Locally based monitoring

A study case from Uluguru North Forest Reserve, Tanzania

M. Sc. Thesis

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January 2006

1. Introduction

1.1. General introduction

1.1.1. Motivation and perspectives

Loss of tropical rain forest

Considerable attention is nowadays directed towards the rapid loss of tropical rain forest. Every year 9.4 million ha of tropical forest cover is being lost, and during the past 20 years up to 14.2 million ha of natural tropical forest has annually been destroyed due to deforestation (FAO 2001). In Africa alone the deforestation accounts for 2.2 million ha/year or 0.43 % of the world's total forest cover (FAO 2001, UN 2002). The continent has already lost approximately 65 % of it's originally wildlife habitat due to agriculture expansion, deforestation and overgrazing as a result of the rapid population growth and poverty (Newmark and Hough 2000).

The destruction of natural forest has many consequences for the conditions for biodiversity and humans living in the surrounding areas. Deforestation often leads to a change in balance of wind, water and solar radiation, which additionally can lead to changes in vegetation structure, microclimate and nutrient status (Whitmore and Sayer 1992, Margules and Pressey 2000). The tropical forests functions include: maintenance of local water supplies, protection against erosion, moderating climate, slowing down global warming and supporting much of the world's biodiversity (FAO 2003).

Loss of biodiversity

In 1992 the Convention on Biological Diversity highlighted the global importance of biodiversity, and the need to protect our natural heritage for future generations with special attention on developments countries (CBD 1992). At the Johannesburg World Summit on Sustainable Development in 2002 190 countries committed themselves to the Convention on Biological Diversity's 2010-goal, which aims at significantly reducing the current rate of biodiversity loss on global, regional and local levels (UNEP 2002). For this goal to succeed more focus needs to be placed on conservation and development in the tropics, since biodiversity is not evenly distributed. Some areas are far richer on biodiversity than others (Mittermeier et al. 1998, Myers et al. 2000, Rodrigues et al. 2004), and these areas are often those with few available resources for conservation (Balmford et al. 2005).

The tropical forests are some of the most important areas for conservation of the world's biodiversity. Although they only cover 7 % of the world's surface, they contain more than 50 % of

the world's species (Raven 1990, Olson et al. 1998, Whitmore 1998). The main threat against tropical forest biodiversity is habitat loss, particularly the loss of natural forest cover (Sheil 2001). The tropical forests are becoming more and more fragmented which constitutes major threat for the biodiversity of the world. Brooks et al. (1999) showed that forest fragments at the size of 1000 ha will loose 50 % of the forest depending species within the first 50 years following a fragmentation. Many species has already gone extinct in this century due to loss of habitat, and at present 11 % of the world's birds, 18 % of the mammals, 5 % of the fishes and at least 8 % of the plants are threatened with extinction (Vitousek et al. 1997). For other taxa extinction rates are difficult to determine, because the majority of species has not yet been identified (Bawa et al. 2004, Jayasuriya et al. 1997). Extinction is a natural process, but the current rate of loss of genetic variation, populations and species is between 100 to 1000 times greater than the background rates (Vitousek et al. 1997, Getz et al. 1999), and many areas with a high level of endemism are under severe threat (Mittermeier et al. 1998, Myers et al. 2000, Rodrigues et al. 2004).

To face the growing threat of biodiversity loss, special attention has been given to the areas, where exceptional high concentrations of endemic species are undergoing exceptional big losses of habitat, the so-called 'Hotspots'. In order to qualify as a 'Hotspot', an area must contain at least 0.5 % of the world's total number of plants as endemics, and it must have lost at least 70 % of its primary vegetation cover. There have presently been identified 25 'Hotspots' around the world, one of which are the Eastern Arc and costal forest (Myers et al. 2000, Mittermeier et al. 1998). Together these 25 hotspots comprising only 1.4 % of the land surface of the earth, but they supports 44 % of all vascular plants and 35 % of all vertebrates (Myers et al. 2000).

Threats to the tropical rain forest

The population growth and increasing poverty experienced by many developing countries constitutes a major threat to the tropical rain forests of the world. In general there is a positive correlation between species richness and the density of the human population across the tropics, which increases this problem (Balmford et al. 2001). Human beings have a great impact on natural tropical ecosystems, and areas supporting high endemism are generally facing rapid habitat loss due to high human population density (Balmford and Long 1994, Balmford et al. 2001, Bawa et al. 2004).

Often the extreme poverty in the rural area in developing countries causes loss of biodiversity, because the poverty forces local people to use short-sighted solutions without any concern of the future (Fjeldså *in press*). Today more than 500 million people are living in severe poverty in or near the world's forests, many of which has the natural ecosystems as their primary source of food, firewood, building poles and other essential resources (FAO 2003, WHO 2005, Newmark and Hough 2000, UN 2002, Becker et al. 2005). This conflict will increase in the future, as the human population are predicted to rapidly increase in the developing countries for many years (WRI 2000,

UN 2002). In Africa access to land is a major concern, as human population are predicted to double within the next 25 years with roughly 75 % of the population living in the rural areas (Hackel 1999). Hence, the greatest challenge for conservation of tropical ecosystem in developing countries in the future will be, to meet the needs of the rapidly growing poor population.

Many ecosystems are also facing commercial threat due to unsustainable exploitation of their resources. During the last two decades the western aid policies has pushed Africa in the direction of more economical liberation. This has led to an increasing need of money, which along with better infrastructure allowing access to forests has increased the human pressure on the tropical forests even further, in the attempt to obtain products with a market value for sale on the urban markets (Heywood and Stuart 1992, Bryceson 2000). Additionally, the increased shortage of timber has forced logging companies to operate in South America and Africa in order to supply the rapidly growing Chinese market with timber (Whitmore 1998).

Local involvement

Increasing human poverty and the losses of biodiversity are two of the critical problems of our time (Hartley and Kaare 2001, UN 2002). Decades of failed conservation projects have made international conservation policies focus on involvement of local communities in the management to combine local people's need with the conservation of natural resources (Van Rijsoort and Jinfeng 2005). Since the mid 1990s more and more attention has been given to integration of conservation and development projects (ICDP), emphasizing the need to involve local people in the decision making and implementation. This is essential, because maintenance of biodiversity and ecosystems often mean limitation for the local communities that live of and around them (Getz et al. 1999). As a consequence rural people are some times against protection of land, either because they think it is wrong to place the needs of wildlife over the needs of people, or because they fear further restrictions will be put on them (Hackel 1999, Van Rijsoort and Jinfeng 2005). Hence, for conservation to be a success it is important, that local communities are involved and that they benefit from the scheme.

The conservation project in Uluguru

This monitoring project is part of a big integrated conservation and development project administrated by the Danish Ornithological Society (DOF) in collaboration with the Wildlife Conservation Society of Tanzania (WCST), and funded by the Danish Development Agency (DANIDA). The project is implemented by WCST in close partnership with the regional and district Natural Resources Offices, the Catchment Forest Office of the Ministry of Natural Resource and Tourism and the Uluguru agriculture project Development project. It is operated from a regional WCST office in Morogoro town.

The project consists of two parts. One is aiming at building capacity within the WCST to enable the organization independently to manage conservation programs in the future. The other part is aiming at integrating the development and conservation efforts in and around the Uluguru North Forest Reserve. The work is done at many different levels: government, local communities and schools to promote sustainable management of the area. The conservation activities include among others: establishment of stakeholder groups, involvement of the local communities in the management, introduction to more profitable agriculture methods, establishment of nurseries that produce seedling for the communities enabling them to produce the resources outside the forest and environmental education in the schools.

1.1.2. Objectives of this thesis

The objectives of the present thesis are:

- To develop simple and cost-effective monitoring methods to use in a locally based monitoring scheme in the Uluguru North Forest Reserve
- To test the efficiency of these methods in comparison to a more scientifically approach
- To test the quality of locally collected data using these monitoring methods
- To add knowledge on locally based monitoring in developing countries

The fieldwork was carried out in collaboration with Rune Bille Hansen from the University of Copenhagen, Mr. Mazengo from the local WCST office and four different field teams consisting of local WCST members and village environmental committee members.

1.2. Eastern Arc geography, geology and climate

The geographical position of the Eastern Arc Mountains, along with the geologically and climatologically histories of the area has created biological unique forests on these mountain blocks (Lovett and Wasser 1993). This section provides a short overview over these factors.

1.2.1. Geography

The Eastern Arc Mountains is an ancient chain of isolated crystalline mountain blocks stretching 900 km from southern Kenya all the way through Tanzania (figure 1.1). They are all directly under

climatically influent by the Indian Ocean (Lovett 1990), and each block can be looked upon as an isolated island in an ocean of arid land.

The rugged mountain blocks rise from subdued topography of the coastal plain of eastern Africa with an altitude around 300 m to the highest peak 2.635 meters (Kimhandu peak in Uluguru Mountains), but most peaks ranges between 2.200-2.500 m. Many of the blocks are so steep that substantial areas are exposed rock, but forest vegetation can be found on slopes up to 50-70 degrees.

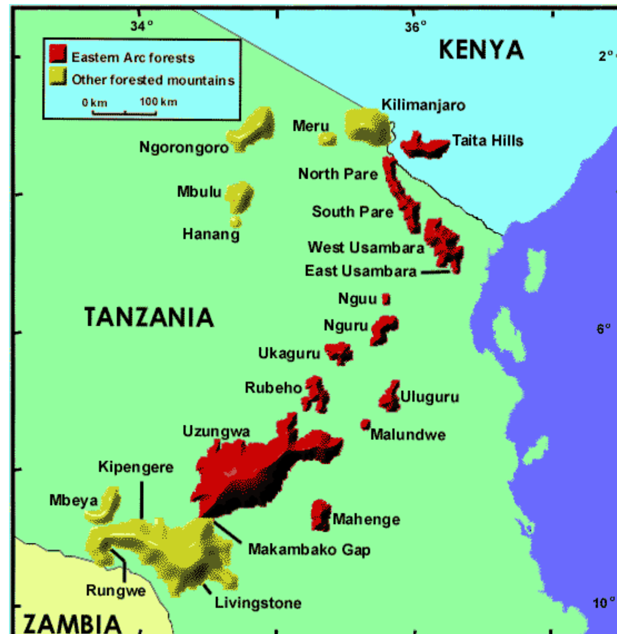

Figure 1.1 A schematically overview over the Eastern Arc Mountains, along with other forested mountains in the area that are not regarded as part of the Eastern Arc, many of these are a lot younger and ascent from volcanic activities

The Eastern Arc Mountains were initially covered with 23.000 km^2 of forest, of which 15.000 km^2 remained by 1900 (CEPF 2005). Today the maximum natural forest cover is 5.340 km^2, which approximately corresponds to 23 % of the original forest cover, from when humans made their first appearance in these forests. Of the current natural forest only 27 % or 1.447 km^2 are considered closed forest (Newmark 1998). The forested area is spread out over more than 150 different forest sites under different ownership and management, of which 106 forest sites are managed by the catchment forestry programme (Madoffe et al. *in press*).

1.2.2. Geology

The underlying rocks of Eastern Arc Mountains consist of ancient crystalline Precambrian rocks, which in most places are covered with younger sedimentary. These Precambrian rocks are part of the Mozambique Belt that dates back to 450 to 2000 million years BP (before present), but the

blocks were probably not initiated until 180 million years BP in the Karroo period, around the same time as the break up of Gondwanaland (Griffiths 1993). At that time the East and West Africa were topographically united, but with the uplift of the central African plateau in the Miocene period (10 million years BP) these areas got separated, and the topography of East and Central Africa transformed dramatically, and changed the drainage patterns for the whole region (Griffiths 1993).

The landscape of Eastern Africa today is produced by a number of geological processes weathering; erosion and deposition have operated since the uplifting of the Mozambique belt. Additionally, earth movements have also resulted in elevation and lowering of different areas, which have led to the isolation of the Eastern Arc Mountain blocks that are seen today (Griffiths 1993).

The soil of the Eastern Arc Mountains has a low fertility, because the Precambrian rock basements are very rich on quartz, which generally produces a low amount of nutrients to the ground. The chemical composition of the underlying rock influences the fertility of the soil, because it determinates the amount of nutrients released to the ground by weathering. The steep slopes have increased this low fertility by quickly removing the weathered products from the area due to erosion by gravity (Griffiths 1993).

1.2.3. Climate

Before the break up of Gondwanaland 180 million years ago East Africa was positioned in the centre, which meant that the area was very dry with no moist forest cover. As Gondwanaland began drifting part the East African coast got more exposed to climatic influences from the Indian Ocean (Lovett 1993). By the beginning of the Tertiary period 65 million years ago, the currents of the Indian Ocean were flowing around Africa, which gave an increasingly wetter climate. The mountains received most of the rain coming from the ocean due to their higher altitude, and about 26 million years ago they became forested (Lovett 1993). At that time the forests of East and West Africa were connected, but 17 million years ago the African forests started to fragment into a western part influenced by the Atlantic Ocean climate and an eastern part under the influence of the Indian Ocean climate. However, in the beginning the separation was probably not bigger than a certain degree of migration between the two forest areas was still possible (Lovett 1993). But with the uplift of the central African Plateau, the West and the East African forests were separated by an arid corridor with a monthly rainfall of less than 10 mm. This stopped the migration between the two areas, even though small migrations may have appeared during wet and warm periods of time (Lovett 1993).

Even within each Eastern Arc forest block, large biological differences exist at a local scale, due to local differences in microclimate (Dinesen 1998). These different microclimates were initiated

some 7 million years ago with the uplift of the Eastern Arc and Nyasa Rift Mountains, which created a rainfall gradient between the eastern and the western side of the mountains (Lovett 1993). The gradient is a consequence of the north-eastern wind that brings moist air from the Indian Ocean, which hits the eastern slopes first resulting in a high rainfall on this side of the mountains, while the western side receives a significant lower amount of rainfall (Póc 1976).

The predominating north-eastern wind direction also influences the seasonal rain patterns between the different blocks. The rainy season in the northern part of the Eastern Arc follows a bimodal curve with peaks in November and April, while the rainy season in the southern parts follows a monomodal curve that peaks in April. During the dry season mist and clouds maintain the moisture and the stream flow in the mountains (Póc 1976). The forest cover also plays an important role in the mountains water catchment ability during the dry season. Póc (1974) found that the midday temperature on agriculture land in Uluguru Mountains were 30 ^{o}C higher than temperature in the forest at the same altitude. This affects the water catchment as warm air is able to contain a higher amount of water than cold air. Thus, when the warm air from the open areas enters the cooler forest the water condenses and results in rainfall. This fact stresses the importance of the forested areas on the Eastern Arc Mountains regarding water supply in Tanzania. Tanzania is a predominantly dry country, where about 50 % of the land receives less than 750 mm rainfall annually. Only 4 % of Tanzania receives more than 1250 mm annually rainfall (Griffiths 1972), and the water supply of Tanzania is therefore very depended on montane areas.

