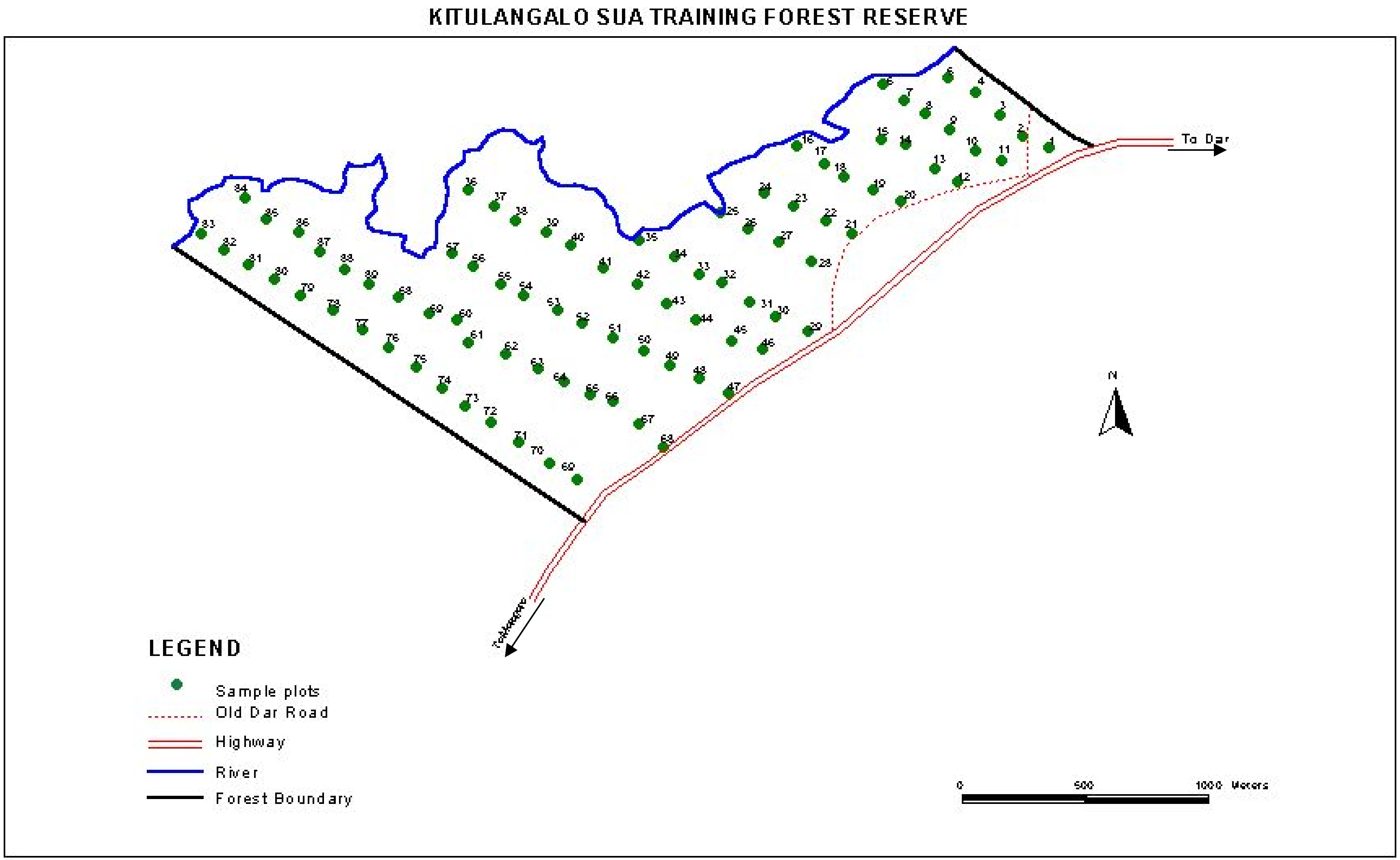


Figure 11. Forest boundary map and plots layout in Kitulangalo SUA Training Forest Reserve. Map prepared by the villagers using mobile GIS techniques.

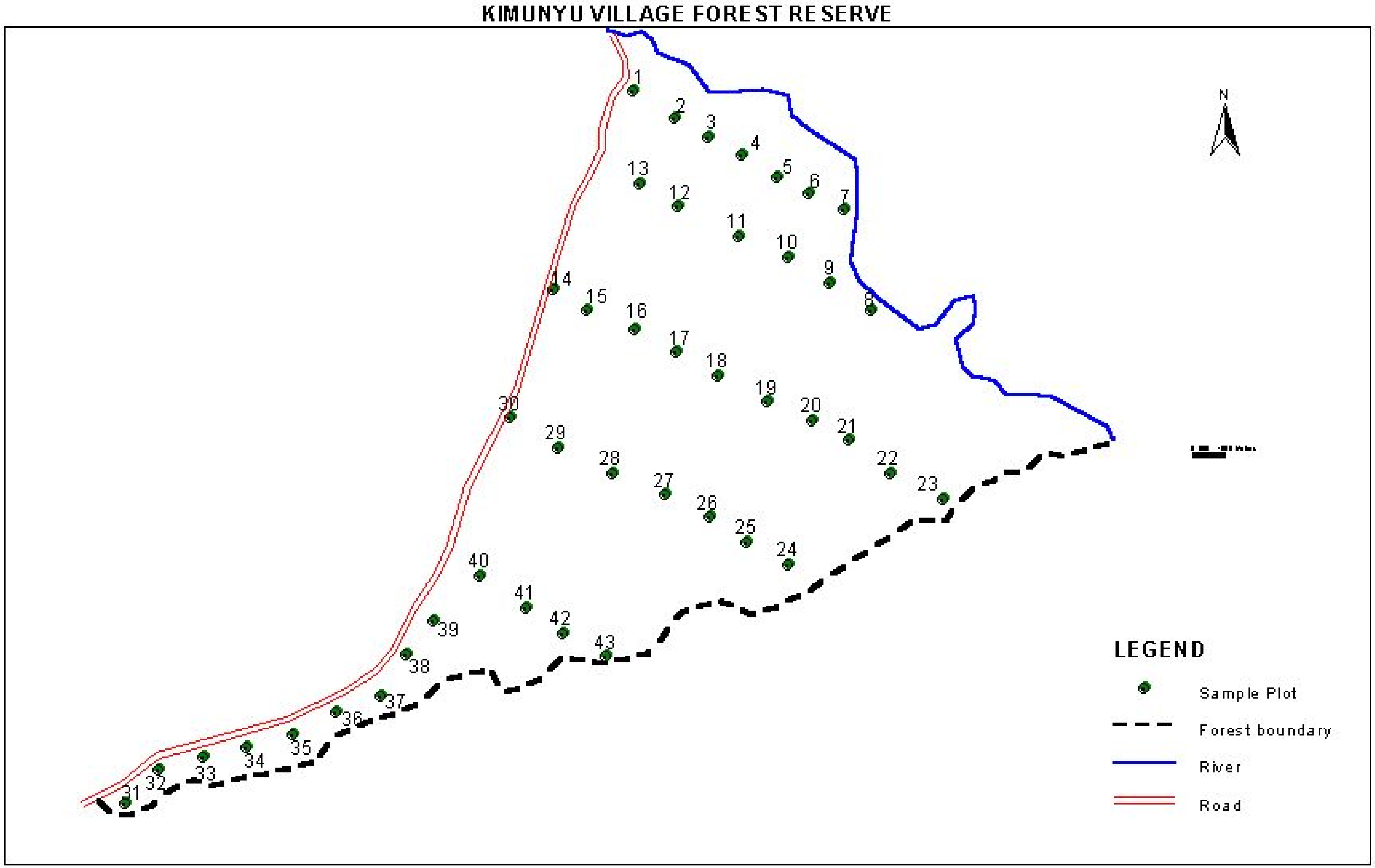


Figure 12. Forest Boundary map and plots layout in Kimunyu VFR. Map prepared by the villagers using mobile GIS techniques.

The trainees were able to operate the system including saving the field shape files to the ArcPad database files. However, downloading the field shape files to other mapping software such as ArcView for further processing and printing was done by GIS technicians at Sokoine University of Agriculture (SUA). Such technicians are also available in other higher learning institutions such as University of Dar es Salaam (UDSM), University College of Lands (UCLAS) and Forest and Beekeeping Division (FBD) headquarters. The resultant maps for KSUATFR and Kimunyu VFR are shown in Figure 11 and 12. The maps also show permanent plots layouts in these forests as it is described in Sub-Sections 5.4.2 and 5.4.3.

5.4.2 Pilot survey to calculate variance

For estimation of variance of carbon stock of the main carbon pool in forests i.e. trees, stand basal area[9] was determined from 15 randomly laid out sample plots. The shape of the plots was circular with different sizes depending on the vegetation of the forests as follows:

- For the dry miombo woodlands, all trees greater than 1 cm diameter at breast height (dbh) were measured all over a plot of 5.6 m radius, i.e. with a total area of 100 m^2.
- For the montane and lowland forests, concentric plots of varying radius were used depending on the sizes of trees. Measurements of dbh of trees/shrubs were done in a plot of 5.6 m radius for all trees of greater than 5 cm dbh, while trees of less than 5 cm but greater or equal to 1 cm dbh were measured in a plot of 2 m radius.

Concentric plots were used for montane and lowland forest since these were observed to have many small trees and few large size trees. It is a standard procedure to adopt different plot sizes depending on the vegetation type. In this case, this is because woodland forests were expected to have few small diameter trees of less than 5 cm dbh and vice versa for montane and lowland forests.

It was difficult to enter data on each tree immediately into the handheld computer in the field as observed during the training. Therefore a paper record was made by the villagers and data entered to the computer later at home by the staff from the supporting organizations who were among the trainees. This increased the field efficiency and the trainees were able to collect all the pilot data needed after only one day in each forest. Existing checklists for the

[9] Stand basal area is the cross-sectional area of all trees at breast height (1.3m) per hectare of a forest. It is a summary of the number and size of trees in a stand and therefore relates much to stand volume and biomass.

areas were used to get the botanical names for species identified by the community teams. One day was spent for matching local names to botanical names, assigning species identification codes and punching the data to the computer for each forest. This work was done by the staff from the supporting organizations.

With data from the 15 plots, it was possible to calculate standard deviation and average basal area per hectare. Then the number of sampling units (n) required to attain a desired precision at sampling error (E) of 10% is given by:

$$n = \frac{CV^2 t^2}{E^2}$$

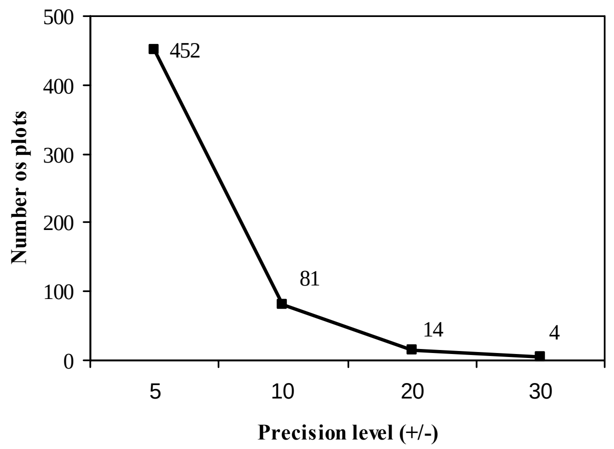
Where: CV = Coefficient of variation = standard deviation/mean

t = the value of t obtained from the students' t distribution table at n-1 degree of freedom of the pilot study plots at 10% probability.

For LULUCF projects, it is recommended by IPCC to adopt a sampling error of 5% which is expected to give estimates within the precision of ±10% of the mean with 95% confidence (IPCC, 2003). Given the nature of CFM forests with fragmented degraded and intact patches as shown in Sub-Section 5.4.1, the 10% sampling error rather than 5% was used as it considerably reduces the number of plots required as shown in Table 10, but this means compromising the level of precision as shown in Figure 13 by Brown (2002). However, the level of precision required for carbon inventory has direct effect on inventory cost. With 5% sampling error four times as many plots would be required (Table 10) and that implies more time needed for the inventory, which of course greatly increases the costs. It is foreseen that the market value for CO_2 credits from REDD policy might be less than that of other mitigation options such as CERs from CDM projects (Stern, 2007). A compromise may therefore have to be made between the precision desired and the costs of a REDD project including the inventory cost. Therefore, bearing in mind the cost element and ease of handling the plots by local communities, it was decided to adopt the 10% sampling error.

Having decided on the use of 10% sampling error the calculation of the number of plots is done. For consistency of the computations of pilot data from all the sites, a pre-designed database on Microsoft Access program was prepared. This database does these calculations by replacing the default data file stored on the computer. This was simple for the staff of the supporting organization to operate. At the end of this step, the number of plots, *n*, needed for each forest was obtained and distributed systematically in the respective geo-referenced base maps of the forests as shown in Table 10. This was done in the office by the staff of the supporting organizations following instructions from the field methodological guide.

For the KSUATFR, the highway which formed the southern border of the forest with a ground distance of about 3,300 m was taken as a basis for transects layout. A total of 11 transects were established at an interval of 300 m. In order to space out these transects the first transect was laid out at 150 m from the eastern boundary of the forest. The total transect length was estimated to be about 13,350 m. For the 89 plots to be established, the interval between plots was 150 m. The first plot was laid out at half plot interval for better spacing out of the plots along the whole transect length. Figure 11 illustrates this layout. Forward bearing of the transects was 300° while the back bearing was 120°. Similarly, plots for the rest of the forests were established as detailed in Table 10.



Source: IPCC, 2003

Figure 13. Relationship between the number of plots and precision level

Table 10. Number of permanent sample plots for the CFM forests in the studied villages

Forest name	Area (ha)	Number of plots		Distance btwn transect	Distance btwn Plots	Forward bearing	Back bearing
		E=5%	E=10%				
SUA Training FR	600	348	89	300	150	300°	120°
Kimunyu VFR	420	181	43	500	170	320°	140°
Mangala VFR	28.5	75	18	225	70	0°	180°
Handei VFR	156	77	19	286	218	0°	180°
Warib	50	103	25	220	74	0°	180°
Haitemba	500	254	67	300	120	0°	180°

5.4.3 Locating permanent sample plots on ground

Actual forest carbon measurement began when the group met at the starting point of the first transect. Then a sequence of activities started as shown in Figure 14. At first a description of the starting point of a transect and associated landmarks was made and recorded. A foreman in a group then sighted the direction and walked forward on the transect. The other members of the group followed and measured the appropriate inter-plot distance using measuring tape or a stand alone GPS. The terrain in the woodlands forests at Kitulangalo area was relatively flat and therefore correction for slope while measuring distances was not necessary. For the woodlands in Ayasanda village, Handei montane and Mangala lowland forests there were high variations of slope but their corrections would have complicated the work to be done by local communities. As such, where possible, distance measurements were done by way of a stand alone GPS that reads horizontal distances between two points automatically.

Plots of the same size as those used during the pilot survey were established on the ground and their dimensions fixed using measuring tapes and compasses. While the plots edges were temporarily marked by coloured pieces of paper/cloth, the centre was marked by brightly painted poles. The plot was then given an identification code and a description of its characteristics and any landmark recorded on the computer. While the handheld computer system worked perfectly well in woodland forests at Kitulangalo and Ayasanda, it hardly worked for Handei montane, and Mangala lowland, closed forests, due to poor GPS signals. As such other techniques of marking the plot centre such as the use of different land marks and stand alone GPS were used. Correct description of the plot especially the plot centre was very important for finding it again for repeat measurements. This was carefully done by recording trees clockwise from the direction of transect and from the plot centre, and descriptions of any nearby permanent landmark such as a ditch or a big stone were recorded.

5.4.4 Measurements taken from the permanent sample plots

As described earlier, trees, shrubs and saplings greater than or equal to 1 cm dbh were measured for dbh within the sample plot of 5.6 m radius for the woodland forests. For the montane and lowland forests measurement of dbh of trees greater than 5 cm dbh was done in the entire plot of 5.6 m while trees of 1 to 5 cm dbh were measured in a subplot of 2 m radius. In addition to dbh measurement, total tree height of a sample tree (a sample tree, is a tree closest to the plot center) was measured for each plot for the montane and lowland forests. This was because the volume allometric equation for these forests requires a height variable for individual tree volume computations. For the woodland forests individual trees heights were not required because the biomass equation uses dbh variable only as an independent input. This information was recorded on paper and later logged onto (pre-designed) data sheets on the computer.

It was also required to take samples for other carbon pools such as herbs, grasses, litter and soil for biomass determination. Data on herbs, grasses and litter were collected but their analysis was not possible because of lack of facilities at local level. The samples were supposed to be oven dried to constant moisture content and the biomass determined. Usually this is done in scientific laboratories that are not available at local level.

5.5 Carbon assessment for unmanaged forests

As pointed out in Chapter 4, immediate forestlands in proximity of reserved forest were considered for forest carbon assessment of unmanaged forests. This was possible for Kitulangalo area, Mangala and Handei forests. At Ayasanda, there are no unreserved forests in the village.

At Kitulangalo area, charcoal is the most important product from the forests. It is usually extracted from the General Land with free access, where the best trees for charcoal have been depleted close to the Dar es Salaam - Morogoro highway (Monela *et al.,* 1993, CHAPOSA, 2002, Malimbwi *et al.,* 2005c). Stratified random sampling was therefore applied for assessing and monitoring forest carbon changes in the General Land of this area. The parameter used for the stratification is distance from the highway into the General Land. The first two strata were laid on opposite sides of the highway while the others were at 5 km, 10 km and 15 km interval away from the highway on either sides of the selected access road to the General Land in the village.

In each stratum a transect was laid out approximately perpendicular to the highway or access road. In each transect a cluster of four plots was laid out at an interval of 500 m x 240 m. Figure 15 illustrates this layout. The plot size and shape as well as trees measurements were the same as those used in the reserved forests.

a 

 b

c 

 d

e 

 f

g 

Figure 14. Community team in the field

(a) A field group deciding on the direction of transect,

(b) Sighting the direction of the transect using a compass,
(c) Measuring distance between plots using a tape measure,
(d) Demarcating a plot using a tape measure,
(e) Recording details of the description of the plot to the handheld computer database,
(f) Taking measurements on trees, and
(g) Recording measurement on paper.

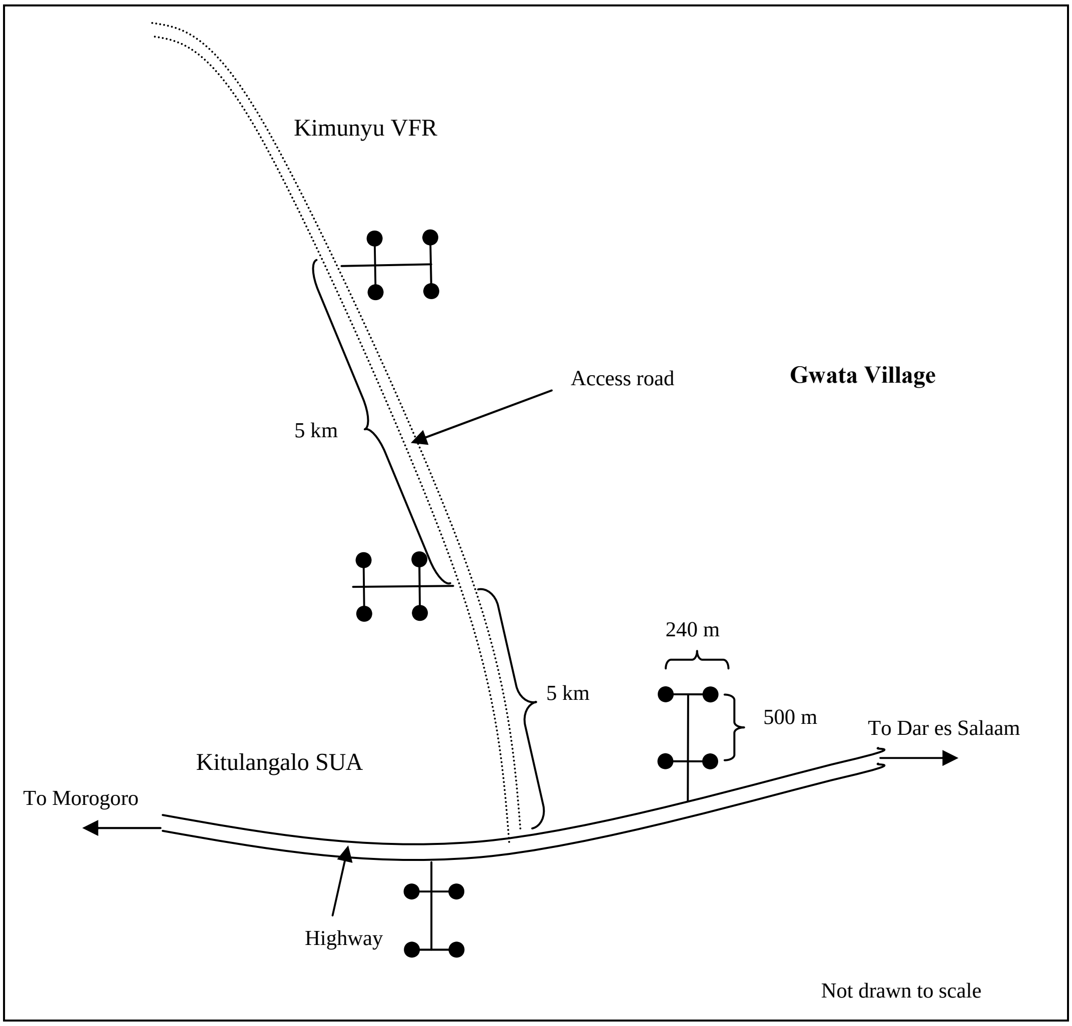


Figure 15. Layout of sample plots in the General Land of Kitulangalo area

As already stated in Chapter 4, Sub-Section 4.3.1, this layout was adopted from a study by CHAPOSA (Malimbwi, *et al.,* 2005c) to enable comparison of the current carbon stocks between the General Land and the reserved forests. The results were also compared with the previous study to determine the rate of forest stock changes in the General Land.

For Mangala and Handei village forests, transects radiating from the forests boundaries to the north, east, south and west directions were established. In each transect, four plots were laid out at an interval of 150 m from the boundary of the forest. The size and shape of the plots together with the tree variables measured and parameters computed were similar to those used for the respective forest reserves. The field work was done by local communities in the same way as had been done in the reserved forests.

5.6 The use of the methodology by local communities

The experimentation with the field forest inventory guide for carbon assessment and monitoring by local communities in Tanzania formed part of the ‘Kyoto: Think Global Act Local’ (K:TGAL) research project involving local NGOs and research institutes in Mali, Senegal, Guinea Bissau, Papua New Guinea, Tanzania, Nepal and Uttranchal (India). The field forest inventory guide was tested for different forest types in these countries and a synthesis of what transpired is given below.

The different essential steps of the procedures and techniques developed for carbon assessment in Tanzania are summarized in Table 11. The table also shows what activities were done easily by local communities and those that were observed to be beyond their ability.

Despite some difficulties encountered during the training, such as the need to limit the amount of data to be logged into the computer in the field, the villagers were able to perform most of the important steps. The role of the staff of the local supporting organizations was also pertinent as regard provision of technical assistance to villagers. The field forest inventory guide was in large part fully suited to use by local communities with some assistance as noted from NGOs. However, it was not possible for these actors to tackle measurements of non-tree carbon pools as facilities were not available.

A major strength of the field forest inventory guide is that the local communities are able to retrieve the sample plots and measure the same trees and recruits in the following years. This to a great extent was made possible by the use of the handheld computers with either the integrated GIS and GPS system or stand alone GPS. Local peoples’ knowledge was very useful in identifying trees and different places (strata) in the forest. They capitalise on their long experience in the local forests, something that external professionals are usually lacking.

It was however noted that there was no capacity and data analysis tool available for the computation of forest stand parameters from the collected data. This tool was developed as part of this work as detailed in Chapter 3. The tool was used by staff of supporting organizations and facilitated immediate sharing of the results with villagers.

Table 11. Steps of the developed procedures and techniques for carbon assessment

Steps for Carbon Assessment	Description	Assistance needed	Availability of assistance
Forest Mapping using handheld computers	• The local trainees were able to make use of the user manuals and operate the handheld computers and draw maps for their forests	Downloading the field maps from handheld computer ArcPad to other mapping software for further processing and printing	GIS technicians at SUA and other institutions of higher leaning
Pilot survey to calculate variance	• The local trainees were able to collect data on trees. Punching of the data to the computer and computation of variance and number of plots was done by the staff from supporting organization who were among the trainees • Allocation of the permanent plots on maps was also done by the staff from supporting organization who were among the trainees	Pre-designed data base for computation of variance and number of plots None	The data base was developed and supporting organization staff were able to use it
Locate permanent sample plots on ground	• The local trainees were able to use the user manuals to locate the permanent sample plots on the ground and record the position and its characteristics on the handheld computer data base for woodlands and or paper form for the montane and lowland forests	None	
Taking measurements from a plot	• The local trainees were able to take data on trees, litter, herbs and soil from the plots.	Handling data on litter, herbs and soil for biomass determination	Not available at local level
Data punching and computation	• Punching of the data to the computer was done by the staff from supporting organization who were among the trainees	Computation of forest stand parameters	Data analysis tool was developed, as detailed in Chapter 4
Retrieved of the permanent plots for other years assessment	• The local trainees were able to use the user manuals to re-locate the permanent sample plots	None	None

The testing in other countries involved in K:TGAL indicates that the field forest inventory guide also worked very well in these other situations (Appendix 7). As was the case with Tanzania, the field teams in the other countries made modifications depending on local conditions such as forest density. Working in Cameroon dense tropical forests, Minang, 2007, also observed that local communities are able to carry out carbon assessment. However, in particular, CFM forests in PNG are very different from those in Tanzania: they are not small areas of degraded forests but are large clan-owned tracts of pristine rainforest. This necessitated a slightly different approach for measuring carbon and necessary modifications were done to make the measurements by local communities successful (Appendix 7). It is clear that in these areas, any claims for carbon credits are likely to be associated not with avoided deforestation or degradation but with forest management or conservation.

5.7 Reliability of estimates

The average stem numbers, stand basal area, volume, biomass and carbon per hectare have already been presented in Table 5, in Chapter 4. The table shows the average estimates, with statistical confidence intervals (expressed as ± values) at 90% precision level. The attained precision levels of estimates (percentage confidence interval to average values of estimates) are given in brackets.

Experience shows that carbon stocks in natural forest can be estimated to precision levels within ±10% of the mean, with 95% confidence (IPCC, 2003). Against this experience, results from the forest studied indicate that the precision levels attained are relatively low (> 21%). This may be explained by the nature of the village forests as detailed in Sub-Section 5.4.1. It is not exactly certain whether the payment of carbon under REDD will be based on average or minimum estimate. As pointed out in Chapter 2, Sub-Section 2.3.1 and shown in Figure 2, it is more likely that minimum estimate (i.e. the low end value of estimates around the means) will be used and as such it is very important to have data of very high quality i.e. carbon estimates with very high precision.

With the need to improve the quality of estimates by local communities, a professional verifier was commissioned to carry out a verification study and give recommendation for improvements on the villagers' measurements. This was done for the KSUATFR by the Tanzania Forest Research Institute (TAFORI). The commissioned verifier was asked to follow the same standard procedures for measuring forest carbon as those used by villagers.

For this forest, instead of using a plot of 5.6 m radius as done by the villagers (Sub-section 5.4.2), the TAFORI team opted to used co-centric circular sample plots in which different sized trees were measured for dbh as follows:

- within 2 m radius: all trees greater than 1 cm dbh were measured,
- within 5 m radius: all trees greater than 5 cm dbh were measured,
- within 10 m radius: all trees greater than 10 cm dbh were measured; and
- within 15 m radius: all trees greater than 15 cm dbh were measured.

For a pilot survey to determine the sampling level, a total of 15 plots with sizes as described above were established randomly to cover possible variations in the entire forest. As for the villagers, stratification was also seen by the professionals to be unnecessary for this forest. Then the number of sampling units (n) required to attain a desired precision at sampling error (E) of 10% was determined to be 87 plots. It was decided to consider 89 sample plots as those used by villagers and to use the same sampling frame. Villagers who carried out forest carbon assessment for the forest were also used to assist in locating the position of plots.

Results from this verification show that, there was no significant difference between the villagers' survey and the professional one as regards estimate of average carbon stocks (Table 12). However, the precision of TAFORI's carbon stock estimate was as higher, at ±9% compared to ±21% attained by the villagers. This could be explained by increased sample plot sizes by TAFORI. With the same number of plots, the larger the plot size, the larger the sampling intensity and therefore the higher the precision of estimates. The sampling intensity employed by TAFORI was higher, resulting in a decrease in confidence interval and rise in the precision of the estimate. High sampling intensity has the positive effects of covering more forest variation in term of tree sizes and tree/shrub species abundance. TAFORI used the concentric plots (four different sub-plots) with maximum radius of 15 m while the villagers used 5.6 m radius plots. The concentric plots with many different sub-plots were not used by the villagers as this could have complicated the field work by them.

During this verification, it was also observed that villagers were able to accurately locate sample plots and to take tree measurements from plots correctly. The measurements by local communities therefore could have improved if the sampling intensity were increased by increasing the plot sizes; this is an important lesson which has been gained from this exercise. However, as pointed out above, the use of concentric plots would have complicated the field work, which is why this method was not selected in the first place. Since it is expected that natural forest have many small trees and few large trees, the use of concentric plots in natural forest inventory are aimed at minimizing field work, by measuring small size trees in small area plots and *vice versa* for large trees. The observed tree size distribution in this study (Figure 7 in Chapter 4), suggests that there are many small size trees of less than 10 cm dbh and few larger ones in all studied forests. Therefore, the instructions in the field forest inventory guide have been adapted and now call for 2 co-centric plots of 5 and 15 m radius to be used for trees of up to 10 and greater than 10 cm dbh. This will make the field work by local communities easier and at the same increase the sampling level by increasing the plot sizes and most likely will also improve the precision of estimates.

Table 12. Stand parameters for KSUATFR by TAFORI and villagers

Stand parameters	Carbon assessment by*		Mean Diff.	Df	*t*-value	*p*-value	Significance
	TAFORI	Villagers					
Basal area (m^2/ha)	9.03±0.69 (8%)	9.15±1.54 (17%)	-0.124	88	-0.160	0.8736	Not significant
Volume (m^3/ha)	65.54±9.18 (14%)	68.12±16.92 (25%)	-2.579	88	-0.283	0.7777	Not significant
Biomass (tons/ha)	43.15±3.75 (9%)	42.19±8.65 (21%)	0.950	88	0.217	0.8286	Not significant
Carbon (tons/ha)	21.14±1.84 (9%)	20.39±4.24 (21%)	0.466	88	0.217	0.8286	Not significant

*The attained precision levels of estimates (percentage confidence interval to average values of estimates) are given in brackets.

5.8 Transaction costs of forest carbon assessment

Throughout the experimentation on the forest carbon assessment by local communities in this study, the costs involved were recorded. The following sub-section summarises all the cost items and compares them with those that would have been incurred if the same work were to be done by professional foresters.

5.8.1 Transaction cost for forest carbon assessment by local communities

The cost items for the whole carbon assessment exercise were recorded. They mainly involved transport, daily subsistence allowance for the researcher and two/one field technician(s), and a daily wage of $5 per person for four to seven villagers in each village (Table 13 and Appendix 8).

Table 13. Costs for carbon assessment by local communities versus the professionals

Study site	Forest area (ha)	If carried out by local communities				If carried out by professionals
		Cost ($/ha)*				
		1st year	2nd year	3rd year	4th year +	Every year
1. Kitulangalo	1020	5	3	2	1	10
2. Handei	156	17	12	8	2	44
3. Mangala	28.5	53	37	24	6	176
4. Ayasanda	550	8	6	5	1	13

* In 2008, $ 1 was equivalent to TShs 1,200

From Table 13, it can be deduced that it is more cost effective to work with villages with large forest areas compared to ones with small forest areas. This is because the cost of training and other overheads are fixed. In all cases in the 2nd, 3rd and 4th years of the assessment costs are considerably reduced as training and participation of the researcher in the field assessments are progressively minimized. The cost in the fourth year, which is expected to be typical for the further years when the villagers work on their own, ranges from $ 1 per hectare for forests with more than 500 ha to $ 6 for small forests with only 28.5 ha. For a forest of 156 ha, which represent a typical village forest size the cost is $ 2 per hectare. In Chapter 7 a cost benefit analysis of a carbon project including these measurements costs is presented.

As regards equipment such as stand alone GPS, tree callipers, diameter tapes, tape measures and hypsometers, these were borrowed from the Department of Forest Mensuration and Management at SUA for the purposes of the research; this kind of equipment is inexpensive and one set could be used by many villages through a coordinating organisation. These costs were therefore not factored in to the calculations below. However handheld computers with associated software had to be purchased at $ 1,000 each. This system has effective life of 5 years. A single piece can on average serve 12 different communities as effective working days per village ranges from 18 to 31 days per year. It is therefore possible to share the equipment among a number of communities working together with an NGO or any supporting organization with the capacity to provide and maintain them. With 12 different CFM of on average 100 ha each, the cost of equipment is only $ 0.17 per hectare per year which is insignificant and can be easily accommodated by the facilitating organization as it was the case with other equipment. Moreover, the handheld computers are only suitable for the woodland forests while for the closed forest the rest of the equipment would suffice. This is due to the problem of weak GPS signals while using the handheld system in closed canopy forests compared to the woodlands.

5.8.2 Comparison between the transaction costs of forest carbon assessment by local communities and professionals

If the same work of carbon assessment in the community managed forests has to be done by professionals, most of the activities will remain the same except that training of the villagers is not required. An additional activity of data analysis will be required since most of professionals are currently not using pre-designed software to accommodate the data.

Professional foresters in Tanzania generally have to be paid consultation as well as institutional fees, so these costs are included.

The cost items for the professionals are shown in Appendix 9 and summarised in Table 13. It is clear from Table 13 that it costs much more to hire professionals for carbon assessment in the studied village forests than for the same work to be done by villagers with support from a technical NGO, even in the first 3 years of the measurements that involve considerable costs for training. If the professionals have to continue with the assessment, they will be paid the same amount annually. It should be stressed that the comparison includes all the costs involved in the intensive training of local villagers and their supporting organizations' staff. The aided villagers undertake the same work at progressively lower cost in successive years as the cost for training and supervision are reduced. From the fourth year, the trained villagers can work without further training although they still require assistance from the staff from their local supporting organization for data processing.

5.9 Summary

This chapter examined whether local communities i.e. villagers and their local supporting organizations may be able to accurately assess and monitor carbon stock changes in their forests and provide this data at a cost which is lower than that of professional surveys. To test this, a field forest inventory guide on the procedures and techniques for assessing and measuring forest carbon by local communities was developed. The experimentation with this guide formed part of the 'Kyoto: Think Global Act Local' (K:TGAL), research project carrying out similar studies in a number of developing countries. For Tanzania, despite some difficulties encountered during the training, which resulted in modifications in the user manuals, the villagers were able to perform most of the important steps. The local communities were also able to retrieve and take plot measurements of the same trees in the following years. Local peoples' knowledge was very useful in identifying trees and different places in the forest. The role of the staff of the local supporting organizations was crucial as regard provision of necessary technical assistance. However, it was not possible for the community to tackle measurements of non-tree carbon pools as facilities were not available. Also the capacity for data analysis was lacking and a special tool for this was developed by the researcher. The tool was used by the staff of supporting organizations and facilitated immediate sharing of the results with villagers. The testing of the field forest inventory guide for carbon assessment in other countries involved in the K:TGAL research project also indicated that it worked very well. As was the case with Tanzania, the field teams in the other countries made modifications depending on local conditions such as forest density.

The reliability of stock measurements made by the local community was tested by commissioning an independent agent (TAFORI) to carry out a verification study and give recommendation for improvements.. This study revealed that there was no significant difference regarding average wood parameters between TAFORI’s estimates and villagers’ estimates. However, the precision of TAFORI’s carbon stock estimate was as higher (± 9% compared to ± 21% attained by the villagers, at 90% confidence level), which was explained by increased sample plot sizes by TAFORI, giving a higher sampling intensity. This has the positive effects of covering more forest variation in terms of tree/shrubs sizes and species abundance. During this verification, it was also observed that villagers were able to accurately locate sample plots and take the tree measurements from plots correctly. The measurements by local communities, therefore, could have been improved if the sampling intensity were increased by way of increasing the plot sizes. This is an important lesson which has been gained from the exercise although the use of large concentric plots would have complicated the field work, which is why this method was not selected in the first place. Based on the nature of the forests and in order to make the field work by local communities easier, the instructions in the field forest inventory guide have been adapted and now call for 2 concentric plots of 5 and 15 m radius to be used for trees of up to 10 and greater than 10 cm dbh.

It costs much more to hire professionals for carbon assessment in the village forests compared to the cost of the same work done by villagers, even taking into account the equipment needed, and the fact that in the first 3 years of the measurements there are considerable costs due to the need for training and considerable supervision. The gain is in the long run, as villagers become increasingly able to carry out the exercise on their own. If the professionals have to continue with the assessment, they will be paid the same amount annually. The villagers undertake the same work at progressively lower cost in the successive years as the cost for training and supervision are reduced. From the fourth year of continuous assessment the trained villagers can work on their own at an average cost of $ 2 per ha, which includes costs of the assistance of the staff from the local supporting organization.

Chapter 6

Costs and Benefits of CFM Projects and the Expected Changes if they Become Carbon Projects

6.1 Introduction

This Chapter seeks to determine the current costs and benefits of CFM projects and addresses the third research question as presented in chapter 3. These costs and benefits will be used in Chapter 7 to estimate the net gains if CFM were to include carbon trading. CFM in Tanzania is undertaken in two main approaches. These are Joint Forest Management (JFM) and Community Based Forest Management (CBFM). In order to depict the sorts of management activities carried out under JFM and CBFM projects, the chapter starts with a description of the distinction between the two approaches and experiences with their establishment. Then, using case studies, an account of the sorts of management activities that are actually carried out, their costs and forest products and services generated by different CFM projects at present is given. From the case studies a comparison of the differences in costs and benefits of CFM projects under JFM and CBFM is made. Finally the chapter examines the likely changes in management that would be associated with carbon benefits.

6.2 General approaches of CFM in Tanzania

As pointed out above, CFM in Tanzania is undertaken either under JFM or CBFM. These approaches are different in terms of forest ownership and the roles played by different actors. The distinction between these approaches and experiences drawn from their operations is given in this section.

Under JFM the government or local authority who owns the forest, enters into a joint management agreement for the management of the forest with any person, organization or village council in the vicinity of the national/local authority forest reserve. According to the Forest Act (URT, 2002), a joint management agreement among other things includes: a statement of objectives of the agreement; rules regulating the use of and access to the forest reserve; and penalties for violation of rules. It also includes the roles of both the government and other actors to be involved in the forest management. In most cases the role of the government or local authority has been the provision of technical assistance through its professional foresters responsible for that area.

In general, forest reserves may be established for either protective or productive purposes. Protective forests are those reserved or used principally for the purposes of protection of watersheds, soil conservation and the protection of wild plants. Alternatively they are used as nature reserves to protect nature and scenic areas of national or international significance and to maintain and enhance bio-diversity and genetic resources in an undisturbed, dynamic and evolutionary state. Productive forests in contrast are used principally for purposes of sustainable production of timber and other forest produce. In Tanzania, only about 3 million ha out of 14 million ha of reserved forests under central and local governments are protective forests (Malimbwi, 2002). However, harvesting for timber in all central and local government forest reserves has been banned since 1987 as a result of recognition of widespread unsustainable harvesting practices (Vihemaki, 2005). The current Forest Act (URT, 2002) stipulates that only with a good forest management plan and strategies to ensure sustainability will harvesting for timber be allowed in the productive forests.