During the last 2.3 million years there have been 21 glacial or near glacial periods (van Donk 1976). Those glacial periods resulted in a dry and cold climate in Africa, and these considerable climate changes caused the moist forest area in West Africa to decline dramatically during this period (Lovett 1993). Meanwhile, the stable temperature of the Indian Ocean (Prell et al. 1980) has maintained the high rainfall over the Eastern Arc throughout these glacial periods, which has enabled the forest to survive on the mountains throughout these arid periods (Rodgers 1998). This climatic stability along with the great age and isolation of the mountain blocks has produced the remarkably high endemism and diversity that is found in the Eastern Arc Mountains today (Lovett and Wasser 1993).

The flat coastal plain from which the Eastern Arc Mountain block raises

1.3. Eastern Arc biodiversity

The combination of a long geological history, climatic stability, isolation and high rainfall has made the Eastern Arc Mountain forests, some of the most biologically diverse and endemic rich montane ecosystem in Africa (Lovett 1998, Stanley et al. 1998, Rodgers 1998).

1.3.1. Globally importance

Although the biological importance of the area is broadly recognised, the forest is facing an increasingly pressure, and as little as 2.000 km^2 (8.6 % of the original forest covered area) are protected to some extent. This fact along with the high level of endemism and genetic variation has resulted in that the Eastern Arc and costal forest has been appointed as one of the world's 25 biodiversity "hotspots". Along with the extreme level of endemism, the Eastern Arc holds numerous threatened species, which positions the Eastern Arc in top five of biodiversity conservation priorities across Africa (Brooks et al. 2001). The global importance of the conservation of this area are emphasized by Myers et al. (2000), who showed that the density of endemic species in the combined hotspot of Eastern Arc and the lowland coastal forest of eastern Africa is the highest in the world. Furthermore Brooks et al. (2002) identified this hotspot as one of the hotspots that can tolerate further habitat loss the least, if further extinction shall be avoided. This is supported by vertebrate surveys from the Eastern Arc Mountain blocks Usambaras and

Udzungwa that ranked Usambaras as the most important location for protection of threatened mammal and Udzungwa for threatened birds in all of Africa (Brooks et al. 2001).

1.3.2. Biodiversity of the Eastern Arc

Flora

The Eastern Arc forests hold at least 4000 plants species of which 1500 (or 0.5 % of all plants) are endemics (Myers et al. 2000), and at least 1000 of the endemic plants are threatened with extinction (Lovett 1998, Burgess *in press*). The endemic and threatened species occur throughout the elevation range of the forests, and new species are still being discovered throughout the Eastern Arc forests (Lovett 1998). The Eastern Arc also houses 700 species of bryoflora, 32 of which are endemic to the area. This might seem as a small percentage, but most bryophytes has a wide distribution, due to easy dispersal of diasporas of cryptogam plants, which leads to low endemism compared to other plant taxa (Pócs 1998).

Fauna

The fauna of the Eastern Arc forests are also extremely rich. A total number of 1019 vertebrate species are found here, of these 121 are endemics (0.4 % of all vertebrate), the endemic vertebrate are counting 22 birds, 16 mammals, 50 reptiles and 33 amphibians (Myers et al. 2000). Additionally, the Eastern Arc supports an unknown number of endemic invertebrate, with 95 % endemism for some taxa (Burgess et al 1998). The majority of all the endemic species are dense forest specialists, and are therefore very sensitive to forest disturbance (Burgess et al 1998).

1.3.3. The future situation for biodiversity

The Afrotropical forests are in general critical endangered, as they are threatened by habitat loss and degradation. This also applies to the Eastern Arc Mountain forests (Olson et al. 1998). The species of Eastern Arc have evolved over millions of year in a stable environment, which have made them very fragile to large scale disturbances, and endemic species have already been lost in some of the areas that have been subjected to disturbance (Lovett 1998). Much of the fauna have a very restricted geographical range, and many of the species are not capable of crossing forest gaps or the big land areas between the individual mountain blocks (Newmark 1998). They will therefore go extinct, if their habitat is lost. A biodiversity survey from East Usambara Mountain showed that 27 % of the total number of plant species and 41 % of the endemic and near endemic plant species depended strictly on primary forests, and the same apply for all of the endemic fauna as well as 89 % of the near endemic fauna recorded (Johansson et al. 1998). The Eastern Arc Mountains have already lost about 77 % of the original forest cover, which suggests that roughly 31 % of the original number species has gone extinct or are threatened to do so, if the deforestation are not put to an end (Newmark 1998).

1.4. Eastern Arc history and status

There has been tropical rain forest in East Africa for the last 30 million years and in the Eastern Arc Mountains for at least 26 million years (Lovett and Wasser 1993). Before the human intervention the mountains were covered by forest and some grassland, but today considerable areas have converted to agriculture and plantations (Burgess et al 1998). Human history from the region shows that there have been great movements of people in eastern Africa through time. People have moved to the forests for many reasons: for water, as refuge during wars, for food and wood (Rodgers 1998). Human history has without a doubt affected the Eastern Arc Mountains forests and their distribution.

1.4.1. Pre-colonial period

For the past 60.000 years humans have used fire to reduce the distribution of moist forests in Tanzania (Lovett 1993). While there properly have existed a small number of hunting and gathering communities in the Eastern Arc forests for many thousand years, the first signs of human exploitation do not occur until about 2000 years ago, where traces of the Azanian culture has been found (Rodgers 1993). Forest clearance increased during a short arid period about 1000 AD, after which the clear areas were held open by fires and grazing. But the human presents did not really intensify until the dry period between 1600 and 1750 AD. This caused many people to move from the dry plains to the moist forests (Rodger 1993).

1.4.2. German colonization period

The forests of the Eastern Arc were first scientifically described in 1860, where it was described as having a great wealth of species. But it was not until 1983 that the first biological work was done in the area by the German botanist Adolph Engler, who wrote about the plant diversity of the Usambara Mountains (Rodgers 1998).

Tanzania was a German colony in the period 1885-1916. In this period only settlers and plantation owners were allowed to own land, and they were given the best land (Chachage 1998). The German colonialism increased the pressure on the forest, as people started moving deeper into the forests and upper slopes to escape from the German occupation (Rodgers 1993). Additionally, the Germans started using forest products commercially, such as wild rubber and timber. Furthermore, the settlements and missions were to a large extent established in highland area due to the more preferable climate, which further increased the pressure on the forests. On the other hand the German administration were already then well aware of the importance of the forests for water catchment and protection against erosion, and as a result the Germans established many forest

reserves in the Eastern Arc Mountains to protect the water supplies. The first forester with responsibility of the area was appointed in 1892, which led to the opening of the Department of forestry and Wildlife in 1912. By the beginning of World War I in 1914 there were 231 forests reserves in Tanzania covering over 7500 km^2 (Rodgers 1993). Today 80 % of the existing closed forest reserves date back to the German colonial time (Rodgers 1998). However, the World War I led to a decline in forest area all over Tanzania, because many forests were cut to provide resources for both for civil and military purposes (Rodgers 1993).

1.4.3. British colonization period

After the end of World War I in 1918 Tanzania came under British administration. The British government's priority was given to establish native authorities (Chachage 1998); a very different approach than the one used by the Germans. In the 1940s the forest reserve boundaries were established, and all large forest blocks were declared Crown land under control by the British government (Rodgers 1993). Due to shortage of land in the 1950s the government allowed people to clear forest to convert it to agriculture land, which led to huge areas of forests being cleared (Chachage 1998). Furthermore local people were encouraged to return to the forests and convert it to coffee or banana plantations by the British administration (Woodcock 1998). Additionally, more attention was given towards production and export of timber, which grew with almost 500 % during the 1950s (Rodgers 1993). All these factors caused further disturbance and deforestation of the forests of the Eastern Arc.

1.4.4. After the independence

By the independence in 1961 Tanzania had about 120,000 km^2 covered by different reserves including 9500 km^2 closed forest. From 1961 to 1985 the areas of forests reserves were increased with about 13,000 km^2, but most of these were created primary for tourist purposes and conservation of large mammals (Rodgers 1993). By the late 1980s the importance of preserving natural forest cover to maintain water supply and prevent soil erosion came on the political agenda, but the drop of Tanzania's economy made action impossible. Until the independence most conservation in East Africa were done by white sport hunters (Fjeldså et al. 2004), who focused on large animals rather than the protection of the forests, although the survival of larger mammals can be considered a luxury, while the forest areas are important for human survival (Rogers 1993).

In 1992 Udzungwa became the first forest National Park in Tanzania focusing on biodiversity rather than on large mammals. Today the need to preserve the Eastern Arc forests is broadly recognised. Unfortunately the means to do so are extremely limited, and even though the official forest policy in Tanzania states that equal attention are given to protecting and managing the forest reserves, in

practice the staffing and the financial resources are inadequate for the protection, that does not receive much attention (Rodgers 1993).

1.5. Benefits and threats of Eastern Arc forests

1.5.1. Benefits of the Eastern Arc forests

The Eastern Arc Mountain forests are of global, national and local importance. Millions of people benefit from resources provided by these forests every day. The forests ability to catch humidity from the Indian Ocean is extremely important for the countries' agriculture and industries, and it is vital for the countries' water supply. As they provide catchment for most of the rivers in the country (Iddi 1998, Rodgers 1993). These rivers supply a large proportion of the urban population in mainland Tanzania with freshwater, especially the maintenance of the dry season flows are crucial for millions of people (Workshop 1997). The rivers are also very important for the country's electricity supplies, as 61.5 % of Tanzania's electricity is generated by hydroelectricity dams using water from the mountains (Iddi 1998, Pfliegner and Burgess *in press*).

It is broadly recognised that healthy forest ecosystems on top of water catchment also provide soil stability and support the nutrition cycle (WRI 2003, Kremen et al. 1994, FAO 2003, Balmford et al. 2002). This also applies for the Eastern Arc forests, that provide protection against soil erosion on the steep slopes during the periods with heavy rain and enriching the soil with nutrients (Iddi 1998, Rodgers 1993). On a more global scale the forests react like a buffer in regulating the climate and pollutant and slow down global warming (FAO 2003, WRI 2003, Rodgers 1993).

The forests are also of major importance for the local communities living in and around them. In many developing countries formal employment are extremely limited, and therefore people are depending on natural resources for survival (Noss 1997, Balmford et al. 2002, WHO 2005). The people of the Eastern Arc that depend directly on the forest resources are typically those living within a 10 km radius from the forests (Rodgers 1993). These people depend on the supply of firewood, building poles, tools, medicine, food and honey from the forest on a more or less daily basis to maintaim their livelihood (Lulandala 1998, Shangali 1998, Iddi 1998, Burgess et al. *in press(a)*). Some products like dug-out canoes, honey, medicines, fruits, gold, gemstones, alcohol and charcoal may be sold to people further away and thereby creating an income for the local people (Rodgers 1993, Burgess et al. *in press*). The medicinal values of forest plant should be given special attention, because traditional medicines are often easier and cheaper to access than western medicine for local people (Workshop 1997).

The forests also play a commercial role for Tanzania, where timber is a major economic resource for the country and a very important industry in many regions (Rodgers 1993). Furthermore, the forests can provide plant species of high economical value, for example wild coffee and medicine plants for commercial production (Svendsen et al. 1995b). These genetic resources are also used in the production of chemical and cosmetic products (Rodgers 1993). Finally, there is also the moral, aesthetic and scientific desire for all species to survive, which is hard to translate into an economic value, but surely should be taken into account (Rodgers 1993).

1.5.2. Threats against the Eastern Arc forests

In general protected areas in developing countries are under tremendous pressure from millions of very poor local people with a low level of education struggling for survival (Danielsen et al. 2000). There are many factors that have led to the extreme poverty Africa experiences today. Among these are: lack of employment, a low productivity, a low level of health, lack of training and education, very limited land ownership, a low level of government support, a high population growth and much corruption and bureaucratic (Hackel 1999).

The Eastern Arc has experienced severe losses of forest and fragmentation due to human disturbance and fires during the last 200 years. Much of the remaining natural forest has also been extensively disturbed by human interactions (Newmark 1998). The losses are caused by a combination of human population growth, unsustainable use of natural resources, economic policies that have failed to value the environment and its resources, along with weak legal and institutional systems (Lulandala 1998).

Population growth is a major issue in Tanzania, which leads to further poverty, diseases and environmental degradation (Chachage 1998). Many have identified the growing poor human population, as the biggest threat to the Eastern Arc forests today. As this leads to habitat loss due to conversion of natural habitat into settlements, farmland or plantations of monocultures or exotic plants, along with the frequently returning dry season fires and overexploitation of forest resources that alter the habitat dramatically (Lulandala 1998, Newmark 1998, Burgess et al. *in press(a)*, Wurster and Burgess *in press*). Besides the threat from habitat loss some animal species are also threatened by hunting. The hunting pressure from the local residents varies a lot, as it is largely determined by tribal and local traditions (Rodgers 1993).

1.5.3. Consequences of forest loss in the Eastern Arc

The Eastern Arc Mountains support the livelihood of millions of people, and many more are dependent on the water supply from these forests (Lulandala 1998). One of the consequences of the deforesting in the Eastern Arc is, that the water immediately will run off the mountain, and only

very little will enter the soil layer. This will lead to an increase in rain season floods and a decrease in the dry season water flow, resulting in rainy season erosion and unstable water supply during the dry season. Studies have shown that an Ecuadorian rainforest receives up to 6.5 times more rainfall per ha in comparison with agriculture land (Becker 1999, Becker et al. 2005). This is support by local comments that the climate is getting warmer, that there is less mist, and fewer days with rain than earlier, and most cities in Tanzania has experienced water shortness in dry periods during the last decade.

The declining flow in the Eastern Arc rivers will have negative affect on the economy of Tanzania and the country's ability to attain the Millennium development goals in the future (Rodgers 1993, Mtalo et al. *in press*, UN 2002). Furthermore, a study of 67 landslides on different sizes around the Uluguru Mountains showed that disturbance and deforestation were the main factors encouraging landslide erosion. The landslides had major economical consequences for the region; as they caused severe destruction of infrastructures, also the Morogoro market and town center were hit resulting in substantial economic losses (Munishi et al. 1998).