Therefore under JFM joint management agreements for the management of central and local government forest reserves are made in the light of the primary objective of the forest. With protective forests, more strict rules on access and use of the forest are made, while with productive forests, strategies for sustainable management and utilization are set, depending on the nature of the forest. Among the 6 different forests involved in this study only KSUATFR is under JFM, and it is designated to have a protective function.

CBFM projects on the other hand are established by village councils on village land. They are therefore sometimes referred to as Village Forest Reserves (VFRs) and there is a possibility that they may be owned and managed by more than one village. CBFM projects are managed by established Village Forest Committees (VFCs) of village councils. It is required by law that the VFCs should constitute members of the village assembly and be gender balanced (URT, 2002). The VFC forms the principal village body concerned with the management of village land forest reserve and reports on a regular basis on its management of the VFR. In order to execute its duties, the committee is guided by a VFR management plan made and agreed by a village council in consultation with other stakeholders, who in most cases are the professional (government) foresters responsible for that area. The committee is also responsible for instituting by-laws and other rules that are made by the village council with respect to the VFR management. Thus management under CFM involves only by-laws.

However, the law falls short in that it does not specify the period during which the VFC will be in power. Also the VFC is required to report to the village government on a "regular basis" on management of VFR without specifying the reporting time interval and the means for cross-checking the reports.

In terms of benefits to villages, experience reveals that many of the early VFRs were established on degraded forest land that had little merchandisable timber left (Blomley and Ramadhani, 2005). This means that utilization opportunities were limited and long times are required before the forests became commercially viable. In JFM even where the forests involved have timber value, there has been resistance to allow utilisation of these resources, due among others things to lack of proper management plans. According to Blomley (2005), technical forest personnel tend to be overcautious in warning villagers about the dangers of over-utilisation.

History shows that since the first pilot VFRs were established in 1990's, their facilitation has been done by local and international NGOs in collaboration with local and central governments. The NGOs include WWF, CARE international, Tanzania Forest Conservation Group (TFCG), Farm Africa, Africare and Wildlife Conservation Society of Tanzania (WSCT). These are financed by both bilateral[10] and multilateral[11] donors such as DANIDA, NORAD, CARE, UNDP – GEF, IUCN, FINNIDA, MFA Finland, GTZ, IDA, SIDA, World Bank, and Danish Hunters Association. The Tanzania government also provides finances through the Forestry and Beekeeping Division (FBD).

Establishment of CFM requires on-site facilitation including activities such as sensitization of villagers as regards the importance of CFM, training of village forest committees on forest management practices, setting-up by-laws through meetings, drawing-up a forest management plan, and enabling them to get started with CFM management.

[10] A donor agency of one government for aid provision to other governments
[11] An international donor agency to which several member states contribute funds

It was difficult to get good estimates per village or forest of the cost of CFM establishment and implementation from the facilitating NGOs. This is because programmes that included CFM establishment, such as the Catchment and Mangrove Programme, the Tanzania Forest Conservation and Management Programme, the Land Management Programme (LAMP) and MEMA-Iringa (Matumizi Endelevu ya Misitu ya Asili i.e. Sustainable Management of Natural Forests) include other forest activities and cover large areas with many villages and different forests. This makes attributing the costs of CFM activities per village or forest difficult. It is however evident that, a large proportion of the costs are overheads such as salaries for own staff, equipment and local staff training, as shown in Table 14.

Table 14. Cost estimates for establishment and development of a village forest reserve

S/N	Activity	Amount $	Source of fund: Facilitating organization / Donor ($)	Source of fund: Local communities Participation ($)
1	Pre-visit	330	330	
2	Village boundary identification	668	668	
3	Village forest identification & mapping	2,403	2,403	
4	Participatory Forest Resources Assessment	1,473	1,473	
5	PRFR results evaluation and preparation of management plan	577	577	
6	Formulation of village forest by-laws	804	804	
7	Approval of village forest by-laws at the village, ward and district levels	1,454	788	667
8	Forest patrol, enrichment planting & working gears	14,401	1,708	12,693
9	Training for VFC on their obligations	530	530	
10	Publicizing the forest	567	567	
11	Training on alternative ways to ease pressure on forest products	3,569	3,035	533
12	Administration and follow-ups	2,677	2,677	
	Total	**29,452**	**15,557**	**13,893**
			53 %	**47 %**

Source: Own survey data based on the actual man days and current rates paid for both villagers and local foresters as detailed in Appendix 10.

Consultation with practitioners involved with some of these programmes i.e. TFCG and LAMP in Babati (Meshack and Rwiza, 2008) revealed 12 different cost items in the process of CFM establishment and management. Appendix 10 shows how the cost for each item was computed based on the actual man days and current rates paid for both villagers and facilitating local foresters according to the practitioners. The cost for establishment and development of a village forest reserve are summarized here in Table 14. The costs include an allowance for the value of the time incurred by the communities themselves through their participation (47%), and those of the facilitating organization (53%), usually funded by donor agents. Community costs include time spent in meetings for environmental awareness raising, conflict resolution, by-law formulation and management activities such as patrolling, boundary maintenance and enrichment planting, which are typical activities in the process of CBFM. Added to this is the material and time the villagers invest in their participation in activities aimed at easing pressure to the forest, such as tree nursery establishment, improved firewood stoves and improved brick making.

Table 14 provides a cost estimation for the first two years of CFM project establishment. These are general estimates for Tanzania. Section 6.3 presents the activities that are carried out in the running of CFM projects some years later, based on observations at the sites that were included in this research.

6.3 Current forest management costs and benefits resulting from CFM projects

This section summarises experiences of different sorts of management activities and benefits in four different villages included in this research (see Map 1, in Chapter 3) in order to determine time and material costs and benefits to the communities involved in JFM and CBFM. To get an understanding of the local communities involved, first a brief socio-economic profile of each village is presented, and then specific management activities undertaken and benefits realized by local communities are described. This will form a basis on which the two CFM approaches will be distinguished in terms of local costs and benefits. The information was collected using multiple methods in order to triangulate the data and to bring out more details about the communities. Methods included Participatory Rural Appraisal (PRA), interviews with stakeholders and participant observation, as detailed in Chapter 3.

6.3.1 Gwata-Ujembe Village

Socio-economic profile of the village

Kitulangalo forest area lies about 50 km to the east of Morogoro town, along the Dar es Salaam-Morogoro highway. Both KSUATFR and Kimunyu VFR are found in Gwata-Ujembe village. Administratively the village is located in Mikese ward, Morogoro Rural District. It borders Maseyu village to the west, Bwawani village to the east, Kinonko army camp to the south and Wami-Mbiki game controlled area to the north. The village is composed of 715 households with a total population of 2,030 people according to the 2008 village government statistics. People started to reside in the village in 1956. They came from other parts of the country in search of good agricultural land and permanent water sources. As such the inhabitants in this village are of mixed ethnic groups of *Wakwere*, *Wazigua* and *Waluguru*. Before the establishment of Gwata-Ujembe village people were scattered all over the area but following Operation Villagization in 1974, they moved closer to the social services such as dispensary, schools and roads.

The village is bisected by the Dar es Salaam-Morogoro highway and is within the dry woodland areas of coastal Tanzania that iare famous for charcoal making. As such the main economic activities are subsistence agriculture, and charcoal extraction. Small businesses (mostly local brew) are attracted by the presence of Kinonko army camp and Bwawani prison in the vicinity. While charcoal extraction is done in the General Land of the village that is under an open access regime, agriculture is practiced on farmland owned by individual villagers. On average an individual household owns about 5 acres of farm land. Agricultural crops grown in the village include maize, millet, rice, cassava, beans and sesame. With the exception of cassava, which is exclusively for sale, the crops grown are both for own consumption and for the market.

According to the villagers' own criteria, there are three wealth categories in the village. These are poor, middle and relatively well-off households, and that they can be distinguished as shown in Table 15.

Table 15. Household wealth category in Gwata village based on villagers' own criteria

Criteria	Poor	Middle	Rich
Nature of the house	Thatched grass roof	Corrugated iron sheets	• Brick houses with corrugated iron sheets and floor tiles • Use electricity
Land owned	1 to 2 Acres	About 3 acres	8-10 acres
Number of meals per day	Mostly one meal	Three meals	Three meals
Children education	Primary school	Mostly primary school	Secondary school

Using these criteria, the villagers during a PRA study categorized the 715 households in the village into 60% poor, and 35% middle while only 5% were considered well-off. The majority of people (60%) in Gwata village are therefore in a poor household category whose major economic activity is subsistence agriculture. However, the harvests are not enough to feed these households and as such they buy food for about 4 months in the year. Their incomes are therefore supplemented by casual labour in the farms of better-off neighbours, and charcoal extraction. The absolute contribution of agriculture to the rich families' incomes is almost equal to that of middle income households but rich families have other means of generating income from retail shops and businesses. However, apart from the cash incomes, both get enough harvest from their fields for their own use throughout the year. This means that the declared cash income of $ 1 and $ 2 per day for middle and rich households is available for other purchases. However, for poor households the declared cash income is $ 0.15 per day meaning that they have little to spend on items such as salt, kerosene, sugar, cooking oil, soap and clothes.

These declared incomes are very low for households with on average 5 members because they do not include non monetary goods such as food they grow on their own farms. Moreover, people tend to undervalue their incomes in questionnaire surveys on expectation that the data will be used in their favour for development assistance from the government or other donor agencies. However, even though these figures are probably underestimates, it is clear that there are very few opportunities to earn cash income in this village.

Forest management activities

The high level of accessibility to the highway made Kitulangalo a prime charcoal production area for the supply of the nearby Morogoro municipality and Dar es Salaam city. But in addition, the forests in this area suffered in the past from timber extraction through the activities of local pit-sawyers and from cutting of tree stems for building poles. The human resources of the Forest Department were insufficient to maintain control over the area and to sustainably utilize the forest. It was *de facto* an open access resource.

In 1995 however, part of the Government Catchment Forest Reserve (600 ha) was given to Sokoine University of Agriculture (SUA) as a Training Forest Reserve. It is now used for training students and for research purposes, although protection was a major reason for its new status. This part of the forest is under JFM with Gwata village, which means that the land is still owned by the government, but the management is mainly in the hands of the university and local community, following jointly prepared management guidelines. In 2000, another 420 ha was demarcated for the village community, and is now called Kiminyu VFR.

As a community forest, the land is now the property of the village, which has full responsibility for its management. Both areas are characterized by *miombo* woodlands vegetation and the predominant species are *Brachystegia* and *Julbernadia.* The fact that this site has two different management regimes operating next door to each other in essentially the same type of forest will provide an opportunity to make comparison between the regimes.

Since the establishment of the VFR in Gwata-Ujembe village in 2000, a VFC has been established and given the responsibility for supervising the management of the forests on behalf of the village government. This committee looks after both the KSUATFR and the VFR. The committee members were elected by general village assembly. The considerations for selection to the committee were: village residence, marriage status, and ability to work. Gender balance was also considered in order to involve women in the management of the VFR. The current committee that was elected in 2005 has 11 members (7 males and 4 females). However, it was noted that all of the VFC members are from the middle income households. These can volunteer to work without daily wages while poor household members need to be paid daily wages to feed their families. To institute its mandate, the village government set by-laws that have been agreed upon by the village general assembly. They consist of different penalties charged against offenders who violate the rules regulating sustainable forest management and use in the village. Examples of the offences include encroachment and harvesting for charcoal, timber and building poles. These by-laws are applicable in both the VFR and the KSUATFR. However, the by-laws have not yet been approved by the responsible district authority and are thus not yet recognised by the court of law.

SUA manages the KSUATFR jointly with the village government through the VFC under JFM. Two members from the VFC are employed by the university as forest guards for the forest. They are responsible for making routine patrols and supervise different forest management activities that are done by villagers who receive daily wages in return. For example, the university involves villagers in clearing of forest boundaries to safeguard against fire. This activity is normally done during the dry season when the grasses are dry and vulnerable to fires. In the same boundary lines, villagers are involved in trees planting, which is used to demarcate the reserves from the General Land. If there is a fire outbreak, the villagers are also involved in extinguishing it. It is noticeable that incidences of fire outbreak in the KSUATFR have been considerably reduced in recent years since local people have been involved in forest management. Villagers also serve as local field assistants for different research activities done in the forest. The average annual direct management cost for the KSUATFR for the past 5 years is $ 2,028 for wages of the 2 forest guards and boundary maintenance i.e. clearing and boundary tree planting.

For the Kimunyu VFR under CBFM the VFC bears full responsibility for managing the village forest. It mobilises local people, and selects villagers to patrol the forests and report to the village government through the committee. Also boundary line clearing is supposed to be done once a year, while fire fighting is done when an outbreak happens. For the past 5 years, there are hardly any revenues collected. The VFC volunteered to conduct at most one patrol per month, while forest boundary maintenance has not been done.

This forest is officially being managed for production purposes but at the start of management in 2000 a decision was made to stop harvesting (since there are not enough large trees) to allow the forest to regenerate naturally. However, in November 2006 a portion of the forest (ca. 30 ha) was sold for agricultural expansion through a dubious deal between the Village Executive Officer and some villagers (Box 3). This has resulted in cutting down trees in that portion and has diminished stocking levels. The cleared forest area was however recovered in early 2007 following advisory support from SUA and the Mikese Ward Executive Officer. This experience gives some signals on how poor village leadership can undermine the effectiveness of CFM projects.

Box 3. Village Forest Reserve land dispute in Gwata Village

Kimunyu VFR was established in year 2000 upon agreement by the village assembly. All village members agreed on the area of village land to be used for this purpose. The forest is located about 14 km from the village headquarters. In November 2006, the Village Executive Officer (VEO) was approached by 4 village members on the sale of their clan land of about 30 ha to a non-resident. The VEO called upon 5 witnesses in the vicinity of the village office and issued the documents for the sale of the land. This was done without seeing the piece of land and also without the consent of the village council as is required by law. According to the Village Land Act, customary land right can be sold to a citizen who is not ordinary resident in the village only with the formal approval of the village council. The role of the VEO is to register land documents but not to make decisions about who may hold or register land.

It later came to the knowledge of the villagers that part of the VFR had been invaded and cleared for agriculture. When asked, the farmer who is from outside the village said he bought the land from the 4 villagers and had all the papers from the village government. The 4 villagers had lied to the VEO as regard the location and ownership of the land sold. At this point, SUA and Ward Executive Officer intervened after being contacted by the VFC and managed to recover the land through a series of meetings whereby the buyer was allocated on alternative different piece of land.

Forest benefits to local communities

For their participation in the KSUATFR, local communities firstly gain some employment, since two village members at a time are employed for a five year period by the university as forest guards. They receive a monthly salary of $ 67 each being a minimum wage paid to government employees. Secondly, villagers participating in different forest management activities such as fire fighting, boundary clearing, boundary tree planting, and research activities are paid daily wages. These activities are done occasionally (usually once per year) and on average 210 man-days are available currently paid at the rate of $ 2 per man-day. Villagers also are allowed to collect vegetables, dry firewood, fruits, mushroom and traditional medicines from the forest for their own use. Harvesting for timber, charcoal, building poles and grazing are forbidden.

In the VFR, the wages that were supposed to be paid to villagers for their participation in management activities such as patrolling, fire fighting and boundary clearing were to be sourced from fines charged to offenders. However, there were no offenders charged for the past 5 years in spite of the illegal activities noted in the forest. Villagers also do not collect minor forest products such as dry firewood, building poles, vegetables, fruits, mushroom and traditional medicines from the VFR since the forest is located far away (about 14 km from their homesteads). At present these products are collected from the farms around villagers' residences. Also the KSUATFR is close to the residential area and provides some minor forest products of this kind. As also reported by Malimbwi *et al.,* (2005c), firewood, charcoal and building poles are not taken from either KSUATFR or VFR but are available from outside these forest reserves.

6.3.2 Mgambo-Miembeni Village

Socio-economic profile of the village

Mgambo-Miembeni village owns and manages Handei VFR that forms part of the East Usambara Mountains forests and is just outside the Amani Nature Reserve. Administratively, the village is found in Misalai ward, Muheza district, Tanga region in the north-eastern part of Tanzania. It is in the neighbourhood of the Mgambo Tea Estate which is managed by the East Usambara Tea Company (EUTCO). According to the village government statistics, the village has a total of 496 households among which 72 are in the tea company's camp (about 238 people). The total population of the entire village is 2,110 people. The village was traditionally established under *Kilindi* kingship and officially registered in 1974 during Operation Villagization. The original ethnic group in the village is *Wasambaa* but currently there are many tribes coming from different parts of the country attracted by the presence of the tea estate in the village and other tea estates in East Usambaras.

The main economic activities in the village are subsistence agriculture, livestock keeping, petty business and casual employment in the tea estate. Main cash crops grown are sugarcane, beans, tea, tomatoes and trees while food crops are cassava, bananas, maize and yams. Average farm size is about 3.3 acres although as detailed below poor households have no land at all.

As was the case for Gwata, PRA was carried out for this village and according to the villagers own criteria, out of the total 424 permanent households in the village; 35% are poor, 60% middle and only 5% are considered as well-off (Table 16). The poor households have no land of their own to cultivate and they usually borrow land from other villagers and supplement their income by engaging themselves as labourers on the tea estate. The majority of households in Mgambo-miembeni (60%) are in the middle income category. They are able to grow enough food crops for household use throughout the year. They also grow sugarcane as a cash crop and supplement their incomes from dairy cows apart from doing some petty business.

Table 16. Household wealth category in Mgambo-Miembeni village based on villagers' own criteria

Criteria	**Poor**	**Middle**	**Rich**
Nature of the house	- Thatched grass roof - No electricity	- Trees/bricks with corrugated iron sheets - No electricity	- Burnt bricks with corrugated iron sheets - Have electricity
Crops grown	No sugarcane and tea	Grow sugarcane	Grow sugarcane or trees or tea
Number of dairy	No dairy cow	1-3	3-5
Number of meals per day	One meal	Two meals	Three meals
Children education	Primary school	Primary and secondary school	Secondary school

The well-off households (5%) in this village are those specialized in raising dairy cows and they grow more sugarcane, tea and or trees. They are also running retail shops taking advantage of a huge demand from the people working in the tea estate who entirely depend on buying food and other items from shops.

Based on declared incomes, the general analysis for this village is therefore that 35% of the households have a cash income of $ 0.3 per day compared with 60% with $ 1 per day and 5% with $ 4.5 per day. As was for the case of Gwata-Ujembe village, these incomes are very low per capita. They are spent on school fees for children and the purchase of non-agricultural food items such as salt, kerosene, sugar, cooking oil, soap and clothes. In Tanzania no school fees are paid for primary school education which is why poor households in this village are able to send their children to primary school but not to secondary school where fees are required.

Forest Management activities

Handei village forest reserve consists of 156 hectares of sub-montane evergreen forest characterized primarily by *Parinari excelsa, Sapium ellepticum, Cynometra sp* and *Alanblankia stulhamanii* species. Part of the forest is on hanging rocky cliffs harbouring *Saintpaulia usambarensis* (African violet) that attracts ecotourism. The forest has been under CBFM by residents of Magambo-Miembeni village since 1996. Formerly, the forest was under open access and suffered considerably from agricultural expansion and uncontrolled harvesting mainly for commercial timber and building material, the consequence of which were changes in micro-climate of the area and drying up of important water sources.

Since the VFR was established in 1996, there has been a VFC composed of twelve members (4 women and 8 men) operating under the village government. Observations have revealed that all VFC members come from the middle income category households. As in Gwata village, this is because rich household members are busy with their business and they have no time to participate in the VFR management while most of the poor household members work in the tea estate where they earn their daily wages[12]. The VFC members participate in the VFR activities on voluntary basis with little and irregular cash wage in return. This is because for the past 5 years the average revenue collected from fines and entrance fees for ecotourism and research was only $ 55 per year. This income was spent partly to remunerate VFC members and other villagers who participated in forest patrols, and partly on other management activities such as meetings, boundary maintenance and enrichment planting. As shown in Section 6.4 the income was not adequate for these activities.

[12] Casual labourers in the tea estate are paid depending on the amount of green leaves they plunk per day. In 2008 they were paid TShs 45 ($0.04) per kg. On average one person can get 50 to 100 kgs a day i.e. from $ 2 to $ 4 per day.

The committee is responsible for all activities regarding the VFR which include monitoring of enrichment planting in open areas of the forest, provision of permits for timber and building poles harvesting, and collection of fees from ecotourism. It is also responsible for following up on legal issues pertaining to the management of the village forest reserve.

To ensure proper utilization, the village has set down various by-laws on how and when forest products can be utilized, the general idea being that utilization is done in a sustainable manner. The committee reports on monthly basis to the village government, district forest officer and the Amani Nature Reserve conservation office (a local supporting organization). However, on ground monitoring is not done. To cross check the committee reports, the village government relies on information from village council members residing in the forest neighbourhood. The role of the district forest officer and the supporting organization is to provide technical support to the forest committee and interpretation of policy.

Forest benefits to local communities

With current management, utilization is confined to a buffer zone of 50 m on all sides of the forest boundary. The interior part of this forest is for complete protection without utilization, while ecotourism is permitted all over the forest. Uses confined to the buffer zone include controlled timber harvesting and collecting dry firewood, vegetable, mushroom and traditional medicines. It was difficult to estimate monetary values for timber, building poles and firewood since these are only for village consumption and are not sold. Uses involving removal of considerable amounts of biomass such as timber and building poles harvesting are restricted to community use, for example school construction and other social services; no private uses are permitted. The decision to cut trees for timber has to be authorized by the Amani Nature Reserve officials who provide technical support for the VFR management. The forest also protects permanent water sources for the village.

6.3.3 Ayasanda Village

Socio-economic profile of the village

Ayasanda village is located in Ayasanda ward, Gorowa Division, Babati District. It borders Endanachan village to the west, Bonga village to the north, Gidas village to the south and Bereko National Forest Reserve to the east. The total population of the village is 2,187 people and is composed of 419 households. The village was traditionally established and registered during Operation Villagization of 1974. The original ethnic groups in the village are *Wagorowa*, *Wairaqw* and *Wabarabaig*. The village also attracts temporary immigrants, mostly agro-pastoralists from neighbouring areas; these include people of the ethnic groups *Warangi, Wamaasai* and *Wanyaturu*.

The main economic activities in the village are subsistence agriculture and livestock keeping. Farming is usually done on valley bottoms while the hills covered by trees are reserved as village forests (Figure 16 (a)). Subsistence mixed cropping of cereals and legumes is practiced whereby on average a household owns 4 acres of land. The crops grown include maize, pigeon pea, beans, sunflower and millet/sorghum. The most important crops grown for both household own use and sale are maize, pigeon peas and beans.

(a) Forests on hills and farms on the bottom (b) *Grevelia robusta* trees on farm plot

Figure 16. Different land uses in Ayasanda village

In some farm plots agroforestry trees of *Grevelia robusta* and some fruit trees such as mangoes and citrus are also grown (Figure 16 (b)). Most households keep livestock such as cattle, goats, sheep, chickens and donkeys. Livestock are kept in sheds at homesteads but they are also grazed on the farm plots after the crops are harvested (Figure 16 (b)). Grazing inside the village forest reserves is allowed from 1st June to 31st December as a way of easing grazing land scarcity when crops are still growing. Livestock keeping is a cultural practice of the villagers and a means for socio-economic security against food shortage, subsistence income source and nonmonetary value exchange such as bride price payments.

According to the villagers own criteria, there are 3 wealth category household groups in the village (see, Table 17). In addition to the criteria used in other studied villages, the PRA meeting in this village included the number of cattle owned and frequency of eating meat as criteria. This is because livestock keeping is an important activity in this village. Out of the total of 419 households in the village, 60% are poor, 35% middle and only 5% are considered well-off. The majority of people in Ayasanda are therefore in a poor household category.

The poor households cannot afford to have even two meals a day and cannot send their children to secondary schools. Also these poor households are unable to own cattle but can borrow cows from other people on a system known as *qasara*. This is an agreement in which the borrower borrows cattle and takes the responsibility to feed and provide essential medicine for them, and in return receives manure and milk as compensation while the progeny remain the property of the owner. In case of food shortage in the village, poor households may receive food, clothes and goats from well-off relatives or friends, without being expected to pay back. This holds also for ceremonies that are expensive households to finance, such as wedding and funerals.

Table 17. Household wealth categories in Ayasanda village based on villagers own criteria

Criteria	Poor	Middle	Rich
Nature of the house	Thatched grass roof	Corrugated iron sheets	Corrugated iron sheets
Land owned	0.5 to 2 Acres	About 3 acres	More than 10 acres
Number of meals per day	One meal	Two meals	Three meals
Children education	Primary school	Mostly primary school	Secondary school
Number of cattle	Only some few on trust ship system)	10 to 40	50
Frequency of eating meat	Occasionally	Sometimes	Frequently

The middle income category households are able to grow enough food crops for household use throughout the year. They also keep cattle of their own and do some petty business while the well-off households in this village are those with large herds of cattle and large farm areas.

The declared cash incomes from these household categories which, as for the other villages, are used for the purchase of non-agricultural goods indicate that the poor households (60%) earn $ 0.4 per day while middle category households (35%) earn $ 0.6 per day. The well-off households that form 5% of the village earn a declared income of $ 1.8 per day.

Forest Management activities

Haitemba (500 ha) and Warib (50 ha) village forests are found in Ayasanda village. These forests form part of the Duru-Haitemba Village Forest Reserves in Babati district, Manyara region northern Tanzania. The forests were formerly managed by local people through their traditional customs and taboos. Elders were responsible to supervise and monitor all activities undertaken in the forest including land uses and cultural/ritual activities. Local people were also participating in all activities pertaining to the forest use and management as assigned or decided by the community at large. Different punishments for offenders of forest management rules included fines like providing a bull, a tin of honey, a sheep or all of thesetogether. These punishments were however not effective in making offenders fear for mismanagement of the forest. The fines were very small and simple to pay compared to what they harvested and sold. As a result the harvesting of the forest products intensified in the late 1970s and early 1980s and thus forests degraded and depleted at an alarming rate. Most areas in the forest were cleared for settlements and agriculture expansion and others were left with no trees or just scattered trees and shrubs. The government therefore intervened and established Duru-Haitemba as a national forest reserve from 1987 to 1994. Despite this government intervention the forests resources depletion increased. Among other things this was due to lack of support from the local communities that were the next door neighbours to the forests. Noticing this situation, villagers were given the forests by the government in the form of VFRs in 1994.

Since then there has been a VFC which is responsible for the VFR management. The members of the VFC were selected among villagers in equal representation from each of 5 sub-villages in each village. The current committee has 10 members (6 males and 4 females). The VFC members are recognized as forest managers, and are working under the supervision of the village government. They implement management strategies pertaining to their sub-village area and frequently make patrols and observations. They work as volunteers and are given irregular wages, the sources of which are fines from offenders and fees paid by visitors. For the past 5 years the average annual revenue from these sources is only $ 120 and as shown in Section 6.4, is not enough to cover the actual cost of the patrols and other management activities such as meetings and forest boundary maintenance.

There are forest management guidelines and by-laws for forest management formulated by villagers and approved by district council for use in the village. These guidelines and by-laws all advocate sustainable forest resource use and management and they are recognized by the court of law.

Forest benefits to local communities

Local communities derive a number of benefits from the forest. Special permits to harvest trees for own private use within the village such as for house construction purposes are offered to villagers. Under such circumstances the VFC selects old trees that have started dying and grant them to villagers upon approval of requests by the village government. The VFC also collects fees from ecotourism and fines from offenders as stated above. Products which are allowed to be collected without permits include mushrooms, dry firewood, local medicines, stones, ropes and fruits (e.g. *Vangueria sp.* and *Flacourtia indica*). Beekeeping and grazing (during the period 1st June – 31st December) are also allowed inside the forest.

6.3.4 Ludewa Village

Socio-economic profile of the village

Ludewa village is located in Kinole ward, Mkuyuni division, Morogoro rural district. The village borders Mifulu village to the west, Milawilila village to the south, Kinole village to the north and Lungala village to the east. It has 340 households with a total population of 2,580 persons. The village is traditionally established and was formally registered during the Operation Villagization of 1974 where almost all the residents (except some few primary school teachers) are *Waluguru*.

Subsistence agriculture is the main economic activity at the village. The area is very fertile and located on the leeward side of the North Uluguru Mountain supporting a rich agroforestry system (Figure 17). The crops grown include coconut, mango, orange, banana, yams, black-pepper, maize, rice, pineapples, groundnuts and beans. The most important cash crops are black-pepper, coconut, banana and pineapples while food crops are rice, maize, millet, groundnuts and beans.

Another important economic activity in the village is casual labour usually involving carrying head loads of farm produce from the village to nearby market located in Mkuyuni township. This is because the road segment (about 7 km) connecting the village with this township is in very bad condition. Most of the households also keep livestock such as goats and chickens, however these make little contribution to the cash economy since they are kept in small numbers for own use only.

Figure 17. Agroforestry system at Ludewa village

As was the case for other villages, participating villagers in a PRA meeting identified three categories of household status in the village as shown in Table 18. The three criteria used are nature of houses (Figure 18), farm size and crop harvest; children's education was not a criterion since, while all children are sent to primary schools, the number of them sent to secondary schools from this village is insignificant.

Table 18. Household wealth categories in Ayasanda village based on villagers own criteria

Criteria	Poor	Middle	Rich
Nature of the house	Wooden poles with thatched grass roof	Sun dried bricks with corrugated iron sheets	Burnt bricks with corrugated iron sheets
Farm size	1 to 2 Acres	About 3 acres with 10 coconut trees	Up to 15 acres
Crop harvest	Sale annually on contract	Own	Own and buying on contract

Typical houses for (a) poor (b) Middle (d) well-off households

Figure 18. Categorization of houses based on household wealth status at Ludewa Village

As a result of this household categorization, out of the total 340 households it appears that 78% are poor, 19% middle and only 3% are well-off. The majority of people in Ludewa village are therefore in a poor household category. This is contrary to expectations, given the productive nature of the land in the village compared to the woodland dry areas of Gwata-ujembe and Ayasanda villages. It can be explained by a system that was not observed in the other studied villages; that of selling crops on ‘contract’, which is practiced here between the poor majority and well-off households. In this system when a poor household is confronted with death of a family member, a marriage or some such event which requires a large amount of cash, the household head approaches a well-off household and enters into a ‘contract’ whereby the well-off household provides the required money and becomes entitled to harvest an agreed number of coconut, banana or orange trees from the farm of the poor family, on an annual basis. During the contractual period the well-off household harvests crops from the agreed trees and the members of the poor household become labourers through ferrying the crops to the market. The situation may become very serious if by bad luck poor households suffer several such events within a short time. The ‘contracts’ are then revised and the well-off households gain more crop trees till the poor households’ entire farm lands are subsumed under this system. Finally the poor households sell their farm lands and have no land to cultivate. Having reached such a situation they become permanent labourers to the well-off households through ferrying crops to the market at $ 1 per trip three times a week.

The middle income households on the other hand own some permanent crops like coconut trees and grow arable crops. They get enough harvest for food for the whole year and supplement their cash incomes from petty business and casual labour for the well-off households, just as the poor households do. The relatively well-off households also harvest enough for own use and for sale. Their incomes also come from businesses whereby they buy crops in the village and sale them outside the village.

There is therefore, a big income gap in the village between the poor majority households (78%) with a cash income of $ 0.08 a day, the middle group households (19%) with $ 0.6, and the well off households who are only 3% with $ 4.6 per day. As pointed out above children in this village hardly get secondary education and this is explained by the fact that the majority of households (97%) are in the poor and middle classes with a limited cash income of less than $ 1.

Forest management activities

Mangala Village Forest Reserve with a total area of 28.5 ha is since 2004 under the management of Ludewa village government. Formerly the forest was owned by the Morogoro Rural District Council when a considerable area was disturbed. Sources of disturbance were wild fires, harvesting and encroachment into the forest area. With support from the Uluguru Mountain Biodiversity Conservation Project (UMBCP), a project component managed and implemented by Wildlife Conservation Society of Tanzania (WSCT), the villagers decided to take over the management. The UMBCP intention is to establish strategies that involve secure active participation of local adjacent communities in forests management around the Uluguru Mountain.

This new village management has taken initiative to restock the forest through enrichment planting using indigenous species such as *Khaya anthotheca*. Protection of the forest from encroachment and wild fires through boundary clearing and border trees planting was also observed. These activities are done by the village government through the VFC established in 2004 and composed of 10 villagers (5 female and 5 male). The committee makes forest patrols and motivates other villagers to participate in different forest activities such as fire fighting, enrichment planting and borderline tree planting. At present, these efforts go hand in hand with strict rules to halt harvesting for timber to allow for the forest to recover. UMBCP, the local supporting organization, provides education and some financial support including purchase of tree seeds and nursery materials for enrichment and border trees planting. They also pay wages of $ 2 per man-day for villagers participating in those activities. However, this has only been possible for the first four years (2004-2007) of forest establishment. UMBCP was spending $ 1,650 annually for this purpose.

Forest benefits to local communities

At present strict protection rules are instituted to halt harvesting for timber and building poles, to allow for the forest to recover. Permitted activities inside the forest include rituals, and collection of dry firewood, traditional medicines, wild fruits, vegetables and mushrooms. Villagers participating in forest activities also get daily wages from UMBCP as shown above. It was however noted that VFC members are participating more in these forest activities than other villagers. Perhaps this was because good wages are involved, and the VFC gets to choose who will get these jobs, so they may keep them for themselves. This has induced the negative perception by other villagers that it is only the VFC members who are responsible for forest management in the village. Other villagers are willing to participate in return for UMBCP support, but they are not given a chance.

6.4 Comparison of JFM and CBFM approaches based on costs and benefits accrued by local communities.

From the four case studies presented above, it can be seen that management activities in JFM and CBFM are almost the same. They include meetings, patrol, boundary maintenance (border tree planting and clearing) and fire fighting. In addition enrichment planting is done in some CBFM that have suffered severe disturbances in the past and where their natural recovery is slow. However, fire fighting is no longer an important activity due to reduced fire incidence since the start of CFM.

Assessment of expenditures for the past five years (Table 19) reveals that for KSUATFR under JFM, the university annually spend $ 2028 for the wages of the 2 forest guards ($1,608) and the rest $ 420 for the forest boundary maintenance. For the CBFM forests, the VFC volunteers to carry out forest patrols without wages except in two cases of Mgambo and Ayasanda where revenues of $ 55 and $ 120 collected from fines for offenders and ecotourism are used to pay wages. These expenditures are in line with those found in a previous study by Meshack *et al.,* (2006) which estimated the cost to the community for their participation in CFM to be $150 per village per year. However, these observed costs do not cover the real local costs given that on average there are 10 VFC members per village who patrol the village forest once every week. Remuneration for this, at local rates of $ 2 per man-day would have costed $ 1,040 per year. Boundary maintenance, enrichment planting and meetings would cost about 270 man-days equivalent to $ 540 per year, making a total of $1,580 per village per year to cover all important management activities by local people. Limited revenue sources clearly restrain villagers managing CFM, as evidenced from Ayasanda and Mgambo, where all revenues collected were spent and yet the VFCs have to volunteer to carry-out other activities free of charge.

Table 19. Revenue and expenditure by the studied CFM for the past 5 years

Name of the village	Name of the forest	Management type	Year of Establishment	For the past 5 years	
				Average annual revenues($)	Average annual expenditure ($)
Gwata-ujembe	KSTFR	JFM	1995		2,028
	Kimunyu	CBFM	2000	-	-
Mgambo	Handei	CBFM	1996	55	55
Ayasanda	Haitemba & Warib	CBFM	1994	120	120
Ludewa	Mangala	CBFM	2004	-	1,650

On the other hand communities get different benefits and services depending on the management type and the nature of the forests. With JFM there is a possibility for some employment opportunities at local level through the partner organization as is happening with KSUATFR. As pointed out above, the partner organization which is the owner of the forest utilizes adjacent communities' labour force in forest management and pays wages in return. This is in addition to what they gain in the way of forest products such as vegetables, fruits, mushroom and traditional medicines. People in this village get enough firewood from farms and agricultural lands and as such they do not need to collect it from the forest. This management is for forest reserved for protection purposes. With this type of management harvesting for timber and building poles is not allowed and only traditional medicine and non-wood forest products are allowed, to ensure the protective function of the forest.

The practice of paying wages for casually employed community members was seen as the only way of providing tangible benefits for local communities and is recommended to be adopted for other government forests that have protective functions (Veltheim and Kijazi, 2002). However, as pointed out earlier (Section 6.2), the majority of government/local authority forest reserves have productive functions. With these government/local authority forest reserves timber harvesting plans based on sustainable harvesting principles could possibly be prepared and implemented under JFM schemes (URT, 2002) and potentially provide more tangible benefits to the communities.

Under CBFM the VFC volunteers to carry out different management activities and small revenues collected from fines from offenders and eco-tourism (Table 19) are used to remunerate them. In some villages such as Ludewa, villagers who participate in different forest management activities are paid daily wages by the supporting organization amounting to $ 1,650 per year. However, this is not sustainable since this organization will end its support in 2008.

The case studies have revealed that apart from relatively well-off households (3-5% of households), the rest of the community in all the villages earn a cash income far below or equal to $ 1 per household per day because of lack of income generating activities and local employment. The remuneration received by villagers from both JFM and CBFM is therefore seen as a benefit by the VFC and those few villagers who are able to secure this employment, since they would have been seeking for alternative casual employment for a daily wage which would usually be much lower. However, the majority of the villagers, particularly those who are not members of VFC, are often not involved and they do not benefit from this employment. Further, as noted from the case studies, the poorest villagers are not members of the VFCs and as such have no chance at all to benefit from the daily wages.

Apart from the cash benefits accruing from direct labour participation, other benefits realised include availability of permanent water sources, collection of dry firewood, vegetables, fruits, mushroom, building materials, ritual sites and traditional medicines. These are common for CFM in almost all sites. In addition, for some areas such as in Ayasanda and Handei villages, harvesting for timber is allowed for private use (not for sale) by villagers upon grant of a special permit and for community members only. This may be seen as a non-cash benefit since no financial transactions are allowed. In other locations where the forests have little to offer as timber, villagers have to purchase it from outside. For these other villages, since their forests are still recovering, it will take some time before timber trees are of harvestable size.

Apart from the direct benefits, other non-tangible benefits of CFM include: improvement of micro climate, watershed, soil erosion control, biodiversity conservation and carbon sink. Villagers also get environmental education through extension services offered by organizations fostering conservation activities. The socio-cultural uses of the forest such as the use of some parts of the forest for rituals and traditional medicine value of some species are also acknowledged. Most of these uses are included or implied in the goals of CFM projects, but the carbon production objective is missing. This is due to low awareness level of both CFM facilitators and the communities of the role of natural forest management in forest carbon storage and sequestration and low awareness nationally of the potential for carbon crediting.

6.5 Likely changes in management associated with the introduction of carbon benefits

The key requirement for any forest carbon project is to show that the current management leads to progressive carbon stock accumulation and retention compared to unmanaged forests. This has been tested through continuous monitoring of the studied CFM projects (Chapter 4) and it has been shown that carbon stocks have been steadily increasing in managed sites, while on unmanaged control sites stocks have decreased. This provides evidence that the current management activities such as patrolling, boundary line clearing, boundary tree planting, controlled harvesting and fire prevention are effective to ensure that the forest stocks are preserved and the forests are given time for recovering. In addition enrichment planting is done in areas where natural recovery is slow.

If these additional carbon stocks were to be traded, the carbon benefit would be added to the current benefits realised by the communities. Since the sequestration and carbon storage happen while other benefits are produced, its production requires no additional activities. However it is important that there is adequate remuneration of participating community members for this carbon service, in proportion to the carbon saved. It would form an incentive for forest protection especially against illegal harvesting and encroachment since considerable amount of forest carbon is lost when forest is converted to other land use through clearing, as observed for Kimunyu VFR in Gwata-Ujembe village.

Equally important is protection against other hazards such as wild fires. For the woodlands, fire can be a good management tool if properly instituted and controlled while for the lowland and montane forests complete fire protection is essential. Although fire is an essential element in woodland ecology (Chidumayo *et al.*, 1988), it is considered to be a very destructive factor in lowland and montane forests (Maliondo, *et al.*, 2000).

Other activities that have detrimental effects on forest biomass include harvesting for timber, building poles and grazing. However evidence from areas where these activities are permitted shows that they have minimal effects on biomass stocks and growth if they are controlled and managed. First, grazing is permitted only during a short period of the year during the dry season allowing the forest to regenerate during the wet seasons. Secondly, harvested trees are those which have reached senescence and instead of leaving the logs to rot in the forest, villagers are allowed to use them to meet their timber needs. Earlier, the same practice of controlled harvesting was allowed for government forest reserves but this failed due to weak supervision (Kessy, 1998). Forest management under CFM appears to be succeeding in this regard. An alternative scientific option for this is sustainable harvesting below the allowable cut determined on the basis of forest growth potential. However, this requires long time observations of the forest growth rates and as such the current option is more appropriate at present.

6.6 Summary

It has been seen from this chapter that significant costs are incurred by facilitating organizations and the communities during the process of CFM establishment (Table 20) and thereafter communities are left on their own to oversee the management of their forests.

Table 20. Typical cost of CFM

Main Item	Sub-item	Cost ($)/village/year
Establishment costs for the 1st 2 years	By facilitating organization	15,557
	By community participation	13,893
	Sub-total	**29,450**
Management costs after establishment	Forest patrols	1,040
	Boundary maintenance, enrichment planting and meetings ($)	540
	Sub-total	**1,580**

As summarized in Table 21, while activities in the actual CFM implementation are common for both JFM and CBFM and are limited to few meetings, patrols, boundary maintenance and some enrichment planting, there is not enough revenue to cover the cost of these activities, especially in CBFM. At present since CBFM in particular has little to offer in terms of timber revenues, fines for offenders and ecotourism are the only sources of income.

A general finding is that in all the villages, cash incomes are very low and opportunities for cash earning are extremely limited. This makes it attractive for VFC members and other villagers to participate in forest management activities, especially those involving payment of wages. However, this is not desirable as most of the people are not given chance to participate and only a small group of people get the benefits. This problem is discussed in detail in Chapter 7, Sub-Section 7.4.2.3 and in Chapter 8, Sub-Section 8.3.5.

The current CFM strategies that result in effective protection and sustainable utilization, guarantee carbon storage and sequestration while offering other benefits and services. Since forest protection is also necessary for the sustainable provision of other benefits and services, there will be no additional management activities required for the carbon production in CFM projects. However, if CFM projects are considered to be carbon projects and enter into carbon trading, apart from adequate spending on common CFM management activities, some additional activities related with the carbon measurements, verification and marketing will inevitably be required. There additional costs are considered to be ‘carbon transaction costs’. Also some benefits that involve biomass removal from the forest, such as harvesting for timber, building poles, firewood collection and grazing, may need to be minimized. An opportunity cost will therefore also be incurred for these products. The magnitude of these costs is dealt with in more detail in Chapter 7.

Table 21. Summary of benefits and costs of management for each village

Name of the village	**Name of the forest**	**Mana-gement type**	**For the past 5 years**				
			Source of revenue	**Average annual revenues ($)**	**Management activities**	**Average annual expenditure ($)**	**Benefits to the villagers**
Gwata-ujembe	KSTFR	JFM	-	-	• forest patrol • boundary maintenance	2,028	• employments, • vegetables, • fruits, • mushroom & • medicines
	Kimunyu	CBFM	-	-	-	-	-
Mgambo	Handei	CBFM	• fines & • fees for ecotourism & research	55	• forest patrols, • meetings, • boundary maintenance & • enrichment planting	55	• permanent water sources, • dry firewood, • vegetables, • fruits, • mushroom, • ritual sites & • medicines
Ayasanda	Haitemba & Warib	CBFM	• fines & • fees for ecotourism	120	• forest patrols, • meetings, & • boundary maintenance	120	• permanent water sources, • dry firewood, • vegetables, • fruits, • mushroom, • ritual sites & • medicines
Ludewa	Mangala	CBFM	-	-	• fire fighting, • forest patrols, • meetings, • boundary maintenance, & • enrichment planting	1,650	• ritual sites, • dry firewood, • vegetables • wild fruits, • mushrooms & • medicines,

Chapter 7
Estimates of Communities Gain from Forest Carbon Trading

7.1 Introduction

This Chapter estimates the expected net revenues from the sale of carbon credits and examines the extent to which these could potentially motivate more communities to participate in CFM. It starts with an analysis of the costs of CFM with carbon management included in order to determine the total cost of a CFM carbon project. This is then followed by the determination of the likely net financial benefits from the sale of carbon at village level, and examines whether these would be sufficient to offer incentives to the participating communities. The chapter then addresses the national level effect of the payments from sale of carbon if CFM were to be undertaken at a much larger scale. Finally the factors that influence communities in taking up CFM are examined and possible strategies to expand CFM activities are proposed.

The estimates of financial benefits from sale of carbon will be based on assumptions that both reduced degradation and forest enhancement for individual CFM projects are going to be credited. In addition to these, avoidance of deforestation is also included under country REDD policy approach at a national level. However, whether these different processes will in fact be included and credited from REDD policy is not entirely clear at the moment.

7.2 Costs of CFM with carbon management included

If CFM projects are to be registered as carbon production projects with a view to payment per ton carbon, apart from the establishment and management costs for the implementation of the day to day activities, additional transaction costs will be incurred in terms of measuring carbon stock changes, validation and marketing. In addition products and services that have negative impacts on the carbon stocks may be foregone as opportunity costs. The following sections examine these costs associated with carbon production in the CFM projects.

7.2.1 Establishment and management costs

In Chapter 6 an attempt has been made to estimate the establishment and current management costs of the four CFM projects. It has been seen that an estimated $ 29,450 is needed for the first 2 years of establishment of a typical VFR of which 53% is needed for external costs and 47% for communities' participation and time input. These cost items are very important for the planning of establishing more CFM projects and therefore need to be considered in the context of expansion of CFM.

For the already established CFM projects, introduction of carbon production adds little in terms of management costs as all the necessary establishment and management activities have to be carried out for other primary management objectives. The estimated total annual management cost is $ 1,580 per village (Chapter 6, Section 6.4), although most villages do not have sufficient sources of revenue to actually pay for this. If further costs are introduced by turning CFM projects into carbon projects, the additional costs at least should be covered, preferably with some profit margin.

7.2.2 Transaction and overhead costs

Introduction of carbon production in the CFM project brings with it direct costs related to measurement, verification and marketing of the credits. It has been demonstrated in Chapter 5 that villagers can measure and monitor carbon changes in their forest at a long term cost of less than $ 2 per ha per year for forests of more than 150 ha. It is not yet clear what the rules will be as regards the use of REDD funds internally, since this is a matter that will be decided by each country for itself, but it is probable that an internal verification mechanism for individual forest project within a country will be necessary. Verification is done by an independent party and establishes that the carbon measurements have been done to a defined standard; it is necessary to avoid fraud at the local level and to ensure that the country does not claim international carbon credits which it has not in fact realized. The independent party would have to be a licensed and registered agent, in the same sense as a chartered accountant, but would not necessarily have to be external to the country; under a REDD approach it is likely that this would be arranged nationally. After verification, communities' carbon will be purchased by the government REDD scheme. With this arrangement, international marketing of carbon by individual CFMs will not be necessary, but probably will be done centrally by a national agency Marketing therefore will form part of the national overhead activities.

As part of this study, an independent consultant was hired to re-measure a forest of 600 hectares, which worked out at a cost for $9 per hectare. Experience from this study also shows that if local consultants are hired to carry out carbon assessment in CFM forests, this kind of cost would be normal, although it will vary depending on the size of the forest (ref. Chapter 5). It is not clear yet whether the verification will be done by re-measuring the entire forests or by spot checking of some sample plots within the forests. The later might be the case since a common standard procedure would be followed by all forest practitioners under the REDD policy. With this system, verification costs will be low since the practice will be done locally rather than by international agencies and it will benefit from economies of scale because the system is country-wide, probably involving spot checking on a random basis. For the purpose of estimations in this study, we have used verification cost of $ 3.5 through $ 10 in the sensitivity analysis.

Other overhead costs will involve marketing, financial handling and setting up national baselines for the implementation of REDD policy. It is not quite certain exactly what amount will be charged to cover these costs. Therefore in order to initiate the estimations a low end overhead cost of 10% of the carbon value will be considered and through sensitivity analysis the probable carbon benefits will be determined.

7.2.3 Opportunity costs of carbon management in CFM

In Chapter 4, it was demonstrated that CFM projects result in carbon storage and sequestration in spite of the fact that a certain amount of harvesting for timber and poles for own village use is permitted in some forests. It is likely however that with the introduction of carbon production, rules on such harvesting will be tightened, and in the analysis that follows, we will adopt the conservative assumption in accounting for the possible foregone products. The conservative assumptions are adopted because of the uncertainty in predicting the growth potential of the forests and thus difficult in setting out sustainable harvesting levels for products such as timber, building poles and fuelwood.

Further, these calculations will only consider marginal costs, i.e. the opportunity costs that would be experienced by a single community. If the whole country practiced CFM, then there would be a dramatic impact (upwards) on the price of many forest products and possibly also on crops. To capture this, a general equilibrium model would have been used to incorporate the effects on prices due to the decrease in food production and reduced availability of forest products that may result from reduced degradation rates. However, no such models have appeared in the literature yet for the estimates of opportunity cost for reduced deforestation; Stern (2007) for example used marginal costs in his analysis.

Using these assumptions the opportunity cost of carbon management for studied CFM forests are shown in Table 22. The details on how costs for different foregone products and activities have been estimated are given below.

Table 22. Opportunity cost per hectare of carbon management for the studied forest

Village Name	Total forest area (ha)	Timber ($/ha)	Building poles ($/ha)	Fodder ($/ha)	Firewood ($/ha)	Charcoal ($/ha)	Agriculture land ($/ha)	Total ($/ha)
Gwata	1020		3			9		**12**
Ludewa	28,5		23					**23**
Mgambo	156	1	4	2				**7**
Ayasanda	550	1	2	6				**9**

7.2.3.1 Timber

Results from case studies in Chapter 6 have shown that, for Ayasanda and Handei villages, harvesting for timber is allowed for private use (not for sale) by villagers. In these villages, harvesting is controlled by way of special permits where only old, nearly dead trees are harvested. This harvesting is likely to be allowed when CFM forests in these villages become carbon project since dead trees if left in the forest rot and quickly release CO_2 to the atmosphere, while harvesting and utilising them as timber prolongs the process and reduces emission of CO_2. With strict rules under carbon project however, the current harvesting levels might be reduced. The benefit the villagers of Ayasanda and Handei get in terms of timber is in practice a non-cash benefit since no financial transactions are allowed. But in other villages where the forests have little to offer as timber, villagers have to purchase it from outside. In these other villages the cost of timber harvesting is not at present really an opportunity cost, but will be considered so in the future when their forest trees attain harvestable sizes. Therefore, while the opportunity cost for timber at present is zero for Gwata and Ludewa villages, reduced harvesting for timber under the carbon project will be estimated to constitute the opportunity cost for Ayasanda and Handei villages.

Estimates from unprotected forests from the case studies show a biomass off-take rate ranging from 1 to 3.5 tons/ha/year while the low end value of MAI is 0.5 tons/ha/year. Sustainable harvesting in principle allows only off-take that does not exceed the natural regeneration growth of the forest (MAI). For Ayasanda and Handei villages, since the main wood products harvested are timber and building poles, the estimation of opportunity cost for timber will consider an off-take rate of 0.3 tons of biomass/ha/year. This is equivalent to 0.6 m^3 of logs per hectare. Logs are estimated to sell at \$3.5 per m^3 (Milledge, *et al.,* 2007) with labour inputs of \$1.5 per m^3. The opportunity cost for timber is therefore estimated to be \$1 per hectare.

7.2.3.2 Building poles

Setting sustainable harvesting criteria for building poles will be rather complex as trees of small diameter (i.e. young trees) are used. There is little prospect of their harvesting being permitted in carbon projects, since they represent the future stock of carbon. That means this product is mostly likely to be foregone. This already occurs in some places such as in Ludewa and Gwata villages in Morogoro, building poles are obtained from outside the managed forests. The shift in harvesting is however a form of 'leakage'. The true opportunity cost is the cost of using building poles from newly planted trees or of using mud bricks for housing. If they opt for the commonly used sun-dried mud bricks, the annual opportunity costs for building poles are estimated to be \$ 23, \$ 4, \$ 1, and \$ 3 per hectare per year for Ludewa, Mgambo, Gwata and Ayasanda villages respectively (Box 4).

Box 4. The option of using mud bricks for housing

In the studied villages, a typical house of 3 rooms will be built with 3,000 bricks. With the current price of TShs 15 per brick, a house will cost TShs 45,000 (\$38). For Mgambo village, taking into account the structure of the population with 35% of people below the age of 17 and other factors influencing the demand for new houses such as death and migration, about 26 new houses will be built annually in the village at a total cost of \$ 624 or \$ 4 per hectare per year. Similarly, for the other villages new houses will be required at a total cost of \$ 650, \$ 3060 and \$ 1,264 for Ludewa, Gwata and Ayasanda villages, equivalent to \$ 23, \$ 3, and \$ 2 per hectare per year.

7.2.3.3 Grazing and fodder collection

Livestock are not kept in Gwata and Ludewa villages due to the problem of tsetse fly. For Mgambo and Ayasanda villages, livestock are kept in sheds around the homesteads, but for Ayasanda they are also grazed on farm plots. In Ayasanda village, grazing is also allowed inside the village forest reserves during the months of June through December as a means to overcome scarcity of fodder. If these forests become carbon projects grazing will obviously be restricted due to its detrimental impact to the forest and the associated difficulties in controlling their intensities. However, fodder collection (of only grasses not branches of trees), would be permitted as alternative to free grazing. The opportunity cost for this will therefore be the added labour cost for fodder collection. In Mgambo and Ayasanda opportunity cost for fodder collection are estimated to be $ 4 and $ 6 per hectare per year (Box 5).

Box 5. The opportunity cost for grazing for Mgambo and Ayasanda villages

In Mgambo and Ayasanda villages, it is a common practice for a livestock keeping household to hire a person to look after cattle for about $ 60 per month. It is estimated that these hired people will accept an extra payment of about 20% for the extra workload of fetching more fodder. For Mgambo village with approximately 25 households with cattle and a forest size of 156 hectares, the opportunity cost for grazing is estimated at $ 2 per hectare per year. Similarly, for Ayasanda village with about 280 households with cattle and forest size of 550 hectares, the opportunity cost for grazing is estimated to be $ 6 per hectare per year.

7.2.3.4 Dry firewood

Collection of dry firewood has little impact in places with large forest areas and where per capita consumption is low. Most low-land areas of Tanzania such as Mwanza and Dodoma have low per capita firewood consumption of 0.9 m^3 per year compared to cooler highland areas such as Arusha and Usambaras where typically 1.8 m^3 per capita per year is used as more wood is needed for heating (Kessy, 1998; Ishengoma and Ngaga, 2000). Kessy (1998) calculated that in East Usambara, if annual firewood off take were to be reduced by 50% in reserved forests, 6,000[13] trees would have to be planted annually by each village to meet a demand of 217,750 m^3 at a consumption rate of 1.7 m^3 per capita per year. However, it seems that this was overly alarmist nor was there a real basis for selecting 50% as the amount to reduce. It is now about ten years after this analysis without the launch of the suggested tree

[13] This number is based on calculations for a fuelwood plantation of *Eucalyptus sp.* with 500 stems per hectare that yield 200 m^3 per hectare at a rotation of six years.

planting and still the villagers are collecting dry firewood from their own farms and the reserved forests without causing visible detrimental impacts. This indicates that the firewood sources are sustainable for the villagers' use and their collection causes little harm to the reserved forests as only dry wood is collected which has already fallen from the trees. Similarly, for other study sites demand for firewood from the reserved forest is very low since firewood collection for own household is partially met from farms and from the General Land forests (Malimbwi *et al.,* 2005c). Thus firewood collection will probably not be discontinued, but allowed under a strict carbon management regime, and therefore will have no opportunity costs associated.

7.2.3.5 Charcoal

Among the case study villages, charcoal is important in Kitulangalo area. The area is famous for charcoal production mainly for Dar es Salaam city and Morogoro municipality. The opportunity cost for charcoal production per year can be estimated from the observed off-take rate ranging from 1 to 3.5 tons biomass/ha/year and MAI of 0.5 tons/ha/year. Together with charcoal, building poles are also extracted from the forests in this area. Considering a sustainable biomass off-take rate of 0.5 tons/ha/year, charcoal is estimated to contribute about 0.4 tons/ha/year. This is equivalent to 0.8 m^3 of wood per hectare. According to Malimbwi, *et al.,* (2005c), 1 m^3 of wood yields 2.6 bags of about 53 kg of charcoal at a labour cost of \$ 3. The opportunity cost of charcoal production is therefore \$ 9 per hectare per year since the current price of charcoal is \$ 5.8 per bag at the roadside.

7.2.3.6 Agriculture land

As regards opportunity costs of the land itself, the land in which CFM forests are already established has zero opportunity cost, since these forests were already received for other purposes and turning them to a carbon project does not change their land status. This is true for both JFM and already established CBFM forests since the land is reserved as forest reserves which are not available for conversion to other alternative land uses. As shown in Sub-Section 7.4.3.2, in most cases the land in which CBFM forests are established is excess land after that for other purposes has already been taken up in the village. However, this is true only when considering the current demand of the land in a village. Although not common, village forest land disputes such as that witnessed at Gwata village are essentially caused by land pressure from out side the village (Chapter 6, Sub-Section 6.3.1). Therefore, for the newly CBFM forests to be established only for carbon production in some areas with high demand for land or forest products such as Amani Tanga and Kitulangalo area, opportunity cost of the land should be considered as shown in Box 6.

Box 6. The possible opportunity costs for land in newly established CBFM forests

For Handei VFR, villagers were taken out of the forest to give way for the forest establishment. Occupants on the land were practicing subsistence agriculture of both food and commercial crops. The most paying commercial crop in the village is tea, where a yield of 4,000 kg of green leaves is obtained per hectare per year and sold at an average price of TShs 113 per kg. Deducting farming costs such as purchase of fertilizers and labour for plucking the tea (50%), this is equivalent to about US$ 188 per hectare and can be considered as an annual opportunity cost of the village forestland.

For Kimunyu VFR in Gwata village, history reveals that the forest was established in order to curb degradation from unsustainable harvesting of charcoal. Forest stocking data observed in this study shows that, if clear felled the forest can produce 136 bags of charcoal per hectare. The price of charcoal is at present $ 5.8 (Tshs 7,000/-) and the labour cost is $ 3 for each 2.6 bags produced in the village. Therefore the opportunity cost of the forestland is $ 632 per hectare but this one off benefit need to be discounted over a number of years.

7.3 Estimated financial benefit from sale of carbon at village level

Individual CFM projects result in carbon sequestration and avoidance of emissions against a 'business as usual' baseline scenario. In this study carbon sequestration in managed forest and emissions or removal in unmanaged forests have been determined, as presented in Chapter 4. While the rate of sequestration will be applied as computed for the individual managed forests from Chapter 4, a nominal rate will be considered for degradation in unmanaged forest. The observed off-take rates in this study range from 1 to 3.5 tons of biomass per hectare per year, between 2006 and 2008. These rates therefore differ significantly. On average a conservative estimate of 2 ton biomass/ha/year (yielding 1 ton of carbon or 3.67 tCO_2)[14] will be considered to represent an average degradation rate in the country.

For seven countries responsible for 70% of emissions from deforestation, Stern (2007) [15], has estimated that avoided deforestation could be achieved for under $ 5 per tCO_2. This estimated

[14] Dry forest biomass consists of 50% carbon and a ton of carbon is about 3.67 tons of atmospheric CO_2.
[15] The cost for avoided deforestation based on the opportunity cost of the land is less than $5/$tCO_2$. If the costs of carbon production are included in the forest management, the equilibrium market price will be around $5/$tCO_2$ or more.

opportunity cost is used here as the per ton price of CO_2 from REDD. Data from study sites (Table 23) shows that at the price of $5 per tCO_2, CO_2 sequestration due to forest restoration alone would be worth something on the order of $16 to $49 per hectare per year, depending on the re-growth characteristics of the forest and how carbon was accounted (Chapter 4). This kind of growth will at some point reach a maximum stocking level, at which point the growth rate per year, at least of above ground biomass, will cease, although this may take some time (perhaps 20- 25 years). In addition to the observed sequestration however, the management puts a stop to degradation processes, at an estimated rate of 3.67 tCO_2/ha/year, as noted above. For the study forests, the average contribution of avoidance of degradation constitutes 40% of the carbon benefits (Table 23). This signifies the importance of including and rewarding this carbon component in the REDD policy.

Table 23. Probable annual income from the sale of carbon credits

Village Name	Total forest area	CO_2 Sequestration (forest restoration) Average annual sequestration rate (tCO_2/ha/yr)	Annual market value ($/ha)	A = Return to whole forest ($)	B = Market value of avoided degradation (3.67 tCO_2 /ha/yr x 5 $)	A+B = Total annual Market Value ($)	Percentage benefit of avoided degradation (%)
Gwata	1020	5.3	27	27,030	19,125	46,155	41
Ludewa	28,5	8.3	42	1,183	534	1,717	31
Mgambo	156	9.8	49	7,644	2,925	10,569	28
Ayasanda	550	3.2	16	8,800	10,313	19,113	54
						Average	**40**

The costs of CFM with carbon management were presented already in Section 7.2 and include: $ 1,580 per village per year for management activities and $ 2 per hectare per year for measurements. For the start-up of iterative computations, the costs of $ 3.5 per hectare per year for the verification and 10% of carbon value for other overhead costs are charged. The opportunity costs for the forests in Gwata, Ludewa, Mgambo, and Ayasanda villages are $ 12, $ 23, $ 7 and $ 9 per hectare per year. The total cost of carbon projects in the study villages are shown in Table 24.

Table 24. Costs and net benefits of carbon projects in the studied villages

Village Name	Forest area (ha)	Management Costs ($)	Transaction Costs ($)	Opportunity Costs ($)	Total annual Costs ($)	Total annual Market Value ($) (from Table 22)	Net Benefit to village ($)
Gwata	1,020	1,580	10,226	12,240	24,046	46,155	22,110
Ludewa	28,5	1,525	328	656	2,509	1,717	-792
Mgambo	156	1,460	1,915	1,092	4,467	10,569	6,102
Ayasanda	550	1,580	4,936	4,950	11,466	19,113	7,647

Table 24 also shows the net carbon benefits from both sequestration and avoidance of degradation per village obtained as the difference between total annual market value of carbon dioxide (at an assumed price of $5 per ton) presented in Table 23 and the total costs in Table 24. The most striking characteristic of these figures is the fact that the net carbon benefits are much higher for villages with large forest areas compared with those with small forest areas. Ludewa village with 28.5 ha has a net benefit of $ -792 meaning that the carbon production costs out-weigh its revenues. This is expected since the total amount of carbon credited depends on the extent of forest area managed; there are considerable economies of scale, particularly as regards transaction costs. However, many CFM projects are small, like Ludewa. Further iterations show that if the price of carbon is raised to $ 7.5 per ton then the village will break even. Working with three different community forests in Nepal, Karky (2008) observed also that small area forests of 96 ha have lower carbon benefits with a break-even price of $ 3.7 compared to large forests of more than 200 ha, which have a break-even price of $ 0.6. However, the estimates for the community forests in Nepal in Karky's study include more revenues from the use of timber and firewood, under the assumption that they would continue to be harvested even under carbon project management. In this study, although firewood collection has been included, it has been assumed that timber and pole harvesting are reduced.

Further, since the VFRs are the property of all villagers and every individual household has a stake the total net benefit would be divided by number of households. The estimated annual shares per household are shown in Table 25. At a selling price of $ 5 per tCO_2 households from Ludewa village will have no benefits and sensitivity analysis shows that in order to make earnings of $ 30 per household per year as the case with other villages, the price would have to be at least $ 40 per tCO_2. With this price a better forest endowed villagers might earn $ 438 per household per year. Although carbon prices under REDD might be low compared to other mechanisms, the growing market for CO_2 might offer this price, since as of June 2008 on the European Climate Exchange, the price of Certified Emissions Reductions (CERs) issued under the Kyoto Protocol's CDM was at € 20 (equivalent to $ 31) per tCO_2 (EU-Observer, 2008).

Table 25 also shows how the net benefits per household could be affected by the different levels of the verification and other overhead costs when the prices of tCO_2 are at $ 5 and $ 40. When the price is $ 5 per tCO_2, and while the verification costs are increased to $ 10 per hectare (Scenario 2) or other overhead cost to 20% (Scenario 3), there is not much effect on household benefits. However, if both increase at the same time, there is a significant reduction in benefit (Scenario 4). The critical situation that results in almost no benefit at all is when verification costs of $ 10 per hectare and 30% of the carbon benefit to cover other overhead costs are charged concurrently (Scenario 5). With the price of $ 40 per tCO_2 even if all costs are charged at higher levels, the villagers will make benefits out of their carbon sales ranging from $ 21 to $ 325 per household per year.

Table 25. Net financial benefit for households in the studied villages at different prices of CO_2

Village Name	Net benefit to village ($)	No. of households	Annual share per household ($)				
			Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
When the per tCO_2 price is $ 5							
Gwata	17,01	715	31	22	25	15	9
Ludewa	-849	340	-2.3	-3	-3	-3.4	-4
Mgambo	5,946	496	12	10	10	8	6
Ayasanda	7,097	419	18	10	14	5	0.6
When the per tCO_2 price is $ 35							
Gwata	266,247	715	438	428	386	377	325
Ludewa	8,423	340	30	29	25	25	21
Mgambo	63,019	496	147	145	130	128	110
Ayasanda	110,307	419	306	297	269	261	224

Key: Scenario 1: Is when $ 3.5 are charged for verification and 10% to cover other overhead costs
Scenario 2: Is when $ 10 are charged for verification and 10% to cover other overhead costs
Scenario 3: Is when $ 3.5 are charged for verification and 20% to cover other overhead costs
Scenario 4: Is when $ 10 are charged for verification and 20% to cover other overhead costs
Scenario 5: Is when $ 10 are charged for verification and 30% to cover other overhead costs

This total net profit per household per year from the sale of carbon covers the participation costs by the communities in CFM projects. In the traditional CFM projects without carbon benefits these participation costs are either not adequately paid or not paid for at all. As such carbon projects will in most cases be welcomed by communities for their tangible benefits. Although these per household earnings appear to be low, for most of the households with cash income of much less than a dollar a day (Chapter 6), they represent a significant opportunity.

The cost/benefit analysis above has been at the level of the villages and the households. Important elements however will be the cost/benefits analysis at the national level (which is dealt with in Section 7.4). Since the REDD funds will be received nationally, a further analysis on how the funds could be fairly distributed among the villages and down to the level of individual households is examined under Sub-Sections 7.4.2 and 7.5.5.

7.4 The effect of forest carbon payments at national level

REDD is likely to be considered as a national sectoral approach to forestry in non-Annex 1 countries rather than a project approach as in CDM (Santilli *et al.*, 2005; Achard *et al.*, 2005), and it is probable that not only the average reductions in national deforestation and degradation but also on the enhanced carbon stock will be included in the mechanism. This section therefore reviews the national rates of emission from deforestation and degradation together with the rate of forest enhancement in order to establish reference baselines scenarios against which carbon payments could be credited. The potential gains from the country's REDD strategy are also estimated to assess whether these could provide incentives for the country to stimulate and initiate further CFM activities.

7.4.1 Current forest enhancement potential and emission rates from deforestation and degradation

According to the Global Forest Resources Assessment (FRA) of 2005 (FAO, 2006), the current rate of deforestation in Tanzania (observed in a span of 10 years from 1984 to 1995 see Box 1 in Chapter 1) is 412,279 ha/year. Considering the total forest area of 35 million ha and average growing stock of 103 tons per ha, this results in the emission of 78 million tons of CO_2 (Table 26). However this amount does not include emissions from degradation (loss of biomass within the forest), for which no data is available centrally, owing to the fact that forest inventories have not been carried out nation-wide. Degradation has been observed to occur very widely and at considerable rates, even in reserved forest, through encroachment of forest areas, illegal mining, pit sawing, illegal harvesting for building materials, firewood collection and medicinal activities (Frontier-Tanzania, 2005; Malimbwi *et al.*, 2005; Forestry and Beekeeping Division, 2005).

This study estimated a low end rate of biomass loss of 2 tons/ha/year through degradation (Section 7.3). The average estimated biomass growth rates range from 0.5 to 1.5 tons/ha/year. For the purpose of estimating annual biomass increment for the entire country, a rate of 1.25 tons/ha/year which is also within the observed range, will be considered as was also suggested by Millington and Townsend (1989). Using this rate the net CO_2 emission from degradation at a national level is estimated to be 48 million tons annually (Table 26).

Table 26. Current net annual CO_2 Emission due to deforestation and degradation

[1] Total Forest Area (million ha)		35		
Average Growing Biomass Stock t/ha		103		
[1] Growing Biomass Stock (million t)		3636		
			Losses	**Gains**
Deforestation	Annual rate of Deforestation (million ha/yr)	0.41		
	Annual CO_2 Emission due to Deforestation (million t)		**78**	
Degradation	[2] Biomass Growth Rate t/ha/yr through forest enhancement	1.25		
	Annual Growing Biomass increment (million t)			44
	Annual Biomass loss at the degradation rate of 2 t/ha/yr (million t)		70	
	Net biomass loss due to degradation (million t)		26	
	Annual CO_2 Emission due to Degradation (million t)		**48**	
Total annual CO_2 Emission due to Deforestation & Degradation (million t)		**126**		

[1] Extracted from the global Forest Resources Assessment (FRA) of 2005 (FAO, 2006)
2 Extracted from Millington and Townsend (1989)

7.4.2 The potential gains from the country REDD strategy

This sub-section is about the estimation of the country's potential earnings from REDD policy. It also expands the discussion on the distribution of carbon funds to households to assess if the likely household earnings would provide sufficient stimulus for more CFM activities.

7.4.2.1 The country's potential for REDD

In Table 26 the current total national annual emissions from deforestation and net degradation[16] together are estimated to be 126 million tons of CO_2. In order for the country's forestry sector to benefit from REDD crediting it has to have overall strategies that will aim at reducing all or some of these CO_2 emissions. If all the deforestation and degradation were to be stemmed completely, and forests biomass allowed to grow at 1.25 tons/ha/year, the country could potentially earn $630 million or around $117 per rural household per year (Table 27) from the REDD policy assuming the selling price of carbon is $ 5 per tCO_2. However, first of all the probability of complete halting of these processes is zero, and second, the funds will not all be for distribution to villagers since the costs for both CFM management and for establishing the country REDD policy will be deducted. If establishment of more CFM projects will be included as an approach under REDD policy for Tanzania, the cost of their establishment will also have to be included.

These estimations are also made under assumptions that REDD policy will include; avoidance of deforestation, reduced degradation and forest enhancement. However, at present if all these processes are going to be included in the REDD policy is not entirely clear.

Table 27. Current 2008 country total population estimates and potential earnings from REDD

Item	Sub-item	Estimates
1. Population estimates	Population in 2002 (million)[1]	34.6
	Annual rate of the population growth (%)	2.9
	Population in 2008 (million)	39.6
	Population in rural areas	26.4
	Average household size (persons)	4.9
	No. of households in rural areas (million)[2]	5,4
2. Potential earnings estimates	**Potential earning from REDD (million $)**	**630**
	Potential earning per household ($)	**117**
3. The costs of REDD strategy	Management costs $ 1,580 for each of the 14,000 villages (million $)	22
	CFM establishment in 13,000 villages @ $16,000 (million $)	208
	Cost of measurements ($2/ha) for the 35 million ha (million $)	70
	Cost of verification ($3.5/ha) 35 million ha (million $)	123
	Other overhead cost (10%) (million $)	63
4. Net potential earnings	**Net potential earning per household ($)**	**27**

[1] From population and housing census of 2002 (URT, 2003b)
[2] About one third of the population is urban (Tibaijuka, 2004) and the rest is in rural areas

Table 27 also shows the net potential earning per household after the likely costs are deducted. Only $ 27 will be available for households when 10% of the total country potential

[16] It is assumed that the overall rate of biomass loss is 2 tons/ha/year while that of forest replenishment is 1.25 tons/ha/year. But in the long run this could be the opposite when conservation activities will increase as a result of REDD programme.

earnings from REDD is charged to cover the costs for national baseline establishment and organizing the payments. It is not certain exactly what amounts will be charged to cover these costs, but sensitivity analysis reveals that if the verification cost is charged at $10, the price of tCO_2 should be $ 7 in order to realize the same benefit of $ 27 per household. Similarly, with the verification cost held at $ 10, if overhead costs are charged at 20% and 30%, the price of tCO_2 should be raised to $ 8 and $ 9 respectively. This further signifies that the initial price used of $ 5 per tCO_2 by Stern (2007) is low. If the price of tCO_2 is set at $ 9 all the overhead and verification costs will be covered and an average household benefit of $ 27 realised.

7.4.2.2. To what extent could carbon funds be used to cover the REDD starting up costs

The current forestry policy (URT, 2002) puts a great deal of emphasis on the involvement of local communities in forests management. As shown in Chapter 1, establishment of VFR was found to reverse the observed deforestation in unreserved forestland. Local communities' participation in government forest reserves management through JFM agreement was also found to be very instrumental in reducing forest degradation (Blomley and Ramadhani, 2007). If CFM is to be part of the solution, more forests should be placed under CFM schemes in order to arrest the deforestation of unreserved forests and degradation of reserved forests. The aggregate of these at national level will provide a good strategy towards participation in the REDD policy. As observed in Chapter 1, at the current rate of CFM establishment, 2 million ha more of unreserved forests are to be converted to CFM forests by 2012. This speed is very low as it will take more than 40 years for the reservation of all the remaining 16 million ha of forestland. The bottleneck is mainly shortage of human resources capacity of the Forest Division and supporting NGOs. Therefore more commitment in terms of political support and resources is needed if more CFM is to be established quickly.

If CFM is to be established for about 13,000 villages in Tanzania that means about $ 208 million will be required. If adopted, the REDD policy could contribute significantly to CFM establishment given that its estimated potential per annum is at $ 630 million at national level and about $ 27 at household level (Table 27). As shown also under Section 7.3, for the individual villages with small forest areas (28 ha), the price of tCO_2 should be at least $ 40 for them to make a minimum earning of $ 30 per household. As already pointed out, this is possible since the current market price goes up to $ 31 per tCO_2 and it is expected to rise as the market grows. With the price of $ 40 even when the country charges 30% of the carbon money to cover overheads and $ 10 per hectare for verification, individual households will earn $ 486 per year. This income could potentially motivate villagers to participate in more CFM activities than that of today since most of them have a cash income of less than a dollar per day.

7.4.2.3 Distribution of carbon money within the village

Experiences from case study sites show that village leaders, particularly the members of the village forest reserve committee, participate more than others in different forest activities, especially those involving payment of wages. Other villagers are not given chance to participate. This situation might be expected to become even worse when the REDD funds become available to villages, because of the quantities of cash income that are concerned. A major consideration is that if villagers as a whole do not see any benefits, then they are likely to withdraw their cooperation from the communal effort for increasing carbon stock. This might jeopardise the anticipated contribution of CFM to the REDD policy. For the success of CFM under REDD therefore a system to ensure fair sharing of benefits among the villagers should be established.

Experience shows that, when villagers get support from higher administration levels such as wards, district councils and the central government, they are able to question their leaders on village management. Wards, district councils and the central government could therefore play a crucial role with respect to the implementation of REDD and distribution of carbon money within the villages. Matching with the proposed national system under Sub-Section 7.5.5, district forest offices can play a coordinating role in implementing REDD across the district through ward offices. The offices also could provide guidance to ensure clear and transparent reporting on the REDD activities and on the distribution of the carbon money in each of the villages. Although villages have to decide on how the REDD money should be spent, some guiding principles on the use of the funds such as to sufficiently fund CFM carbon projects management, ensuring participation of most of the villagers, contribution to poverty alleviation and socio-economic development can be stressed. Since the net profit to be distributed among the villages might be small (especially for villages with small CFM forest areas), the money can be put under some legal monetary institutions established in each village such as the Savings and Credit Co-operatives (SACCOs) in which all villagers become members and can easily assess credits with less bureaucracy. With clear and transparent rules to access credits, this will ensure fair distribution of the money in villages and the fact that the money comes from CFM management will stimulate villagers to participate. Other factors that may influence communities in taking up CFM activities are discussed in the following section.

7.5 What influences communities in taking up CFM today?

As pointed out in Chapter 6, CFM projects are either managed jointly between the government and village councils (JFM) or by village councils (CBFM). At present only 382 villages out of the total of around 14,000 villages are involved. As also described in Chapter 1 much of the communities involvement in forest management occurred from year 2002 to the present. This was due to presence of "a positive forward looking legal and policy environment" (Wily, 2003a); and "growing numbers of experienced facilitators with grounded local experience; and availability of internal and external financing for CFM" (Blomley and Ramadhani, 2006). These are enabling factors for the establishment of CFM, but availability of forest land and villagers' interest in forest management are the grass root factors. In order to examine why some communities take up CFM and others not it is important to analyse influencing factors both at the grass root and as regards the enabling factors. The possible factors that influence CFM scaling up are therefore discussed below.

7.5.1 Availability of forestland

The extent of available forestland in Tanzania for CFM activities has already been shown in Chapter 1, Section 1.3. It is stressed here that Tanzania has 16 million hectares of forestland that is still unmanaged and which can potentially be sustainably utilized and managed under CBFM. It is important also to note that all this potential land for CBFM establishment is in areas of low population density. Villages in urban and peri-urban areas have no potential areas for CBFM establishment. This is also the case with highly populated areas such as the Usambaras, Kilimanjaro, Iringa and Mbeya. However in the latter areas, there is much more potential for JFM establishment because these have large reserved forests managed by the local and central governments. Of the 14 million hectares of reserved forests under local and central governments, only 1.6 million hectares are currently under JFM with local communities (URT, 2006). Thus there is much potential area for JFM activities in reserved forests as well as CBFM in unreserved forests.

However, this assumes that all the forestland in the country is in close vicinity to villages. Figure 19 (A) shows the population density by regions for Tanzania in 2002. Apart from few densely populated regions of Dar es Salaam, Tanga, Kilimanjaro and Lake Zone regions, and in Zanzibar, the rest have a population density of less than 50 persons per squire km. Further, the regions of Lindi, Rukwa, Ruvuma, Singida, Tabora, Manyara, Morogoro, Iringa, Pwani and Arusha where the lowest population densities are found, have large tracks of forestland under protected areas as National Parks (Figure 19 B) or Forest Reserves. Therefore most of the people in these regions are found only in some few towns and villages. Even in the regions with highest population densities, most of the population is in some localized areas around towns and major productive areas e.g. mountainous areas of Lushoto compared to dry lowland areas of Tanga region. More areas in the country are also inhabited due to the influence of the Operation Villagization of 1974 under which people were encouraged to settle in villages closer to social services such as schools, roads, dispensaries and water. Therefore, in places where the forestlands are located far away from villages and therefore inaccessible, CFM activities will be difficult to practice. This does not however, imply that forests in these inhabited areas are intact, as studies provide evidence that almost all forests in the country are not pristine. An alternative management approach different from CFM may therefore be needed for these forests.