Deforestation also leads to a decrease in soil fertility in the surrounding agriculture land. Because the underlying rocks of the Eastern Arc Mountains are not rich on nutrients (for detailed description see 1.2.2. Geology). The low fertility of the soil is however offset by the mountains high average rainfall that enhances the rate of the chemical weathering and sustains a productive vegetation cover that results in a high amount of organic matter in the soil. This compensates for the low nutrients value of the parent rock. Hence, the fertility of the soil will rapidly be lost, if the vegetation is removed (Griffiths 1993).

The disturbance also alters the species' composition from forest dependent species to more open land species, which will lead to a decline in endemic species (Lawton et al. 1998). Much of the Eastern Arc forests have been lost or heavily disturbed by cultivation, timber extraction, pole cutting and dry season fires already (Dinesen 1998, Lulandala 1998). If these disturbances are not minimized in the future, many of the Eastern Arc Mountains' endemic species will become extinct over the next century (Lovett 1998). Studies from Usambaras has shown that forest reserves are in general in a considerable better state in comparison to the public forests (Johansson et al. 1998), but in many places almost all forest outside the reserves has disappeared. Thus, if the conservation and development actions are not taken soon, the reserves will probably face an enormous pressure in the near future.

1.6. Monitoring

More and more emphasis is given to the importance of monitoring data, since it is necessary for evaluating the impact of management interventions in conservation projects. There is a need to base conservation efforts on evidence rather than undocumented assumptions, as budgets are very limited and priorities must to be made (Sutherland et al. 2004). One of the major obstacles for conservation of the tropical biodiversity is the lack of monitoring to provide information of, where the efforts should be concentrated (Howard et al. 1998). The responsibility for the monitoring of the Catchment Forest Reserves in Tanzania are positioned in five regional catchment offices, but there are no history of any actual forest monitoring programs in these reserves (Rodgers 1993). However, people from the catchment offices, donors, scientists, NGOs and other stakeholders are at the moment working on establishing and standardizing such a program (Birdlife 2005). Before setting up a monitoring program, it is very important to consider why, what and how to monitor (Yoccoz et al. 2001). Some of the thoughts on these issues will be presented in this section.

1.6.1. Why monitor?

Monitoring is defined as a process of gathering information about a system to detect changes over time and space (Yoccoz et al. 2001). The main objectives with the monitoring in the Eastern Arc Mountains are to detect changes in the forest structure and composition over time, which can be used by the management personnel to priorities and evaluate conservation efforts on biodiversity and forest areas (Birdlife 2005, Workshop 1997). Monitoring and evaluation are central components in successful conservation programmes, because they enable managers to objectively identify the threats, so effective action can be taken to face the given problems. Even when resources are limited monitoring activities remain essential to ensure, that threats are identified and addressed in a proper manner (Sheil 2001, Kremen et al. 1994, Newmark and Senzota 2003, Andrianadrasana et al. 2005, Danielsen et al. 2005).

In general there are two different objectives with monitoring: the scientific and the management. The goal of management monitoring is to identify the state of the system and to provide information on the system's response to management actions. Where the goal of monitoring from a scientific point of view is to learn and understand the behaviour and dynamics of a system (Yoccoz et al. 2001). It is broadly recognised, that a scientific approach provides more accurate results. However, taxonomical identification relies on educated national or international experts, who are often not very cost-effective, and high expenses can cause a monitoring program to collapse when donor funds stops (Sheil 2001, Danielsen et al. 2000, Dinesen 1998, Danielsen et al. 2003, Getz et al. 1999, Margules and Pressey 2000).

The lack of funding has raised the awareness on how to reduce cost of conservation (Myers et al 2000). Some have argued that monitoring and research activities actually may hinder rather than improve conservation in the tropical countries, if realities are not taken into account (Sheil 2001). Hence monitoring programmes are very important in efforts to manage and conserve biodiversity, but it is important that the theories and field methods fit with the scale and cost of management.

1.6.2. How to monitor?

How and what to monitor largely depends on the available funds, and who are doing the actual monitoring. The monitoring approaches used in the developed parts of the world are often not suitable for use in developing countries, where funds in general are very limited. Consequently, the successful implementation of any environmental project in most developing countries needs a simple and cost-effective monitoring program to evaluate its effects (Dinesen 1998). A good cost-effective monitoring scheme must require a minimum amount of training and equipment to make it sustainable. Furthermore it needs to encourage local stakeholders to participate and strengthen existing local systems for monitoring; hence for a monitoring system to be sustainable it needs to be based on local personal and resources for when the funding stops (Danielsen et al. 2000, Andrianadrasana et al. 2005). Additionally local involvement will have a positive effect on any project, because the level of environmental awareness and ownership towards the project among local people will increase.

For locally based monitoring schemes to be successful the standard of the methods must be lower than those used by scientists. This can pose a problem, because efficient conservation and planning depends on accurate data to minimizing the risks of drawing wrong conclusions (Rodgers 1993). Therefore it is necessary to test the efficiency of a monitoring method and make sure, that can be used accurately by the people collecting the data, before the information is being used. In general a good cost-effective monitoring scheme should be based on indicators, which reflect the status of the whole system, for example disturbance or key-species (Margules and Pressey 2000).

1.6.3. The challenges for future monitoring

The past decades has shown that popular biodiversity data collection activities often do not apply to local conservation requirements in developing countries. Furthermore, they are often too expensive to be sustained after the funding stops (Sheil 2001, Lawton et al. 1998). In order to make a project more sustainable local villagers must be able to participate (Getz et al. 1999). This requires development of simple cost-effective monitoring schemes that are capable of detecting true tendencies, when the data collecting are conducted by local participants. To face this challenge it is important for a successful monitoring scheme to enhance the focus on the field and village level, to

involve the local communities and use their expertise, to simplify the monitoring methods for local use and to make sure that government staff are also involved in the process to ensure actions will be taken following the monitoring (Danielsen et al. 2003). Many projects have failed in the past, because the local participants have receives inadequate training or have not been involved in the project at all (Sheil 2001). Hence, it is very important that the local people are provided with an accurate amount of training in using the monitoring methods.

2. Site description

2.1 Uluguru Mountains

2.1.1. Location and history

Uluguru North Catchment forest reserve is a 8356 ha forested area located 170 km west from the Indian Ocean in Morogoro region ($6^o51'$ – $7^o01'$ S 37^o37 – $37^o45'$ E). It is located about 6 km from Morogoro Town, and ranges in altitudes from 600 m and to the Lupanga peak 2138 m. Uluguru North Catchment forest reserve is one of 6 reserves (Uluguru North, Uluguru South, Nyandidumi, Vigoza, Shikurufumi and Bunduki I-III) in the Uluguru Mountains. These mountains are characterised by a particularly high rainfall with no actual dry season, and an exceptionally amount of rare and endemic species (Lovett and Pócs 1993).

The rainfall varies a lot between the per-humid eastern slopes facing the Indian Ocean that receives at least 100 mm rainfalls each month of the year and an annual rainfall of 3000-4000 mm, and the western slopes facing away from the Indian Ocean with an annual rainfall of 1200-3100 mm (Lovett and Wasser 1993, Burgess et al. 2002). The soil consists of acidic litosols and ferralitic red, yellow and brown latosols over Precambrian granulite, gneiss and migmatite rocks (Lovett and Pócs 1993, Baker and Baker 2002). Landslides have often exposed large granite surfaces on the 50-70° steep slopes, although even these slopes are some times forested (Lovett et al. 1995).

The Uluguru Mountains cover roughly 1500 km^2 of highland with a 45.5 km long main ridge running north-south. This main ridge consists of two mountain blocks: Uluguru North and Uluguru South (see figure 2.1). The mountain blocks are separated from each other by the heavily populated Bunduki Gap. The Uluguru North and Uluguru South reserves should be considered together, as they cover the Uluguru Mountain ridge and slopes that provide catchment for the Ruvu River and a number of smaller rivers of local importance (Lovett and Pócs 1993).

The first conservation work in the Uluguru Mountains started back in 1909 with the establishment of a 277 km^2 big reserve covering both the Uluguru North and the Uluguru South reserves. In the 1940s a major project was initiated by the English administration, which was aimed at protecting the forest's water catchment value (Bhatia and Buckley 1998). Between the 1960s and the 1990s the Uluguru Mountains were a sensitive area with military importance and was used as a training base of the African National Congress of South Africa. Today the reserves are managed by the Morogoro District Catchment office under the central governmental Forestry Division.

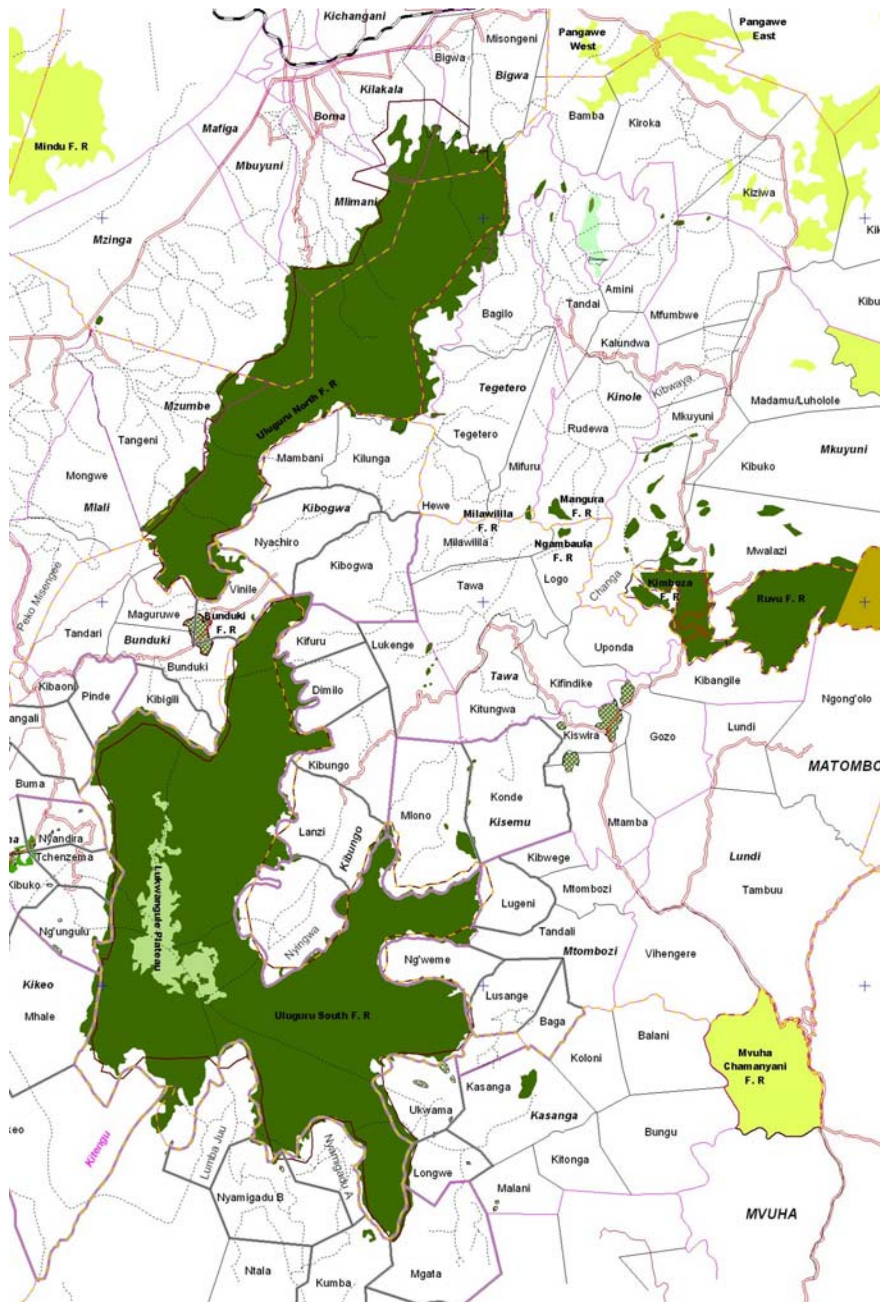

Figure 2.1 A map over the Uluguru North and the Uluguru South forest reserves, including forest cover and boundaries.

2.1.2. Population, poverty and threats

The general human population growth rate in Tanzania is between 2.8-3.2 % annually. But in some areas around the Uluguru Mountains it is close to 6.5 % (Lulandala 1998, Burgess et al. 2000, Svendsen and Hansen 1995). Hartley and Kaare 2001 found evidence that all local communities

around the forest, due to poverty are very dependent on forest resources to maintain their livelihood. The growing population leads to an increased demand on forest products like firewood, building poles, timber, medicines, bush meat, food, ropes and pombe brewing (Hymes 2001, Bhatia and Buckley 1998), which along with the frequently dry season fires - most due to varies illegal activities - poses the biggest threats against the reserve and its biodiversity (Burgess et al. 2002, Baker and Baker 2002, Svendsen et al 1995b). In some areas around River Ruvu in the Uluguru lowland, gemstone mining provides incomes for a number of local people. This activity causes forest damage in the areas close to the river (Burgess et al. *in press*).

Another aspect is the growing requirement of more agriculture land, which is necessary to feed the growing population due to ineffective agriculture practices. Consequently, clearance for new farmland has been the primary cause of forest loss outside the reserve boundaries (Burgess et al. 2002, Svendsen et al 1995b). Today cultivation extends all the way up to the reserve boundaries, and the small forested areas outside the reserve are rapidly being removed to create banana plantations or other agriculture land (Baker and Baker 2002, Lovett and Pócs 1993, Hymes 2001).

The disappearance of forests on the public lands has further positioned the Catchment Reserve, as the local people's source of firewood, building poles and other wood products (Hartley and Kaare 2001, Svendsen et al 1995b). In order to protect the reserve boundaries the Catchment Forest Department has started enforcing legislation, which forbid any agriculture activity in a distance of 20 m from the boundaries of a forest reserve. This has however caused conflicts to some parts of the local communities, because they feel that agriculture land is being taken away from them without any compensation.

In the remote areas the infrastructure, education and marketing opportunities are declining, leading to resurgence of traditional values and norms. But in areas with better infrastructure, the influences of the market economy and of Christianity and Islam have degraded traditional management authorities. Such an example is the DANIDA funded road between Dar es Salaam and Morogoro, which has improved the market opportunities considerably in the area of the Uluguru Mountains. Among other things it has resulted in a growing demand for fruits and vegetables to the urban markets. Today more than 50 % of the vegetables and fruits sold in Dar es Salaam come from the Uluguru Mountains, which further has increased the demand of land for cultivation in the area (Burgess 2001, Hartley and Kaare 2001).

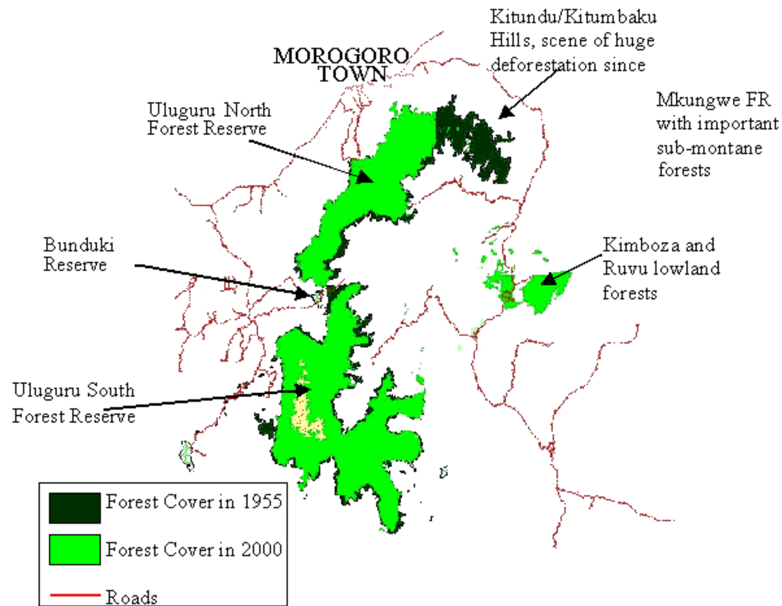

Figure 2.2 The forest cover of the Uluguru Mountains today in comparison with the forest cover in 1955.

Uluguru is the third largest area of natural forest in the Eastern Arc Mountains (Newmark 1998), but the conversion of forest to agriculture land is still happening continuously. An aerial survey of forest distribution in the Uluguru Mountains showed that the annual deforestation rate in the period between 1955 and 1980 was 0.74 % (Quinn 2000). Although there is no aerial evidence of the deforestation rate since 1980, deforestation is still a major problem in the Uluguru Mountains (Doggart et al. 2001, Hymas 2001). The original forest cover of the Uluguru Mountains has been estimated to be 500 km^2, in 1955 it had declined to 300 km^2, and today as little as 220 km^2 are covered with forest. The remaining forest is almost totally restricted to the Catchment Forest Reserves. The majority of forest area has been lost on the lower altitudes outside the forest reserves, and except a bit of submontane forest down to 1000 m in Uluguru North, all submontane and lowlands forest has been entirely lost (see Figure 2.3) in the period between 1955 and 2000 (see Figure 2.2) (Mbilyni and Kashaigili *in press*, Burgess et al. 2000, Burgess et al. 2002, Newmark 1998, Lovett 1998).

The Uluguru Mountains forest has been ranked to be the most important catchment forests in the country (Lovett 1998, Lovett and Pócs 1993). The forests provide water catchment for Wami River, River Ruvu, Ngerengere River and Morogoro River. Ruvu River provides the water supply for Dar es Salaam, and thus around 4 million inhabitants as well as breweries and other industries. Other rivers create water supply for Morogoro Town and the high population on the agriculturally rich Uluguru Mountains. This makes these forests of highest management priority (Iddi 1998, Svendsen and Hansen 1995, Lovett and Pócs 1993).

The continuous deforestation of the Uluguru Mountains has caused some of the minor rivers to dry up, and it has reduced the dry season flow in others during the last 20 years (Rodgers 1993). River Ruvu has experienced a decrease in flow over the last 50 years; as a result of forest loss (Mtalo et al. *in press*). There are two alternatives to secure the future water supply to Dar es Salaam. Either the mountain forest of the Uluguru Mountains must be maintained or the Ruvu River must be dammed. The latter solution is estimated to cost a minimum of 300 million USD$ (Svendsen et al 1995b, Baker and Baker 2002).

Landslides are another consequence of deforestation. Heavy rain has caused a number of serious mudslides in the area due to loss of forest cover over the years, leaving behind infertile and unproductive soil (Lovett and Pócs 1993, Munishi et al. 1998). In 1993 hundreds tonnes of mud eroded from the Uluguru Mountain slopes and flooded Morogoro town, which severely damaged the city's infrastructure and market with substantial economic losses for the whole region (Lulandala 1998).

2.1.3. Biodiversity

The Uluguru Mountains have for a long time been recognized as one of the most important sites for the conservation of biodiversity in Africa (Svendsen and Hansen 1995). In 1988 Collar and Stuart ranked these mountains as the fourth most important area for conservation of rare forest birds in East Africa and as 16th must important of the whole continent. In 2002 they were categorized as one of the 10 most important forests for biodiversity in all of Africa (Burgess et al. 2002). The exceptional biodiversity of the Uluguru Mountains is the result of a long geological history along with a long period of isolation and unique climate, which have created a great variation in microclimates around the mountains. Even within a relatively limited area many different vegetation communities are found in these mountains: the eastern slopes are dominated by submontane and montane rain forest, mossy and subalpine elfin forests are dominating the ridge, while dry forests and woodlands are occupying the western slopes (Póc 1976, Lovett 1998).

The level of endemism within both flora and fauna is extremely high in the forest of the Uluguru Mountains. The mountains support a minimum of 135 strictly endemic plant species, and hundreds of species endemic to the Eastern Arc, among others 26 Eastern Arc endemic tree species (Burgess et al. 2002, Burgess et al. 2000, Burgess 2001, Burgess *in press*, Temu and Nsolomo 2000). The mountains also sustain at least strictly 16 endemic, 45 Eastern Arc endemic and 82 near-endemic vertebrate (Burgess et al. 2000, Burgess 2001, Burgess et al. 2002, Burgess *in press*, Doggart et al. 2001). Furthermore, the area sustains 169 known species of endemic invertebrate; a number that is strongly correlated with the collecting effort (Burgess et al 1998). The 16 endemic vertebrate species count 2 birds, 3 mammals, 5 reptiles and 6 amphibians, all of which are forest dependent species that are threatened of extinction by deforestation and illegal hunting (Burgess et al 2002,

Burgess et al. (2001), Kristiansen 1995, Svendsen et al 1995b). In addition to the endemic species, the Uluguru Mountains also supports other forest dependent red listed species counting 8 birds, 17 reptiles, 20 amphibians and an unknown number of invertebrate (Svendsen and Hansen 1995, Baker and Baker 2002, Svendsen et al. 1995). Therefore, if the loss of forest continues it will lead to great species extinction throughout all taxa (Burgess et al. 2002).

The birds are the vertebrate taxon that has received the greatest attention in the past, because of the mountains' global importance for bird conservation (Collar and Stuart 1988, Baker and Baker 2002, Svendsen et al. 1995). Furthermore, birds are currently the only source of ecotourism in the area, although only a few birdwatchers visit the forest each year.

2.1.4. Status

Since only a little forest cover is left outside the reserve boundaries, the Uluguru Mountains' forest is among the most critically threatened areas in Eastern Arc (Mbilyni and Kashaigili *in press*). The biggest threat towards the forest is a poor and rapidly growing population living around the forest, whose daily needs require more land to agriculture (partly due to bad agriculture techniques), firewood, building poles, bush meat and other resources (Hymes 2001, Bhatia and Buckley 1998, Svendsen and Hansen 1995). These basic needs force local people to extend their activities across the rarely patrolled boundaries to the forest reserves, which entail illegal hunting, deforestation and dry season fires (Svendsen and Hansen 1995). Even though there are attempts from local villagers to replant trees in farmland areas for fruit, building pole and fire wood production, these are presently not sufficient to fulfil the demands. Considering the fact that the population is expected to double within the next 20 years, the pressure on the forest will increase (Baker and Baker 2002).

The available information on the biodiversity, erosion protection and catchment ability emphasize the importance of this relatively small area of forest on the Uluguru Mountains. Therefore many donors are involved in conservation projects in this area. The most important ones are the UNDP/CARE project in the Uluguru South ($2.86 million) and the DOF/WCST project in Uluguru North ($1 million) (Mashauri and Sabuni *in press*). However, these projects only represent a part of, what is necessary, if these forests shall be saved.

2.2. Location of study sites

For this survey, four study sites within the Uluguru North Forest Reserve were selected in close collaboration with local WCST staff. The criteria for the selection were that the sites should represent different levels of disturbed forest habitats, altitude and climatic forest types. This was done to ensure the presence of one disturbed and one undisturbed reference site, and to test whether the methods applies to use in different microclimates. The four sites were located inside the reserve boundaries in the areas of Bigwa, Tegetero, Bunduki and Choma.

Bigwa is on the northern side of the mountain (see figure 2.1). The centre of the permanent plot bears the coordinates 06°49.9' S 037°43.3' E, and the altitude ranges between 750-900 m. The forest is heavily disturbed and experiences frequent fires during the dry season. For example, the permanent plot that we established in Bigwa burned down shortly after we left Tanzania presumably as a result of an illegal hunting fire, which went out of control.

Tegetero is on the eastern side of the mountain (see figure 2.1). The centre of the permanent plot bears the coordinates 06°56.6' S 037°42.5' E, and the altitude ranges between 1200-1500 m. The sampling site was positioned over an hours walk inside the forest, where the forest is relatively undisturbed, since it is rarely visited by local people. It represents the last bit of submontane forest left in the Uluguru Mountains. The position on the eastern slope makes it extremely important for water catchment, and it also possess a rich biodiversity.

Bunduki is on the southern side of the mountain (see figure 2.1). The centre of the permanent plot bears the coordinates 07°00.0' S 037°37.3' E, and the altitude ranges between 1600-1800 m. The forest is in some places heavily dominated of tree fern (*Cyarthea manniana*). It has experienced some degree of human disturbance from pit sawing, collection of firewood and building poles, and degraded plantation and farms do occur inside the reserve boundaries.

Choma is on the western side of the mountain close to Morningside. The centre of the permanent plot bears the coordinates 07°06.0' S 043°39.4' E, and the altitude ranges between 1200-1500 m. The forest is to some degree disturbed by humans mainly from collecting of firewood and building poles, but also due to some timber being illegally extracted for local uses.

All four sites are located in economically sensitive areas, where people to a certain degree are dependent on the forest in and around the reserve for their livelihood. This creates a conflict regarding use of resources. The exploitation of resources in Bigwa, Bunduki and Choma are not believed to be sustainable.

3. Methods

The samples for this survey have been conducted at four different sites (see section 2.2.). The data was collected in the Uluguru North, Tanzania between the 9th of May and the 12th of September 2005.

3.1. Permanent vegetation plots

Data for more comprehensive vegetation analysis was collected by establishing permanent plots of 60 m x 20 m (figure 3.1). Each permanent plot was divided into three subplots 20 m x 20 m. The plots were established so the 60 m was following a north-south direction and the 20 m was perpendicular in an east-western direction. We established one permanent plot at each of the four different sites within the Uluguru North Forest Catchment Reserve (for site descriptions see 2.2.).

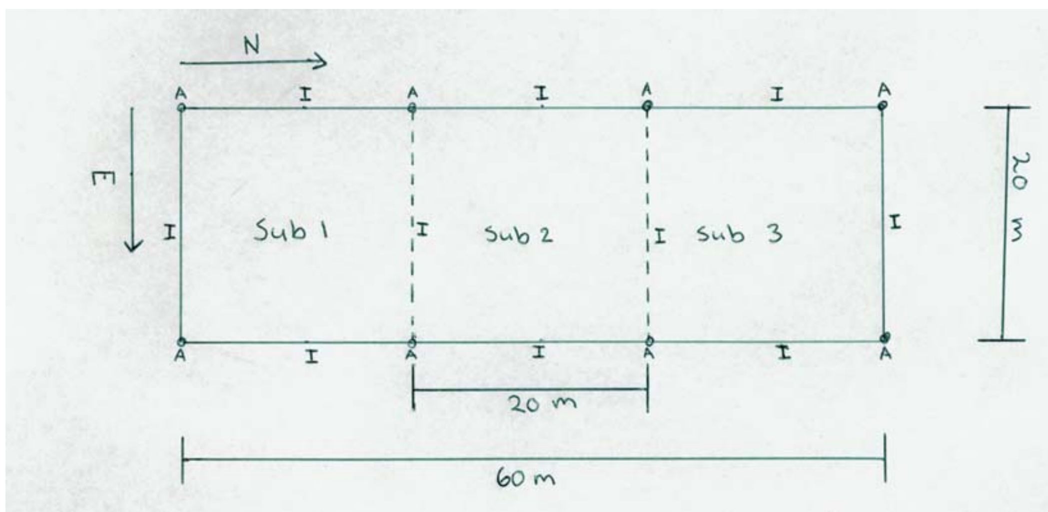

Figure 3.1. A schematic drawing of a permanent plot. The altitude was measured at each point marked A, and the inclination was measured for each distance marked I.

Within each of our permanent plots all wooden plants with a DBH (Diameter at Breast Height ≈ 1.3 m) above 5 cm was measured and numbered with white oil paint. The numbered plants were then identified to species, and local uses were described (see Appendix 2). The identifications were done in close collaboration with Professor C.K. Ruffo.

The altitude was measured on each corner of a subplot and the inclination was measured with a clinometer along each side of the subplots (figure 3.1). The inclination measurement was carried out with the help of an assistant positioned at the next corner of the subplot holding his arms out in 90 degrees angle. The clinometer was then levelled with the outstretched arms before reading the

slope. In cases where the view was blocked by for instants large trees, rocks or dense shrub, the measurement was made on the closest parallel line with a clear view. Canopy cover was measured 10 randomly distributed points within each plot using a concave mirror densiometer with 37 grid intersections forming 24 squares. The readings were done, by holding the densiometer in level at elbow-height away from the body. The percentage of overhead canopy cover was obtained by estimating the fraction of the 24 squares not reflecting light. Finally, the geographical position of each plot was noted using GPS, and markings were made from the main path to the plot.

In addition to our four permanent plots we have been allowed access to data from 36 permanent plot established by Frontier Tanzania in their biodiversity survey of the Uluguru Mountains during autumn 2004.