7.5.2 Villagers' interest in forest management

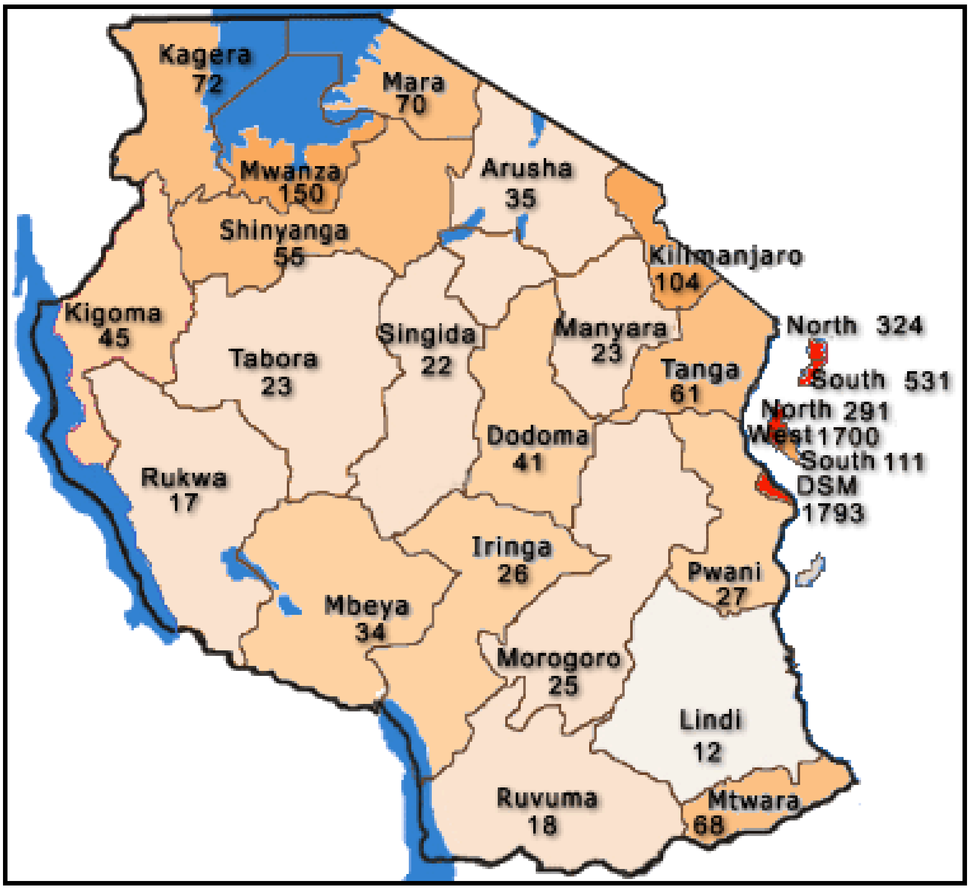
Experience from earlier CFM establishment shows that villagers are motivated to take part in CFM because of their perception of the negative effect on environment and because of the danger of running short of basic products and services from the forests (Blomley and Ramadhani, 2005). Similar findings were also reported for the implementation of national wide tree planting campaign, where success was much more in areas that faced critical fuelwood shortage (Skutsch, 1985; Johnsen, 1999). In the absence of pressing concern about environmental threats and scarcity of products and services from the forests, it is the rational choice from village or individual point of view not to invest their time and resources in forest management if they are not going to gain materially from this.

Interestingly, in Tanzania to date there have been no recorded cases of resistance to CFM establishment when villagers are approached by facilitating organizations officials. This is due to the fact that there are obvious signs of environmental degradation through out the country (Malimbwi *et al.,* 2005c; FAO, 2006). As such facilitators stand a good chance of winning villagers' interest when they raise awareness on possible threats among the villagers and try to convince them to establish CFM. Notably, areas with forests of high water catchment and biodiversity potential have received much more attention from government and NGO officials, because of the observable threats they face and the perceived value of such forests among officials. As such most of the early CFM projects were under JFM and can be found in areas with forests of high biodiversity and water catchment values (Blomley and Ramadhani, 2007). This explains why these areas are relatively advanced in CFM activities.

On the other hand, the dry forests that provide less timber but more of other products such as firewood, charcoal, building material and honey are increasingly reserved under CBFM schemes. These draw the interest of villagers due to diminishing supply of the products that are intrinsic to their livelihood. Establishment of CFM in these areas also receives emphasis from both the government and the donors due to its contribution to national poverty reduction strategy through forest ownership and increased access to forest products. The National Strategy for Growth and Reduction in Poverty through Goal 4 operation target 4.7 stresses the need to scale up CFM activities as a mechanism for increasing income of rural communities from natural resources management (URT, 2005). As such CBFM areas are increasingly being established in the dry woodlands of Iringa, Lindi, Tabora, Arusha, Pwani, Mbeya, Shinyanga, Dodoma, Kilimanjaro, Mtwara and Morogoro regions. It is envisaged that in the future much more emphasis will be given to this strategy owing to its potential for rural development that is in line with the government strategy for poverty alleviation, addressing the millennium development goals.

7.5.3 Supporting institutional structure

In order to examine the institutional structure supporting the establishment of CFM it is important to get an overview of the general government structure in which the villages and forestry sector are embedded and pinpoint the factors that influence the system. Relevant laws for the establishment of CFM are also reviewed and their importance highlighted.



Sources: Tanzania Bureau of Statistics, 2002 population and household census

A: Population density (persons per squire km) by regions in 2002.

B: Location of National Parks

Figure 19. Maps of Tanzania showing the population density by regions in 2002 and location of National Parks.

7.5.3.1 General government structure and the forestry administrative structure

In Tanzania the government sector is structured at national, regional, local/district and sub-district government levels. Mainland Tanzania comprises 21 regions which form de-concentrated administrative units of the central government. The local/district government level consists of more than 114 local governments. These are autonomous legal entities governed by elected councils with their own expenditure budgets, revenue sources and with ability to borrow funds. However, at present they are about 85% dependent on allocations from the central government to fund their core responsibilities (Fjelstad, 2004) as providers of public services such as primary education, water, basic health, local roads maintenance and extension services. Therefore while CFM establishment is a priority for the forestry sector, the districts councils usually have other pressing priorities to be done with a squeezed available budget. As pointed out by Blomley (2006), CFM funds for district councils are disbursed from the central government on the basis of flat rate ‘ceiling’ where districts themselves plan and budget for their use. As such it is likely that district councils with already tight budgets divert CFM resources such as funds, manpower and vehicles given by donors for CFM, to other activities. The consequence of this could be limited spread of CFM projects in the country.

From the district level the local governments are further subdivided into wards, then villages and finally sub-villages (hamlets). The village is governed by a village government which is elected by the village assembly comprised of all community members of 18 years and above. The village council has the roles of planning and coordination and encourages village residents to participate in development activities. However, villages have no real budgetary powers of their own but just facilitate smooth execution of activities by the district governments’ extension officials. In this regard the planning role of villages seems to be undermined since they do not have financial capabilities but receive directives to implement activities from the district authorities. This top-down management approach limits villages in CFM establishment since this is not a priority at the district level and the villages have no capabilities for initiating it themselves. Therefore, for wider CFM establishments it would appear that district councils should delegate more of their powers in this regard to the villages.

Within the village organizations there are also problems related to the integrity of village leadership. In one of the study sites (Gwata-ujembe village) the village leadership re-allocated a portion of the forest for other activities without the consent of village members. This example not only provides some indication about how powers vested on village leadership could be misused but also the fact that the forest portion was eventually recovered,which indicates the ability for self correction. In this case, this happened with strong and timely support from villages' higher authorities such as the ward officials and a facilitating organization, which indicates the importance of other stakeholders in the successful management of VFRs.

Furthermore, although inter-sectoral activities are carried out at village, district and region levels, administratively these lower government levels are under the ministers of Regional Administration and Local Governments. Consequently, other ministries such as the Ministry of Natural Resources and Tourism in which the Forest and Beekeeping Division sits, have no direct link to the lower government levels. This limits sectoral communications from the village level to the ministerial levels and vice versa. The Ministry of Lands, which is responsible for all land planning matters including CBFM establishment, faces the same bureaucratic barriers. With the current system, the lands and forestry extension staff are placed at district level under the district councils and lack direct communication with their sectoral ministries. This to a great extent limits sectoral activities such as CFM establishment since these are masked by other priority activities at the district level.

7.5.3.2 Relevant legal and policy framework

The Village Land Act (URT, 1999), recognizes village land as the area that the villagers have occupied or have been using since 1987 including woodland, fallow land, rangeland or other land through which stock customarily passes; or the area agreed between the village council and neighbouring village councils or the area demarcated under any procedure or programme since then and irrespective of whether or not this has been formally approved. Village area is also the area described when the village was first registered, the area designated as village land under the Land Tenure Act of 1965, or the area as agreed by the village council with any other body in charge of land which borders the village's land.

This flexibility in the land law not only guarantees villages the right to land they currently own but also recognizes that the capacity to demarcate and map village boundaries in the country is limited. As such boundaries using permanent features such as pathways, rivers, gullies, rocks are used, provided that these are agreed with neighbouring villages. The process of village land survey and mapping, which is the responsibility of the Ministry of Lands and Human Settlements, is very slow. Current statistics show that out of the total estimated 14,000 villages, only 6,500 have been formally surveyed and mapped (Ministry of Lands and Human Settlements, 2007), which means the exact number and sizes of existing villages is not known since most of them are simply established through agreement between neighbours. Lack of the knowledge on village sizes and the extent of land used for different uses in a particular village is limiting the establishment of village forest reserves since the extent of areas for communal activities in the villages are not known.

According to the Village Land Act, the village land is divided into: communal village land, not to be available for individual occupation and use; individual and family land, over which land ownership titles may be issued to villagers; and reserved land, land to be set aside for future individual or communal use. The communal land is then agreed by Village Assembly as their common property for uses such as forest, grazing areas, school area, churches and mosques. Village Forest Reserves (VFRs) fall within the village communal land and to avoid confusion, reserved land could have been termed 'spare land' (Wily, 2003b). However, as pointed out above, to date about 50% of the villages do not have a land use plan in place as is required by the law. This hinders the establishment of VFRs.

The Forest Act (URT, 2002) provides procedures for the creation of VFRs. Under this law, all VFRs in existence at the commencement of the Act were declared to be VFRs. In order to create new VFRs a village council by resolution declares an area of the land to be a village forest reserve and establishes a committee for its management. If the village council wants to further formalize the creation of the VFR, it submits an application to the Director of Forestry through the district government authority. Although the procedures for establishing VFRs are very clear and there is an established supporting institutional structure, at present only 382 villages out of 14,000 have the VFRs in place. Apart from other reasons discussed here, there is also a low awareness of the laws among the general public. This problem is exacerbated by the fact that those responsible for disseminating the law, such as forest officers, are often unwilling to transfer powers on for example licensing of forest products to villagers (Blomley and Ramadhani, 2005). Simple interpretations of the law such as those proposed by Wily, (2003b) would be needed to raise awareness. Other dissemination means through mass media such as radio, television and traditional shows could also be used.

7.5.4 Human resources

As already pointed out in Chapter 6 (Section 6.2), establishment of VFR requires on-site facilitation including activities such as: sensitization of villagers on the importance of VFRs, training of village forest committees on forest management practices, setting-up by-laws through meetings, drawing up a VFR management plan, and enabling them to get started with VFR management. All these require practitioners with village level experience in both facilitation and forestry practices. The early CFM projects that have been in operation for more than 15 years involved a lot of capacity building among forest officers and local practitioners. Field manuals such as the CFM establishment guidelines (MNRT, 2007) are available. These provide standard practical guidelines on CFM establishment and implementation in the country. These are simple guidelines which can easily be used by practitioners in other parts of the country. Other manuals such as the methodology for carbon assessment by communities developed in this study also are aiming to provide practitioners with tools for CFM activities.

As also already pointed out in Chapter 6, there are a number of national and international NGOs facilitating CFM which apart from the on-ground CFM facilitation, these NGOs are also involved with capacity building among practitioners. Their long experiences in Tanzania are a valuable resource for CFM implementation.

7.5.5 Funding sources

Since the first pilot VFRs were established in 1990’s, their facilitation has been done by local and international NGOs in collaboration with local and central governments. These are financed by both bilateral and multilateral donors as shown in Chapter 6 but the process of CFM establishment is slow because their contribution is limited. For this reason, the potential forREDD policy to cover the gap has been investigated in this study. It has been shown from Sub-Section 7.4.2.2 that if adopted, the REDD policy could contribute significantly to CFM establishment.

Continuing support from these donors would be very helpful and if coupled with REDD funds could make a significant contribution to the ground work on CFM activities in the country. However as pointed out above (Sub-Section 7.5.3), the donor and central government funds are channelled from the central government to the districts on a flat rate basis. The flat rate has been issued to the districts in order to simplify administration without taking into account huge differences in terms of forest resources endowment or other factors such as land sizes, location and population densities (Blomley, 2006). A fair distribution system could have considered these factors since, some district are larger, highly rural and heavily forested while others are smaller, more densely populated and with limited forest area. If REDD funds become available it is proposed that a transparent institutional arrangement which allow payments to be distributed in efficient and fair way among the participating districts should be set in place.

A system of ‘nested baselines’ proposed in this study (Chapter 2), implemented either by the Forest Division or Designated National Authority (DNA) will provide the basis for a clear and transparent national system of administration for incentives and rewards for participation in activities which lead to reductions in forest emissions. How cases of non-compliance, or increase in losses due to deforestation and degradation are dealt with, need careful thought and discussion. The Forest Division can play a coordinating role in implementing REDD policy pertaining to CFM across the country. Payments for credits and possible penalties for failing to comply may be monitored by this department through District Forest Offices. As explained in Sub-Section 7.4.2.3, with this system the districts through their ward offices are expected to play a crucial role of providing support and guidance to the participating villages on REDD implementation and the financial handling.

With respect to the problem of small villages and some CFM forests extending to other villages, it might be necessary to mobilize villages to form groups of several CFM forests grouped together to benefit from large economies of scale. These can take the form of the Duru-Haitemba VFRs in Babati and SULEDO in Kiteto where a consortium of neighbouring CBFM forests is formed. With these groups, expected net profit of the carbon projects will be high as a result of minimized costs due to large economies of scale.

7.6 Summary

The net carbon benefits from both sequestration and avoidance of degradation are much higher ($ 31 per household) for villages with large forests compared with those with small forests, which would hardly get any returns for carbon if this is valued at $ 5 per tCO_2. Villages with 156 and 550 ha of forests could earn about $ 12 and $ 18 per household per year respectively. If the selling price were to go up to $ 40 per tCO_2, which has been suggested as a possible future level given the existing market forces, villages even with small (20 to 50 ha) areas of forest could earn about $ 30 per household while more better forest endowed villagers (with > 1000 ha) might earn $ 438. This is the net income after all the operational costs are deducted. Carbon projects could therefore provide significant income generation opportunities at the village level through villagers' participation, and this may be rather an attractive option given the present severe scarcity of cash income in all the case study villages.

At a national level the theoretical potential income from the sale of carbon under a national REDD approach is about $630 million or $ 117 per rural household per year if all deforestation and degradation were to be halted and assuming the market price is $ 5 per tCO_2. However, apart from the fact that halting all deforestation and degradation is impossible, the funds will not all be for distribution to villagers since the costs for both CFM establishment and management and for establishing the country REDD policy will be deducted (overheads for administration and trading). Taking these costs into account, the research estimated that only $ 27 would be available for households. If the price of per tCO_2 were to rise to $ 40, then even when the country charges 30% of the carbon money to cover overheads and $ 10 per hectare for verification, individual households will earn $ 486 per year. This income could potentially motivate villagers as most of them currently have a cash income of less than a dollar per day. However, these figures are illustrative only. It remains to be seen what the future price of carbon will be, and what share of this will be retained by the government to cover its own costs.

The factors that may negatively influence communities as regards taking up CFM are unfair benefit sharing or fears of this, lack of availability of forest land, lack of community interest in forest management (which may itself relate to opportunity cost involved in foregoing other activities, or to the availability of alternative income sources), an unfavourable legal and policy environment, lack of facilitation capacity, and lack of availability of internal and external financing. Experience from case study sites show that village leaders, particularly the members of the village forest reserve committee, participate more than others in different forest activities, especially those involving payment of wages. Other villagers are not given the chance to participate. This situation can only be expected to become worse when the REDD funds become available to villages. A major consideration is that if villagers as a whole do not see any benefits, then they are likely to withdraw their cooperation from the communal effort for increasing carbon stock. This might jeopardise the anticipated contribution of CFM to the REDD policy. For the success of CFM under REDD therefore a system to ensure fair sharing of benefits needs to be established. This was not adequately addressed in the current research but it is acknowledged as a problem that will have to be dealt with in the future and which needs further study.

The districts through their ward offices are expected to play a crucial role of providing support and guidance to the participating villages on REDD implementation and the financial handling. Although villages have to decide on how the REDD money should be spent, some guiding principles on the use of the funds such as to sufficiently fund CFM carbon projects management, ensuring participation of most of the villagers, contribution to poverty alleviation and socio-economic development can be stressed. Since the net profit to be distributed among the villages might be small (especially for villages with small CFM forest areas), the money can be put under some legal monetary institutions established in each village such as the Savings and Credit Co-operatives (SACCOs) in which all villagers become members and can easily assess credits with less bureaucracy. With clear and transparent rules to access credits, this will ensure fair distribution of the money in villages and the fact that the money comes from CFM management will stimulate villagers to participate in their management.

Furthermore, it has been revealed that in most forest areas, villagers are interested to undertake CFM activities and there is sufficient land for that purpose. It was also seen that central government has succeeded in decentralising its powers and responsibilities to the districts councils. However, district responsibilities have not yet been divested to the villages and this calls for more empowerment of the village governments. Also, although there exists a favourable legal framework for CFM at national level, awareness of this among villagers and general public is still limited and should be raised. There are human and financial resources available to promote CFM (local NGOs and some donor funds) but it was observed that a flat ceiling rate is issued to the district for CFM activities without taking into consideration the district's location, population and forest resources endowment. It is therefore proposed that the system of 'nested baselines' should be used to provide a transparent institutional arrangement which will allow payments to be disbursed in efficient and fair way if REDD funds become available.

A system of 'nested baselines' proposed in this study, implemented either by the Forest Division or Designated National Authority (DNA) will provide the basis for a clear and transparent national system of administration for incentives and rewards for participation in activities which lead to reductions in forest emissions. How cases of non-compliance, or increase in losses due to deforestation and degradation are dealt with, needs careful thought and discussion. The Forest Division can play a coordinating role in implementing REDD policy pertaining to CFM across the country. Payments for credits and possible penalties for failing to comply may be monitored by this department through District Forest Offices.

With respect to the problem of small villages and some CFM forests extending to other villages, it might be necessary to mobilize villages to form groups of several CFM forests grouped together to benefit from large economies of scale. These can take forms similar to those of the Duru-Haitemba village forest reserves in Babati and SULEDO in Kiteto where a consortium of neighbouring CBFM forests was created. With these groups, expected net profit of the carbon projects will be high as a result of economies of scale.

Chapter 8

Conclusions and Recommendations

8.1 Introduction

This Chapter presents conclusions based on answers to the hypothesis and the research questions and gives recommendations for policy and further study. It starts with a statement of the objectives of the research. Then the main findings are presented and finally recommendations for policy and further studies are given.

8.2 Objectives of the study

CFM projects involve management of natural forests, which results in carbon sequestration through avoidance of deforestation and reduced forest degradation, but this cannot be credited under the current UNFCCC carbon payment mechanisms. An alternative mechanism, REDD, is still under discussion by the Parties to the UNFCCC. If this policy is adopted, it is possible that CFM (together with many other approaches regarding forest management) could be credited under a national sector-wide approach. In Tanzania, CFM was introduced in 1990's and is considered to be a very appropriate way of bringing about sustainable forest management with involvement of local people. It is emphasised by the National Forest Policy of 1998 and the Forest Act of 2002 as a major strategy to combat deforestation and degradation. However, the current speed under which CFM projects are established is very low. Access to carbon finances under REDD could potentially facilitate and speed up this process. However, if CFM projects are to be seen as climate projects under REDD, there will be considerable additional transaction costs, both for the government and for the participating communities.

The thesis argues that to minimize the transaction costs, local communities could be trained and equipped to use reliable, valid, easy to implement and cost effective techniques to carry out some of the activities that would be required, particularly as regards mapping the forest and carrying out annual carbon stock measurements themselves. The central hypothesis that the research has tested was *local communities can be trained to carry out forest measurements, and as a result benefit and participate more in forest management if carbon saved through CFM could be credited*. REDD policy for crediting forest carbon is still being debated, thus the second part of this hypothesis is still pending. The thesis therefore, also plays a role in informing the policy debate on the possible strategy of involving CFM projects in the REDD policy.

8.3 Main findings

8.3.1 Baselines for REDD in developing countries

In most systems which credit carbon emissions reductions, a baseline is required against which the savings can be compared. The setting up of baselines for REDD policy is still being debated thus the first contribution of this study is on how baselines for REDD could be determined. This was approached through a literature review and presented in Chapter 2 to answer the following questions: *What constitutes REDD? What is the importance of including emissions from degradation and the effects of forest enhancement? What are the principles of baseline construction including the technical and political problems related to developing baselines for deforestation, degradation and forest enhancement? How could baselines for crediting CFM under REDD be determined?*

Under REDD, the baseline is the reference scenario against which achievements made by a country can be measured and credited. There is considerable uncertainty at the moment about how baselines will be determined for operationalisation of REDD, since it is not yet decided what will be included. As explained in Chapter 2, the possible options include crediting reductions in emissions from deforestation, reductions in emissions from degradation, enhancement, forest conservation, and static carbon stock. The last two options relate to forests with long protection status which would be credited based on the maintenance of carbon stock. The other three options relate to forests that are used for different wood products such as those under CFM. They require either historical baselines or assessments of stock change over a given time interval.

Although the policy debate on how baselines for crediting reduced emissions from deforestation is still going on, it recognizes that forest degradation also results in considerable levels of carbon emissions. As such a degradation baseline will be needed in addition to a deforestation baseline so as to allow for the claim of credits for avoided degradation and provide incentives for countries to maintain their forests intact. What has not been clearly recognised in the policy debate is that measures taken to reduce deforestation and forest degradation will lead into increase in woody biomass and thus CO_2 sequestration through forest enhancement. It makes sense therefore from the point of view of rationalizing forest management and reducing CO_2, that forest enhancement should be credited as well. This calls for a need to establish a baseline for rewarding forest enhancement.

Baseline principles associated with various mitigation mechanisms include net-net accounting and gross-net accounting. Net-net accounting compares emissions or removal in the commitment period to those of a reference period. This approach is concerned with comparing changes in rates of loss of forest carbon. This is different from gross-net accounting where measurements of carbon stock change are compared only over the commitment period itself, in other words what is being assessed is the absolute change in carbon stock, not the change in its rate of loss.

Deforestation baselines can be determined using net-net accounting by depicting historical land use changes from satellite imageries and typical carbon stock data for different types of forests to calculate the changes in terms of tons of carbon. Recent developments in advanced remote sensing technologies are providing increasingly accurate data but there are difficulties of obtaining such high quality data on forest area for the past periods. Also carbon stock data on different forest types are lacking in most countries due to the fact that forest inventories are not carried out. This means that (conservative) default values have to be used. But as explained in detail in Chapter 2, the problems of deforestation baselines are relatively simple compared to those for degradation. Degradation baselines pose much greater challenges since they have to deal with rates of biomass loss within a forest, often under the canopy, or involving very small reductions in canopy cover which are difficult to identify, let alone measure, using remote sensing techniques. It is possible to estimate some types of degradation from high resolution remote sensing techniques (techniques have been applied for the case of selective logging, for example), but these require not only expensive imagery but also highly developed interpretation skills. To measure other types of degradation, particularly slow degradation as caused by over-exploitation of rural communities in dry forests, the only way to determine rates would be (a) estimates from the local people; (b) estimates from stumps counts; (c) modelling, using estimated rates of take off, (d) default values (rules of thumb), or (e) measurements from control sites. Estimates from control sites i.e. unmanaged forests with conditions similar to those of managed forests, would provide the most reliable data. Countries that wish to access REDD funding will in any case need to carry out periodic forest inventories in order to get detailed information on the rate at which carbon stock is being lost in the areas that are subject to degradation. This should in fact be a major activity under the 'readiness' mechanisms that are being proposed e.g. by the World Bank under the new Forest Carbon Partnership Facility (FCPF), as well as in demonstration activities for REDD that may be carried out between 2008 and 2012. Alternatively, this together with baselines for forest enhancement could be done under gross-net accounting system.

After developing national level reference scenarios for the whole country, a system of 'nested baselines' will be needed to operationalize REDD internally for the different geographic regions. This will also account for different forest regimes e.g. national parks, reserve forest, community forest, and private forest. This system is needed in order to provide incentives to stakeholders who are responsible for reductions in carbon losses within the country. Baselines for individual forest projects could be determined by measuring standing carbon stock in both managed project area and unmanaged forests in proximity. The difference between the two will then represents the carbon value of an individual project. The sum of the 'nested baselines' for deforestation from different regions, and degradation and forest enhancement from different projects will add up to the national reference scenario.

With these ideas in mind, the carbon benefits of CFM forests in this study were determined by assessing and monitoring carbon stock changes from CFM managed forests and unmanaged forests in their vicinity. From these measurements, the rate of forest degradation and enhancement were established from which the carbon benefits were computed. The results from the forests that were studied are presented in the following sections.

8.3.2 Carbon storage and sequestration in community managed and unmanaged forest

It is clear from Chapter 2 and Sub-Section 8.3.1 that individual projects (in this case, villages that are carrying out CFM) will need to determine their own baselines. As detailed in Chapter 4, the carbon storage and sequestration in community managed and unmanaged forests were determined in four locations with different vegetation types in Tanzania, in order to answer the first research question and provide evidence on: *how effective are CFM projects in carbon storage and sequestration.* The results of the measurements provide answers to the following specific questions: *What are the levels of carbon stock in CFM projects compared to unmanaged forests? What are the growth rates in CFM and in unmanaged forests? What are the differences in terms of species composition between CFM and unmanaged forests?* and, *How much carbon per ha per year is sequestered (under CFM) and lost (in the unmanaged forests, through forest degradation)?*

The findings from this study (Chapter 4) show that CFM projects store considerably more carbon than unmanaged forests. For example, while the biomass stock in 2008, for KSUATFR was 42.2 tons/ha, that of unmanaged forest in its proximity, was 7 tons/ha. The reason for higher stocking in CFM is that these were highly degraded a few years ago and were therefore handed over for village management. As a result they are now beginning to recover.

The low end value of biomass increment in this study is typically 0.5 tons/ha/year in managed forests while in unmanaged forest biomass off-take rates range from 1 to 3.5 tons/ha/year. The study provides evidence of continuous carbon sequestration in managed forests whereas in unmanaged forests carbon stocks are declining. On average the rate of biomass increment is 2.8 tons/ha/year for the miombo woodland forest of KSUATFR which is equivalent to the CO_2 sequestration of 5.3 tCO_2/ha/year. Biomass increment for Warib and Haitemba woodlands is 1.7 tons/ha/year equivalent to sequestration of 3.2 tCO_2/ha/year. For Mangala (lowland forest) and Handei (montane forest) the biomass increment rates are 4.4 and 5.2 tons/ha/year and their equivalent CO_2 sequestration rates are 8.3 and 9.8 tCO_2/ha/year. The variation in rates between the different forests is due to tree growth differences influenced by soil type, climate, species composition and age of the stands. For unmanaged forests the trend of the data shows that the stocking levels are fluctuating with average net biomass loss of 1 and 3.5 tons/ha/year (equivalent to CO_2 emission of 1.8 and 6.5 tCO_2/ha/year) for the woodland forests at Kitulangalo and in the lowland and montane forests around Mangala and Handei VFRs.

The number of individual tree species in managed forests is also higher compared to unmanaged forests, further indicating over-utilization in unmanaged forests. At Kitulangalo, while there is a total of 56 and 47 different tree species for KSUATFR and Kimunyu VFR, the number of species in unmanaged forests is 21. Only 7 different tree species were encountered for unmanaged forests at Mangala and Handei while the managed forests had 35 and 41 different tree species. A few species, particularly *Xeroderis Stuhlmanii* (66%), *Ficus* *sp* (47%) and *Anona sp* (78%) over-dominate unmanaged forests around Kitulangalo, Handei and Mangala while in managed forest there is a good mix with individual species dominance hardly reaching 40%.

The implication of these results is that if 'business as usual' had been allowed, the managed forests would have acquired the status observed in the unmanaged forests. That is to say, due to competing uses such as shifting cultivation and harvesting for firewood and charcoal, carbon emissions would have been much higher. However, it must be said that it is difficult to distinguish to what extent the situation in the unmanaged forests reflects the real 'business as usual' or 'leakage'. This is because some of the activities formerly carried out in the now-managed areas might have been displaced to these unmanaged sites. The research was not able fully to separate out these facts, and as recommended in Sub-Section 8.4.2, this merits further study.

8.3.3 Carbon assessment and monitoring by local communities

It was also the aim of this study to find out whether local communities i.e. villagers and their local supporting organizations, may be able to assess and monitor carbon sequestered in their forests at costs lower than if the same tasks were to be carried out professionally. A field forest inventory guide on the procedures and techniques for assessing and measuring forest carbon by local communities was developed in order to answer the second research question: *to what extent can local communities provide valid data to substitute for professionally gathered data of forest inventory?* The specific research questions were: *Are local communities able to assess and monitor carbon sequestered in their forests? Does carbon assessment and monitoring by local communities result in accurate and reliable estimates compared to professionally gathered data?* and, *What is the relative cost of community gathered data compared to professionally gathered data?*

Experimentation with this guide formed part of the 'Kyoto: Think Global Act Local' (K:TGAL) research project, involving local NGOs and research institutes in Mali, Senegal, Guinea Bissau, Papua New Guinea, Tanzania, Nepal and Uttranchal (India). As detailed in Chapter 5, for Tanzania, despite some difficulties encountered during the training of the communities such as modifications needed for the user manuals and the need to limit the amount of data to be logged into the computer in the field, the villagers were able to perform most of the important steps. The local communities were also able to retrieve and take plot measurements of the same trees in the following years. Local peoples' knowledge was very useful in identifying trees and different places in the forest. The role of the staff of the local supporting organizations was crucial as regard provision of technical assistance. However, it was not possible for these actors to tackle measurements of non-tree carbon pools as facilities were not available. Also the capacity for data analysis was lacking in the first instance and a special tool for this was developed by the researcher. This tool was used by the staff of the supporting organizations and facilitated immediate sharing of the results with the villagers. The testing in other countries involved in K:TGAL indicates that the field forest inventory guide also worked very well in these other situations. As was the case with Tanzania, the field teams in the other countries made modifications depending on local conditions such as forest density.

The reliability of stock measurements made by the local community was tested by commissioning a verification study, which was done by TAFORI. There was no significant difference on average measured wood parameters between their estimates and villagers' estimates. However, the precision of TAFORI's carbon stock estimate was as higher as ± 9% compared to ± 21% attained by the villagers (at 90% confidence level). This was explained by increased sample plot sizes by TAFORI, which gave a higher sampling intensity which has the positive effects of covering more forest variation in terms of tree/shrubs sizes and species abundance. During this verification, it was also observed that villagers were able to accurately locating sample plots and takes the tree measurements from plots correctly. The measurements by local communities, therefore, could have been improved if the sampling intensity were increased by way of increasing the plot sizes; this is an important lesson which has been gained from the exercise. Based on the nature of the forests and in order to make the field work easier by local communities, the instructions in the field forest inventory guide have been adapted and now call for 2 concentric plots of 5 and 15 m radius to be used for trees of up to 10 and greater than 10 cm dbh.

It costs much more to hire professionals for carbon assessment in the village forests compared to the same work done by villagers, even taking into account the equipment needed, and the fact that in the first 3 year of the measurements there are considerable costs due to the need for training and considerable supervision. The gain is in the long run, as villagers become increasingly able to carry out the exercise on their own. If the professionals have to continue with the assessment, they will be paid the same amount annually. The villagers undertake the same work at progressively lower cost in the successive years as the cost for training and supervision are reduced. From the fourth year of continuous assessment the trained villagers can work on their own at an average cost of $ 2 per ha, which includes costs of the assistance of the staff from the local supporting organization.

8.3.4 Costs and benefits of CFM projects and the expected changes if they become carbon projects

At present CFM projects are managed for protection of environment and sustainable production of products and services, and the effect of the inclusion of carbon production (the costs that would be incurred in measuring it, and the benefits that might be gained by selling carbon credits) need to be understood. Therefore, in order to determine the likely changes if CFM were to include carbon trading, through research question three, it was necessary to find out as: *to what extent will community costs and benefits be altered by the inclusion of carbon trading in CFM projects.* The specific research questions used were: *What sorts of management activities are supposed to be used by communities under CFM projects and what activities are in practice used? What are the current forest products and services generated by CFM projects? What changes in management will be associated with carbon management?* and, *Will there be losses of other benefits if CFM projects are turned into carbon projects?*

As detailed in Chapter 6, meetings, patrols, boundary maintenance and some enrichment planting are the typical activities in the CFM implementation in Tanzania and these are common in both JFM and CBFM. The typical cost for CFM establishment per village has been estimated as $ 29,452, of which 53% come from donor support and the remaining 43% from community's participation (this is based on community members' time inputs: in reality they are not usually paid for this). After establishment, it is estimated that management costs for the typical CFM activities could have required $ 1,580 per village per year. Most CFM projects however, have little to offer in terms products which could be sold to bring in this income as the forests are usually rather degraded and lacking in harvestable timber.

A general finding is that in all the villages, cash incomes are very low and opportunities for cash earning are extremely limited. This makes it potentially attractive for villagers to participate in forest management activities especially those involving payment of wages. However, there is undesirable tendency for only a small group of people get the benefits, particularly the members of the VFC. This problem is discussed in detail in Chapter 7, Sub-Section 7.4.2.3 and in this Chapter in Sub-Section 8.3.5.

The current CFM strategies that result in effective protection and sustainable utilization, guarantee carbon storage and sequestration while offering other benefits and services. Since forest protection is also necessary for the sustainable provision of other benefits and services, there will be no additional management activities required for the carbon production in CFM projects. However, if CFM projects are considered to be carbon projects and enter into carbon trading, apart from adequate spending on common CFM management activities, some additional activities related with the carbon measurements, verification and marketing will be required, as has been explained in Chapter 5 and above in Sub-Section 8.3.3. Additional costs for the implementation of these activities will therefore be involved ('carbon transaction costs'). Also some benefits that involve biomass removal from the forest, such as harvesting for timber, building poles, firewood collection and grazing, may possibly need to be reduced. An opportunity cost will therefore also be incurred for these products. The magnitude of these costs related with the CFM carbon projects are dealt with in Chapter 7 and summarised in the following section.

8.3.5 Estimates of communities' gain from forest carbon trading

The cost and benefits of CFM were estimated in this research in Chapter 6 and used to examine the extent to which the gains from the sale of carbon credits could potentially motivate more communities to participate in CFM, in other words, to bring about CFM on much larger scale than it is carried out in Tanzania today. This is done in Chapter 7 through the fourth research question: *to what extent could sale of carbon credits potentially motivate more communities to participate in CFM?* The specific research questions were: *What are the management (in financial and time terms), transaction (verification and marketing) and opportunity costs of CFM with a carbon management activity included? What is the likely overall financial benefit to the community per ton of carbon? How much the rate of deforestation and degradation could be driven down if payment system for carbon were set-*

up for CFM in Tanzania, and how much carbon will be saved? What will the country earn as a result? and finally, *What stops communities from taking up CFM today and to what extent could payments under REDD remove these barriers?*

As shown in Chapter 7, the costs of CFM with carbon management include: $1,580 per village per year for management activities, $ 2 /ha/year for measurements, $ 3.5 per hectare per year for the verification and 10% of carbon value for other overhead costs, these together forming the transaction costs. The opportunity costs for forests in Gwata, Ludewa, Mgambo and Ayasanda villages were $ 12, $ 23, $ 7 and $ 9 per hectare per year. The net carbon benefits were then computed using these costs and the data on carbon gains in each village studied.

The net carbon benefits from both sequestration and avoidance of degradation are much higher ($ 31 per household) for villages with large forests compared with those with small forests, which would hardly get returns for carbon if this is valued at $ 5 per tCO_2. Villages with 156 and 550 ha of forests could earn about $ 12 and $ 18 per household per year respectively. If the selling price were to go up to $ 40 per tCO_2, which has been suggested as a possible future level given the existing market forces, villages even with small (20 to 50 ha) area of forest could earn about $ 30 per household while more better forest endowed villagers (with >1,000 ha) might earn $ 438. This is the net income after all the operational costs are deducted. Carbon projects could therefore provide significant income generation opportunities at the village level through villagers' participation, and this may be rather an attractive option given the present severe scarcity of cash income in all the case study villages.

At a national level the theoretical potential income from the sale of carbon under a national REDD approach is about $630 million or $ 117 per rural household per year if all deforestation and degradation were to be halted and assuming the market price is $ 5 per tCO_2. However, apart from the fact that halting all deforestation and degradation is impossible, the funds will not all be for distribution to villagers since the costs for both CFM establishment and management and for establishing the country REDD policy will be deducted (overheads for administration and trading). Taking these costs into account, the research estimated that only $ 27 would be available for households. If the price per tCO_2 were to rise to $ 40, then even when the country charges 30% of the carbon money to cover overheads and $ 10 per hectare for verification, individual households will earn $ 486 per year. This income could potentially motivate villagers as most currently have a cash income of less than a dollar per day. However, these figures are illustrative only. It remains to be seen what the future price of carbon will be, and what share of this will be retained by the government to cover its own costs.

The factors that may negatively influence communities as regards taking up CFM are unfair benefit sharing or fears of this, lack of availability of forest land, lack of community interest in forest management (which may itself relate to opportunity cost involved in foregoing other activities, or to the availability of alternative income sources), an unfavourable legal and policy environment, lack of facilitation capacity, and lack of availability of up-font internal and external financing. Experience from case study sites show that village leaders (Chapter 6), particularly the members of the village forest reserve committee, participate more than others in different forest activities, especially those involving payment of wages. Other villagers are not given the chance to participate. This situation can only be expected to become worse when the REDD funds become available to villages. A major consideration is that if villagers as a whole do not see any benefits, then they are likely to withdraw their cooperation from the communal effort for increasing carbon stock. This might jeopardise the anticipated contribution of CFM to the REDD policy. For the success of CFM under REDD therefore a system to ensure fair sharing of benefits needs to be established. This was not tackled in the current research but it is acknowledged as a problem that will have to be dealt with in the future and which needs further study.

Furthermore, it has been revealed that in most forest areas, villagers are interested to undertake CFM activities and there is sufficient land for that purpose. It was also seen that central government has succeeded in decentralising its powers and responsibility to the districts councils. However, district responsibilities have not yet been divested to the villages and this calls for more empowerment of the village governments. Also, although there exists a favourable legal framework for CFM at national level, awareness of this among villagers and general public is still limited and should be raised. There are human and financial resources available to promote CFM (local NGOs and some donor funds) but it was observed that a flat ceiling rate is issued to the district for CFM activities without taking into consideration the district's location, population and forest resources endowment. It is therefore proposed in Sub-Section 8.4.1 that the system of 'nested baselines' as detailed in

Chapter 2 could provide a transparent institutional arrangement which will allow payments to be disbursed in efficient and fair way, if REDD funds become available.