3.2. Simple cost-effective monitoring methods

We have developed and tested the efficiency of four simple and cost-effective approaches for monitoring disturbance and habitat loss within the boundaries of the Uluguru North Catchment Forest Reserve to use by local participants. These methods will be described in detail in this section.

3.2.1. 21-trees method

This method is focusing on the forest structure by recording the DBH (Diameter at Breast Height ≈ 1.3 m) of 20 neighbouring trees around a randomly selected centre-tree. This is a slightly modification of the method used by Lovett (1996) in a study of trees association with elevation and latitude in the Eastern Arc. A high basal area is an indicator of undisturbed forest (Jans et al. 1993, Wilder et al. 1998). After a centre-tree was selected and measured, the 20 nearest trees with a DBH above 5 cm were also measured. Finally, the distance to the tree furthest away was measured. The basal area (BA) of a tree was then calculated (equation 3.1):

$$\mathbf{BA} = \boldsymbol{\pi} \times \mathbf{r}^2 \quad (3.1)$$

The sum of the 21 trees BA (m^2) was then divided by the land area in ha for standardisation of all basal areas to unit m^2/ha.

The objectivity in choosing the centre-tree is very important, since there is a great variability within even a limited area. It is therefore necessary to have a randomly chosen centre-tree in order to get unbiased results, which truly describe the condition of a given area (Cottam and Curtis 1956). The centre-trees in our surveys were found by taking the direction to the furthest tree in the 21-trees

method from the centre-tree and continue walking in that direction for 30 meters from the furthest tree, after which the closest tree were pointed out to be the next centre-tree.

At each centre-tree terrain inclination was measured in four directions North, East, South and West with an inclinometer, in order to test whether there were a significantly negative correlation between tree diameter and steep slopes (de Castro et al. 1993). Furthermore, ground covers were estimated in four qualitative categories: dense, semi-dense, semi-bare and bare. The canopy covers were measured using a concave mirror densiometer (for further description see 3.1). The measurements were done half distance between the centre-tree and the tree furthest away in the Tree centered quarter method, which will be described in details below. Finally the number of species within the 21 trees was counted, and the number of trees hosting epiphytes and the presence of lianas was also noted, because earlier studies have shown a relation between disturbance and both epiphytes and large lianas (Budowski 1970).

3.2.2. Tree centered quarter method

This method is a modified combination of two plotless sampling distance based monitoring methods: the Quadrat method (Curtis and McIntosh 1950) and the Point centered quarter method, which has been used in the federal surveys of government land in the USA for more than 150 years (Cottam and Curtis 1956, Mueller-Dombois and Ellenberg 1974). These two methods are the simple distance surveillance with the lowest coefficients of variation and therefore the most reliable (Cottam and Curtis 1956).

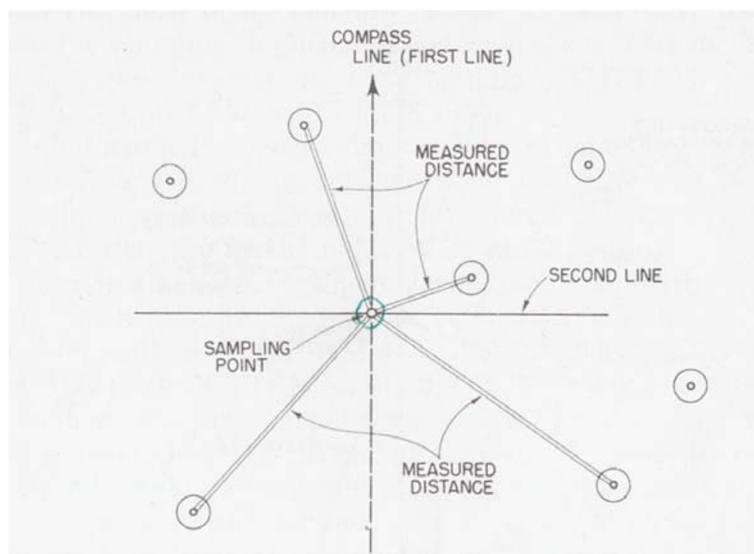

Figure 3.2 shows how data according to the centered tree quarter method is collected, four quarters are established using a compass, and then the distance to the nearest tree in each quarter is measured.

The starting point for the Tree centered quarter method was on the same randomly chosen centre-tree as used for the 21-trees method. For this method four quarters were established around the centre-tree using compass lines North, East, South and West (figure 3.2.). The distance between the nearest tree in each quarter and the centre-tree was then measured adding the radius of both trunks. The maximum reference area was then estimated by using the distance between the closest tree in each quarter and the centre-tree as radius (R_i) in a circle. The reference area was then calculated using equation 3.2:

$$\textbf{Reference area} = 0.25 \times (\pi \times R_1^2 + \pi \times R_2^2 + \pi \times R_3^2 + \pi \times R_4^2) \quad (3.2)$$

The tree density (DT) was then calculated using equation 3.3:

$$\textbf{Tree density} = \textbf{Number of trees / Reference area} \quad (3.3)$$

The number of trees using this method will always equal 5, the centre-tree and the closest tree in each quarter.

3.2.3. Disturbance index transect

We also developed an index, designed to describe the degree of disturbance caused by human activities for an area. The Disturbance index transects grades a location using the point score system shown in table 3.1.

Disturbance index	**Points**
No burning	3
No cut	3
< 9 old cuts	2
< 3 new cuts	1
presence of liana	3
3 trees with Circumference ≥ 200 cm	3
2 trees with Circumference ≥ 200 cm	2
1 tree with Circumference ≥ 200 cm	1
> 8 trees 130 ≤ Circumference < 200 cm	3
5-8 trees 130 ≤ Circumference < 200 cm	2
2-4 trees 130 ≤ Circumference < 200 cm	1
Total	**Max. 15**

Table 3.1 the more point the less disturbed. If the number of new cuts is 3 or more, no points can be granted for few old-cuts and if the number of very big trees (Circumference > 200 cm) exceeds 3 the excess number will be counted under big trees (130 ≤ Circumference < 200 cm).

This index focuses on the results of all major disturbances from human activities in the Uluguru Mountains (further description see 2.1.) into account: burning, cutting and the number of big trees as an estimate of previous logging and disturbance. Finally, the presence of large living lianas is also part of the grading, since earlier studies has shown a strong correlation between abundance of large lianas and low level of disturbance (Budowski 1970, Senbeta et al. 2005), partly because large lianas usually has old hosting trees and are often cut in the process of human disturbance (Kjeldsen 2003). The lianas do however need to be of a certain size, because there are often a greater number of medium size lianas in intermediate disturbed forests (Senbeta et al. 2005). Thus, lianas were noted, if it was not possible to touch the thump with the little finger, when grapping around it.

A lot of effort has been put into making this approach as simple and equipment sustainable as possible to ensure that the method will apply to local needs, and are able to function in the future without further major investments for equipment.

The Disturbance index transect covers an area of 60 × 20 meters, within this area all burns, cuts, big trees (130 cm ≤ circumference ≥ 200 cm) and very big trees (circumference ≥ 200 cm) were noted along with the presence of lianas. The starting point of the transect was randomly chosen. The transect was randomly laid out using a 20 meters long piece of rope as baseline, from the middle of which a 60 meters long rope was laid out perpendicular to the baseline forming the midline of the transect.

The person taking the notes was walking along the midline, on each side one person was responsible for keeping the distance of approximately 10 meters to the midline and determining, which burns, cuts, trees and lianas should be counted, and which was outside the transect. To estimate the circumference of trees within the transect, two differently coloured pieces of string were used respectively 130 cm (red) and 200 cm (blue) in length.

3.2.4. Bitterlich gauge method

This method was described by Bitterlich in 1948 and is designed to estimate the stem cover for a forest area. It has been used for many years in forest inventory work, particularly in North America (Mueller-Dombois and Ellenberg 1974).

The method uses an angle-gauge as shown Figure 3.3; it is 50 cm long and has a 1 cm wide cross piece at the end. The gauge is placed at one cheek under the eye with the cross piece horizontally

away from the face. Closing the other eye the observer then slowly turn 360 degrees around the randomly chosen centre-tree, while counting all trees with a diameter wider than the cross piece. Consequently, the distance to the counted trees varies with the diameter of each specific tree; for example trees with small DBH have to be close to being counted, while trees with a wide DBH will be counted from a distance further away depending on their proportions (equation 3.4):

$$\mathbf{D = 50 \times DBH} \quad \leftrightarrow \quad \mathbf{DBH = D/50} \quad (3.4)$$

, where D = distance between the observer and the tree.

The basal area can be calculated using equation 3.5 (Mueller-Dombois and Ellenberg 1974):

BA = mean count per point × reference area / area enlargement factor (3.5)

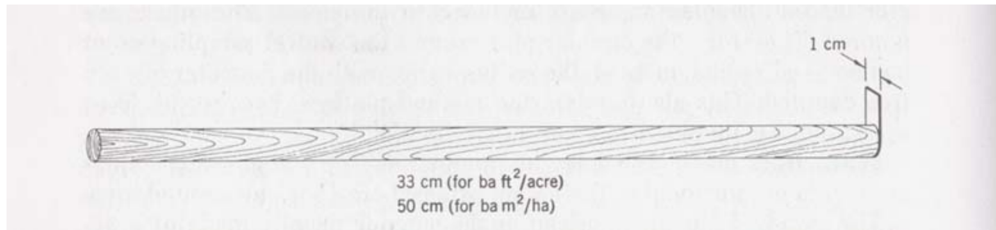

Figure 3.3 The 50 cm long Bitterlich gauge with a 1 cm wide aim at one end.

The selection of the 1:50 ratio is designed to enlarge the radius of an area. The radius is enlarged so it now describes a circle area with a diameter of 100 cm. Imagine a stem with a 1 cm diameter that is 50 cm away. The radius of the actual stem is 0.5 cm, and it has a basal area of 0.5^2 cm × π, while the enlarged area equals 50^2 cm × π. This means that the basal area is enlarged by 50^2 cm /0.5^2 cm = 100^2. Therefore, the basal area converted to the unit m^2/ha for a gauge with the 1:50 ratio follows equation 3.6:

$$\mathbf{BA = mean\ count\ per\ point \times 10.000\ m^2 / 100^2} \leftrightarrow$$
$$\mathbf{BA\ in\ m^2/ha = mean\ counted\ trees\ per\ point} \quad (3.6)$$

Hence, this method provides an estimate of the basal area, but not of the density of trees, therefore it only apply to an area where a stem cover value is sufficient.

3.3. Testing of local data collection

Prior to the beginning of our fieldwork, introduction meetings were held with the leadership, members of the village environmental committee and local WCST members at each of the four chosen villagers, to ensure local participation and involvement in the project.

In order to test the developed methods' durability in a locally based monitoring scheme and to promote local participation, we worked with four different field teams one for each of the locations. Each field team consisted of two members of the village environmental committee and two local WCST members, which all were living within the local community. All the field team members were chosen democratically by the participants at the introduction meeting.

The field teams were hired for two times five days in the field. The field teams helped establishing the permanent plots at each location. Furthermore, they received training in how to perform the four developed monitoring methods. Finally, they collected data using the four developed monitoring methods. At each location we also collected data using the methods, in order to test the creditability of the data collected by local people.

In the beginning of every field period we collected our own data using the four methods in designated areas. After collecting our data, the centre-trees were marked. The following day the local field teams were taken to the marked centre-trees. Here they were left on their own to perform the data collection for themselves using the same centre-trees, as we had used the day before.

For the field teams of Bunduki, Choma and Tegetero the field team were left unattended for their data collecting. The field team of Bigwa was monitored and supervised during their data collecting using the 21-trees method and the Tree centered quarter method by a local forest officer, who for this occasion had not participated in our data collection the previous day. The forest officer was for this assignment instructed not to perform the monitoring methods himself, but only attend the work and only answer general questions about the methods.

To test the effect of an increased amount of time of working and training with the methods in the field, the field team of Tegetero received an additional two days in the field compared to the other field teams.

3.4. Data analysis

All the ANOVA analysis used in the this chapter were performed using SAS 9.1, while the graphs, regression test as well as the calculation of mean value and standard deviation were done using Microsoft Excel .

3.4.1. Permanent plots

The vegetation data from our permanent plots as well as the plots established by Frontier Tanzania were used in testing both basal area (BA) and tree density (DT) in relation to inclination, altitude and the interaction between these two parameters using a one-way ANOVA analysis. Furthermore, the general species richness was tested in relation to both inclination and altitude by a simple analysis of regression.

The permanent plots in the Frontier Tanzania survey were 50 m x 20 m, and only trees with a DBH above 10 cm were measured. In order to standardize the data from the two surveys, the trees recorded in the last 10 meters of our subplot 3 were removed from the data and only trees with a DBH above 10 cm used for these tests.

We have also tested the effect of inclination and altitude on the basal area and tree density using a one-way ANOVA analysis, to see whether it is reasonable to assume that higher basal areas and tree density indicate a less disturbed forest, without taking the inclination and altitude into consideration.

The species abundances for each of our permanent plots were shown by constructing a species abundance curves. The relative abundance was accumulated, and shown in relation to the species ranked with the most common first.

The Shannon-Wiener diversity index H’ was calculated for each location in accordance to Begon et al. (1996) (equation 3.7):

$$H' = \sum p_i \times \ln p_i \quad (3.7)$$

, where p_i = the total basal area or number of trees of the ith species as a proportion of the total basal area or total number of tree for the plot

The Shannon-Wiener equitability index J was also calculated using equation 3.8:

$$J = H' / \ln s \quad (3.8)$$

, where s = the number of species

The effect of human disturbance on the abundance of endemic species was tested by a simple linear regression test. For this purpose and the Shannon-Weiner index, it was only the data from our own permanent plots that were used, since the Frontier Tanzania surveys were not found accurate enough regarding neither identification records nor disturbance description. Thus, all trees recorded in our permanent plots were included in these calculations. Additionally, both basal area and tree density were tested in relation to disturbance and abundance of endemic species, as well as the relation between abundance of species in general and endemics by using a one-way ANOVA analysis. Finally, the accumulated abundances of endemic species were calculated in relation to the total number of individuals for each location.

3.4.2. Simple cost-effective monitoring methods

For all of the data collected by using the four simple cost-effective monitoring methods, the mean value and the standard deviation ($P < 0.05$) was calculated to see, if there was statistical differences between the mean values for each site. Furthermore, the data has been tested in level of disturbance using a one-way ANOVA analysis. The data collected from the 21-trees method and the Tree centered quarter method was logarithmical transformed prior to this test, in order to minimize the effect of outlying values.

The data from the 21-trees method was also used to look at the DBH distribution for each of the four locations. For this purpose octavo intervals were created as described below.

The octavo distributions (d) were calculated following equation 3.9:

$$d = \log m + \frac{1}{2} \times \log 2 \quad (3.9)$$

, where m = previous midpoint

Then the octavo midpoints (OM) were calculated using equation 3.10:

$$OM = 10^{d} \quad (3.10)$$

The octavo intervals were then formed by using the geometric averages of the octavo midpoints (equation 3.11):

$$\textbf{Geometric average} = (A \times B)^{1/2} \quad (3.11)$$

, where A and B are octavo midpoints

The numbers of trees within each octavo intervals were logarithmically transformed, before the correlation were tested in relation to the octavo midpoints using a simple linear regression test, where both statistical significance and equations were determined.

In order to see if the locations differed in the distribution pattern for DBH, the slopes of the equations for each location were then tested in relation to each other by simple linear regression. Since the octavo midpoints (representing the X-values) were the same for all locations, the locations could be tested against each other simply by looking at the correlation between the differences in logarithmic number of trees plus 1 for each octavo interval. If a significant correlation was found between the differences, the slopes were regarded as significantly different. It was expected that the lesser disturbed areas would have more gentle slopes, because more big trees were expected to be found at these locations (Wilder et al. 1998).

Canopy cover and presence of epiphytes in the canopy was tested as indicators of forest disturbance using a one-way ANOVA analysis of variance.

The density of the ground cover was also tested in relation to disturbance. The ground area around each centre-tree had been estimated in proportion to four qualitative categories dense, semi-dense, semi-bare and bare. The distribution of the different categories of ground cover was tested in relation to the disturbance levels using a chi-square test for two independent groups of samples (Fowler et al. 1998). Denser ground vegetation in the more disturbed area was expected, due to the higher light exposure of the ground (Wilder et al. 1998).

3.4.3. Testing of local data collection

The data collected by local participants, and the data collected by us were compared by using the non-parametric Mann-Whitney U-test (Fowler et al. 1998), to test whether there were significant differences between the data. Then the data were compared to each other by using a Monte-Carlo randomizing test, to test if the results could be regarded as statistically identical.

The Monte-Carlo randomizing test was performed by taking the matched pairs of data (data collected by respectively locals and us at the exact same point), the differences were then summed. Subsequently, the same procedure was repeated 100 times with numbers randomly chosen from the interval defined by our results, which were compared to the data collected by local field assistants. The results of the summed differences between local collected data and randomly selected values were then compared with the summed differences of the matched pairs. If less than 5 % of the results from the summed differences between local collected data and randomly selected values were equal or smaller in comparison to the reference matched pairs value. Then the data collected by local field teams was considered statistically identical to the data collected by us.

4. Results

4.1. Permanent plots

4.1.1. Altitude and inclination

The influences of altitude and inclination on the basal area and tree density were tested on 40 permanent plots (50m × 20m) in the Uluguru North. The plots were ranging in altitude from 720 m to 1810 m, and were representing inclinations ranging from 0 to 50 degrees slopes.

The relationship was tested by using a one-way ANOVA analysis, where altitude, inclination and the interaction between both parameters were incorporated into the model. There was found no significant relation between either altitude or inclination and the basal area (P<0.6831) or the tree density (P<0.1440). Because of the relative low P-value, the tree density was also tested against the altitude and inclination alone, without taking the interacting into consideration. There was still not found any significant relation (P<0.9537). Finally, there was found no effects from altitude or inclination on species richness (table 4.1). On this background it was chosen to ignore altitude and inclination, when testing the simple cost-effective methods in relation to forest disturbance.

Model	F-value	P <	R^2
BA = Al In Al*In	0.50	0.6831	0.0401
DT = Al In Al*In	1.92	0.1440	0.1378
DT = Al In	0.05	0.9537	0.0026
Sp = Al In Al*In	0.62	0.6073	0.0491

Table 4.1 The results of the one-way ANOVA analysis that was used in testing the effect of difference in altitude (Al), inclination (In) and the interaction between these two parameters (Al*In) of respectively the basal area (BA), the tree density (DT) and species richness (Sp).

4.1.2. Basal area, tree density and species richness

The basal area and tree density were tested in relation to the species richness using a one-way ANOVA, to see how suitable these two variables are as indicators for species richness. There proved to be a strong relation between tree density and the species richness in a permanent plot (P<0.0001), hence the more trees that are present in a plot the higher number of species can be expected to be found (figure 4.1, table 4.2).

Model	F-value	P <	R^2
Sp = BA	3.18	0.0826	0.0772
Sp = DT	43.21	0.0001	0.5321

Table 4.2 The results of the one-way ANOVA analysis that was used in testing the basal area (BA) and the tree density (DT) respectively in relation to species richness (Sp).

Table 4.2 shows that there is no significant ($P < 0.0826$) relationship between the basal area and the species richness, and that the basal area is capable of explaining far less of the variance in species richness (figure 4.2), than the tree density which is capable of explaining 53.21 % of the total variation in species richness among woodened plants present in the permanent plots (figure 4.1).

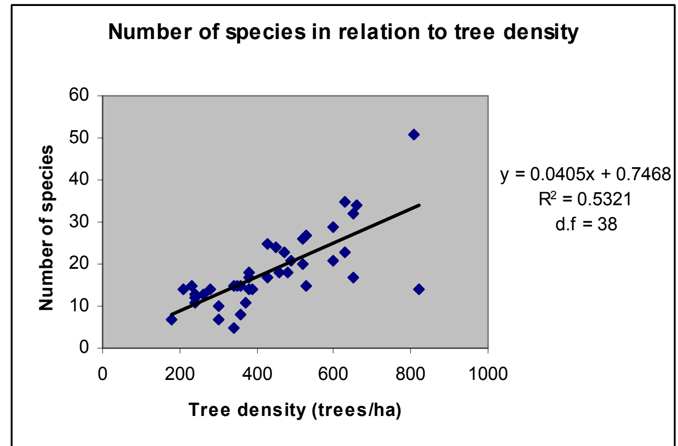

Figure 4.1 shows the correlation between tree density and the species richness

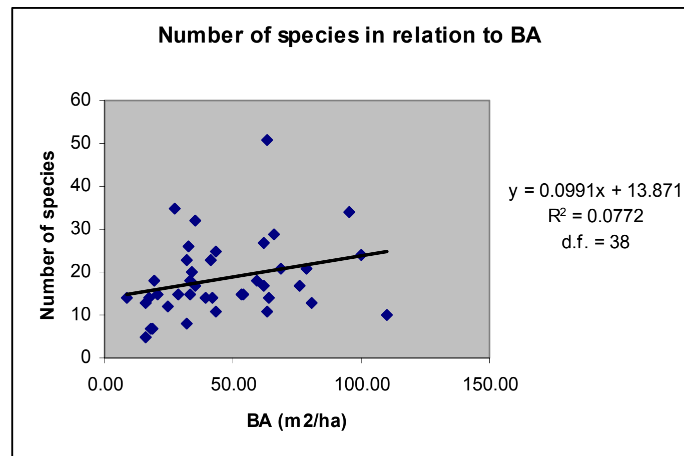

Figure 4.2 shows the correlation between the basal area (BA) and the species richness

A total of 77 tree species were recorded in our four permanent plots. Due to the climatic differences and the differences in disturbance levels, the plots had very few overlapping species (Appendix 1). The location with the highest species richness was Choma with 29 species, while Bigwa had the lowest with 13 species, Tegetero and Bunduki had 27 and 24 respectively. The accumulated abundance curves are shown in figure 4.3.

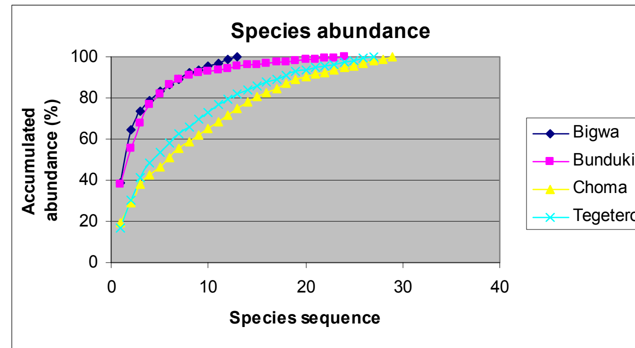

Figure 4.3 shows the species abundance curves for the four permanent plots. Relative abundance is accumulated, and the species are ranked with the most common first

However, species richness is not necessarily a good indicator for disturbance. Disturbed forest may have as many or more species as a mature forest, while the species composition varies much (Finegan 1996, Michelsen et al. 1996). This point is illustrated by the fact that the vegetation in Bigwa and Bunduki are dominated of a few species with very high abundances, while the dominance of single species is less pronounced in Choma and Tegetero. The two species with the highest abundances in Bigwa are *Brachystegia bussei* and *Margaritaria discoidea* that respectively account for 38.5 % and 26.2 % of the total number of individuals. Both of these species are characterized by a relative high fire tolerance, due to the frequent dry season fires often started by humans, typically as a result of clearance for farmland or illegal hunting.

In Bunduki 38.3 % of the total number of individuals are *Cyarthea manniana*, while *Scolopia zeyheri* constitute 17.0 %. In both Choma and Tegetero the vegetation are less dominated by single species. The two most abundant species in Choma are *Caloncoba welwitschii* and *Myrianthus holstii* that respectively constitute 19.5 % and 9.8 % of the total number of individuals, whereas *Uvariodendron anisatum* and *Myrianthus holstii* are the two species with the highest abundance in Tegetero with respectively 16.9 % and 13.4 %. The total species list for the four plots can be seen in Appendix 1.

Location	Bigwa	Bunduki	Choma	Tegetero
Species number	13	24	29	27
H' diversity	1.86	2.07	2.99	2.87
J equitability	0.73	0.65	0.89	0.87
Endemic % abundance	0.00	0.40	8.70	14.30

Table 4.3 shows the species richness, diversity, equitability and accumulated abundance of endemic species for the four permanent plots.

The measures of diversity and equability in the species composition for the four permanent plots were calculated in relation to the Shannon-Wiener index (table 4.3). Wilder et al (1998) found the

highest diversity (H') in the Kenyan Taita Hills forests to be 2.75, and they also found that high diversity correlate with low disturbance. In comparison our results show that Choma and Tegetero had very high diversity H': 2.99 and 2.87 respectively, while the diversity H' at Bunduki and Bigwa were low. The equitability (J) describes the evenness, with which individuals are distributed among species in the community. Hence, if few species are very dominating, the equitability (J) will be low (table 4.3).

4.1.3. Endemic species and disturbance

In testing the efficiency of basal area and tree density as indicators of abundance of endemic species and forest disturbance, we only used the data from our own collected permanent plots, because the neither species identification records nor disturbance descriptions from the Frontier Tanzania surveys were found accurate enough for these purposes. Therefore all woodened plants with a DBH above 5 cm were included.

Endemics
A total of 5 different endemic species were found in the four different plots. Three of these were found in Tegetero (*Allanblackia uluguruensis*, *Alsodeiopsis schumannii* and *Bertiera pauloi*), one species was found in Choma (*Vitex arminensis*) and the last was found in Bunduki (*Zenkerella egregia*). The most unique of the five endemic species was *Bertiera pauloi*, which had not been recorded since 1956 (Ruffo pers. Comm.).

Tegetero was clearly the location with the highest abundance of endemic individuals. 14.3 % of the total number of individuals in Tegetero was endemic to the Eastern Arc Mountains. Also in Choma the abundance of Eastern Arc endemics were relatively high (8.7 %), while only a single individual were found to be endemic in Bunduki and non in Bigwa (Table 4.3). The high abundance of endemic trees along with the high diversity and equability in Tegetero and Choma indicate that these two areas are of greater biodiversity conservation value than Bigwa and Bunduki. Tegetero is considered to be the most important, as this location had the highest number of endemic and rare species.

Disturbance
The efficiency of the basal area and tree density as indicators for disturbance has been tested using a one-way ANOVA analysis. There was found no significant relation between the tree density and the level of disturbance ($P<0.7833$). Although the correlation between the basal area and the level of disturbance was not found to be significant ($P<0.1521$), the low P-value with only 1 degree of freedom indicate that there may be some relation. Therefore, it would be necessary to collect more data before drawing a conclusion.

Model	F-value	P <	d.f.	R^2
BA = Disturbance	21.11	0.1521	1	0.9769
DT = Disturbance	0.31	0.7833	1	0.3864
Sp = Endemics	1.54	0.3410	2	0.4342
Endemics = BA	42.02	0.0230	2	0.9546
Endemics = DT	0.02	0.9101	2	0.0081

Table 4.4 The results of the one-way ANOVA analysis when testing the basal area (BA) and the tree density (DT), in relation to disturbance level, number of endemic species (Endemics), and relationship between species richness and number of endemic species.

By using a one-way ANOVA analysis, there was found no significant relation between the species richness and the number of endemic species (table 4.4). The relationship between the tree density and the number of endemic species also found not to be significant. However, the correlation between the basal area and the number of endemic species was found to be significant ($P<0.0230$) (figure 4.4). This indicates that basal area based methods are more suitable than tree density based methods, when permanent plots are being used for monitoring.

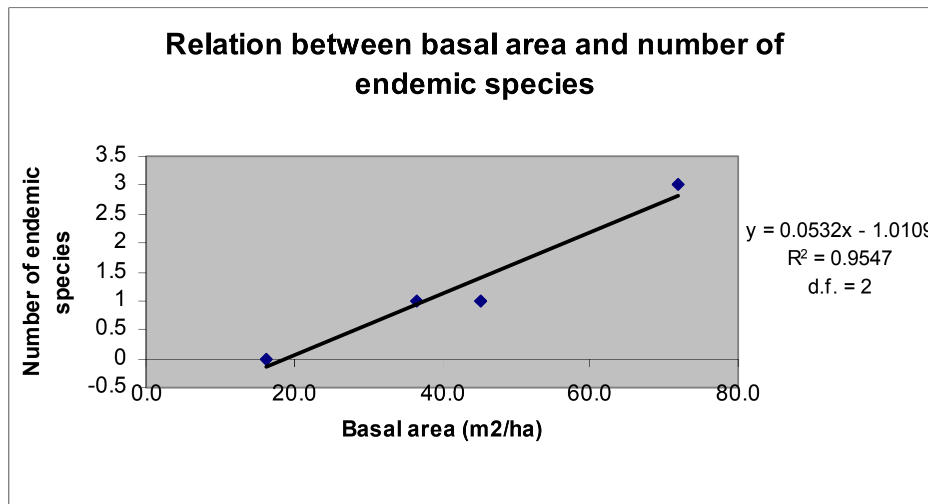

Figure 4.4 The relation between the basal area (m^2/ha) and the number of endemic species

4.1.4. Local uses of woodened plants

The local communities around the forest are to some extent relying on forest products in their daily life. Almost every plant is used for one or more different purposes, the local different uses of forest resources in relation to accessibility at the locations are shown in figure 4.5.