8.4 Recommendations

In the light of the above findings, policy and further studies recommendations can be made.

8.4.1 Policy recommendations

- **REDD policy should include deforestation, avoidance of degradation and forest enhancement**

As pointed out in Sub-Section 8.3.1, the policy debate on how to develop baselines for crediting reduced emissions from deforestation is still going on, but it recognizes that forest degradation also results in considerable levels of carbon emissions. What has not been clearly recognised in the policy debate is that measures taken to reduce deforestation and forest degradation will lead into increase in woody biomass and thus CO_2 sequestration through forest enhancement. It is therefore recommended that apart from deforestation, the REDD policy should also credit reduced degradation and forest enhancement.

- **Governments are urged to consider CFM as part of their approach under REDD**

This study estimated sequestration and degradation rates for forests under CFM in Tanzania. As shown in Sub-Section 8.3.2, these CFM forests store and sequester considerably more carbon than unmanaged forests. This signifies the importance of CFM not only for sustainable management of forests but also as valid means of reducing emissions from deforestation and forest degradation. Governments are therefore urged to consider CFM as part of their approach under REDD policy.

- **Carbon benefits should be equitably shared among participating stakeholders**

Payments for REDD credits or through a fund, will be made by at the national level on the basis of verified reductions in carbon lost through deforestation and degradation over a given commitment period. This will be based on national reference scenarios for deforestation, degradation and enhancement agreed by the country and UNFCCC. How the funds are used by the national government concerned, is in principle a matter of national sovereignty. Nevertheless, the international agreement will in all probability require assurance that the rights of forest dependent people are respected.

Experiences from case study sites show that village leaders, particularly the members of the village forest reserve committee, participate more than others in different forest activities, especially those involving payment of wages. Other villagers are not given chance to participate. This situation would also be expected when the REDD funds become available to villages. For the success of CFM under REDD therefore a system to ensure fair sharing of benefits should be established. Moreover, it was observed that a flat ceiling rate is issued to the district for CFM activities without taking into consideration the district's location, population and forest resources endowment. A system of 'nested baselines' is therefore proposed as detailed in Chapter 2 and Sub-Section 8.3.1 above. This system should be established in order to provide transparent institutional arrangements to allow payments to be disbursed to the districts in efficient and fair way if REDD funds become available in the future.

With this system, the Forest Division will have to play a coordinating role in implementing REDD policy pertaining to CFM across the country. Payments for credits and possible penalties for failing to comply may be monitored by this department through District Forest Offices. The districts through their ward offices are expected to play a crucial role of providing support and guidance to the participating villages. Although villages have to decide how the REDD money should be spent, some guiding principles on the use of the funds are needed to sufficiently fund CFM carbon project management, to ensure participation of a range of villagers, and to contribute to poverty alleviation and socio-economic development. Since the net profit to be distributed to the villages might be small (especially for villages with small CFM forest areas), the money could for example be put under some legal monetary institutions established in each village such as the Savings and Credit Co-operatives (SACCOs) in which all villagers become members and can easily access credits. With clear and transparent rules to access credit, this will help to provide a fair distribution of the money in villages and possibly stimulate villagers to participate in the scheme.

With respect to the problem of small villages, it might be necessary to mobilize villages to form groups of several CFM forests to benefit from large economies of scale. There is a precedent for this in the Duru-Haitemba village forest reserves in Babati and SULEDO in Kiteto where a consortium of neighbouring CBFM forests is formed. With these groups, expected net profit of the carbon projects will be higher as a result of economies of scale.

8.4.2 Recommendations for further studies

- **Carbon stock data be collected using methodology such as that developed by the researcher**

Carbon stock data on different forest types that are needed for baseline determination are lacking in most countries because forest inventories are not carried out systematically or comprehensively. Continuous forest stock monitoring in permanent sample plots covering all vegetation types is therefore imperative and should be pursued with vigour from now on. This will generate not only mean annual increment rates needed for deforestation forecasting and forest enhancement but also for the determination of the rate of biomass loss for the construction of degradation baselines. Since forest inventories are costly and there is not enough forest staff, national programmes based on the methodology such as that developed by this study for forest assessment and monitoring by local communities is recommended.

- **The problem of 'leakage'**

Another challenge is the possibility that a village might have improved the status of its managed forest because it shifts the harvesting to other areas outside the project area, a situation referred to as 'leakage', as noted already in Sub-Section 8.3.2. The unmanaged forests in this case were considered as 'control sites' to portray a 'business as usual' situation (i.e. what would have happened in the absence of the CFM). The question is whether they are really 'control sites' or whether what has been measured is in fact 'leakage' or more likely a bit of both. This merits some further study.

- **Equitable sharing of carbon benefits**

Although the system of 'nested baselines' proposed in this study, if implemented either by the Forest Division or Designated National Authority (DNA), should provide the basis for a clear and transparent national system of administration for handling incentives and rewards for participation in REDD policy, the operation of such a system will not be simple. For example the case of a CFM group that does not comply, and increases its losses of carbon due to deforestation and degradation, needs careful thought and discussion. The losses incurred by this community would have to be deducted at national level from any gains in stock, meaning that the payout to CFM groups that have worked hard to reduce their emissions will be reduced. Further there is the problem that some communities (e.g. in areas where the forest has earlier been much degraded) stand to gain more than communities who have been careful with their forests in the past and have had less degradation. These problems, together with the problem of equitable sharing of carbon benefit within the villages, have not been adequately addressed in this study and therefore need further research.

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Appendix 1. Previous experiences with baselines determination

S/No.	**Model** (all at national level, unless otherwise specified)	**Baseline type**	**Accounting system**	**What is accounted/credited**	**Data sources**
1	Emissions and removals from afforestation, reforestation and deforestation (art 3.3) and forest management (art 3.4) in Annex 1 cos.	No baseline (used existing land use and barrier analysis on alternative land use)	Gross-net	Net emissions over the commitment period	Remote sensing and forest inventory
2	Emissions and removals from cropland management, grazing land management and re-vegetation in Annex 1 countries	Base year 1990	Net-net	Difference in average emissions over commitment period and base year	Remote sensing and ground level measurement
3	CDM afforestation/reforestation (project based)	1. For strata with no trees of shrubs, baseline taken as zero net removals/emissions 2. For strata with a few trees: baseline has to show steady or declining carbon stock, but is not accounted in the claim for credits	Gross-net	Increases in sequestered carbon in the newly planted tree stock	Forest inventory on project site
4	Compensated reductions	Reference case: average rate of deforestation during a selected historical base period (eg during 1990s) x carbon stock/ha	Net-net	Calculated carbon emission reduction due to average reduction in rate of deforestation in commitment period compared to base period	Remote sensing, with some ground truthing/calibration
5	Compensated reductions model with modification for countries with low deforestation rates	A negotiated reference case which is above the historical rate of deforestation	Net-net plus	Average reductions in emissions due to reduced deforestation PLUS an allowance for the fact that deforestation was reduced earlier	Remote sensing, with some ground truthing/calibration
6	Compensated reductions model with addition of forest management (as proposed eg by Indonesia)	Reference case: average rate of deforestation during a selected historical base period (eg during 1990s) x carbon stock/ha	Net-net	Includes also the increases in carbon due to forest management in defined, target areas (projects)	Unclear, but would need much more forest inventory data to ascertain carbon stock increases
7	Joint Research Centre model	Global, and national, average deforestation rate during a selected historical base period	Net-net	1. Countries starting above the global rate: average rate of reduction of emissions. 2.Counties starting below the global	Remote sensing to determine areas of intact, non-intact and non-forest. Carbon density of intact forest derived from literature: non-

S/ No.	**Model** (all at national level, unless otherwise specified)	**Baseline type**	**Accounting system**	**What is accounted/credited**	**Data sources**
				rate: will be credited provided deforestation emissions do not increase (unclear on what basis)	intact forest at 50% of this.
8	Stock model (project based)	No baseline	Gross-net	Credits for all standing carbon stock in project areas. Any losses at end of the commitment period would have to be made up by replacement planting.	Remote sensing and forest inventories. The credits would not be fungible with CERs as they are of a different nature.
9	Regional deforestation modeling	Extrapolated BAU based on regression model of causes of deforestation over historical period	Net-net	Difference between extrapolated and actual deforestation emissions	Remote sensing and considerable secondary data on processes influencing deforestation
10	Compensated conservation	Unclear, possibly no baseline	Gross-net?	Increases in forest cover x carbon density over commitment period (PLUS the standing stock?)	Remote sensing and forest inventories
11	Stabilisation fund for countries with zero deforestation	Unclear	Unclear	A negotiated payment for maintenance of stocks	Unclear

Appendix 2. A field forest inventory guide for carbon assessment and monitoring by local communities

December 2003

Preamble

This protocol gives a step-by-step guide to the procedures that need to be undertaken at field level, the idea being that each team uses the same standard procedure (i.e. trains local people to use the same standard procedure). Some steps however have to be undertaken by technical/scientific personnel: this is clearly indicated. The procedure draws heavily on MacDicken (1997), Weyerhaeuser (2000) and on Intergovernmental Panel on Climate Change (IPCC), (2003) *Good Practice Guidance for Land Use, Land-Use Changes and Forestry*. IPCC, National Greenhouse Gas Inventory Programme, Technical Support Unit, Institute for Global Environmental Strategies, Kanagawa, Japan.

The methodology described indicates how carbon can be measured in any given piece of forest. For each individual case study, measurements would have to be done for the project area, and possibly in other areas to represent the 'without project' case. The same kinds of methods can be used in each. This guide does not give information on how to determine the 'without project' baseline area: this would have to be decided in situ according to local conditions. As far as possible the methodology is in line with the latest Good Practice Guidelines of the IPCC, which were distributed at CoP9 earlier this month.

Other, non-carbon GHGs are not included in our methodology, since changes in their levels are not likely to be great in the CFM sites we are studying (no burning, no major loss of soil cover, no use of fertilizers etc).

The method as given here includes a scant part on data analysis (i.e. to convert from tree volume to biomass weight and eventually to carbon weight). In order for this to be applied by local communities (with minimum assistance), a user friendly Database will be prepared for this purpose after getting acceptable allometric equations from the participating countries.

An overview of the logic of steps is first given, then the means of carrying them out is described. It is assumed that prior to this work there is already known background information on land-use history, maps, landownership and socio-economic. Data recording forms are given in MacDicken 1997, they need to be adapted for our purpose and put on the laptop/handheld computer for field use.

Monitoring require provisions for quality assurance and quality control to be implemented through documentation and procedures. It is expected that this guideline provide Standard Operating Procedures (SOPs) that should be adhered to all times (with some agreed modifications to suit local conditions). In the field the following should be ensured: the involved field-team local community members should be fully cognizant of all procedure and the importance of collecting data as accurately as possible; test plots in the field should be installed as part of training and measure all pertinent components using the SOPs; all field measurements are checked by qualified person in cooperation with the local communities and correct any error in techniques; a document is filed with the project documents that show that these steps have been followed. The document will list all names of the field team and the project will certify that the team is trained; and new members to participate in filed work are adequately trained.

We are still experimenting with this methodology, and some aspects may not work perfectly in all environments. Therefore field teams have to take local decisions themselves if necessary to deviate from what we have suggested here. Please however record exactly what you did, and why you deviated from the method as proposed here! Then we can all learn from this.

1. Steps

Here, a brief overview is given of the steps that have to be undertaken. Thereafter each step is described in more detail.

Steps to be led by the technical team, but which may be done in conjunction with the community in many cases:

i. Divide the forest area into strata if necessary: strata being areas of forest which are distinctly different from each other in type and which will almost certainly have different amounts of carbon stored. E.g. heavily degraded forest area, normal forest, area of plantation within forest, age class within a plantation etc. In some cases this will relate to topography or soil or species types.

> ***The project area should be stratified into sub-population or strata that form relatively homogeneous units, if the project is not homogeneous. Stratification can increase the accuracy and precision of the measuring and monitoring in a cost-effective manner through diminishing the sampling effort necessary to achieve a given level of confidence (IPCC Good Practice Guidelines, Section 4.3.3.2 Page 4.97).***

ii. Community input may be very valuable in identifying types of forest; this could be a joint exercise. For each stratum make a list of the species likely to be found and give each a code with a default code for 'others'. Community should be heavily involved in this as they have to be able recognize the trees in the sample plots. It is essential that a species checklist is prepared before hand with scientific and vernacular names of the trees, possibly this may require services of a botanist.

iii. In each stratum, make a pilot survey to estimate how much variance there is in the tree stocking. This will allow an estimate to be made of how many sample plots are required (the greater the variance, the more samples need for any given level of precision). (Community may be involved in this exercise also)

iv. Calculate the number of sample plots needed per stratum and allocate these systematically within each of the strata, on the geo-referenced base map. Probably best done by the technical team.

Community team unaided (after training):

v. Locate the sample plots on the ground using compass and tape and mark the center on the ground (temporarily) using a coloured pole, for example. A GPS reading can also be taken.

vi. Give each sample plot an identification code and record (on the computer) a description of characteristics of the plot and any landmarks. Data should be recorded that will allow exactly the same plot to be found at a later date (exactly same trees).

vii. Measure the dbh of all trees greater then minimum decided dbh within the sample plot areas and log this information onto (pre-designed) data sheets on the handheld computer. A spread sheet programme has been designed for this and will be sent separately. For each tree recorded, identify type if possible using system of codes. Fallen trees also to be recorded.

viii. Set out the sub-plots for the shrub and herb layer, cut all vegetation from each subplot, weigh it, take a small sample of this in a small bag and label with plot and subplot identification code and record this in the handheld computer.

ix. Collect all litter from the subplot: bag, label, weigh and record.

x. Take soil samples randomly within the plot; bag and label.

xi. Record the total time taken including the travel time to the plot

Sustainability assessment:

i. Together with representatives of the community, decide how ‘sustainability’ could be measures (i.e. using criteria and terms suggested by villagers themselves)

ii. Make an assessment, using these criteria and indicators, of the current ’sustainability’ of each stratum of the forest

2. The steps worked out

2.1 Stratifying the forest area

This exercise is supposed to be done jointly between the technical staff and the local community people. For it we need the best geo referenced materials – maps, air photos, satellite imagery – available, combined into one 'base map' which can be scanned into the computer.

As community forests are characteristically small in size, boundary tracking and forest stratification is to be done by means of a hand held computer equipped with GPS and ArcPad GIS software. Data base format in ArcPad has already been developed with space for description of each stratum and codes for tree species. Forest boundaries, if not already mapped, can easily be established by community members by walking the boundaries with the GPS, (boundaries will be automatically plotted onto the basemap). This can then be displayed in a participatory process in which community members discuss what different types of forest there are (i.e. strata) and where their boundaries are. These can also be established by walking in the forest along the edges with the GPS recorder. When this is resolved, the boundaries should be logged/traced onto the base map and the characteristics recorded on the (computer) database, ie the characteristics that define this stratum as different from the others (typical tree species and typical condition of trees (stunted, harvested etc)).

2.2 Pilot survey to calculate variance of trees/shrubs species

i. For estimation of variance of the variable i.e. carbon stock of the main pool (in this case trees), at least 15 randomly laid out samples plots (*IPCC Guide, 2003, page 4.99, Sec. 4.3.3.4.1*) distributed to cover all possible variation should be established **in each stratum**.

ii. For the Pilot we will use nested sample plots (a larger circle containing smaller sub-units *(IPCC Guide, 2003, page 4.102, Sec. 4.3.3.4.2)).*

- Saplings (ie all woody stems longer than 1.3m high but with $1 \geq$ dbh≤ 5 cm) will be measured in a small circular plot of 1m radius at the middle of the large circle. A count of regenerating tree species (i.e. very small saplings less than 1cm diameter) will also be made in this subplot.
- All trees greater than 5 cm dbh will be measured all over the larger circle (normally 5.6m radius, i.e. with a total area of 100 sq m)
- Data on each tree will be entered immediately into the hand held computer. A paper record can also be made as a back-up.

Our calculation of sample size required is going to be based on the trees and saplings, so in the pilot survey it is not necessary to sample the herb and grasses layers (although, if the pilot survey is being used as a training exercise, herbs & shrubs and soil could also be sampled)

Exceptions:
In areas of low tree density a large plot may be needed, otherwise too few trees will be included. For savanna conditions a large circle of 15m may be more suitable, and the sub-plot at the center may have to be increased in proportion. If field teams decide to use larger plot sizes this is fine, but please record this and explain reasons.

iii. While walking inside the forest and at a particular plot, try as much as possible to record tree/shrubs names. These species names will be used to finalize compilation of species checklist to be used for the main inventory.

iv With data from the 15 plots, it is possible to calculate standard deviation and mean of the basal areas (Pilot survey file in Microsoft Excel, with instructions in Pilot Survey data in Microsoft Word). Then the number of sampling units (n) required to attain a desired precision at sampling error (E) of 10% (we have decided on 10% error rather than 5% as this considerably reduces the number of plots required) is given by:

$$n = \frac{CV^2 t^2}{E^2}$$

Where: CV = Coefficient of variation = standard deviation/mean

t = this is a value of t obtained from n-1 degree of freedom of the pilot study at 10% probability.

At the end of this step, we should have a calculation of the number of plots, n_i, needed, in each stratum.

2.3 Permanent plots layout

The required number of permanent plots then need to be laid out in each stratum (permanent plots statistically are more efficient than temporary plots because of high covariance between observations at successive sampling. Plots of the same size as for pilot survey should be used. Systematic layout of plots with a random start should be used (*IPCC Guide, 2003, page 4.100, Sec. 4.3.3.4.1*) for the advantage of uniform coverage of the forest area. The procedure for systematic layout of transects and plots described in the following subsections:

2.3.1 Locate permanent plots on the map

- Use the map developed in Section 2.1. Within each stratum, we need to establish transects perpendicular to the longest side of the stratum (or from the side with maximum accessibility - this results in transects that are easy to work with).
  i. Decide how many transects you need on the basis of a reasonable spread of the plots over the whole area and aim at intervals between lines (transects) being greater than between plots
  ii. Randomly locate the starting points of the transects along the chosen boundary line (later these can be physically marked in the field with recognizable beacons)

Hints:

- Depending on the number of plots to be established and the size of the stratum, the distance between transects should be greater than distance between sample plots.
- In order to have a random start, the first transect should be established at a distance determined by a randomly drawn number between 0 and *k,* where k is the length of the side of the forest from which you have chosen to approach.
- To get distance between transects, get the distance along chosen boundary and divide this distance to the decided number of transects

iii. Draw the transects parallel to one another to the far side of the forest

iv. Carefully note the bearing on these transects
v. Calculate the total length of the transects
vi. Allocate the plots systematically along this total length
vii. Mark the locations on the map

The result of this process is a combined random and systematic sampling frame, with the advantage that the plots can always be found again if the start points along the chosen boundary are known, as well as the bearings and the distances along the transects to each plot.

Worked example, sampling frame

See illustration

1. Let us say that the pilot study has indicated that you need 28 samples from stratum A and 14 from stratum B.

2. Using random number tables pick a number between 0 and 2.6 (the length of the road) and mark that point on the road. This is the Starting Point (SP1) for laying out the whole frame for stratum A. It is important that the point is really randomly chosen using some probabilistic method such as random number tables.

3. To spread 28 points our relatively evenly over the area you could use 7 transect lines, this means that they will lie exactly 0.4km (4 cm) from each other.

4. Starting from the SP measure 0.4 in each direction and mark the starting points of these transects. Draw the transects parallel to one another across the area and note the bearing (70 degrees).

5. Measure the total length of the transect (in our case it is 6.55kn or 65.5 cm)

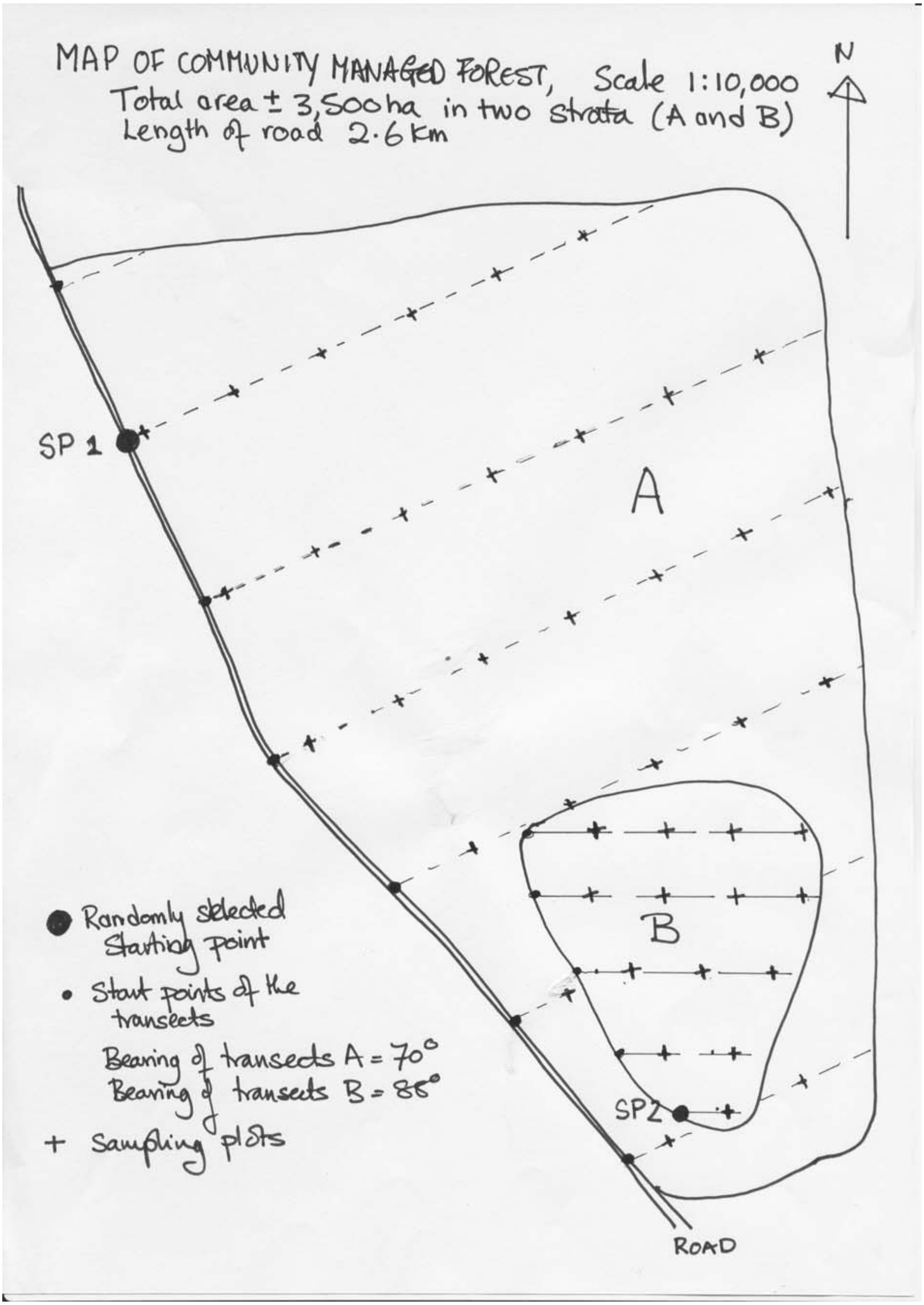
6. Divide 65.5 by 28 gives a distance of 2.2

7. Starting with the topmost transect, measure 2.2 from its start point. In this case the transect is only 2 cm long so there is no sampling plot possible. Carry the remaining 0.2 cm over to the next transect and mark the first sample plot, continue from there marking plots at 2.2 cm intervals (i.e. operate as if there were one transect of 65.5 cm rather than seven shorter ones)

8. Randomly select a Starting Point on the boundary of B (SP2). 5 transects should spread 14 sampling plots well across this area: transects spaced at 0.2 km (2 cm) from each other. Transects have been drawn at 88 degrees, total length of transect is 2.39 km (23.9 cm) so spacing should be 0.16 km (1.6 cm).

The higher density of sampling in plot B is due to it greater natural variability (as discovered in the pilot).

The transect Starting Points can be permanently signaled in the field by use of a beacon or some other permanent marker, from this the plots can always be found again using compass and measure tape. GPS recordings can also be made and used.


MAP OF COMMUNITY MANAGED FOREST, Scale 1:10,000
Total area ± 3,500ha in two strata (A and B)
Length of road 2.6 Km
N
SP 1
A
B
SP2
ROAD
Randomly selected Starting point
Start points of the transects
Bearing of transects A = 70°
Bearing of transects B = 85°
+ sampling plots

2.3.2 Locate the permanent plots on the ground

Locate the plots on the ground by using measuring tape and compass and mark the center with a brightly painted pole. Measure out the circle of selected radius (normally 5.6m) from this point using length of rope. Trees which are on the border are ‘in’ if more than 50% of the basal area falls within the circle and ‘out’ if less than 50%. Overhanging trees are not ‘in’ but trees with trunk in and branches out, are ‘in’.

If the slope in the plot is more than 10% it is necessary to correct for this using a clinometer or Abbney level using the formula:

$$Ls = L/\cos S$$

Where Ls is the correct plot radius, S is the slope angle in degrees, cos the cosine decimal taken from the back of the clinometer or from a table, and L is the plot radius.

For retrievability of the plot, it would be easiest to mark all of the trees in the plot with bright paint spots, and to leave the center marker permanently standing. However this could bias the way people manage this particular part of the forest. However, if the transect start point are well marked, the bearings and the distance along the transect to each plot is know, they should not be necessary. The GPS may assist in re-finding the plots but is unlikely to be accurate to more than 5m.

2.3.3 Measurements to be recorded from a plot

We are including in the measurements the carbon pools trees/shrubs (above ground biomass only; below ground biomass will be estimated mathematically as a proportion of above ground), litter, dead wood and soil organic carbon. However, not all the research teams will be looking at all the pools: particularly for the case of soil carbon, it is up to the local team whether they want to include this or not.

Trees

The simple way to do this is as we did in the pilot survey, to measure all trees over dbh of 1 cm within the small central plot (or 1m radius), and all trees over 5 cm dbh in the whole plot (5.6m radius). For this calipers or a diameter tape can be used,, starting from the edge and working inwards, marking each tree as it is done to prevent accidental double counting and entering data into the hand held computer as you go along. A staff of 1.3 m should be used to ensure that readings are taken at exactly the correct height. Each tree is recorded individually with its local name and botanical name. A checklist of the area/forest should be used for consistency in tree naming. The database for this should be on the computer and data entered directly, using species or tree type codes.

From the point of view of carbon storage, it is in fact the smaller trees, which are growing relatively fast, that are of the most interest, so special care should be taken to make accurate assessments of the groups between 1 cm and 5 cm dbh. Trees which are already as tall as 1.3 m but which are less than 1 cm dbh can hardly be measured, but they can be counted, and this count will be important especially if comparisons are made from year to year. We are not sure how to include this directly in carbon counting, but they could act as an indicator of rate of forest growth (also of sustainability).

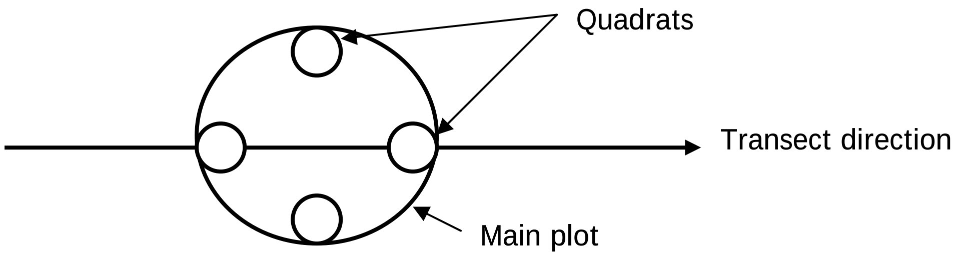
For what to do with trees of ‘unusual’ shape, please see the last two pages.

On the basis of our understanding that most allometric tables are based on dbh only (not on dbh plus height) we have not suggested measuring the tree heights. however, obviously if the local allometric tables are dual variable, height parameters will also have to be collected and recorded per tree.

Non-tree vegetation, litter and soil

Subplots are taken with fixed size quadrats or circles (metal, they usually fold up) that are placed on the ground. They are usually one square meter whether round or square.

According to the Winrock method, the subplots do not have to be randomly located within the main plot. However, certain amount of randomization is essential to obviate human bias. Four subplots are recommended (*IPCC Guide, 2003, page 4.105, Sec. 4.3.3.5.1*) to be sampled for each plot as shown in the figure below.



In the quadrats, sample first for herbs and grasses, then for standing litter and lastly for soil.

Include only vegetation that originates within the quadrat, but include and branches that originate within the quadrat hang over to the outside.

Clip all the vegetation down to ground level, place in a sample weighing bag, weigh, and record weight. Take a small sub sample of this vegetation and put in a small bag, label, weigh and take away (has to be dried and reweighed later to account for the moisture content).

Collect all biomass litter on the ground, put in a large bag and weigh, record. Take a small sub sample in a small bag, label, weigh and take away for dry weight comparison.

Use soil core or slice (first 30 cm of soil), and take one sample from each of the quadrants. Put them all together on a plastic sheet, sieve through a 5 mm mesh and mix well. Take a small sample in a bag, label and take away for lab analysis.

2.4 Record the time

Record the time taken, and number of people involved:

- To find and reach the plot
- To record all information related to trees
- To do the herb and shrub sampling

- To do the litter sampling
- To do the soil sampling

Including time taken to enter data into the computer

2.5 Sustainability assessment

The methodology for this will probably be different in each of the field locations. The idea is to work in a participatory manner with the community to establish their own criteria for 'sustainable forest', including not only biophysical aspects but also the benefits to humans. Projects under CDM and under other sources of funding will be assessed for their sustainability and it is important that we have worked out ways of involving local people in determining this.

Please will field teams develop their own procedures for this share their ideas on how to do this!

3. Data analysis

All the biomass data obtained in field measurements must be expressed on an oven-dry basis, and converted to carbon by multiplying the oven dry matter values by the carbon fraction of dry biomass. The value varies slightly by species and biomass component (trunk, branches etc), but we will use 0.5 (MacDicken, 1997) if no local value available.

Trees

Basal area of the trees has to be calculated separately for trees above 5cm dbh (which have been sampled over the whole plot) and for trees 1cm-5cm (which have only been measured in the smaller, central, plot). The results of both should be expressed in terms of basal area per hectare and then summed.

Though below ground estimate of roots biomass represent about 10 to 40% of total tree biomass, it is expensive to determine, so we will not do this but include instead an estimate on the basis of mathematical calculation. It is recommended that the best available literature values relating to a comparable area be used for this purpose.

For above ground biomass estimations, there are two approaches: Direct approach using allometric equations and in-direct approach using biomass expansion factor. We will use the direct approach:

i. First secure the data on diameter at breast height (dbh) of all trees in the permanent sample plots.
ii. Use appropriate/available allometric equations applied to measured trees to estimate both biomass and carbon stock. Allometric equations may not include trees down to the decided minimum dbh (1 cm), so we may have to extrapolate to estimate the biomass of smaller diameter classes.

Ideally we should check the allometric equations by destructive sampling but we have decided that this is not within our remit at present.

Non-tree vegetation, litter and soils

Herbaceous, grasses and shrubs can be measured by simple destructive sampling techniques in up to four small subplots per plot as explained above. A small frame circular or squire is used, and all vegetation is cut to ground and weighed. Well-mixed sub-samples from each plot are then oven dried to determine dry-to-wet matter ratios. These ratios are then used to determine the entire sample to oven dry matter.

For soil and litter samples required for laboratory analysis, it is recommended to discuss sample needs thoroughly with laboratory technicians before hand to ensure that samples are properly prepared. Would field teams who are intending to do soil analysis please share their procedure with us by recording in detail what method was used.

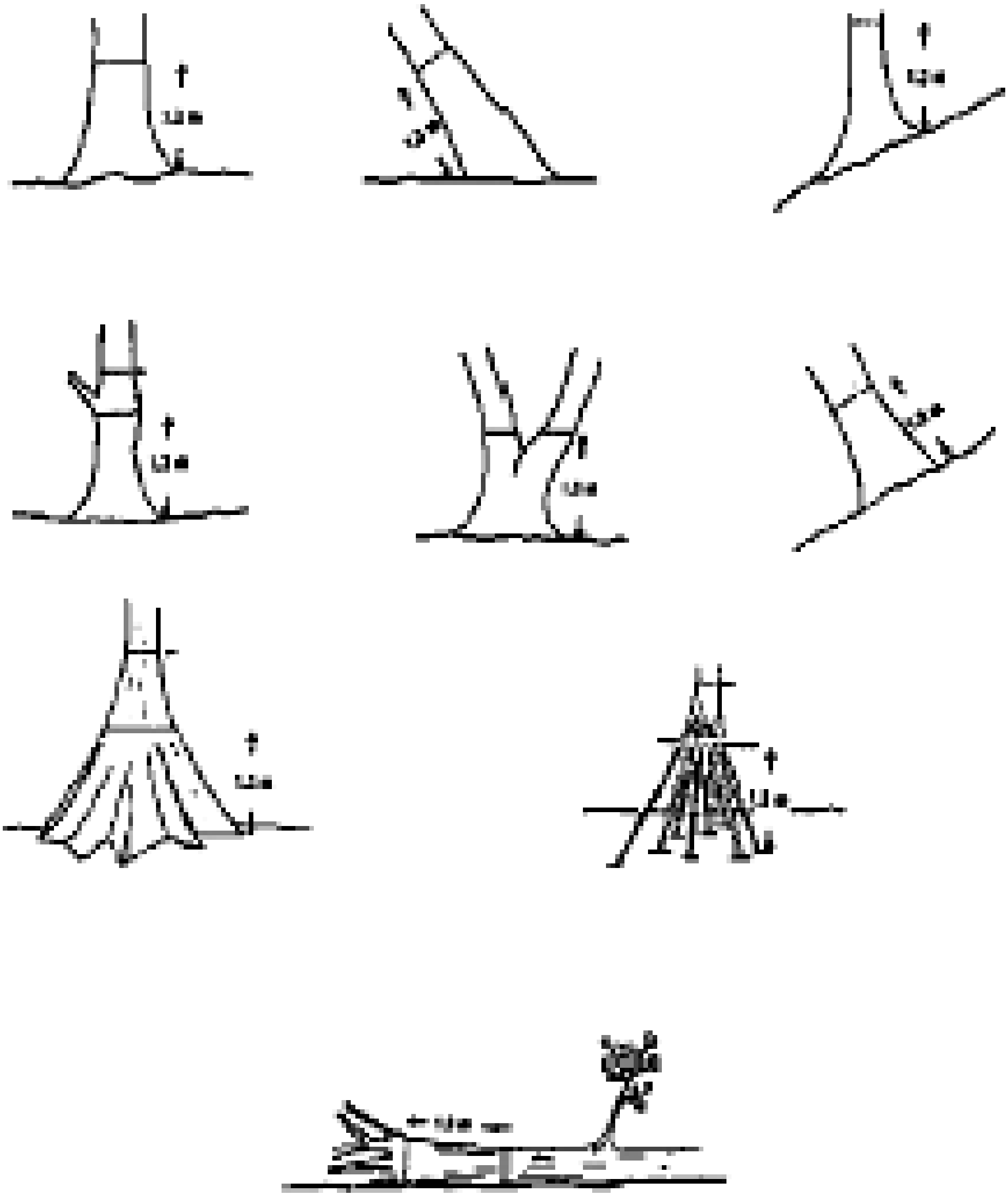
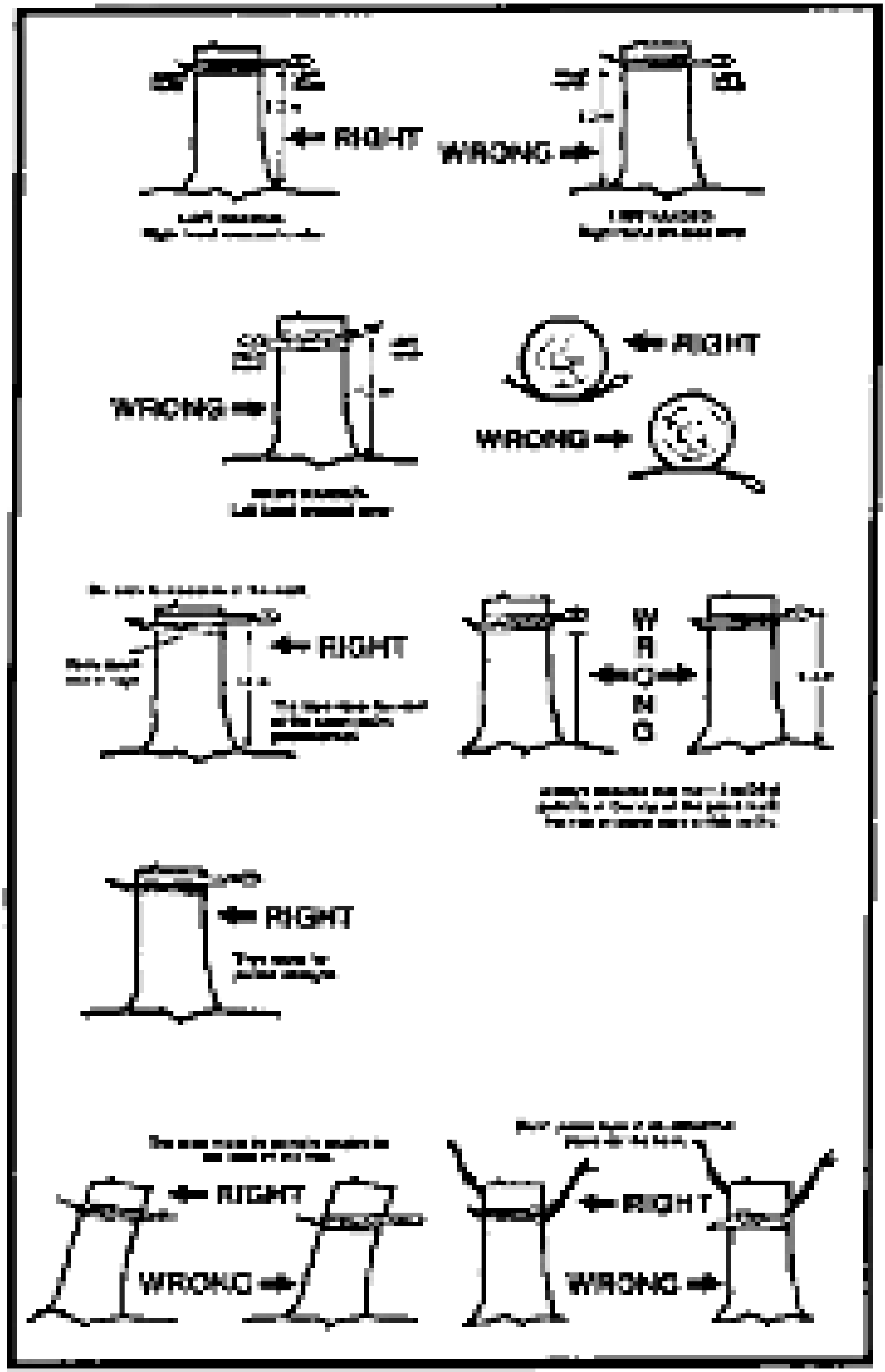


Figure 4. Proper use of a diameter tape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Appendix 3. A field manual for the handheld computer system

Mobile GIS Users' Manual

By

Verplanke, J.J. and Zahabu, E.