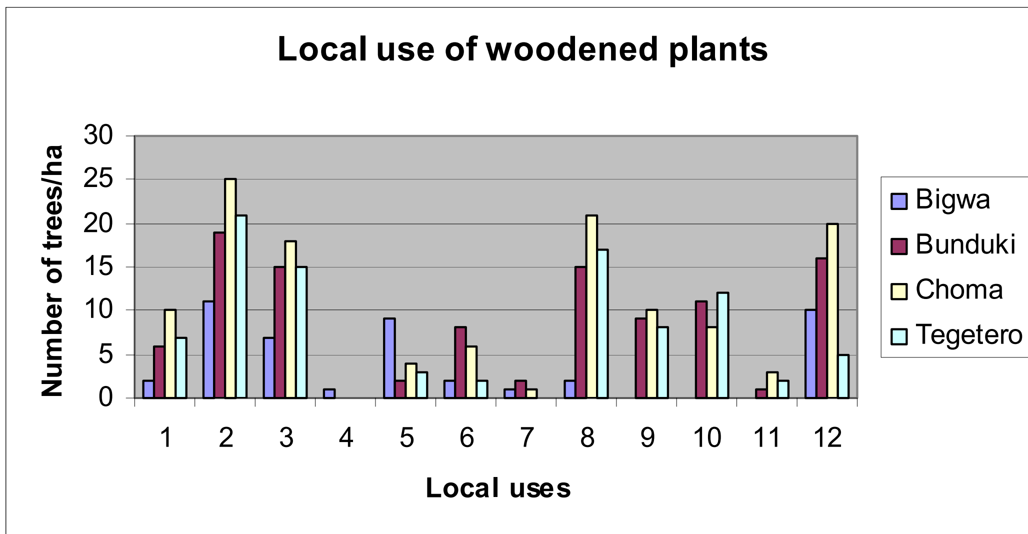

Figure 4.5 The different local uses of plant in the relation to the total number of individual trees ha^{-1} at each location. Keys for uses: 1 = Timber, 2 = Firewood and charcoal, 3 = Building poles, 4 = Fish poison, 5 = Medicine, 6 = Ornament, 7 = Live fence, 8 = Ropes, 9 = Edible fruits, 10 = Tool handles, 11 = Dye and 12 = Bee forage

Bigwa has generally the lowest amount of available resources, except regarding medicinal plants that are more abundant here. However, it is not possible to statistically distinguish between the other three locations regarding the different forest resources. In the light of these data it is not possible to reach a synonymous conclusion regarding the effect of disturbance on the accessibility of locally used forest resources. Although there is no doubt that these will decline dramatically, if the forest is cleared.

4.2. Simple cost-effective monitoring methods

4.2.1. 21-trees method

By using the 21-trees method, the mean basal areas were found to be lowest in the disturbed location and highest for the undisturbed location. The intermediate disturbed locations had mean basal areas between these two extremities. However, the standard deviation was also highest at the less disturbed locations (table 4.5).

Location	Disturbance	Samples	Individuals	Mean	SDTEV	Minimum	Maximum
Bigwa	D	22	462	17.43	4.55	12.87	21.98
Bunduki	ID	20	420	42.81	21.58	21.23	64.40
Choma	ID	19	399	41.05	28.34	12.71	69.39
Tegetero	UN	22	462	61.36	29.41	31.95	90.77

Table 4.5 The number of samples and the individuals counted at each location that make the basis for the mean basal area (m^2/ha) and the standard deviation (SDTEV) for each location. Furthermore the level of disturbance is indicated for each of the four location disturbed (D), intermediate disturbed (ID) and undisturbed (UN).

The only significant ($P < 0.05$) difference concerning the mean basal area values was found between the disturbed and the undisturbed locations (table 4.5). There are no significant differences between the other locations due to the high standard deviation, caused by the high variability among the results of the samples collected at each location (Fowler et al. 1998). To minimize the impact of a few outlying values, the data was logarithmically transformed. A one-way ANOVA analysis done on the logarithmically transformed data showed a very significant ($P<0.0001$) relation between the basal area and the disturbance. 48.84 % of the total variability of logarithmic basal area could be explained by the level of disturbance using a Pearson correlation coefficient.

DBH distribution

All four locations shows a very significant ($P<0.0001$) logarithmic correlation in the DBH distribution, using octavo calculated midpoints for DBH intervals (figure 4.7 and table 4.6).

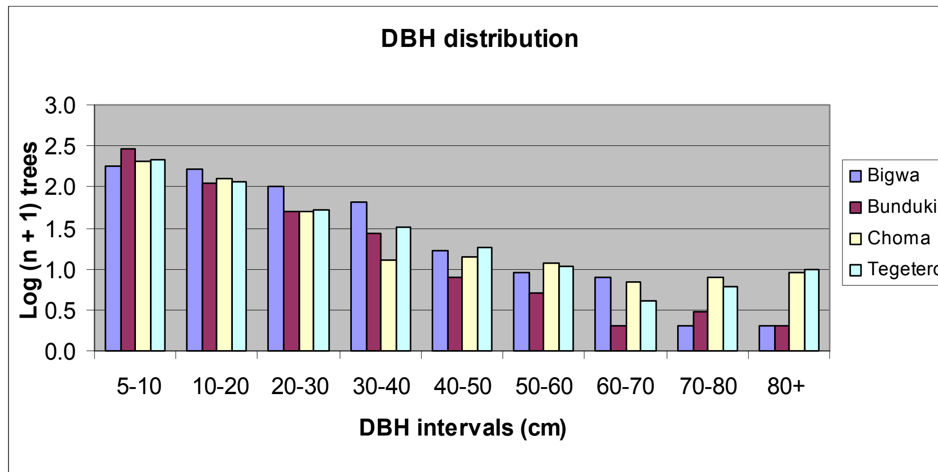

Figure 4.6 The logarithmic (n + 1) tree distribution in relation to DBH intervals

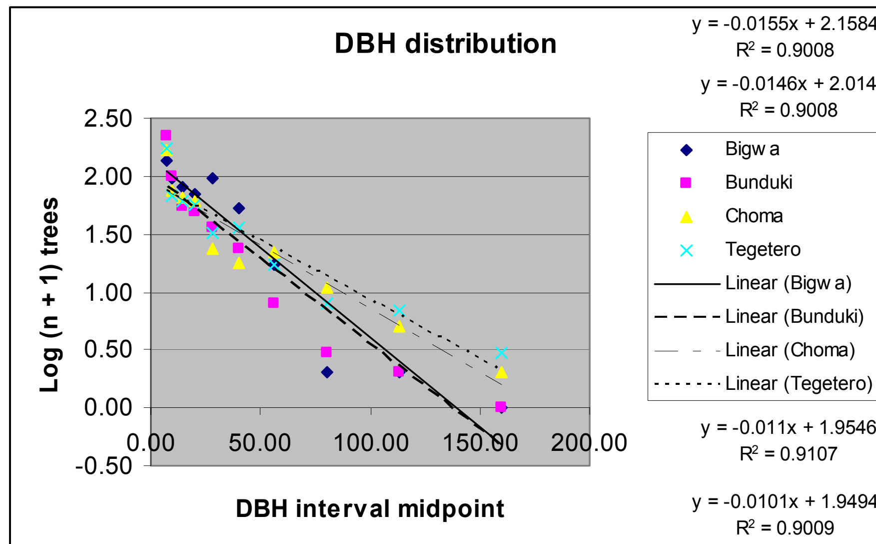

Figure 4.7 The correlation between the logarithmic number of trees + 1 and the octavo calculated midpoint of DBH intervals

Location	Equation	d.f.	P <	R^2
Bigwa	Log y = -0.0155x + 2.1584	8	0.01	0.9008
Bunduki	Log y = -0.0146x + 2.014	8	0.01	0.9008
Choma	Log y = -0.011x + 1.9546	8	0.01	0.9107
Tegetero	Log y = -0.0101x + 1.9494	8	0.01	0.9009

Table 4.6 The equations that describes the logarithmic DBH distribution and their coefficient of determination and significance level.

The steep slopes found for the DBH distribution for Bigwa and Bunduki is due to the presence of very few big trees, which indicate a higher level of disturbance (Wilder et al. 1998). Hence, gentle slopes indicate presence of many big trees and a low level of disturbance, this indicate that Tegetero and Choma are the least disturbed locations. The slopes of the four equations (figure 4.7) were tested in relation to each by simple regression. The slopes were significantly (P< 0.01) different between Bunduki and Tegetero, and there were also significant differences (P < 0.05) between Bigwa and respectively Choma and Tegetero. However, there were no significant differences between Bigwa and Bunduki, Bigwa and Choma or Choma and Tegetero (table 4.7).

Locations	**Big/Bun**	**Big/Cho**	**Big/Teg**	**Bun/Cho**	**Bun/Teg**	**Cho/Teg**
P	N.S.	N.S.	< 0.05	< 0.05	< 0.01	N.S.

Table 4.7 shows the results of the regression analysis of the distribution equation slopes for the locations Bigwa (Big), Bunduki (Bun), Choma (Cho) and Tegetero (Teg).

4.2.2. Tree centered quarter method

The mean tree density was found to be 589.48 trees/ha in Bigwa, 976.67 trees/ha in Choma, 3184.65 trees/ha in Bunduki and 1303.12 trees/ha Tegetero (table 4.8). The lowest score was, thus found for the most disturbed forest, while the highest score was found in the intermediate disturbed forest of Bunduki, as a result of an extreme abundance of tree ferns (*Cyarthea manniana*). The standard deviations however are extremely high especially for Bunduki, as a result of great variation in the data between the different samples.

Location	Disturbance	Samples	Individuals	Mean	SDTEV	Minimum	Maximum
Bigwa	D	22	110	589.48	291.99	297.49	881.48
Bunduki	ID	20	100	3184.65	3816.62	-631.98	7001.27
Choma	ID	19	95	976.67	570.31	406.36	1546.98
Tegetero	UN	22	110	1303.12	615.16	687.96	1918.28

Table 4.8 The number of samples and the number of individuals at each location that make the basis for the mean tree density (trees/ha) and the standard deviation (SDTEV) for each location. Furthermore the level of disturbance is indicated for each of the four location disturbed (D), intermediate disturbed (ID) and undisturbed (UN).

In order to minimize the extreme variation in tree density for the samples, the data was logarithmic transformed before tested in relation to disturbance with a one-way ANOVA analysis. After the logarithmic transformation, there was found to be a significant relation (P<0.0001) between the density of trees and the level of disturbance. The disturbance level could be used to explain 25.42 % of the total variation in tree density.

4.2.3. Disturbance index transect

The disturbance index is an index designed to describe the degree of disturbance caused by human activities in a forest area. This is done by grading the area with a score between 0 and 15 with 0 being extremely disturbed (for further description, see section 3.2.3). The Disturbance index transects can be used in describing the different levels of disturbance in the Uluguru North Forest Reserve (table 4.9).

Location	**Disturbance**	**Samples**	**Mean**	**SDTEV**	**Minimum**	**Maximum**
Bigwa	D	11	3.25	1.71	1.54	4.96
Bunduki	ID	11	7.91	1.30	6.61	9.21
Choma	ID	11	10.45	0.82	9.63	11.27
Tegetero	UN	12	12.42	0.79	11.62	13.21

Table 4.9 shows the number of samples at each location that make the basis for the mean Disturbance index transect score and the standard deviation (SDTEV) for each location. Furthermore the level of disturbance is indicated for each of the four location disturbed (D), intermediate disturbed (ID) and undisturbed (UN).

Figure 4.9 shows that the standard deviation is not high enough to create any overlaps between the means value, thus there are significant differences ($P < 0.05$) between the mean values for all the four locations (Figure 4.8). This indicates that the disturbance level of Choma is in between those of Bunduki and Tegetero, which is in accordance with the results described in section 4.1.2 and 4.1.3.

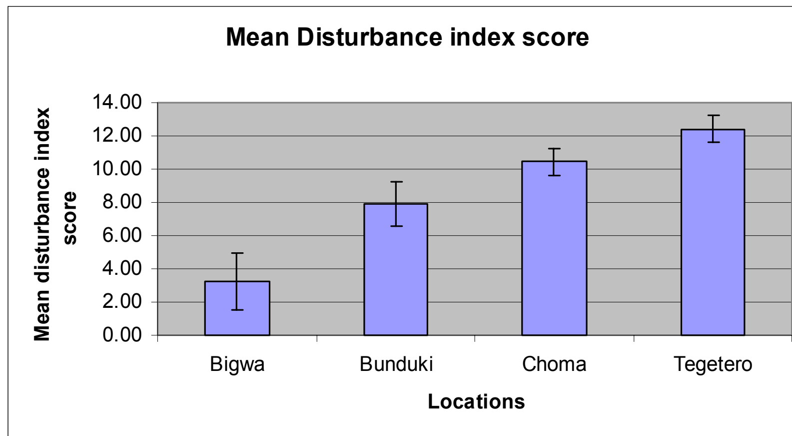

Figure 4.8 shows the mean Disturbance index transect scores and the standard deviation for these value respectively for the four location.

When using a one-way ANOVA analysis, there was also found to be a strong significant relation ($P<0.0001$) between the Disturbance index transect score and the level of disturbance.

4.2.4. Bitterlich gauge method

The mean Bitterlich score was found to be 13.44 in Bigwa, 21.25 in Bunduki, 19.18 in Choma and 29.34 in Tegetero. Hence the disturbed location, Bigwa, had the lowest score, and the undisturbed location had the highest score (table 4.10).