March 2003

1. Introduction

Handheld computer with ArcPad™ 6.0 software and Global Positioning System (GPS) can facilitate forests carbon assessment and monitoring. The software provides the user with the ability to bring geo-referenced maps and images into the field with the possibility to add and change the attributes attached to the maps and images during the actual observations. It offers users the ability to connect a Global Positioning System (GPS) to the handheld computer. The field handheld computers are manufactured to accommodate jacket GPS mounted directly on them where a position on ground in real time can be shown on the handheld computer screen map. With this system it is possible very simply to locate forestry boundary, sample plots and record measurement data for further processing. The data processing can also be done by way of fitted computation procedures in a spreadsheet/database computer programme such as MS Access.

It is expected that, with a step-by-step guide to the procedures, local communities can be trained on the use of the system and be able to map their forest reserves rapidly and with precision, locate permanent sampling plots with accuracy, and record measurement data on the trees and other vegetation in these plots, from which increases in carbon sequestration over time can be calculated. After training, the local communities will implement actual field assessment under the supervision and technical assistance from the researcher and two local forest field staff. This will facilitate checks on reliability of the data collected and acknowledge of what kind of technical support local people require, its availability and costs involved.

2. Quality of the data collected using this system

2.1 What Is GPS?

GPS is a satellite-based positioning system operated by the United States Department of Defence (DoD). GPS encompasses three segments: space, control, and user. The space segment includes the 24 operational NAVSTAR satellites that orbit the earth every 12 hours at an altitude of approximately 20,200 kilometers. Each satellite contains several high-precision atomic clocks and constantly transmits radio signals using a unique identifying code.

One Master Control Station, five Monitor Stations, and Ground Antennas comprise the control segment. The Monitor Stations passively track each satellite continuously and provide this data to the Master Control Station. The Master Control Station calculates any changes in each satellite's position and timing. These changes are forwarded to the Ground Antennas and transmitted to each satellite daily. This ensures that each satellite is transmitting accurate information about its orbital path.

The user segment, comprised of both civilian and military users worldwide, acquires signals sent from the NAVSTAR satellites with GPS receivers. The GPS receiver uses these signals to determine where the satellites are located. With this data and information stored internally, the receiver can calculate its own position on earth. This positional information can be used in many applications such as mapping, surveying, navigation, and mobile GIS.

2.2 What GPS Can Do for GIS

GPS is an excellent data collection tool for creating and maintaining a GIS. It provides accurate positions for point, line, and polygon features. By verifying the location of previously recorded sites, GPS can be used for inspecting, maintaining, and updating GIS data. GPS provides an excellent tool for validating features, updating attributes, and collecting new features.

2.3 How GPS Works

A GPS receiver must acquire signals from at least four satellites to reliably calculate a three-dimensional position. Ideally, these satellites should be distributed across the sky. The receiver performs mathematical calculations to establish the distance from a satellite, which in turn is used to determine its position. The GPS receiver knows where each satellite is the instant its distance is measured. This position is displayed on the datalogger and saved along with any other descriptive information entered in the field software.

2.4 Some Limitations

GPS can provide worldwide, three-dimensional positions, 24 hours a day, in any type of weather. However, the system does have some limitations. There must be a relatively clear "line of sight" between the GPS antenna and four or more satellites. Objects, such as buildings, overpasses, and other obstructions, that shield the antenna from a satellite can potentially weaken a satellite's signal such that it becomes too difficult to ensure reliable positioning. These difficulties are particularly prevalent in urban areas. The GPS signal may bounce off nearby objects causing another problem called multipath interference.

2.5 What's the Differential GPS?

Until 2000, civilian users had to contend with Selective Availability (SA). The DoD intentionally introduced random timing errors in satellite signals to limit the effectiveness of GPS and its potential misuse by adversaries of the United States. These timing errors could affect the accuracy of readings by as much as 100 meters.

With SA removed, a single GPS receiver from any manufacturer can achieve accuracies of approximately 10 meters. To achieve the accuracies needed for quality GIS records--from one to two meters up to a few centimeters requires differential correction of the data. The majority of data collected using GPS for GIS is differentially corrected to improve accuracy.

The underlying premise of differential GPS (DGPS) is that any two receivers that are relatively close together will experience similar atmospheric errors. DGPS requires that a GPS receiver be set up on a precisely known location. This GPS receiver is the base or reference station. The base station receiver calculates its position based on satellite signals and compares this location to the known location. The difference is applied to the GPS data recorded by the second GPS receiver, which is known as the roving receiver. The corrected information can be applied to data from the roving receiver in real time in the field using radio signals or through post processing after data capture using special processing software.

Experience with our system shows that it is possible to locate a point well within 5 to 10 meters. For the purpose of our work this can be quite sufficient and therefore eliminates the need for differential correction.

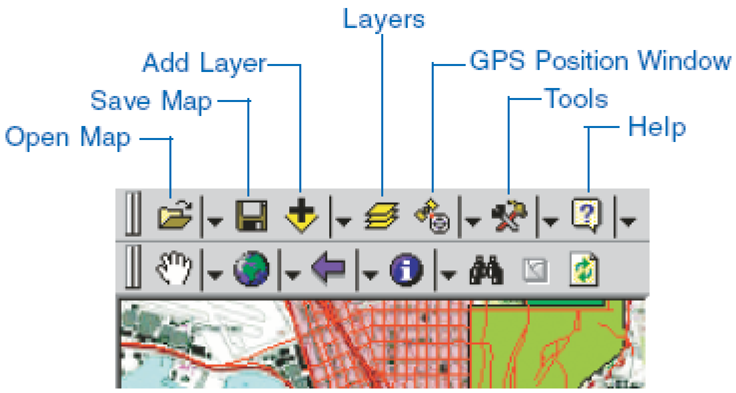
3. Carbon assessment

In this research, the system including Ipaq handheld computer with ArcPad™ 6.0 software and Navman jacket GPS is being developed. The system can be used in carbon assessment and monitoring. It can facilitate the following:

- marking the forest reserve boundaries and delineation of different vegetation zones
- locate permanent sampling plots, and
- record measurement data on trees, regenerations, herbs/grasses and litter in the plots.

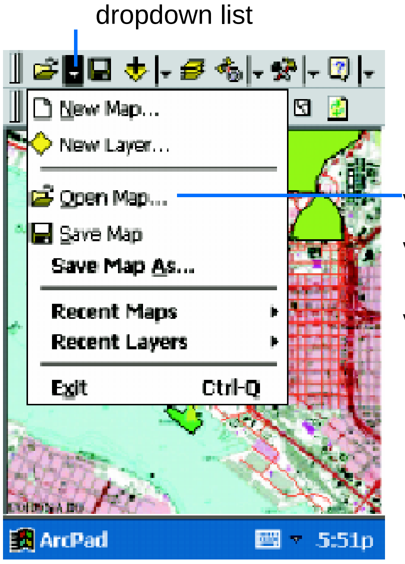
3.1 Marking the forest reserve boundaries and delineation of different vegetation zones

Forest boundary mapping could be made possible by utilizing GPS Tracklog in ArcPad 6 software. The GPS Tacklog is stored in a shapefile format in the ArcPad. It can be started or activated when the GPS is activated. ArcPad automatically records each GPS position it receives as a point feature in the GPS Tracklog shapefile, as long as the GPS Tracklog is running and the GPS is active. The GPS Tracklog is an electronic breadcrumb trail that shows the path that you have travelled. ArcPad uniquely displays these GPS positions, or points, in the Tracklog as a red line. If the travelled path is along the forest reserve boundary, then the marking of the boundary will be shown directly on the map on the computer screen.



Procedures:

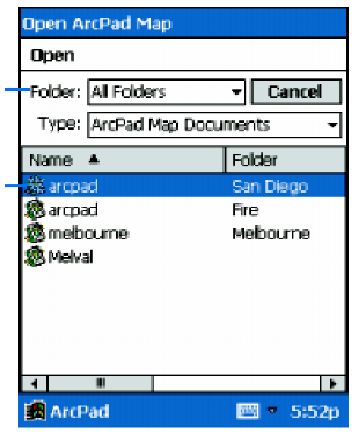
i. Connect the GPS to the Handheld computer
ii. Switch on the computer
iii. Tap Start
iv. Tap Programs and then tap ArcPad 6.0 to start the ArcPad program
v. Tap the down arrow to the right of the Open Map button on the main toolbar to display the dropdown list



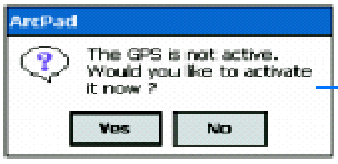
vi. Tap Open Map

vii. Navigate to the location of existing map file

viii. Tap the ArcPad map file you would like to open. Your map will appear on the screen of the computer.



ix. Activate the GPS by tapping the arrow next to the GPS positioning button to display the drop list. Then tap 'GPS Active' **OR** Tap the GPS positioning button to open a GPS positioning window. A message box will be displayed if the GPS is not active.



Tape "Yes to activate the GPS and open the GPS Positioning window

x. Then repeat the same procedure and tap 'GPS Tracklog' to activate the GPS Tracklog. Your route will be recorded on the screen. The GPS Tracklog layer display status is automatically changed to visible when the GPS Tracklog is started.

xi To deactivate the GPS Tracklog, tap the arrow to the right of GPS Position Window button to display the dropdown list. Then tap GPS Tracklog to stop capturing the tracking points.

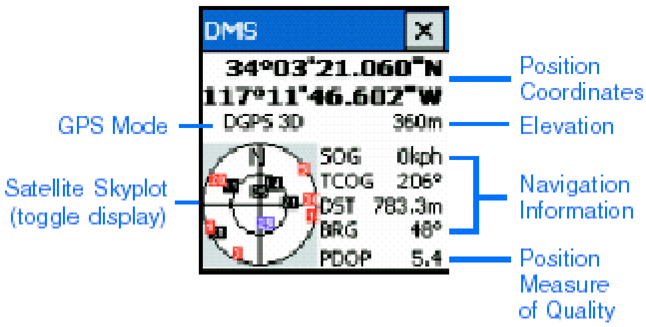
xii Activate the GPS by tapping the arrow next to the GPS positioning window to display the drop list. Then tap 'GPS Active'

Tips on activating a GPS in ArcPad

i. When activating a GPS by tapping the arrow next to the GPS positioning button, a GPS Positioning Window is not displayed. To view the GPS positioning window, repeat procedure (ix) and Tap GPS Positioning Window. A GPS Positioning window will appear.

To close the GPS Positioning Window, Tap the X button

ii. The GPS Positioning Window displays a rich variety of information about the GPS satellites, position coordinates and navigational information



iii. GPS Mode displays the type of position being received by the GPS (a) NOFIX indicates no position is being received (b) 2D/3D or DGPS indicates that a position is fixed by the GPS.

Alert!
No current position fix available: Will be displayed when there is no position fixed by the GPS. You may move to an open space to enable the GPS to fix a position.

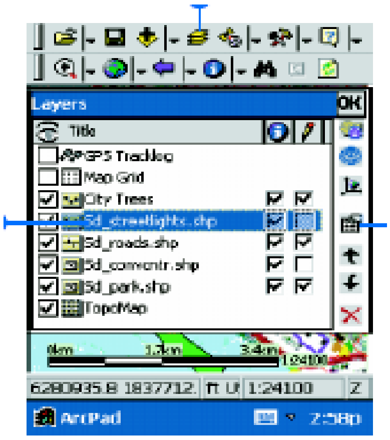
3.2 Locate permanent sampling plots

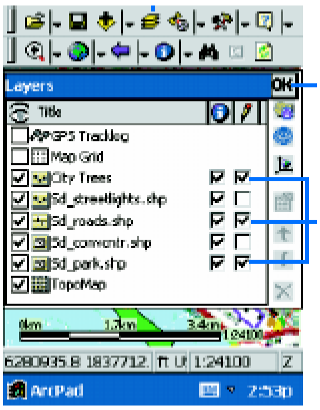
Procedures:

i. Open your existing map by following step i to viii as in the case of marking forest boundary above

ii. Tap layers button to open the Layers dialog box, the layers dialog box opens and lists all of the layers in the current ArcPad map with a corresponding icon to indicate the type of layer

iii. Tap the PlotSample.shp layer



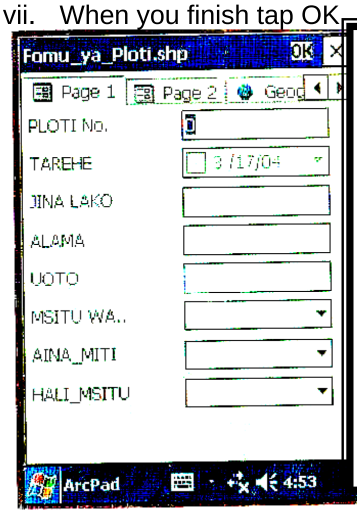


iv. Check the Edit check box for each layer your PlotShape layer

v. Tap Ok, Edit/Drawing toolbar will be displayed

vi. Then tap at the position shown by GPS pointer to mark your plot, The plot Attribute form will appear and you can fill in different attributes

vii. When you finish tap OK

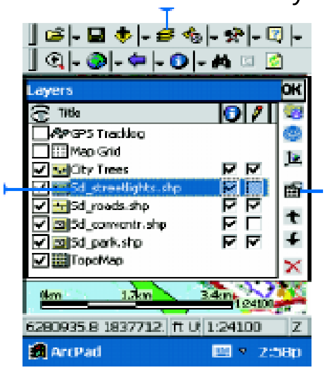


ATTRIBUTES TO BE FILLED IN THE PLOT FORM

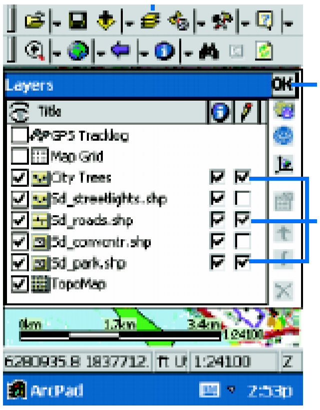
- **PLOT NO. – The number of a plot for its identification**
- **RECORDER – Name of the person doing the recording**
- **SYMBOLS – Unique permanent symbols that will be used to identify the plot in the future**
- **VEGETATION – Vegetation type where the plot is located e.g. closed miombo, montane forest**
- **MANAGEMENT – Purpose of management at that part of the forest e.g. production, conservation etc.**
- **BIODIVERSITY – Species richness at the plot area: either high, medium or low.**
- **STATUS - General current status of the forest: be either degraded, open or closed**

3.3 Record measurement data on trees and other vegetation in the plots

i. As soon after finishing making your plot (3.2 above), tap layers button to open the Layers dialog box, the layers dialog box opens and lists all of the layers in the current ArcPad map



ii. Tap the TreeSample.shp layer

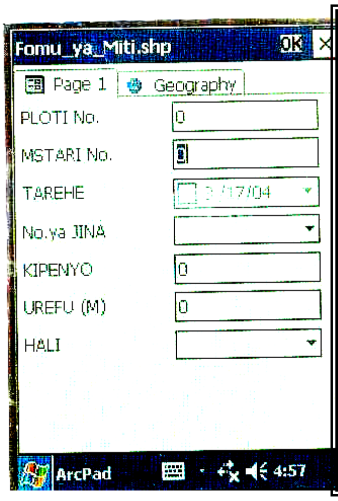


iii. Check the Edit check box for your TreeShape layer

iii. Tap Ok, Edit/Drawing toolbar will be displayed

iv. Then tap on GPS pointer while standing closer to the tree, the trees attribute form will appear and you can fill in different trees attributes

v. When you finish tap OK and proceed to the next tree.

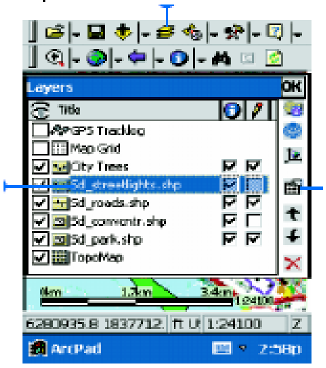


ATTRIBUTES TO BE FILLED IN THE TREES FORM

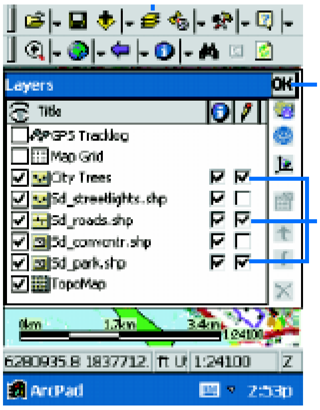
- **PLOT NO.** – **The number of a plot for its identification**
- **TRANSECT No.** – **The number of a transect for its identification**
- **SPECIES CODE** – **A unique number identifying each tree species**
- **DBH (cm)** – **Diameter at Beast Height in cm.**
- **Height** – **Tree total height in meters.**
- **STATUS** – **Species richness at the plot area: either high, medium or low.**
- **STATUS** - **State of the measured tree e.g. Normal, burned, fallen etc.**

3.4 Recording tree species regenerations, herbs/grasses and litter (All these are recorded for each of the four smaller plots in the main plot)

i. Tap layers button to open the Layers dialog box, the layers dialog box opens and lists all of the layers in the current ArcPad map



ii. Tap the TreeSaplings.shp or Herbs_Grass.shp or LitterSamples.shp layer.

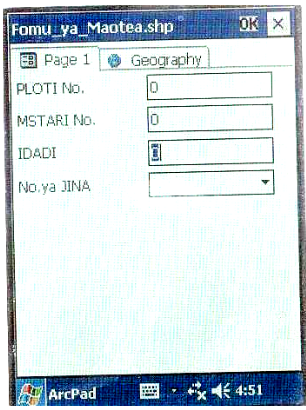


iii. Check the Edit check box for your TreeSaplings.shp or Herbs_Grass.shp or LitterSamples.shp layer.

iv. Tap Ok, Edit/Drawing toolbar will be displayed

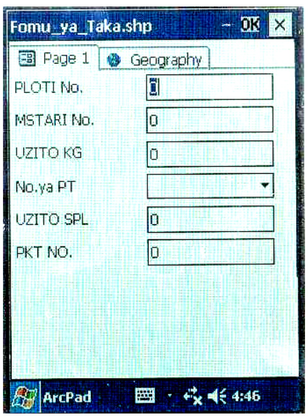
v. Then tap on the GPS pointer above the plot, the trees attribute form will appear and you can fill in different trees attributes

vi. When you finish tap OK



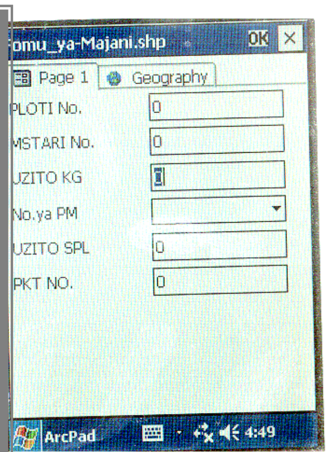
<u>ATTRIBUTES TO BE FILLED IN THE TREE SPECIES REGENERATION FORM</u>

- **PLOT NO.** – **The number of a plot for its identification**
- **TRANSECT No.** – **The number of a transect for its identification**
- **SPECIES CODE** – **A unique number identifying each tree species**
- **IDADI** – **Total count of the regenerations of a particular species**



<u>ATTRIBUTES TO BE FILLED IN THE TREES FORM</u>

- **PLOT NO.** – **The number of a plot for its identification**
- **TRANSECT No.** – **The number of a transect for its identification**
- **WEIGHT (KG)** – **Weight of litter or grass & herbs**
- **No. P(T or M)** – **Number of litter or grass $ herbs plot**
- **WEIGHT SPL** – **Weight of the sample**
- **PKT** – **Number on the sample packet**



Appendix 4. Kiswahili field manual for the handheld computer system

Maelezo ya mtumiaji wa computa ya mkononi

Na

Zahabu, E.

September, 2004

1. Utangulizi

Komputa ya mkononi iliyo na Programu ya kuchorea ya “ArcPad™ 6.0” na dira inayoonyesha mahali popote ulipo yaani “Global Positioning System (GPS)” inawezesha kufanya makisio ya kiasi cha kaboni iliyopo msituni kwa sasa na kwa vipindi vijavyo. Programu hiyo ya kuchorea inamuwezesha mtumiaji kuwa na ramani katika eneo analofanyia kazi ili aweze kuongeza au kubadilisha vitu vilivyoonyeshwa kwenye ramani hiyo wakati anapoviona mwenyewe moja kwa moja. Inamuwezesha pia mtumiaji kuunganisha computa ya mkononi na GPS. Ukiwa na vitu hivyo viwili vinavyofanya kazi kwa pamoja unaweza kuweka mpaka wa msitu, kuweka ploti za kuchukulia vipimo na kuingiza vipimo kwenye computa.

Inatarajiwa kuwa kukiwa na maelezo ya hatua kwa hatua, wananchi wa kawaida wanaweza kufundishwa na kuweza kuchora ramani ya msitu kwa haraka na umakini mkubwa, kuweka ploti za kuchukulia vipimo na kuchukua vipimo vya miti na majani. Kutoka kwenye vipimo hivyo kiwango cha ongezeko la kaboni kwenye msitu kinaweza kukokotolewa. Baada ya mafunzo wananchi watafanya kazi ya kuchukua vipimo chini ya uangalizi wa watafiti pamoja na mabwana miti. Hii itafanyika ili kuangalia ubora wa vipimo vinavyochukuliwa pamoja na kuangalia ni aina gani ya msaada wa kiufundi unatakiwa na gharama zake.

2. Mambo ya kufanya

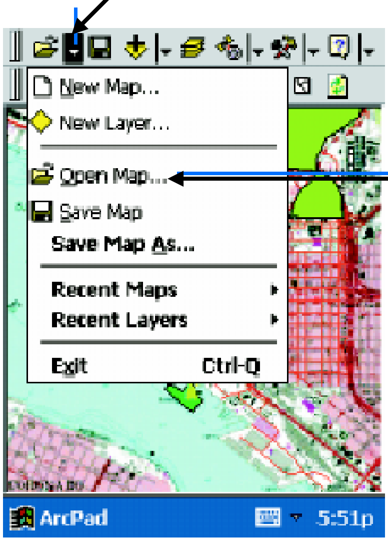
Katika utafiti huu, komputa ya mkononi tutakayoitumia inaitwa “Ipaq Pocket PC” iliyo na Programu ya kuchorea ya “ArcPad™ 6.0” na imeunganishwa na GPS. Vitu hivi kwa pamoja vinaweza kufanya mambo yafuatayo:

- Kuchora ramani ya msitu
- Kuweka ploti za kuchukulia vipimo, na
- Kuchukua vipimo vya miti na majani

3.2 Kuchora ramani ya msitu

Hatua za kufanya:

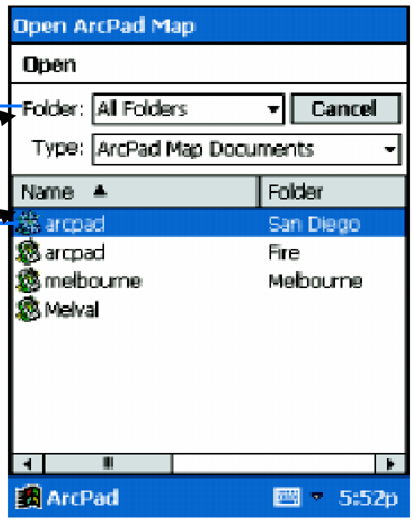
i. Unganisha GPS kwenye computa
ii. Washa computa
iii. Bonyeza “Start”
iv. Bonyeza “Programs” na kisha bonyeza “ArcPad 6.0” kufungua programu ya kuchorea
v. Bonyeza mshare unaoelekea chini uliopo kulia kwa kitufe cha kufungulia ramani na kutatokea maneno kama ilivyoonyeshwa kwenye picha hapo chini.



vi. Bonyeza “Open Map”

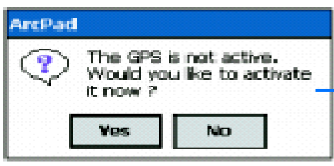
vii. Chagua ramani ya eneo lako

viii. Bonyeza ramani ya eneo lako. Ramani hiyo itaonekana kwenye kioo cha computa.



ix Iwezeshe GPS ifanye kazi kwa kubonyeza mshale uliopo pembeni mwa kitufe cha GPS

x. Kisha bonyeza ‘GPS Active’ **AU** bonyeza kitufe cha GPS, ambapo utapata ujumbe kama GPS haifanyi kazi.



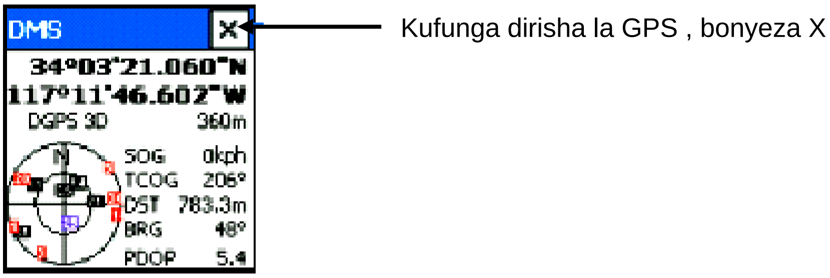
Bonyeza “Yes” kuiwezesha “GPS” kufanya kazi.

xi. Rudia hatua ya ix na x na bonyeza ‘GPS Tracklog’ kuiwezesha GPS kuonyesha mstari wa njia unayotembea. Your route will be recorded on the screen.

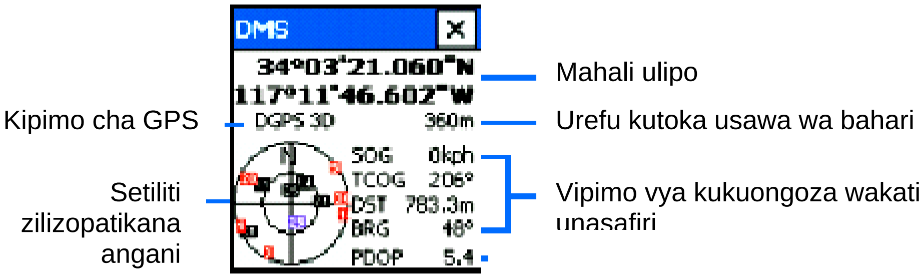
i. Kuisimamisha GPS isionyeshe njia unayopitia, bonyeza mshale uliopo kulia kwa kitufe cha GPS na kasha bonyeza “GPS Tracklog”.

Mambo ya kuzingatia wakati wa kuiwezesha GPS kufanya kazi

i. Unapoiwezesha GPS kufanya kazi kwa kutumia mshale uliopo kulia kwa kitufe cha GPS, dirisha la GPS halitokei. Ilikuliona dirisha la GPS, bonyeza mshare huo na kasha bonyeza "GPS positioning window". Dirisha la GPS litaonekana:



ii. Dirisha la GPS litaonyesha mambo mengi kuhusu GPS setilaiti, mahali ulipo na jinsi ya kukuongoza unaposafiri.



iii. Kipimo cha GPS huonyesha upatikanaji wa taarifa za GPS

a. Ikionyesha "NOFIX" hiyo inamaanisha hakuna mawasiliano kati ya GPS na setiliti

Alert!
No current position fix available:

Hali hii inapotokea, unaweza kusogea kwenda kwenye eneo la wazi ili kuweza kupata setiliti nyingi angani.

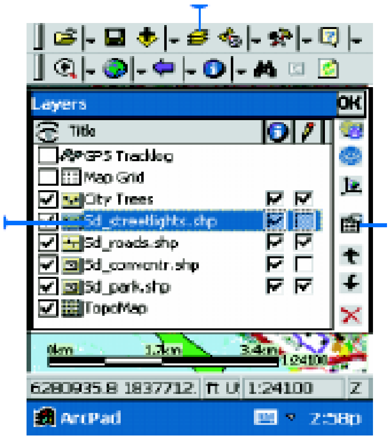
b. Ikionyesha 2D/3D or DGPS inamaanisha mawasiliano yapo na taarifa za GPS unazozipata ni sahihi.

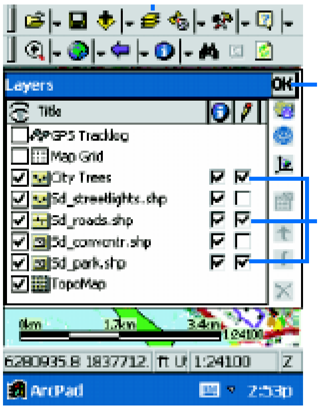
3.2 Kuweka ploti za kuchukulia vipimo

Hatua:

i. Fungua ramani ya eneo lako kama ilivyoonyeshwa juu kwenye kuchora ramani ya msitu
ii. Bonyeza kitufe cha matabaka ya ramani, dirisha la matabaka litaonekana.

iii. Bonyeza tabaka la Ploti.shp

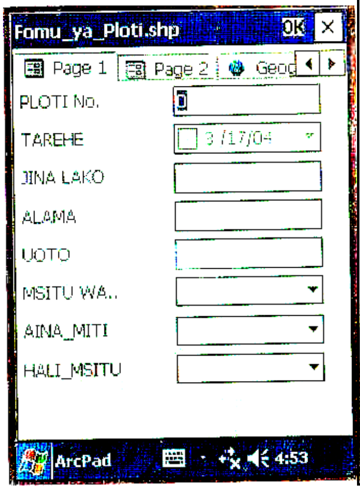




iv. Weka alama ya ‘V” kwa kubonyeza kwenye kiboksi cha pili kwenye tabaka la Ploti.shp.

v. Kisha bonyeza “OK” iliyoko kwenye kona ya juu kulia ya dirisha la matabaka.

viii. Bonyeza mahali palipoonyeshwa na alama ya GPS kuweka ploti yako, hapa fomu ya ploti itatokea na unaweza kujaza taarifa mbalimbali zinazohusu ploti hiyo.
ix. Ukimaliza bonyeza “OK” iliyopo kwenye kona ya kulia ya fomu ya ploti.

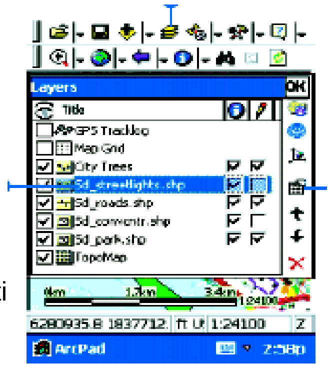


TAARIZA ZAKUJAZA KWENYE FOMU YA PLOTI

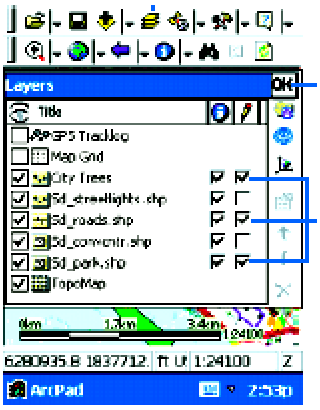
- PLOTI NO. – Namba ya utambulisho ya ploti
- JINA LAKO – Jina la anayeingiza taarifa
- ALAMA – Alama zisizo hamishika zitakazowezesha utambilisho wa ploti hapo baadaye
- UOTO – Aina ya msitu mahali ulipoweka ploti kama: miombo iliyofunga, isiyofunga n.k.
- MSITU WA – Onyesha kama ni msitu wa hifadhi, matumizi n.k.
- AINA ZA MITU – Eleza kama aina za miti ni nyingi, za wastani au ni chache.
- HALI_MSITU - Eleza kama msitu uko wazi, umefunga au umeharibiwa

3.3 Kuingiza vipimo vya miti

i. Mara baada ya kumaliza kuweka alama ya ploti (3.2 hapo juu), bonyeza kitufe cha "layers" kufungua dirisha la tabaka, dirisha la tabaka litafunguka na kuonyesha orodha ya matabaka yote yaliyopo.

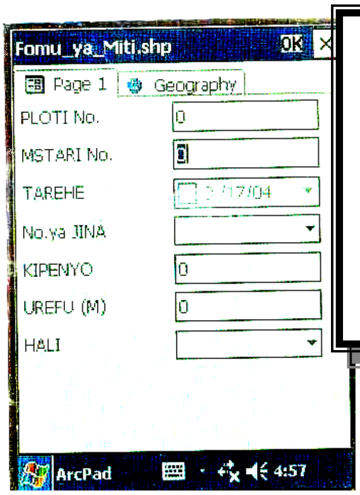


ii. Bonyeza tabaka la form ya miti Fomu_ya_Miti.shp



iii. Weka alama ya 'V' kwenye kiboksi cha kulia mwa tabaka la Fomu_ya_Miti

iii. Bonyeza "Ok" iliyoko kwenye kona ya juu ya kulia ya dirisha la tabaka
iv. Kisha bonyeza kwenye alama ya GPS na fomu ya miti itaonekana
v. Ukisha maliza mti husika bonyeza "Ok" kuendelea na mti mwingine.

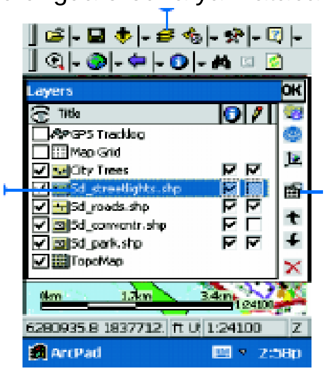


TAARIFA ZA KUINGIZA KWENYE FOMU YA MITI

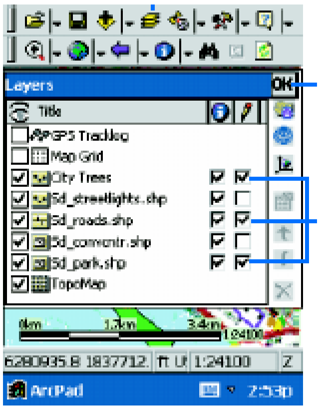
- PLOTI NO. – Namba ya utambulisho wa ploti
- MSTARI No. – Namba ya utambulisho wa mstari
- NO. YA JINA – Namba ya utambulisho wa aina ya mti
- KIPENYO (cm) – Kipenyo cha mti (cm).
- UREFU (m) – Urefu wa mti (m).
- HALI – Hali ya mti, kawaida, umeungua, umeanguka n.k.

3.5 Kuingiza vipimo vya maotea, majani mabichi na makavu

i. Bonyeza kitufe cha tabaka kufungua orodha ya matabaka yaliyopo kwenye lamani



ii. Bonyeza tabaka la Fomu_ya_Maotea.shp au Fomu_ya_Majani.shp au Fomu_ya_Taka.shp

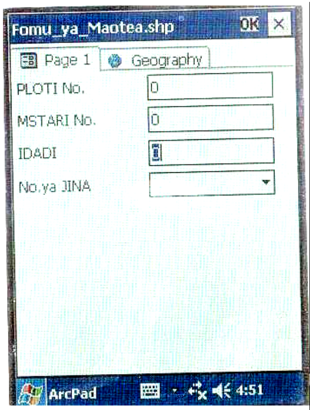


iii. Weka alama ya ‘V’ kwenye kiboksi cha kulia mwa tabaka unalotaka kulifanyia kazi.

vii. Bonyeza “Ok” iliyoko kwenye kona ya juu ya kulia ya dirisha la tabaka

viii. Kisha bonyeza kwenye alama ya GPS na husika itaonekana

ix. Ukisha maliza fomu husika bonyeza “Ok” kuendelea na fomu nyingine.

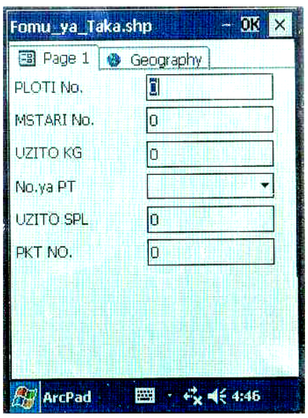


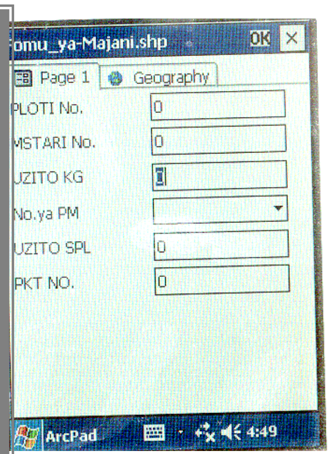
TAARIFA ZA KUINGIZWA KWENYE FOMU YA MAOTEA

- PLOTI NO. – Namba ya utambulisho wa ploti
- MSTARI No. – Namba ya utambulisho wa mstari
- IDADI – Jumla ya maotea ya aina moja ya miti
- NO. YA JINA – Namba ya utambulisho wa aina ya mti

TAARIFA ZA KUINGIZ KWENYE FOMU ZA MAJANI NA TAKA

- PLOTI NO. – Namba ya utambulisho wa ploti
- MSTARI No. – Namba ya utambulisho wa mstari
- UZITO (KG) – Uzito wa majani/taka
- No. ya P(T or M) – Namba ya utambulisho ya ploti ya majani au taka
- UZITO SPL – Uzito wa sampuli
- PKT – Namba ya mfuko wa kufungia sampuli





Appendix 5. Household questionnaire

Questionnaire No………..

Social activities of the respondent……………

Part A: Personal/Household information

1. Name of respondent…………………………………… (Optional)
2. Sex:……………….Male/Female
3. Age……………… Years
4. Level of education;
    (a) Primary
    (b) Secondary education
    (c) No formal education
    (d) Others:…………………………………………….(Specify)
5. Household profile

	0-18 years		18-60 years		>60 years	
	Male	Female	Male	Female	Male	Female
No. of household Members						
Daily activities done						

6. Land ownership

Land parcel	Area (ha)	Current use (agriculture, fallow, forestry, others)	Ownership within the family

7. Types of the crops grown:

Crop	Average annual harvest	Amount for own use	Average price (Tshs/……….)

8. Types of domestic animals kept

Animal	Where grazed	No. sold in a year	Average price (Tshs)

Main Economic Activities

6. Principal economic activities of the village

(i) ……………………………………………………….

(ii) ………………………………………………………

(iii) ………………………………………………………

(iv) ………………………………………………………

(v) ………………………………………………………

7. Secondary economic activities

(a) ……………………………………………………….

(b) ………………………………………………………

(c) ………………………………………………………

(d) ………………………………………………………

(e) ………………………………………………………

8. Major Sources of Income

(a) ……………………………………………………….

(b) ………………………………………………………

(c) ………………………………………………………

(d) ………………………………………………………

(e) ………………………………………………………

Part B: Forestry Management issues

9. Profile of forest reserves in the village

Name of the forest	Area (ha)	Ownership (Village, government, JFM, Private)	Management purposes (Productive/Protective)

10. Who are different stakeholders/Institutions involved with forest management in the village

Name of the forest	Stakeholders	Role (s)

11. What benefits does the household derive from the forest?

(i) ……………………………….

(ii) ………………………………..

(iii) ………………………………..

(iv) ………………………………..

(v) ……………………………….

12. How are the benefits shared among the household members?

(i) ………………………………………..

(ii) ………………………………………….

(iii) ………………………………………..

(iv) ………………………………………..

(v) …………………………………………

13. How is the household involved in the management of the forest?

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………..

14. What are the costs and benefits of CFM in the past 5 years?

Year	Income		Expenditure		
	Source of fund	Amount	Management activity	Frequency (yr/month/week)	Amount paid
	• Fines • Donor		• Meetings • Patrol • Fire fighting • Boundary maintenance		

15. What are the problems/constraints experienced in managing the forest?

(i) ………………………………………………………

(ii) ……………………………………………………..

(iii) ………………………………………………………

(iv) …………………………………………………………

16. How does the village resolve these problems/constraints?

(i) ……………………………………………….

(ii) ……………………………………………….

(iii) ………………………………………………

(iv) ………………………………………………

17. Is there a significant trading in timber and non-timber forest products?

(i) Yes …………… (ii) No. …………..

18. If yes what are these products?

Product	With who do you normally trade and where do they come from?	Sources (village forest, JFM, public, private)	Availability	Alternative sources

19. How do you regard the current status of the forest as compared to the past?

(i) Very good

(ii) Good

(iii) Satisfactory

(iv) Poor

(v) Don’t know

20. What are the indicators/signs that helped you to make such judgment/conclusions?

(i) ……………………………………………..

(ii) ……………………………………………..

(iii) …………………………………………….

(iv) ……………………………………………

(v) ……………………………………………

Appendix 6. Village checklist

Village Name **Date:**

Identification

1 Village Name ……………………

2 Ward …………………………….

3 District …………………………..

4 Region ……………………………

5 Forest Name ……………………..

6 Forest management type (JFM, CBFM ect) …………………….

Village Demographic Data

7. Number of household in the village
8. Population: Males ……. Female ……………
9. Population below 15 (school going age) Males ……….. Females …………
10. Population movement
    (i) Most are in coming …………..
    (ii) Most are outgoing ……………
    (iii) It's the same ………………….

Village Assets and services

11. Number and status of schools ………………
12. Adequacy of schools (i) Adequate ………… (ii) Inadequate ………………..
13. Number and status of health facilities ……………………
14. Adequacy of health facilities (i) Adequate ……… (ii) Inadequate ……………
15. Are markets available in the village (i) Yes …… (ii) No …….
16. If yes is the market serving all year around (i) Yes …… (ii) No …..
17. What types of goods are sold in the market?
    (i) ……………………………………….
    (ii) ……………………………………….
    (iii) ……………………………………….
    (iv) ………………………………………..

Main Economic Activities

18. Principal economic activities of the village

(vi) ……………………………………………………….

(vii) ………………………………………………………

(viii) ………………………………………………………

(ix) ………………………………………………………

(x) ………………………………………………………

19. Secondary economic activities

(i) ……………………………………………………….

(ii) ………………………………………………………

(iii) ………………………………………………………

(iv) ………………………………………………………

(v) ………………………………………………………

Forestry

20. Profile of forest reserves in the village

Name of the forest	Area (ha)	Ownership (Village, government, JFM, Private)	Management purposes (Productive/Protective)

21. Who are different stakeholders/Institutions involved with forest management in the village

Name of the forest	Stakeholders	Role (s)

22. What benefits does the village derive from the forest?

(vi) ……………………………….

(vii) ………………………………..

(viii) ………………………………..

(ix) ………………………………..

(x) ……………………………….

23. What are the sources of revenues available for the village

Source of revenue	Amount per year

24. How are the benefits shared among the villagers?

(vi) ………………………………………..

(vii) ………………………………………….

(viii) ………………………………………..

(ix) ………………………………………..

(x) …………………………………………

25. How is the village involved in the management of the forest?

………………………………………………………………………………………

26. What are the problems/constraints experienced in managing the forest?

(v) ………………………………………………………

(vi) ……………………………………………………..

(vii) ………………………………………………………

(viii) ……………………………………………………….

26. What are the costs and benefits of CFM in the past 5 years?

Year	Income		Expenditure		
	Source of fund	Amount	Management activity	Frequency (yr/month/week)	Amount paid
	• Fines • Donor		• Meetings • Patrol • Fire fighting • Boundary maintenance		

27. How does the village resolve these problems/constraints?

(v) ……………………………………………….

(vi) ……………………………………………….

(vii) ………………………………………………

(viii) ………………………………………………

28. Is there a significant trading in timber and non-timber forest products?

(ii) Yes …………… (ii) No. …………..

29. If yes what are these products?

Product	With who do you normally trade and where do they come from?	Sources (village forest, JFM, public, private)	Availability	Alternative sources

30. How do you regard the current status of the forest as compared to the past?

(vi) Very good

(vii) Good

(viii) Satisfactory

(ix) Poor

(x) Don't know

31. What are the indicators/signs that helped you to make such judgement/conclusions?

(vi) ……………………………………………..

(vii) ……………………………………………..

(viii) …………………………………………….

(ix) ……………………………………………

(x) ……………………………………………

Appendix 7. The use of developed field forest inventory guide in other countries

In tests of the field forest inventory guide for carbon assessment by local communities in the countries of Mali, Senegal, Guinea Bissau, Papua New Guinea (PNG), Nepal and Uttranchal (India), it was also found to work very well. As was the case with Tanzania, the field teams in these countries have made necessary modifications depending on local conditions. As part of K:TGAL project, I visited PNG and gave training in the field methods to a team of local researchers after which they proceeded to train the local communities on how to carry out field assessment, on my presence. Remarkable difference in terms of CFM management and forest conditions were noted.

In terms of forest management the main difference is that for PNG the community's forests are owned and managed by clans, while in Tanzania CFM are either owned by state or village governments. The clan system is built on related individuals with a common ancestral base. The clan that was involved in this exercise in PNG follows the maternal system where male members of the family move to live with the other family when get married. As such the female members inherit land from their parents and have strong feelings that the forests belong to them. Because of this 6 out of the 7 trainees were female, which is not occurred in Tanzania.

While community forest management in Tanzania involves management of secondary small sized forests, in PNG communities manage large forest areas most of which are in pristine condition. This necessitated a slightly different approach for measuring carbon. For example, the guide indicates how carbon can be measured in any given piece of forest and for each individual case study, measurements would have to be done for the project area, and possibly in other areas to represent the 'without project' case. The 'without project' case is supposed to indicate a 'business as usual' situation happening in unmanaged forests. For the PNG case, forests are under clan ownership since long time in memorial, it was therefore not possible to separate intact forests as control sites from previous and currently selective low scale logged forest parts since all forest are managed. It is clear that in these areas, any claims for carbon credits are likely to be associated not with avoided deforestation or degradation but with forest management or conservation. Other modifications made to suit the specific forest conditions in PNG are given below.

1. Stratifying the forest area

Communities in Papua New Guinea (PNG) have managed their clan forests for many years. These forests are not only recognized by the neighbouring clans but also by the state through the land ordinance. Maps for the forests in the selected project sites are already in place and stratification can be done by way of GPS coordinates and included in the maps. This can then be displayed in a participatory process in which community members discuss the different forest types identified and possible stratifications.

ForPNG, the stratum could be intact forest, currently logged and previously logged forest areas. It is expected that the intact forest will form a reference point against which the other two forest areas will be compared. While the carbon stock in previous logged areas is expected to increase (if the areas is not deforested and converted to other land uses) as the forest recovers, the opposite is true with the current logged areas where carbon stock will decrease following selective harvesting.

2. Pilot survey to calculate variance of trees/shrubs species

For the pilot survey, nested sample plots i.e. a larger circle containing smaller sub-units were used (Figure 1)

- Saplings (ie all woody stems longer than 1.3m high but with 1 ≥ dbh≤ 10 cm) were measured in a small circular plot of 5.64 m radius at the middle of the large circle. A count of regenerating tree species (ie very small saplings less than 1cm diameter) was also made in four satellite plots around the main plot.
- All trees greater than 10 cm dbh were measured all over the larger circle with 12.62 m radius, ie with a total area of 500 sq m)[17]
- Data on each tree were recorded on pre-designed field forms.

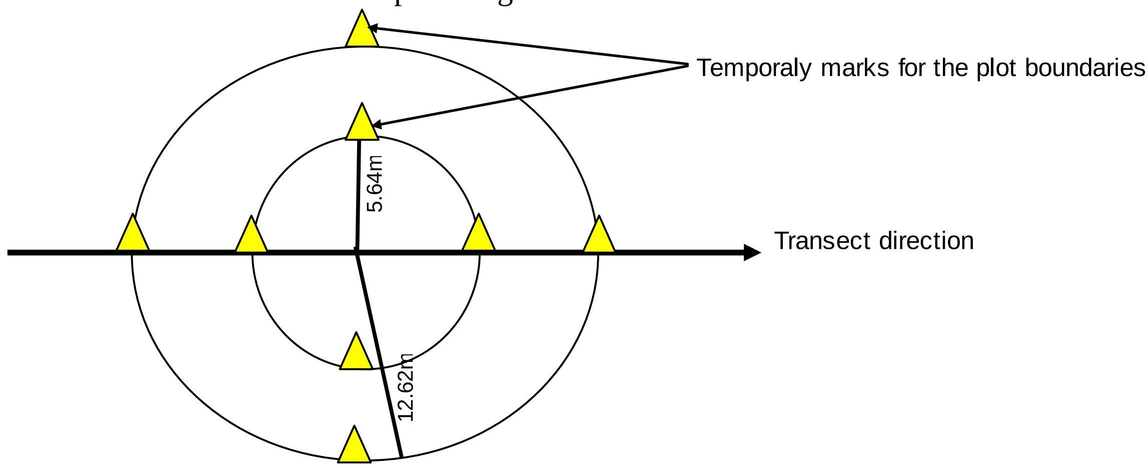


Figure 1. Nested plot layout

3 Permanent plots layout

Sample plots were located on the ground using compass and tape and the centre was marked on the ground (temporarily) using a coloured pole. Where possible (if the effect of crown closer allowed), stand alone GPS readings were also taken. Each sample plot was then given an identification code and a description of characteristics of the plot and any landmarks recorded. A sketch drawing of the location of the plot centre in relation to available landmarks on the back of the field plot forms was also made.

In some locations slope in the plot is more than 10% and was necessary to correct for this using a clinometer using the formula:

Ls = L/cos S

Where Ls is the correct plot radius, S is the slope angle in degrees, cos the cosine decimal taken from the back of the clinometer or from a table, and L is the plot radius (Ref. The field forest inventory guide).

Trees/shrubs were measured as for the pilot survey, i.e. all trees over dbh of 1 cm within the small central plot (or 5.64m radius), and all trees over 10 cm dbh in the whole plot (12.62m radius). For this a diameter tape was used, starting with the small plot moving clockwise from the direction of transect, marking each tree as it is done to prevent accidental double

[17] This plot area was chosen as a precaution for areas of low tree density where a large plot may be needed, otherwise too few trees will be included.

counting and recording data into the pre-designed field forms. A staff of 1.3 m was used to ensure that readings are taken at exactly the correct height. Each tree was recorded individually with its local name and botanical name. A checklist of the area/forest was used for consistency in tree naming. For what to do with trees of ‘unusual’ shape, descriptions from Winrock manual page 63 and 64 were used.

Trees/Shrubs Height

The PNG team is still searching for good allometric tables to use. The use of these or even general volume equations with a form factor, require height estimation of all trees as well as dbh. However, it is not practical to measure the height of all trees in a sample plot and usually only a few trees are measured.

Since this inventory might serve other purposes such as timber harvesting planning and certification by FORCERT (a local supporting organization), it was proposed to take height measurement of at least one tree of above 50 cm dbh and another small tree from each plot.

Tree height measurements were done using clinometers. The principle behind is that the observer stands at a convenient position, (D) to see the top (A) and bottom (C) of the tree (Figure 2). The line of site DB is horizontal. Assuming the tree is vertical, triangles ABD and CBC are both right angle triangles so that:

$\tan Q_1 = AB/BD$ or $AB = BD (\tan Q_1)$

$\tan Q_2 = BC/BD$ or $BC = BD (\tan Q_2)$

and the total tree height, $AC = BD (\tan Q_1 + \tan Q_2)$. The distance BD should be measured and angles Q1 and Q2 are read directly in degrees on the clinometer. Where it is difficult or impossible to measure BD, one can measure CD and calculate BD as CD ($\cos Q_2$), then proceed as above.

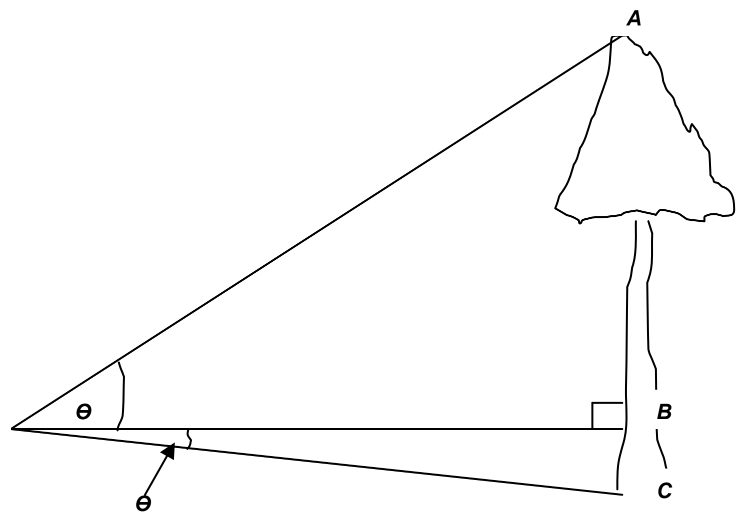


Figure 2. Height measurement using clinometer

4. Non-tree vegetation, litter and soil

It was observed that for some of the forests in PNG such as Baikakea, there is very litter herb layer, grasses and litter (Figure 3). The forest floor is open and the rate of litter decomposition is very high. Therefore the contribution of these to the total forest carbon stock is very litter. As such the measurement of these biomass pools is not recommended.

However, whenever different conditions are noted such data for these will make significant contributions. Quantrant plots should therefore be used as described in the field forest inventory guide and also Figure 3.

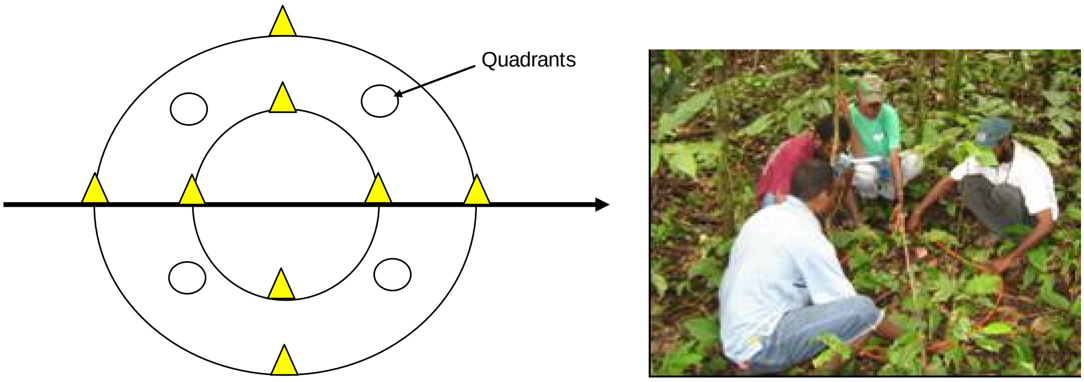


Figure. Herbs, grasses and litter assessment for Baikakea forest

Appendix 8. Detailed costs for carbon assessment by local communities

Study site	Activities	No. of Days	1st Year	2nd Year	3rd Year	4th Year +
			Cost ($/ha)			
1. Kitulangalo	1. Training and Pilot	10	1750	875	350	-
	2. Field Assessment - Kitulangalo SUATFR (600 ha)	10	1750	1200	980	650
	- Kimunyu VFR (420 ha)	6	1050	720	610	390
	- Without Project Case	5	875	545	435	250
	Total	31	5425	3340	2375	1290
	Per ha costs		5	3	2	1
2. Handei	1. Training and Pilot	10	1390	965	710	-
	2. Field Assessment - Handei (156 ha)	7	763	541	393	245
	- Without Project Case	6	436	288	214	140
	Total	**23**	**2589**	**1794**	**1317**	**385**
	Per ha costs		**17**	**12**	**8**	**2**
3. Mangala	1. Training and Pilot	10	1090	665	410	-
	2. Field Assessment - Mangala (28.5 ha)	5	225	200	180	100
	- Without Project Case	4	200	180	100	80
	Total	**19**	**1515**	**1045**	**690**	**180**
	Per ha costs		**53**	**37**	**24**	**6**
4. Ayasanda	1. Training and Pilot	10	2575	1975	1690	-
	2. Field Assessment - Warib	3	394.5	345	257	171
	- Haitemba	5	657	508	395	285
	- Without Project Case		526	426	326	228
	Total	**18**	**4153**	**3253**	**2668**	**684**
	Per ha costs		**8**	**6**	**5**	**1**

Appendix 9. Comparison of costs for forest carbon assessment by professionals against local communities

Activities	Kitulangalo No. of Days	Kitulangalo Cost ($/ha)	Handei No. of Days	Handei Cost ($/ha)	Mangala No. of Days	Mangala Cost ($/ha)	Ayasanda No. of Days	Ayasanda Cost ($/ha)
1. Pilot and Inventory Planning	3	426	3	990	3	450	3	450
2. Field Assessment								
-	10	1,620	7	1218	5	670	3	402
-	6	972					5	670
- Without Project Case	5	810	4	696	4	536	4	536
3. Data punching and analysis	10	1500	6	980	5	850	10	1500
4. Consultation fees (120 Euro per day UNDP Rates)								
- 1 Inventory specialist	34	4080	20	2400	17	2040	25	3000
5. Institutional fees (10%)		940.8		628.4		454.6		655.8
Total		10,349		6912		5001		7214
Costs per hectare if carried out by professionals		**10**		**44**		**176**		**13**
Years		***1 2 3 4***		***1 2 3 4***		***1 2 3 4***		***1 2 3 4***
Costs per hectare if carried out by aided villagers		**5 3 2 1**		**17 12 8 2**		**69 47 35 11**		**8 6 5 1**

Appendix 10. Detailed cost estimates for establishment and development of a village forest reserve

S/N	Activity	Details	Involved	Needed	Quantity		Unity cost (TShs)	Amount (TShs)	Source Donor	Source Participation
1	**Pre-Visit**	Meeting with the Village Forest Committee (VFC) for the briefing and preparation of the work plan	VNRC & Facilitators	Facilitator	Days	2	45,000	90,000	90,000	
				VFC	Days	2	4,000	96,000	96,000	
				DFO	Days	2	45,000	90,000	90,000	
				Transport	km	160	750	120,000	120,000	
							Sub-total	**396,000**	**396,000**	**0**
2	**Village boundary identification**	Facilitators, VNRC, VFC and village leadership to identify the village boundary	Facilitators, VNRC, VFC and village leadership	Facilitator	Days	10	45,000	450,000	450,000	
				VFC	Days	2	4,000	96,000	96,000	
				DFO	Days	3	45,000	135,000	135,000	
				Transport	km	160	750	120,000	120,000	
							Sub-total	**801,000**	**801,000**	**0**
3	**Village forest identification**									
3.1	Identification and agreement on forest boundary	Walking along the forest boundary in order to agree and mark the boundary with rocks, paints etc.	Facilitators, VNRC, VFC and village leadership	Facilitator	Days	15	45,000	675,000	675,000	
				VFC	Days	2	4,000	96,000	96,000	
				DFO	Days	2	45,000	90,000	90,000	
				Paint	Lita	15	3,000	45,000	45,000	
				Thinner	Lita	10	2,500	25,000	25,000	
				Brush	No.	5	3,500	17,500	17,500	
				Transport	km	260	750	195,000	195,000	
							total	**1,143,500**	**1,143,500**	**0**
3.2	Forest map drawing	After taking the details, facilitators will draw the VFR map	Facilitators	Facilitator	Days	24	45,000	1,080,000	1,080,000	
				VFC	Days	5	4,000	240,000	240,000	
				DFO	Days	5	45,000	225,000	225,000	
				Transport	km	260	750	195,000	195,000	
							total	**1,740,000**	**1,740,000**	**0**
							Sub-total	**2,883,500**	**2,883,500**	**0**

S/N	Activity	Details	Involved	Needed	Quantity		Unity cost (TShs)	Amount (TShs)	Source Donor	Source Participation
4	**Participatory Forest Resources Assessment**	Facilitators and VFC visiting the forest to assess the forest resources, identify uses and areas that need special attention	Facilitators and VFC	Facilitator	Days	20	45,000	900,000	900,000	
				VFC	Days	7	4,000	336,000	336,000	
				DFO	Days	7	45,000	315,000	315,000	
				Note books	No.	14	1,000	14,000	14,000	
				Ball pens	No.	14	500	7,000	7,000	
				Transport	km	260	750	195,000	195,000	
							Sub-total	**1,767,000**	**1,767,000**	**0**
5	**PFRA results evaluation and preparation of a management plan**	Facilitators and VFC evaluate the PFRA results and drawing up a sustainable management plan	Facilitators and VFC	Facilitator	Days	4	45,000	180,000	180,000	
				VFC	Days	2	4,000	96,000	96,000	
				DFO	Days	3	45,000	135,000	135,000	
				Papers	No.	5	7,200	36,000	36,000	
				Flip charts	No.	4	7,200	28,800	28,800	
				Ball pens	No.	14	500	7,000	7,000	
				Maker pens	No.	2	7,200	14,400	14,400	
				Transport	km	260	750	195,000	195,000	
							Sub-total	**692,200**	**692,200**	**0**
6	**Formulation of village forest by-laws**	The Village Government (VG) with assistance from facilitators and VFC formulate VFR by-laws	VG, facilitators, VFC and district courcil lawyer	Facilitator	Days	4	45,000	180,000	180,000	
				VFC, VG (20)	Days	4	4,000	320,000	320,000	
				DFO	Days	4	45,000	180,000	180,000	
				Lawyer	Days	4	25,001	100,004	100,004	
				Papers	No.	5	7,200	36,000	36,000	
				Flip charts	No.	2	7,200	14,400	14,400	
				Ball pens	No.	1	500	500	500	
				Maker pens	No.	2	7,200	14,400	14,400	
				Transport	km	160	750	120,000	120,000	
							Sub-total	**965,304**	**965,304**	**0**
7	**Approval of village forest by-laws**									

S/N	Activity	Details	Involved	Needed	Quantity		Unity cost (TShs)	Amount (TShs)	Source Donor	Source Participation
7.1	Approval by the village general assembly	VG, VFC, Layer and facilitators tabling the forest bylaws for approval	VG, facilitators, VFC and district courcil lawyer	Facilitator	Days	1	45,000	45,000	45,000	
				VFC, VG (20)	Days	1	4,000	80,000	80,000	800,000
				DFO	Days	1	25,000	25,000	25,000	
				Lawyer	Days	1	25,001	25,001	25,001	
				Transport	km	160	750	175,001	175,001	
							total	**350,002**	**350,002**	**0**
7.2	Approval by the Ward development Committee (WDC)	VG, Layer and facilitators tabling the forest bylaws for approval	VG, facilitators, VFC and district courcil lawyer	Facilitator	Days	1	45,000	45,000	45,000	
				VG & WDC (20)	Days	1	4,000	80,000	80,000	
				DFO	Days	1	25,000	25,000	25,000	
				Lawyer	Days	1	25,001	25,001	25,001	
				Photocopying	Pages	600	50	30,000	30,000	
				Transport	km	160	750	120,000	120,000	
							total	**325,001**	**325,001**	**0**
7.3	Approval by the District Council (DC)	WDC, DFO, Layer and facilitators tabling the forest bylaws for approval	WDC, DFO, facilitators and district courcil lawyer	Facilitator	Days	1	45,000	45,000	45,000	
				VG & DC (20)	Days	1	4,000	80,000	80,000	
				DFO	Days	1	25,000	25,000	25,000	
				Lawyer	Days	1	25,001	25,001	25,001	
				Photocopying	Pages	600	50	30,000	30,000	
				Transport	km	160	750	120,000	120,000	
							total	**325,001**	**325,001**	**0**
							Sub-total	**1,000,004**	**1,000,004**	**0**
8	**Forest patrols**									
8.1	Forest guarding in each sub-village	The VFC & 6 different villagers will make patrol 2 days a week	VFC & selected villagers	VFC & Villagers	Days	3808	4000	15,232,000		**15,232,000**
							total	**15,232,000**	**-**	**0**

S/N	Activity	Details	Involved	Needed	Quantity		Unity cost (TShs)	Amount (TShs)	Source Donor	Source Participation
8.2	Working gears	Purchase of weasels, rain boots, rain coats & field dresses	VG, facilitators, and VFC	Weasels	No.	6	1,500	9,000	9,000	
				Rain boots	No.	24	25,000	600,000	600,000	
				Rain coats	No.	24	25,001	600,024	600,024	
				Field dresses	No.	24	35,000	840,000	840,000	
							total	**2,049,024**	**2,049,024**	**0**
							Sub-total	**17,281,024**	**2,049,024**	**15,232,000**
9	**Training for VFC**	Training for VFC on their obligations	VFC & Facilitator	Facilitator	Days	5	45,000	225,000	225,000	
				VFC (12)	Days	5	4,000	240,000	240,000	
				Note books	No.	15	1,000	15,000	15,000	
				Flip charts	No.	2	7,200	14,400	14,400	
				Ball pens	No.	15	500	7,500	7,500	
				Maker pens	No.	2	7,200	14,400	14,400	
				Transport	km	160	750	120,000	120,000	
							Sub-total	**636,300**	**636,300**	**0**
10	**Publisizing the forest**	Pulishing the forest in the government gazete for its advacase	Facilitators, Lawyer, DFO	Publisizing	sum	1	50,000	50,000	50,000	
				Lawyer	Days	6	45,000	270,000	270,000	
				DFO	Days	4	45,000	180,000	180,000	
				Facilitator	Days	4	45,000	180,000	180,000	
							Sub-total	**680,000**	**680,000**	**0**
11	**Training on alternative ways to ease pressure on forest products**									
11.1	Tree planting	Facilitating villagers on raising trees in nurseries	Facilitators and Villagers	Facilitator	Days	6	45,000	270,000	270,000	
				Villagers (15)	Days	6	4,000	500,000		500,000
				Material	No.	15	1,000	15,000	215,666	
				Transport	km	160	750	120,000	120,000	

S/N	Activity	Details	Involved	Needed	Quantity		Unity cost (TShs)	Amount (TShs)	Source Donor	Source Participation
							total	**905,000**	**605,666**	**500,000**
11.2	Improved firewood stoves	Facilitating villagers on the making and use of improved stoves	Facilitators and Villagers	Facilitator	Days	6	45,000	270,000	270,000	
				Villagers (15)	Days	6	4,000	360,000	360,000	
				Note books	No.	15	1,000	15,000	15,000	
				Ball pens	No.	15	500	7,500	7,500	
				Clay soil	Ton 7	1	70,000	70,000		70,000
				Transport	km	160	750	120,000	120,000	
							total	**842,500**	**772,500**	**70,000**
11.3	Improved brick making	Facilitating villagers on the making and use of improved mud & cement bricks that do not require burning	Facilitators and Villagers	Facilitator	Days	6	45,000	270,000	270,000	
				Villagers (15)	Days	6	4,000	360,000	360,000	
				Brick machine	No.	2	700,000	1,400,000	1,400,000	
				Cement	Bags	5	100,000	100,000	100,000	
				Sand & clay	Ton 7	1	70,000	70,000		70,000
				Note books	No.	15	1,000	15,000	15,000	
				Ball pens	No.	15	500	7,500	7,500	
				Flip charts	No.	1	7,200	7,200	7,200	
				Transport	km	160	750	120,000	120,000	
							total	**2,349,700**	**2,279,700**	**70,000**
							Sub-total	**4,097,200**	**3,657,866**	**640,000**
							Total	**31,944,531**	**15,473,197**	**16,672,000**
12	**Administration and follow-ups**	District and VG to make follow-up on project activities	District & VG		10%			3,194,453	3,194,453	
							Grand-Total	**35,138,984**	**18,667,650**	**16,471,334**

Summary

At present only the sink ability of forest to sequester atmospheric CO_2 through establishing new forests is credited under the current UNFCCC climate change mitigation mechanisms in developing countries, i.e. the Clean Development Mechanism (CDM) of the Kyoto Protocol. Other forest practices such as the Community Forest Management (CFM) in Tanzania which involve management of natural forests that would otherwise degrade or be deforested and result in carbon emissions, are not at present credited. However, under a new policy currently under discussion by the Parties to the UNFCCC, reductions in deforestation and degradation may be credited in the future. This thesis provides evidence in support of this new policy, known as Reduced Emissions from Deforestation and forest Degradation (REDD), which considers forests as 'sinks and sources' of atmospheric CO_2. This policy would operate on the basis of overall national efforts to slow down loss of carbon from forests, and CFM might contribute to such national efforts, thus involving communities in the global climate change mitigation policy.

Out of 34 million hectares of forestland in Tanzania, only 18 million hectares are reserved and the rest, about 16 million hectares, are unprotected forests in General Lands. Forests in General Lands are typically 'open access', and subject to deforestation estimated at between 130,000 to 500,000 hectares per annum as well as degradation (loss of biomass within the forest) over much of the total forest area. Reservation of forests is aimed at reversing these trends, but studies reveal a considerable level of human disturbance even in the reserved forests. CFM, on the other hand, has been found to be effective in halting deforestation and reversing degradation in unreserved forests and is now included as a major element in Tanzania's National Forest Policy and its subsequent Forest Act of 2002. However, at present only 11% of the country's forests are under such management owing to lack of funds and capacity.

Accessing carbon finances from REDD could potentially provide financial resources for more CFM establishment. However, for the transformation of regular CFM projects into community carbon forest management projects and to register the resulting carbon gains, there will be additional transaction costs involved, particularly in making accurate forest inventories to measure stock changes over time. In this thesis, it is argued that in order to minimize these transaction costs, local communities could be trained and equipped to do

reliable, valid, easy to implement and cost effective techniques to carry out the necessary forest measurements by themselves. The thesis therefore explores the possibility for more CFM establishment in Tanzania through the anticipated global carbon payment mechanisms under REDD policy. The guiding hypothesis is that the local communities can be trained to carry out forest measurements, and, provided REDD policy is adopted they may be entitled to part of the financial value of the carbon saved.

REDD policy is still being discussed, thus the thesis has in part been written to contribute to the policy debate on how baselines for crediting REDD can be determined. The debate also recognizes that forest degradation results in considerable amounts of carbon emissions but what has not been clearly recognised is that measures taken to reduce deforestation and forest degradation will lead into increase in woody biomass and thus CO_2 sequestration through forest enhancement. It is therefore recommended that apart from deforestation, the REDD policy should also include avoided degradation and forest enhancement. With these different components in mind, the difficulties of developing baselines for individual CFM projects and integrating these into the national baseline are explored. In this research six CFM projects in four different villages are studied to assess and monitor carbon stock changes in CFM managed forests, and this is compared to unmanaged forests in their vicinity. The villages were Gwata-ujembe in Kitulangalo (KSUATFR), Ayasanda in Babati (Warib and Haitemba VFRs), Ludewa in Morogoro (Mangala VFR) and Mgambo-miembeni in Amani Tanga (Handei VFR). From the measurements, both the average rates of forest degradation in unmanaged areas, and forest enhancement in managed areas were established, so that increased carbon stocks could be computed.

It was observed that CFM projects store considerably more carbon than unmanaged forests. Observed natural low end rate of biomass increment is typically 0.5 tons/ha/year, for the managed forests. On average the rate of biomass increment is 2.8 tons/ha/year for the miombo woodland forest of KSUATFR which is equivalent to sequestration of 5.3 tCO_2/ha/year. The rate of biomass increment for Warib and Haitemba woodlands is 1.7 tons/ha/year equivalent to sequestration of 3.2 tCO_2/ha/year. For Mangala (lowland forest) and Handei (montane forest) the biomass increment rates are 4.4 and 5.2 tons/ha/year and their equivalent CO_2 sequestration rates are 8.3 and 9.8 tCO_2/ha/year. The variation in these rates between the different forests is due to tree growth differences, influenced by soil type, climate, species composition and age of the stands. For unmanaged forests the trend of the data shows that the stocking levels are fluctuating with average net biomass loss ranging from 1 and 3.5 tons/ha/year (equivalent to CO_2 emission of 1.8 and 6.5 tCO_2/ha/year) for the woodland forests at Kitulangalo and the lowland and montane forests around Mangala and Handei VFRs. The number of individual tree species in managed forests is also higher than in unmanaged forest. The implication of these results is that if 'business as usual' were continued, i.e. without community management, these forests would be as degraded as the unmanaged forests.

In this study, the forest inventories were done by the local communities. It was necessary to involve local communities since currently there are no reliable data on forest stocks in Tanzania due to limited financial and human resources for forest inventories. It was also therefore the aim of this study to find out whether local communities i.e. villagers with their local supporting organizations, would be able to carry out reliable inventories in their forests, and to compare the cost of this with inventories carried out by professionals. A field forest inventory guide on the procedures and techniques for assessing and measuring forest carbon by local communities was developed and tested for this purpose. A few difficulties were encountered during the training and some modifications were needed along the way, but it was found that the villagers were able to perform most of the important and time consuming steps without difficulty. The local communities were also able to retrieve the plot locations and take plot measurements of the same trees in the following years. Local peoples' knowledge was very useful in identifying trees and different places in the forest. The role of the staff of the local supporting organizations was crucial as regards some types of technical support. It was also found that it costs much more to hire professionals for carbon assessments than to employ the local people, even when costs of training and supervision in the early years and the costs of the equipment are included. In long run the trained villagers can work largely on their own at an average cost of $ 2 per ha, which includes the costs of assistance of the staff from the local supporting organization.

At present CFM projects are managed for the protection of environment and sustainable production of products and services. Prior to this study, the costs and benefits that would be associated with carbon crediting have not been considered. This research therefore determines the current costs and benefits of CFM projects and it examines how these will be affected by the introduction of carbon production. The cost for CFM establishment per village is $ 29,452 of which 53% typically comes from donor support while the remaining 47% covers the community's time inputs (this is based on community members' time inputs:

in reality they are not paid for this). After establishment, it is estimated that management costs to cover the typical CFM activities such as meetings, patrols, boundary maintenance and enrichment planting could require $ 1,580 per village per year. Most CFM projects however, have little to offer in terms of products which could be sold to bring in this income as the forests are usually rather degraded and lacking in harvestable timber.

From the general village socio-economic profiles, the main finding is that in all the villages, cash incomes are very low and opportunities for cash earning are extremely limited. This means that even though earnings from carbon may be small, they may be attractive enough to create an incentive for participation in forest management activities.

The current CFM strategies that ensure effective protection and sustainable utilization result in reduced degradation and increased sequestration while providing a variety of other benefits and services at the same time. Since forest protection is also necessary for the sustainable provision of these other benefits and services, there will be no additional management activities required for the carbon production in CFM projects. However, if CFM projects become carbon projects and enter into carbon trading, some additional activities related to carbon measurements, verification and marketing will inevitably be required, meaning that there will be additional 'carbon transaction costs'. Also some current benefits that involve biomass removal from the forest, such as harvesting for timber, building poles, firewood collection and grazing, need to be reduced. An opportunity cost will therefore also be incurred for these products.

In this study, the costs of CFM local transactions associated with carbon are estimated to be $ 1,580 per village per year for management activities, $ 2 /ha/year for measurements, $ 3.5 per hectare per year for the verification and 10% of carbon value for other overhead costs. The opportunity cost for forests in Gwata, Ludewa, Mgambo and Ayasanda villages is $ 12, $ 23, $ 7 and $ 9 each per hectare per year, the variations relate to the different activities that might be curtailed. The net carbon benefits were then computed using these costs. Taking into account both sequestration and avoidance of degradation, the net benefits are much higher ($ 31 per household) for villages with large forests compared with those with small forest, some of which would hardly get any positive returns if carbon were to be valued at $ 5 per tCO_2. Villages with 156 and 550 ha of forests, could earn about $ 12 and $ 18 per household per year respectively. If the price were to rise to as much as $ 40 per tCO_2, which may be possible in the future as a result of market forces, even villages with small (20 to 50 ha) areas of forest could earn about $ 30 per household while better forest-endowed villagers (with >1000 ha) might earn $ 438. This is the net income after all the operational costs involved in the carbon project are deducted. Carbon projects could therefore provide significant income generation opportunities at the village level and though the financial benefits may not look very large to outsiders, they may be very attractive locally given the present severe scarcity of cash income in the villages.

At a national level the theoretical potential income from the sale of carbon under a national REDD approach is about $630 million or $ 117 per rural household per year if all deforestation and degradation were to be halted and assuming the market price is $ 5 per tCO_2. However, apart from the fact that halting all deforestation and degradation is impossible, the funds will not all be for distribution to villagers since the cost for both CFM establishment and management and for establishing the country REDD policy will be deducted (overhead for administration and trading). Taking these costs into account, the research estimated that only $ 27 would be available for households. If the price of carbon were to rise to $ 40, then even when the state charges 30% of the carbon money to cover overhead and $ 10 per hectare for verification, individual households will earn $ 486 per year. This income could potentially motivate villagers as most of them currently have a cash income of less than a dollar per day. However, these figures are illustrative only. It remains to be seen what the future price of carbon will be, and what share of this will be retained by the government to cover its own costs.

The factors that may negatively influence communities as regards taking up CFM are unfair benefit sharing or fears of this, lack of availability of forest land, lack of community interest in forest management (which may itself relate to opportunity cost involved in foregoing other activities, or to the availability of alternative income sources), an unfavourable legal and policy environment, lack of facilitation capacity, and lack of availability of internal and external up-front financing. Experience from case study sites shows that village leaders, particularly the members of the village forest reserve committee, participate more than others in different forest activities, especially those involving payment of wages. Other villagers are not given the chance to participate. This situation can only be expected to become worse when the REDD funds become available to villages. A major consideration is that if villagers as a whole do not see any benefits, then they are likely to withdraw their cooperation from the communal effort for increasing carbon stock. This might jeopardise the anticipated contribution of CFM to the REDD policy. For the success of CFM under REDD therefore a system to ensure fair sharing of benefits needs to be established. This was not tackled in the current research but it is acknowledged as a problem that will have to be dealt with in the future and which needs further study.

Furthermore, it has been revealed that in most forest areas, villagers are interested to undertake CFM activities and there is sufficient land for that purpose. It was also seen that central government has succeeded in decentralising its powers and responsibility to the districts councils. However, district responsibilities have not yet been divested to the villages and this calls for more empowerment of the village governments. Also, although there exists a favourable legal framework for CFM at national level, awareness of this among villagers and the general public is still limited and this should be raised. There are human and financial resources available to promote CFM (local NGOs and some donor funds) but it was observed that a flat rate is issued to the district for CFM activities without taking into consideration the district's location, population size and forest resources endowment. A system of 'nested baselines' is therefore proposed to provide a transparent institutional arrangement which will allow payments to be disbursed in efficient and fair way if REDD funds become available.

In the light of the above findings, three main recommendations each for policy and further studies are made. It is recommended that REDD policy should be developed in such a way that avoidance of deforestation, avoidance of degradation and forest enhancement are included. Also since forests under CFM are efficient in carbon storage and sequestration, governments are urged to consider CFM as part of their approach under REDD. To ensure equitable distribution of carbon benefits among participating villages, governments are advised to use the system of 'nested baselines' proposed in this study. Since there are no data on carbon stocks, studies on forest inventories using methodology such as that developed by the researcher are recommended. Other areas which need further studies relate to controversial 'leakage' issues, and equitable sharing of the carbon benefits.

Samenvatting (Summary in Dutch)

Onder de huidige UNFCCC mechanismen ter vermindering van klimaatverandering wordt in ontwikkelingslanden alleen het vermogen van bossen om CO2 uit de atmosfeer op te vangen gehonoreerd, namelijk via Clean Development Mechanism (CDM) van het Kyoto Protocol. Andere bosbouwpraktijken, zoals Community Forest Management (CFM) in Tanzania, die zich richten op het beheer van natuurlijke bossen die anders zouden degraderen of ontbossen en daardoor carbonuitstoot veroorzaken, worden op dit moment niet gehonoreerd. Echter, onder de bepalingen van een nieuw beleid waar nu over onderhandeld wordt door de Partijen betrokken bij UNFCCC worden mogelijk in de toekomst ook ontbossing en degradatie van bossen gehonoreerd. Dit proefschrift voert bewijsmateriaal aan ter ondersteuning van dit nieuwe beleid, bekend als Reduced Emissions from Deforestation and forest Degradation (REDD), waarin bossen worden gezien als 'opslag en bron' van atmosferische CO2. Dit beleid zal gebaseerd zijn op nationale inspanningen gericht op het afremmen van carbonverlies van bossen, en CFM zou daartoe een bijdrage kunnen leveren waardoor lokale gemeenschappen betrokken worden bij het beleid ter vermindering van klimaatverandering.

Van de 34 miljoen hectaren bosgrond in Tanzania zijn slechts 18 miljoen hectaren beschermd en de overige 16 miljoen hectaren onbeschermde bossen bevinden zich op zogenoemde General Lands, publiek terrein. Bossen op dit publiek terrein worden gekenmerkt door 'vrije toegang' waardoor een ontbossing plaatsvindt, naar schatting op een schaal van 130.000 tot 500.000 hectaren per jaar en een degradatie (verlies van biomassa binnen het bos) in het grootste deel van het totale bosgebied. Bescherming van bossen is gericht op het keren van deze ontwikkelingen maar onderzoek wijst uit dat er een aanzienlijke verstoring door menselijk handelen plaatsvindt, zelfs binnen de beschermde bossen. Anderzijds, CFM is doelmatig gebleken in het stoppen van ontbossing en het terugdraaien van degradatie in de niet beschermde bossen en is nu als belangrijk onderdeel opgenomen in het nationale bosbouwbeleid van Tanzania en in de daarop volgende Bosbouw Wet van 2002. Op dit moment valt echter slechts 11% van alle bossen in het land onder zulk beheer als gevolg van gebrek aan fondsen en aan kundigheid.

Toegang tot carbonfondsen via REDD kan in principe financiële middelen opleveren voor de uitbreiding van CFM. Echter, om de reguliere CFM om te vormen in carbon bosbeheerprojecten uitgevoerd door lokale gemeenschappen en voor het registreren van de

carbonwinsten als gevolg daarvan, zijn aanvullende transactiekosten nodig, in het bijzonder voor het maken van nauwkeurige bosinventarisaties om over een bepaalde tijdsperiode de veranderingen in carbonvoorraden te meten. In dit proefschrift wordt beargumenteerd dat om de transactiekosten te verkleinen, de lokale gemeenschappen getraind en toegerust kunnen worden in de uitvoering van betrouwbare, geldige, makkelijke en kost effectieve technieken om zelf de noodzakelijke bosmetingen te verrichten. Dit proefschrift verkent daarom de mogelijkheden voor uitbreiding van CFM in Tanzania door te anticiperen op wereldwijde carbon betaalmechanismen onder het REDD beleid. De leidende hypothese hierbij is dat lokale gemeenschappen getraind kunnen worden in het uitvoeren van bosmetingen, en, onder voorwaarde dat het REDD beleid wordt aanvaard, dat zij dan gerechtigd zijn een deel te ontvangen van de financiële waarde van het uitgespaarde carbon.

Het REDD beleid staat nog steeds ter discussie, vandaar dat dit onderzoek ten dele is geschreven met het doel een bijdrage te leveren aan het beleidsdebat over de wijze waarop richtlijnen kunnen worden vastgesteld om REDD te kunnen honoreren. In het debat wordt ook erkend dat degradatie van bos leidt tot aanzienlijke hoeveelheden carbonuitstoot maar wat niet duidelijk wordt onderkend is dat maatregelen tot vermindering van ontbossing en degradatie van bos zullen leiden tot vergroting van biomassa door hout en dat daarom de CO2 opvang door het verbeteren van het bosbestand wordt versterkt. Om die reden wordt aanbevolen dat behalve het honoreren van het tegengaan van ontbossing en degradatie van bos in het REDD beleid ook het honoreren van het verbeteren van het bosbestand wordt opgenomen. Met deze componenten in het achterhoofd worden in het onderzoek de problemen besproken die zich kunnen voordoen wanneer individuele CFM projecten hun eigen ijkpunten (*baselines*) zouden moeten ontwikkelen. En ook op welke wijze die dan kunnen worden opgenomen in een landelijke *baseline* voor metingen. In dit onderzoek zijn in zes CFM projecten in vier verschillende dorpen de hoeveelheden carbon vastgesteld door de veranderingen in carbonvoorraden te bepalen en te meten in bossen in beheer van CFM vergeleken met die in onbeheerde bossen in de omgeving. De dorpen zijn: Gwata-ujembe in de Kitulangalo regio (KSUATFR); Ayasanda in Babati (Warib en Haitemba VFRs); Ludewa in Morogoro (Mangala VFR) en Mgambo-miembeni in Amani Tanga (Handei VFR). Op basis van metingen zijn zowel de typische mate van degradatie van bos in onbeheerde gebieden als ook de versterking van het bosbestand in de beheerde gebieden vastgesteld, en de voordelen van carbonvoorraad berekend.

Het is waargenomen dat CFM projecten aanzienlijk meer carbon opslaan dan onbeheerde bossen. De waargenomen typische natuurlijke ondergrens van biomassa toename is 0,5 ton/ha/jaar voor de beheerde bossen. Gemiddeld is de biomassa toename voor het miombo bosgebied van KSUATFR 2,8 ton/ha/jaar wat gelijk is aan een CO2 opvang van 5,3 tCO2/ha/jaar. De mate van biomassa toename voor de Warib en Haitemba bossen is 1.7 ton/ha/jaar, gelijk aan de opvang van 3,2 tCO2/ha/jaar. Voor Mangala (het laaggelegen bosgebied) en Handei (de bossen in berggebied) zijn de biomassa toenames 4,4 en 5,2 ton/ha/jaar, gelijk aan een CO2 opvang van 8,3 en 9,8 tCO2/ha/jaar. De variaties in deze mate van toenames in de verschillende bostypen wordt veroorzaakt door verschillen in boomgroei onder invloed van bodemsoort, klimaat, samenstelling van boomsoorten en de leeftijd van het bosbestand. Voor onbeheerde bossen geven de gegevens aan dat de niveaus van de voorraden wisselen met gemiddeld een netto verlies aan biomassa variërend tussen 1 en 3,5 ton/ha/jaar (gelijk aan 1,8 en 6,5 tCO2/ha/jaar CO2 uitstoot) voor respectievelijk de bossen in Kitulangalo en de laag- en hooggelegen bossen rondom de VFRs in Mangala en Handei. Het aantal boomsoorten in beheerde bossen is ook groter dan die in onbeheerde bossen.

In deze studie werden de bosinventarisaties uitgevoerd door de lokale gemeenschappen. Het was noodzakelijk de lokale gemeenschappen in te schakelen omdat er op dit moment geen betrouwbare gegevens bestaan over de stand van de bossen in Tanzania vanwege de beperkte financiële middelen en het gebrek aan deskundigheid om bosinventarisaties uit te voeren. Om die reden was het ook een doel van dit onderzoek om na te gaan of lokale gemeenschappen, dat wil zeggen dorpelingen ondersteund door hun lokale organisaties, hiertoe instaat zouden zijn, en om die resultaten te vergelijken met de kosten wanneer die inventarisaties zouden worden verricht door beroepskrachten. Hiertoe werd een handleiding ontworpen voor een bosinventarisatie met procedures en technieken voor het bepalen en meten van biomassa door de lokale gemeenschappen en werd die handleiding getest. Tijdens de training werden een aantal problemen gesignaleerd die aanleiding waren voor het aanbrengen van enkele aanpassingen maar het bleek dat de dorpelingen de meeste belangrijke en tijdvergende stappen zonder moeilijkheden konden verrichten. De lokale gemeenschappen waren ook in staat de locaties van de bossen te traceren en van dezelfde bomen metingen uit te voeren in de volgende jaren. De kennis van de lokale bevolking bleek erg nuttig voor het vaststellen van bomen en van de verschillende plekken in de bossen. De rol van de begeleidende lokale organisaties bleek van cruciaal belang voor sommige technieken. De uitkomst was dat het veel duurder bleek te zijn om beroepskrachten in te huren, ook wanneer de kosten voor training en begeleiding in de beginjaren en de uitgaven voor materiaal zijn meegenomen. Na verloop van tijd kunnen de opgeleide dorpelingen zelfstandig werken tegen een bedrag van $ 2 per ha, inbegrepen de kosten voor begeleiding door de staf van de ondersteunende lokale organisaties.

Op dit moment worden de CFM projecten beheerd met het oog op de bescherming van het milieu en een duurzame productie van bosproducten en diensten. Tot aan dit onderzoek werden de kosten en voordelen gepaard aan een carbonhonorering niet mee geteld. Dit onderzoek berekent daarom de huidige kosten en voordelen van CFM projecten en onderzoekt hoe die zullen worden beïnvloed wanneer carbonproductie wordt geïntroduceerd. De uitgaven voor het opzetten van een CFM project per dorp is $ 29.452 waarvan 53% betaald wordt door donoren en de overige 47 % betreft de kosten voor de tijdsinbreng door de gemeenschap (dit is gebaseerd op een fictieve betaling want in werkelijkheid worden de dorpelingen niet betaald). Nadat een CFM is opgericht worden de beheerskosten voor de typische CFM activiteiten, zoals vergaderingen, patrouilles lopen, grensbewaking en bijplanting, geschat op $ 1.580 per dorp per jaar. De meeste CFM projecten hebben echter weinig te bieden wat betreft producten die verkocht kunnen worden om deze uitgaven te dekken omdat de bossen gewoonlijk nogal verwaarloosd zijn en geen hout produceren voor de handel.

De belangrijkste constatering uit de sociaal economische dorpsprofielen is dat in alle dorpen de inkomsten in geld erg laag zijn en dat de mogelijkheden om geld te verdienen uiterst gering zijn. Dit betekent dat zelfs wanneer de inkomsten van carbon gering zijn, zij aantrekkelijk genoeg blijken als aanmoediging om deel te nemen aan bosbeheer activiteiten.

De huidige CFM strategieën die voorzien in effectief beheer en duurzaam gebruik leiden tot vermindering van degradatie en toename van carbonopvang terwijl zij tegelijkertijd voorzien in een verscheidenheid aan andere voordelen en diensten. Omdat bosbescherming ook noodzakelijk is voor die andere voordelen en diensten zijn er geen aanvullende beheersactiviteiten vereist voor de carbonproductie in CFM projecten. Wanneer echter CFM projecten carbonprojecten worden en toegelaten worden tot de handel in carbon dan zijn enkele aanvullende activiteiten gekoppeld aan carbonmetingen, verificatie en verhandeling onvermijdelijk; dit betekent dat er extra ‘carbon transactiekosten’ zullen zijn. Ook zullen enkele huidige voordelen die verband houden met een inperking van biomassa uit het bos, zoals houtkap, palen voor de bouw, sprokkelhout en het laten grazen van vee, verminderd moeten worden. Vervangende waarde (*opportunity cost*) hiervoor zal daarom moeten worden meeberekend.

In deze studie worden de kosten voor lokale CFM transactiekosten verbonden met carbon geschat op $ 1.580 per jaar per dorp voor beheersactiviteiten, $ 2/ha/jaar voor het verrichten van metingen, $ 3,5 per hectare per jaar voor de verificatie en 10% van de carbonwaarde voor overige overheadkosten. De vervangende kosten voor de bossen in de dorpen Gwata, Lukdewa, Mgambo en Ayasanda zijn respectievelijk, $ 12, $ 23, $ 7 en $ 9 per hectare per jaar; de variaties zijn afhankelijk van de verschillende activiteiten die ingeperkt moeten worden. De netto carbonvoordelen zijn voor deze kosten uitgerekend. Indien zowel carbonopvang als het vermijden van degradatie worden meegenomen zijn de netto voordelen veel hoger ($ 31 per huishouding) in dorpen met grote bossen vergeleken met die met kleine bossen, waarvan sommige zelfs helemaal geen inkomsten ontvangen indien de carbonprijs op $ 5 per tCO2 wordt gesteld. Dorpen met 156 en 550 ha bos kunnen respectievelijk rond de $ 12 en $ 18 per huishouding per jaar verdienen. Indien de prijs zou stijgen tot wel $ 40 per tCO2, wat in de toekomst mogelijk is gezien de bestaande marktkrachten, dan kunnen zelfs dorpen met kleine (20 tot 50 ha) arealen aan bos rond de $ 30 per huishouding per jaar verdienen terwijl dorpelingen met rijkere bosarealen (› 1000 ha) wel $ 438 kunnen verdienen. Dit is het netto inkomen nadat alle operationele kosten voor een carbonproject zijn afgetrokken.Carbonprojecten kunnen daarom voorzien in belangrijke inkomsten genererende mogelijkheden op dorpsniveau en hoewel de financiële voordelen niet erg hoog lijken voor buitenstaanders, kunnen zij erg aantrekkelijk zijn in de lokale omstandigheden gezien de huidige ernstige schaarste aan geld in de dorpen.

Op nationaal niveau is het potentiële inkomen van carbonhandel onder een REDD beleid ongeveer $ 630 miljoen of $ 117 per plattelandshuishouding per jaar indien wordt uitgegaan dat alle ontbossing en degradatie kunnen worden gestopt en bij een aangenomen prijs van $ 5 per tCO2. Behalve dat een volledige stop van ontbossing en degradatie onhaalbaar is, zullen de fondsen ook niet in hun geheel worden uitbetaald aan de dorpelingen omdat zowel de kosten voor de oprichting en beheer van CFM als ook die voor het opstellen van een landelijk REDD beleid (overhead voor beheer en handel) in mindering zullen worden gebracht. Wanneer deze kosten worden meegewogen schat het onderzoek in dat slechts $ 27 voor de huishoudingen beschikbaar komt. Indien de prijs voor carbon echter zou oplopen tot $ 40 dan kunnen individuele huishoudingen $ 486 per jaar verdienen, ook als de staat 30 % overheadkosten inhoudt en $ 10 per hectare voor verificatie berekent. Dit inkomen zou mogelijk de dorpelingen motiveren omdat de meesten van hen minder dan één dollar per dag aan geldelijk inkomen hebben. Deze cijfers zijn slechts ter illustratie. Men zal moeten afwachten hoe de carbonprijs zich ontwikkelt en welk deel hiervan door de overheid wordt ingehouden om de eigen gemaakte kosten af te dekken.

Factoren die mogelijk een negatieve invloed hebben op de bereidheid van de gemeenschappen te participeren in CFM zijn: oneerlijke verdeling van de inkomsten of de vrees daarvoor, gebrek aan beschikbare bossen, gebrek aan interesse in bosbeheer van de kant van lokale gemeenschappen (mogelijk als gevolg van inkomstenderving uit andere diensten die niet meer mogen, of als gevolg van de aanwezigheid van alternatieve inkomstenbronnen), een ongunstig wettelijk kader en een dito politie optreden, gebrek aan faciliteiten en een gebrek aan mogelijkheden voor interne en externe vóór financiering. Op basis van ervaring in de onderzoeksgebieden blijkt dat dorpsleiders, in het bijzonder de leden van het dorpsbosbeheer comité, meer dan anderen deelnemen aan verschillende bosactiviteiten, speciaal als lonen worden uitbetaald. Andere dorpelingen krijgen geen kans tot deelname. Deze situatie zal waarschijnlijk alleen maar verslechteren indien REDD fondsen op dorpsniveau beschikbaar komen. Een belangrijke overweging hierbij is dat wanneer niet alle dorpelingen voordeel zien zij waarschijnlijk hun medewerking aan de gemeenschappelijke inzet tot het vergroten van de carbonvoorraad zullen intrekken. Dit kan de verwachte bijdrage van CFM aan het REDD beleid op het spel zetten. Om CFM succesvol te betrekken bij REDD is het daarom van belang een systeem te ontwikkelen waarbij een eerlijke verdeling van de voordelen wordt verzekerd. Dit vormde echter geen onderdeel van deze studie maar is als probleem waaraan in de toekomst aandacht moet worden gegeven onderkend; dit vereist nader onderzoek.

Dit onderzoek heeft verder aangetoond dat in de meeste bosgebieden de dorpelingen belangstelling hebben in CFM activiteiten en dat daar voldoende land voor beschikbaar is. Ook bleek dat de centrale overheid erin is geslaagd haar bevoegdheden te delegeren aan districtsraden. Echter, de bevoegdheden op districtsniveau zijn nog niet doorgevoerd tot dorpsniveau en dit vereist een versterking van de dorpsbesturen. Bovendien, ook al bestaat er een gunstig wettelijk kader voor CFM op nationaal niveau de dorpelingen, en het publiek in het algemeen, zijn zich hiervan nog nauwelijks bewust wat verbeterd zou moeten worden. Er zijn middelen beschikbaar, zowel in mankracht als in geld (van lokale NGOs en van sommige donoren), om CFM aan te bevelen maar er is waargenomen dat de hoogte van de bedragen aan de districten voor de CFM activiteiten aan elkaar gelijk gesteld waren zonder rekening te houden met de ligging, de bevolkingsomvang en de beschikbaarheid aan inkomsten uit de bossen van de districten. Daarom wordt voorgesteld een systeem van '*nested baselines*' (ijklijnen die per regio worden vastgesteld) op te stellen om te voorzien in een doorzichtig institutioneel arrangement dat het mogelijk maakt de betalingen op een efficiënte en eerlijke wijze te verdelen indien REDD fondsen beschikbaar komen.

Op basis van het voorgaande worden drie belangrijke aanbevelingen gedaan, elk voor beleid en verder onderzoek. Het wordt aanbevolen dat REDD beleid ontwikkeld wordt waarin het vermijden van ontbossing, het vermijden van degradatie en de groei van het bosbestand zijn opgenomen. Omdat bossen onder CFM beheer op efficiënte wijze carbon opslaan en carbon voorraden vergroten, worden overheden indringend gevraagd CFM op te nemen als deel van het REDD beleid. Om een gelijke verdeling van carbonvoordelen onder de deelnemende dorpen te verzekeren, worden overheden aangeraden het systeem van '*nested baselines'* zoals voorgesteld in dit onderzoek, toe te passen. Omdat er geen gegevens bestaan over carbonvoorraden, worden studies over bosinventarisaties met een methodologie zoals ontwikkeld door de onderzoeker aanbevolen. Andere onderwerpen die nader onderzoek vereisen houden verband met het controversiële '*leakage*' probleem (het ongeregistreerd verdwijnen van carbon) en de eerlijke verdeling van de carbonvoordelen.

Muhtasari (Summary in Kiswahili)

Uwezo wa misitu wa kusafisha hewa mkaa (yaani kaboni dioksaidi) iliyoko angani kwa kupanda misitu mipya ndiyo kwa sasa unaweza kupata malipo kupitia mpango wa Umoja wa Mataifa wa kuthibiti mabadiliko ya hali ya hewa dunia (UNFCCC) hususan sera ya maendeleo safi (yaani *Clean Development Mechanism* (CDM)) ya Protokali ya Kyoto. Shughuli zingine za misitu kama vile utunzaji shirikishi wa misitu ya jamii yaani *Community Forest Management* (CFM) nchini Tanzania unaohusisa misitu asilia ambayo ingetoweka ama kuharibika na kutoa hewa mkaa, hauwezi kupata malipo kwa sasa. Hata hivyo kupitia sera mpya ambayo bado inajadiliwa na UNFCCC, upunguzaji wa upotevu na uharibifu wa misitu unaweza kupata malipo siku zijazo. Utafiti huu unatoa ushahidi katika kujenga hoja ya sera hii mpya iitwayo upunguzaji wa uzalishaji wa hewa mkaa itokanayo na uharibifu na upotevu wa misitu yaani *Reduced Emissions from Deforestation and forest Degradation* (REDD), ambayo inaiona misitu kama "hifadhi na chanzo" cha hewa mkaa. Sera hii itafanya kazi kwa msingi wa matokeo ya jumla ya nchi nzima ya kupunguza uzalishaji wa hewa mkaa kutokana na misitu, ambapo misitu shirikishi ya jamii inaweza kuchangia juhudi hizo za kitaifa, na hivyo kuzishirikisha jamii kwenye sera za kimataifa za kudhibiti mabadiliko ya hali ya hewa.

Kati ya hekta 34 milioni za misitu nchini Tanzania, ni hekta 18 millioni tu ndizo zimehifadhiwa na zilizobakia, kama hekta 16 milioni, hazijahifadhiwa na ziko kwenye maeneo huria yaani *General Lands*. Misitu iliyoko kwenye maeneo huria iko wazi kwa matumizi ya kita mtu, na inakabiliwa na upotevu unaokadiriwa kuwa kati ya hekta 130,000 hadi 500,000 kwa mwaka na uharibifu (upotevu wa miti kwenye misitu) kwenye eneo kubwa la misitu. Uhifadhi wa misitu ulilenga kudhibiti hali hii, lakini tafiti zilizofanyika zinaonyesha kuwa kuna uharibifu mkubwa unaosababishwa na watu hata ndani ya misitu iliyohifadhiwa. Utunzaji shirikishi wa misitu, kwa upande mwingine, umeonekana kudhibiti upotevu na uharibifu wa misitu isiyohifadhiwa na kwa sasa umeingizwa kama mpango kabambe wa uhifadhi misitu kwenye sera ya taifa ya misitu na kwenye sheria ya misitu ya mwaka 2002. Hata hivyo, hadi sasa ni 11% tu ya misitu yote nchini ndiyo iko kwenye utunzaji shirikishi hali inayosababishwa na kutokuwa na fedha na uwezo.

Upatikanaji wa malipo kupitia sera ya REDD unaweza ukatoa fedha kwa ajili ya uanzishaji wa misitu shirikishi. Hata hivyo, kuibadilisha misitu ya kawaida ya jamii kuwa miradi ya misitu ya hewa mkaa na kuandikisha kiasi cha faida ya hewa mkaa, inahitaji gharama za uwezeshaji hususan za upimaji wa misitu kujua kiwango cha ongezeko la mkaa kwa muda. Utafiti huu unajenga hoja kwamba, ili kupunguza gharama za uwezeshaji, jamii zinaweza kuwezeshwa kwa mbinu sahihi, rahisi na zisizo za gharama za upimaji wa misitu yao. Utafiti huu kwa hiyo, unaangalia uwezekano wa uanzishaji wa misitu mingi ya jamii nchini Tanzania kwa kutumia malipo ya hewa mkaa kupitia sera ya kimataifa ya REDD. Matarajio ya awali ni kwamba, jamii zitafundishwa na kuweza kupima misitu yao, na kama sera ya REDD itapitishwa, wanaweza kufaidika na kiasi cha malipo ya hewa mkaa itakayohifadhiwa.

Sera ya REDD bado inajadiliwa, kwa hiyo kitabu hiki kina sehemu iliyoandikwa kuchangia mjadala wa ni kwa vipi misingi (yaani *baselines*) ya malipo ya sera ya REDD inaweza kufanywa. Mjadala huu pia unatambua kuwa upotevu wa misitu unasababisha utoaji wa hewa nyingi ya mkaa, lakini ambacho hakijatambuliwa vizuri ni kwamba juhudi zinazofanywa kupunguza upotevu na uharibifu wa misitu pia zinachangia kukua kwa miti na kuhifadhi hewa mkaa nyingi zaidi kupitia ukuaji wa misitu. Kwa hiyo inashauriwa kuwa mbali na upotevu wa misitu, sera ya REDD ijumuishe pia upunguzaji wa uharibifu wa misitu pamoja na ukuaji wake. Kwa kuzingatia vitu hivi vinavyoweza kutengeneza msingi wa malipo ya sera ya REDD, matatizo ya kutengeneza misingi ya mradi mmoja mmoja wa misitu jamii na kuiingiza kwenye msingi wa kitaifa yanaangaliwa. Katika utafiti huu miradi sita ya misitu jamii katika vijiji vinne tofauti ilifanyiwa utafiti kupima na kufuatilia mabadiliko ya kiwango cha mkaa (kaboni) kwenye misitu ya hifadhi ya jamii na kulinganishwa na misitu huria iliyopo karibu. Vijiji hilivyohusishwa ni Gwata-ujembe kilichopo Kitulangalo (KSUATFR), Ayasanda kilichopo Babati (misitu ya Warib na Haitemba), Ludewa kilichopo Morogoro (msitu wa Mangala) na Mgambo-Miembeni kilichopo Amani Tanga (msitu wa Handei). Kutokana na upimaji uliofanyika, kasi ya uharibifu kwenye misitu huria, na ukuaji wa misitu ya jamii iliyohifadhiwa ilijulikana ili kukokotoa kiasi cha mabadiliko ya kiwango cha kaboni.

Ilionekana kwamba misitu jamii inahifadhi kiasi kikubwa cha kaboni ukilinganisha na misitu isiyohifadhiwa kwenye maeneo huria. Kasi ya chini ya ongezeko la *biomass* ni 0.5 tani/ha/mwaka, kwa misitu iliyohifadhiwa. Kwa wastani, kasi ya ongezeko la *biomass* ni 2.8 tani/ha/mwaka katika msitu wa miombo wa KSUATFR sawa na 5.3 tCO_2/ha/mwaka za hewa mkaa. Kasi ya ongezeko la *biomass* katika misitu ya miombo ya Warib na Haitemba ni 1.7 tons/ha/mwaka sawa na hewa mkaa ya 3.2 tCO_2/ha/mwaka. Kasi ya kuongezeka la *biomass* ni 4.4 tani/ha/mwaka (sawa na hewa mkaa ya 8.3 tCO_2/ha/mwaka) kwa msitu wa Mangala (misitu ya kijani ya ukanda wa chini), na 5.2 tani/ha/mwaka (sawa na hewa mkaa ya 9.8 tCO_2/ha/mwaka) kwa msitu wa Handei (misitu ya kijani ya milimani). Tofauti ya viwango kasi hivi baina ya misitu mbalimbali inatokana na tofauti za ukuaji wa miti, aina za udongo, hali ya hewa, aina za miti na umri wa msitu. Kwa misitu huria, takwimu zinaonyesha kuwa viwango kasi vinashuka na kupanda kwa wastani wa upotevu wa *biomass* wa kati ya 1 na 3.5 tani/ha/mwaka (sawa na hewa mkaa ya 1.8 and 6.5 tCO_2/ha/mwaka) katika misitu ya miombo ya Kitulangalo na misitu ya kijani ya chini na milimani kuzunguka misitu ya Mangala na Handei. Pia kuna idadi kubwa ya aina za miti kwenye misitu ya jamii ukilinganisha na misitu huria isiyohifadhiwa. Matokea haya yanamaanisha kuwa, kama hali ingeachwa iendelee kama ilivyo, yaani bila uhifadhi wa misitu jamii, misitu hii ingekuwa imeharibiwa kama ilivyo misitu huria.

Katika utafiti huu, upimaji wa misitu umefanywa na wana-jamii. Ilikuwa ni muhimu kuwashirikisha wana-jamii kwa kuwa kwa sasa hakuna takwimu za uhakika za kiasi cha miti kwenye misitu hapa Tanzania kwa sababu ya uhaba wa fedha na watu wa kufanya upimaji. Hivyo ilikuwa pia ni lengo la utafiti huu kuona kama wana-jamii yaani wanakijiji na wataalamu wanaowasaidia kwenye shughuli zao za uhifadhi, wanaweza kupima misitu kwa uhakika, na kulinganisha gharama kama kazi hii ya upimaji ingefanywa na wataalamu pekee. Mwongozo wa upimaji wa misitu (*a field forest inventory guide*) unaoonyesha hatua na mbinu za upimaji wa kaboni kwa wana-jamii uliandaliwa na kufanyiwa majaribio. Mbali na matatizo kidogo yaliyojitokeza wakati wa kutoa mafunzo ambayo yalirekebishwa, wana-jamii waliweza kufanya mambo muhimu na yanayohitaji muda mwingi wa upimaji wa misitu bila matatizo. Wanakijiji pia waliweza kuzitafuta ploti za kuchukulia vipimo na kupima miti miaka mingine iliyofuata. Elimu asilia ya wanakijiji hao ilikuwa na umuhimu mkubwa kwenye kutambua aina mbalimbali za miti na sehemu mbalimbali msituni. Wataalamu wanaosaidia shughuli za uhifadhi walikuwa na jukumu muhimu la kutoa msaada wa kiufundi pindi unapohitajika. Imebainika pia kuwa gharama za upimaji kwa kutumia wataalamu ni kubwa ukilinganisha na zile za wanakijiji hata kama gharama za mafunzo na msimamizi kwenye miaka ya mwanzo zitahusishwa. Wakiwa na uzoefu wa muda mrefu, wanakijiji waliopata mafunzo wanaweza kupima misitu kwa wastani wa $ 2 kwa hekta, ambazo zinajumuisha gharama za usaidizi kutoka kwa wataalamu wanaosaidia kazi za uhifadhi.

Kwa sasa misitu shirikishi ya jamii inahifadhiwa kwa lengo la utunzaji wa mazingira na uvunaji endelevu. Kabla ya utafiti huu, gharama na faida zinazoambatana na uuzaji wa hewa mkaa hazikuwahi kutafitiwa. Kwa hivyo, utafiti huu umefanya tathimini ya gharama na faida za misitu jamii kwa sasa na kuona ni kwa vipi zitaathiriwa na kuingiza uhifadhi wa hewa mkaa. Gharama ya kuanzisha msitu jamii kwa kijiji ni $ 29,452 ambazo 53% zinalipwa na wahisani na kiasi kinachobaki 43% ni nguvu za wanakijiji (hii inatokana na muda wa wanakijiji: hali halisi ni kwamba hawalipwi kwa ajili hii). Baada ya uanzishaji wa msitu wa jamii, inakadiriwa kuwa gharama za uendeshaji kwa ajili ya shughuli kama vile mikutano, ulinzi, kufyekea mpaka na kupanda miti kwenye maeneo ya wazi zinahitaji $ 1,580 kwa kijiji kwa mwaka. Hata hivyo, misitu mingi ya jamii haina mazao ya kutosha kuuza na kupata kipato cha kutosheleza matumizi haya kwa kuwa misitu hii iliharibiwa siku za nyuma na haina miti ya kuvuna kwa ajili ya mbao.

Hali halisi ya maisha ya watu inaonyesha kuwa katika vijiji vyote vilivyofanyiwa utafiti, kipato cha fedha ni kidogo mno na vyanzo vya pesa ni duni. Hii inamaana kuwa hata kama kipato cha hewa mkaa kitakuwa kidogo, kinaweza kutoa ushawishi mkubwa kwa wana-vijiji kujihusisha na uhifadhi wa misitu.

Mkakati wa sasa wa uhifadhi wa misitu jamii unaowezesha utunzaji na uvunaji endelevu wa misitu unapunguza uharibifu na kuongeza kiwango cha uhifadhi wa hewa mkaa na wakati huo huo kutoa faida nyingine. Kwa kuwa uhifadhi wa misitu ni muhimu kwa matumizi endelevu kama inavyofanyika sasa, hakutakuwa na gharama za ziada za uendeshaji kama misitu ya jamii itakuwa miradi ya kaboni. Hata hivyo kama misitu ya jamii itakuwa miradi ya kaboni na kuingia kwenye biashara hiyo, shughuli za ziada zinazohusiana na upimaji wa kaboni, uhakiki na uuzaji zitahitajika, ikimaanisha kuwa na ‘gharama za biashara ya kaboni’. Pia baadhi ya faida zinazopatikana kwa sasa hususan zile zinazohusisha kuondoa *biomass* msituni kama vile uvunaji wa miti kwa ajili ya mbao, mijengo, kuni na kuchunga mifugo, zitapunguzwa. Kwa hiyo kutakuwa na gharama ya kununua mazao haya yatakayokatazwa.

Katika utafiti huu, gharama za misitu jamii zinazohusiana na mradi wa kaboni zinakadiriwa kuwa $ 1,580 kwa kijiji kwa mwaka kwa ajili ya shughuli za uendeshaji, $ 2 /ha/mwaka kwa ajili ya upimaji, $ 3.5 /ha/mwaka kwa ajili ya uhakiki na 10% ya thamani ya kaboni kwa ajili ya gharama za utawala. Gharama za kununulia mazao ya misitu yatakayokatazwa kwenye vijiji kwa hekta/mwaka ni $ 12 (Gwata), $ 23 (Ludewa), $ 7 (Mgambo) na $ 9 (Ayasanda), tofauti inatokana na mazao mbalimbali yatakayokatazwa. Faida halisi ya kaboni imekokotolewa kwa kutumia gharama hizi. Kwa kuzingatia viwango vya kasi ya uhifadhi wa hewa mkaa na upunguzaji wa uharibifu wa misitu, faida halisi ni kubwa ($ 31 kwa kila familia) kwa vijiji vilivyo na misitu mikubwa ukilinganisha na vile vyenye misitu midigo, ambapo baadhi havitapata kitu kama bei ya hewa mkaa itakuwa $ 5 kwa tCO_2. Vijiji vyenye misitu ya hekta 156 vinaweza kupata $12 na vile vyenye hekta 550 vinaweza kupata $ 18 kwa familia kwa mwaka. Kama bei itaongezeka hadi $ 40 kwa tCO_2, kitu kinachowezekana ukizingatia hali ya soko ya sasa, hata vijiji vyenye misitu midogo (hekta 20 hadi 50) vinaweza kupata $ 30 kwa familia ambapo vijiji vyenye misitu mikubwa (zaidi ya hekta 1,000 ha) vinaweza kupata hadi $ 438 kwa familia. Hii ni faida halisi baada ya kuondoa gharama zote za mradi wa kaboni. Kwa hiyo miradi ya kaboni inaweza kutoa fursa muhimu ya kipato kijijini na ingawa kiasi hiki kinaonekana kidogo kwa mtu aliyeko nje ya vijiji, kinaweza kuwa na umuhimu mkubwa hasa ukizingatia hali duni ya vyanzo vya mapato vijijini.

Kitaifa, pato linaloweza kupatikana kutokana na biashara ya hewa mkaa kupitia sera ya REDD ni $630 milioni au $ 117 kwa familia ya kijijini kwa mwaka kama upotevu na uharibifu wote wa misitu utasimamishwa na bei ya hewa mkaa ikiwa $ 5 kwa tCO_2. Hata hivyo, mbali na ukweli kwamba haiwezekani kusitisha upotevo na uharibifu wote wa misitu, fedha zitakazopatikana hazitagawanywa zote kwa familia kwa kuwa gharama za utunzaji wa misitu na za kuanzisha sera ya REDD kitaifa zitaondolewa. Kwa kuzingatia gharama hizi, utafiti huu umekadiria kuwa, $ 27 tu ndizo zitapatikana kwa kila familia kwa mwaka. Kama bei ya hewa mkaa itapanda na kuwa $ 40, basi hata kama nchi itakata 30% ya pesa za hewa mkaa kwa ajili ya gharama za uendeshaji na $ 10 kwa ajili ya uhakiki, kila familia itapata $ 486 kwa mwaka. Kipato hiki kinaweza kutoa ushawishi wa kutosha kwa familia hasa ukizingatia kwamba nyingi zina kipato cha chini ya dola moja kwa siku. Hata hivyo viwango hivi ni kwa ajili ya kielelezo tu. Viwango halisi vitategemea bei halisi ya hewa mkaa itakavyokuwa pamoja na kiwango halisi kitakachokatwa na nchi kufidia gharama za uendeshaji.

Sababu zinazoweza kuwafanya wanajamii wasishiriki kwenye uhifadhi shirikishi wa misitu ni ugawaji usio wa haki wa mapato au wasiwasi juu ya hilo, uhaba wa maeneo ya misitu, kutokuwa na ari ya shughuli za uhifadhi (ambayo inaweza kuchangiwa na matumizi yatakayokatazwa, au upatikanaji wa kipato mbadala), kutokuwa na sera na sheria nzuri, kutokuwa na wataalamu wawezeshaji, na kutokuwa na fedha za uanzishaji. Uzoefu kutoka kwenye vijiji vilivyofanyiwa utafiti unaonyesha kuwa viongozi wa vijiji, hasa wajumbe wa kamati ya msitu, wanahusika zaidi kwenye shughuli za uhifadhi, hasa zile zinazokuwa na malipo kwa kutwa. Wanakijiji wengine hawahusishwi. Hali hii inategemewa kuwepo zaidi kama malipo ya REDD yatapatikana kwenye vijiji. Tatizo ni kwamba kama wanakijiji wote hawatapata faida, wanaweza kutotoa ushirikiano wa kutosha kwenye shughuli za uhifadhi wa kijamii ambazo zitaongeza kiwango cha kaboni. Hii inaweza kuondoa matarajio ya mchango wa misitu jamii kwenye sera ya REDD. Kwa hiyo, kwa mafanikio ya misitu jamii chini ya sera ya REDD, mfumo mahsusi wa kuhakikisha mgawanyo wa haki wa mapato unahitajika. Mfumo huu haujafanyiwa kazi kwenye utafiti huu lakini imeonekana kuwa ni tatizo ambalo linahitaji kufanyiwa utafiti zaidi.

Imeonekana kuwa katika maeneo mengi ya misitu, wanakijiji wana ari kubwa ya kushirika katika shughuli za uhifadhi na kwamba kuna ardhi ya kutosha ya kuanzisha misitu shirikishi ya jamii. Imebainika pia kuwa, serikali kuu imefanikiwa kwa kiasi kikubwa kutoa madaraka kwa halmashauri za wilaya. Hata hivyo, halmashauri za wilaya hazijatoa madaraka ya kutosha kwa serikali za vijiji kwa hiyo madaraka zaidi kwa serikali za vijiji yanahitajika. Pia ingawaje kuna sera na sheria nzuri kwa ajili ya kuanzisha misitu shirikishi ya jamii, uelewa wake kati ya wanakijiji na wananchi kwa ujumla ni mdogo na unahitaji kuongezwa. Kuna wataalamu wawezeshaji wa kutosha kwa ajili ya shughuli za misitu jamii (mashirika yasiyo ya kiserikali na wahisani) lakini imeonekana kuwa pesa kwa ajili ya misitu jamii zinatolewa kwa halmashauri za wilaya kwa mafungu yanayolingana bila kujali wilaya ilipo, wingi wa watu na ukubwa wa misitu. Mfumo wa 'misingi kiota' yaani '*nested baselines*' unapendekezwa kuleta uwazi wa namna ambayo fedha zitagawanywa kwa haraka na haki pindi pesa za REDD zitakapopatikana.

Kwa kuzingatia matokea ya utafiti huu, mapendekezo matatu ya sera na matatu ya utafiti zaidi yanatolewa. Inapendekezwa kuwa muundo wa sera ya REDD uhusishe kupunguza upotevu na uharibifu wa misitu, pamoja na kuongezeka kwa kiwango cha uhifadhi wa hewa mkaa kutokana na kukua kwa misitu. Pia kwa kuwa utunzaji wa misitu jamii unaongeza uhifadhi wa hewa mkaa, serikali inashauriwa kuhusisha misitu jamii kama moja ya njia za kutekeleza sera ya REDD. Ili kuhakikisha mapato ya hewa mkaa yanagawanywa kwa haki kwa kila kijiji kinachohusika, serikali inashauriwa kutumia mfumo wa 'misingi kiota' unaoshauriwa kwenye utafiti huu. Kwa kuwa hakuna takwimu za kiasi cha kaboni kwenye misitu, ufanyike upimaji wa misitu kwa kutumia njia shirikishi kama iliyovumbuliwa katika utafiti huu. Maeneo mengine yanayohitaji utafiti zaidi yanahusika na swala tete la '*leakage*' na mgawanyo wa haki wa mapato ya kaboni.