Location	Disturbance	Samples	Individuals	Mean	SDTEV	Minimum	Maximum
Bigwa	D	54	726	13.44	2.69	10.76	16.13
Bunduki	ID	36	765	21.25	4.26	16.99	25.51
Choma	ID	40	767	19.18	2.11	17.06	21.29
Tegetero	UN	41	1203	29.34	3.42	25.92	32.77

Table 4.10 The number of samples and the number of individuals at each location that make the basis for the mean Bitterlich score (m^2/ha) and the standard deviation (SDTEV) for each location. Furthermore the level of disturbance is indicated for each of the four location disturbed (D), intermediate disturbed (ID) and undisturbed (UN).

The standard deviations for the Bitterlich score are relatively small. Thus, the mean values found at Tegetero and Bigwa were both significantly ($P < 0.05$) different from the mean values for all of the other locations. However, there was no significant difference between the mean values of the two intermediate disturbed locations Bunduki and Choma (Figure 4.9). This indicates that the Bitterlich method can be used monitoring of changes in disturbance.

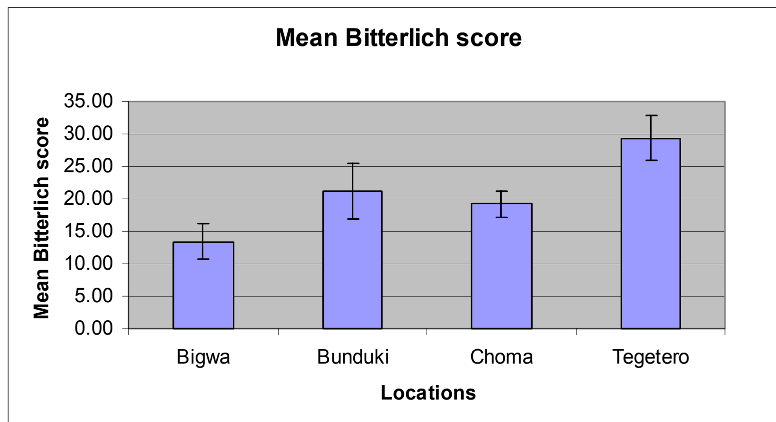

Figure 4.9 shows the mean Bitterlich score (m^2/ha) and the standard deviation for these value respectively for the four location. Note that there is significant difference between the three different disturbance levels; hence Bunduki and Choma are both intermediate disturbed locations.

When testing with a one-way ANOVA analysis, there was found to be a significant relation ($P < 0.0001$) between the observed Bitterlich scores and the level of disturbance. The Bitterlich scores were generally higher in the less disturbed areas. The correlation between these two parameters was capable of explaining for 77.17 % of the total variability.

Model	F-value	P <	d.f.	R^2
Log BA = Disturbance	37.24	0.0001	81	0.4884
Log Density = Disturbance	13.30	0.0001	81	0.2542
Bitterlich Score = Disturbance	283.94	0.0001	169	0.7717
DIT Score = Disturbance	120.76	0.0001	43	0.8520

Table 4.11 summarizes the results of all the models tested against disturbance using a one-way ANOVA. Logarithmic basal area, logarithmic tree density, Bitterlich score and Disturbance index transect score (DIT Score) in relation to disturbance and sites respectively.

The Bitterlich gauge and the Disturbance index transect (table 4.11) are the best methods in detecting differences in the disturbance. Therefore, these two methods are the most suitable to use in a locally based monitoring scheme. It should however be noted that the results from the 21-trees method and the Tree centered quarter method might have been more accurate, if more samples had been taken. Unfortunately, we did not have the time or resources to do so.

4.2.5. Some qualitative parameters

During collection of the data for this survey, some qualitative parameters were also noted, to see if these would be useful in other simple monitoring schemes.

Canopy cover

There were no significant differences in the canopy cover between the undisturbed and the medium disturbed samples. However, the canopy covers from the disturbed areas significantly ($P < 0.0001$) differed from the canopy covers taken at the other locations, when tested with a one-way ANOVA analysis.

Presence of epiphytes

Presence of epiphytes indicates old forest growth. Although old secondary forest can also support a large epiphyte growth, the diversity is considerably lower than in primary forest (Budowski 1970). In this study the epiphytes was not identified to species, but by using a one-way ANOVA analysis the presence of epiphytes was found to significantly ($P < 0.0001$) correlate with the level of disturbance. Furthermore, the presence of epiphytes can be used to explain 38.9 % of the total variability in disturbance.

Ground cover

The ground cover denseness was tested in relation to disturbance by using a chi-square test for two independent groups of samples (Fowler et al. 1998). The ground cover was found to be significantly denser at the disturbed location in comparison with the intermediate disturbed locations ($P < 0.01$) and the undisturbed location ($P < 0.01$). However, there was found no significant difference

between the denseness of ground cover in the intermediate disturbed locations and the undisturbed location (figure 4.10).

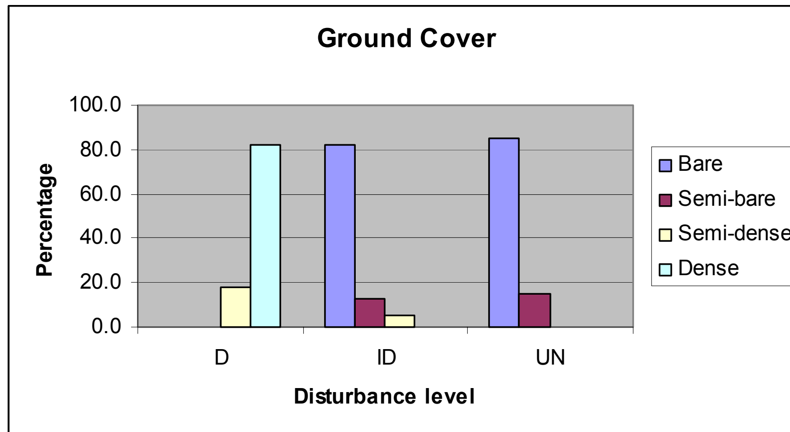

Figure 4.10 shows the percentage distribution of different ground covers in relation to different level of disturbance disturbed (D), intermediate disturbed (ID) and undisturbed (UN).

Figure 4.10 indicates that it is not suitable to use estimates of the ground cover denseness as indicator for disturbance in a monitoring scheme, since the differences are not visible unless the forest is heavily disturbed.

4.3. Testing of local data collection

The data collected by the four field teams were tested in relation to data collected by us, to ensure that the local participants can use the developed methods to collect reliable monitoring data.

4.3.1. 21-trees method

When the data collected using the 21-trees methods was tested by a Mann-Whitney U-test, there was found no significant differences between the data collected by neither the Bigwa nor the Tegetero field team in comparison to data collected by us. However, the data collected by the field teams of both Choma and Bunduki were tested significantly different from ours using a Mann-Whitney U-test.

The data collected by the four field teams were also compared to our data by using a Monte Carlo randomization test. This was done to test, whether the data collected by locals could be considered statistically identical to ours. The data collected by the field teams of Choma and Bunduki were both found not to be statistically identical to our data. Whereas the data collected by the Tegetero ($P < 0.05$) field team and the Bigwa ($P < 0.01$) field team both were found to be statistical identical in comparison to the data collected by us.

When comparing the mean values of the data, there was only found to be significantly difference between data collected by the Choma field team and our data (figure 4.11). When the data was logarithmically transformed, there was found to be no significant differences between any of the data collected by local field teams and ours, when using mean values. However, the standard deviation is extremely big in both cases. When the data collected by the field teams were compared with each other, there is found no significant difference between any of the mean values.

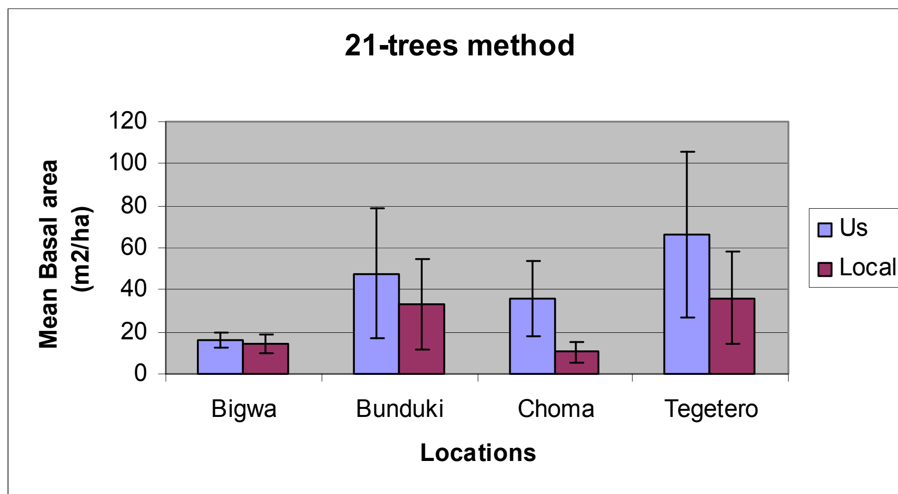

Figure 4.11 The mean basal area (m^2/ha) for the 21-trees method with standard deviation for both our data and the data collected by local field teams on the same test grounds.

4.3.2. Tree centered quarter method

When testing the Tree centered quarter method data with a Mann-Whitney U-test, only the data collected by the Tegetero field team found to be significantly ($P < 0.05$) different from our data. However, the Tegetero field team experienced a misunderstanding on how to use the compass, which might explain, why their data differs from ours.

Concerning the mean values, the data collected by the Tegetero field team was also the only data that significantly differed ($P < 0.05$) from ours. The mean values of the data collected by the other field teams were not found to be statistically different in comparison with our data. However, this is probably due to high standard deviation values (Figure 4.12). When the data are logarithmically transformed none of the mean values are significantly different, but the standard deviation is extremely high for these data (table 4.15). If the data collected by the field teams using the Tree centered quarter method are compared with each other, there is found no significant difference between any of the mean values.

A Monte Carlo randomization test showed that only the data collected by the Bigwa field team could be considered statistically identical ($P < 0.01$) to our data (table 4.13).

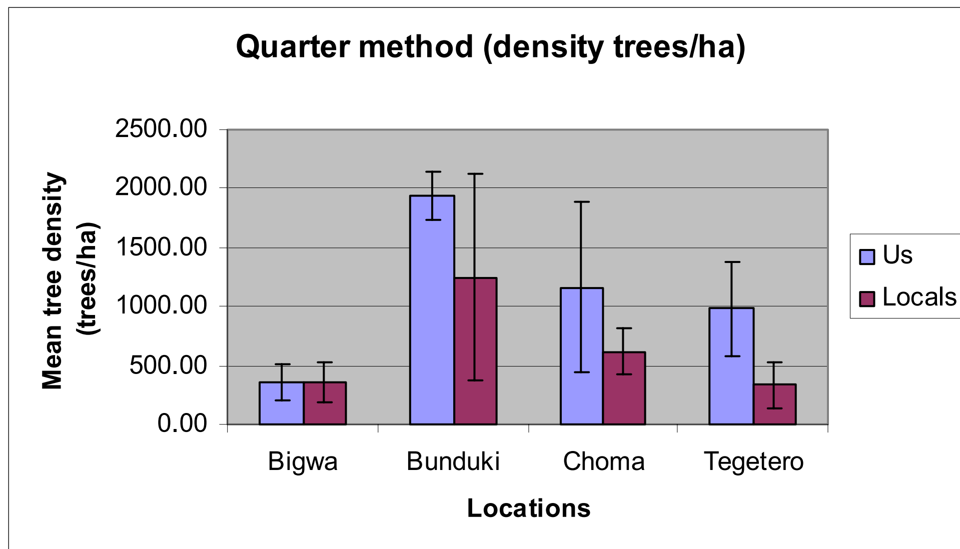

Figure 4.12 shows the mean density of trees (trees/ha) for the Tree centered quarter method with standard deviation for both our data and the data collected by local field teams on the same test grounds.

4.3.3. Disturbance index transect

Using the Disturbance index transect only the field team from Bunduki collected significantly different ($P < 0.05$, Mann-Whitney U-test) data in comparison to ours. When calculating the mean values Bunduki was also the only field team, which had a mean value that was significantly ($P < 0.05$) different from ours (figure 4.13).

Tegetero was the only field team that by using the Disturbance index transect collected statistically ($P < 0.02$) identical data in comparison to our data (table 4.13), when tested by a Monte Carlo randomization test. But the mean values of the locally collected data from Bigwa, Choma and Tegetero were distributed in accordance with the disturbance level, although the standard deviation creates a small overlap between Choma and Tegetero (figure 4.13 and table 4.14).

This indicates that the disturbance index transect are suitable for locally based monitoring, and if the field teams receive further training, this method can provide valuable information of forest disturbance for the management personnel.

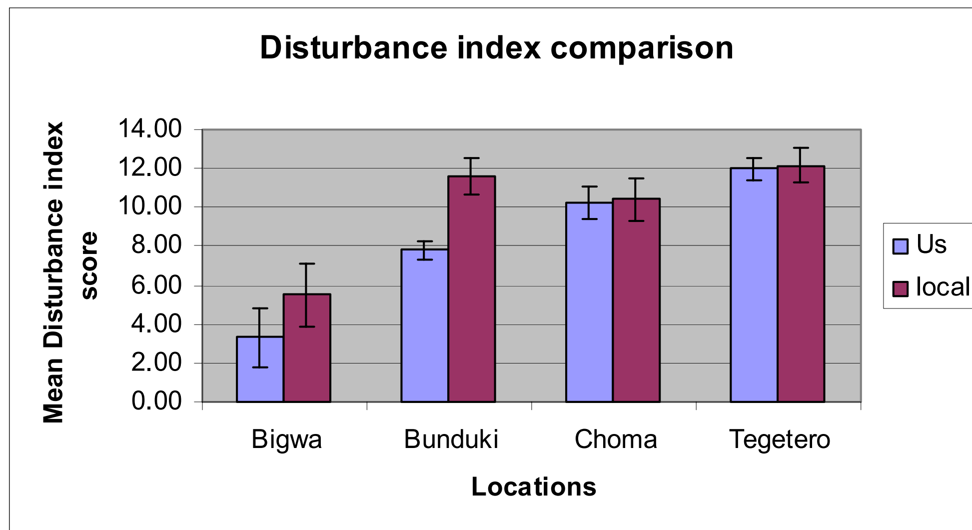

Figure 4.13 The mean score for the Disturbance index transects with standard deviation for both our data and the data collected by local participants on the same test grounds.

The results of the Mann-Whitney U-test, the Monte Carlo randomization test and the comparison between the mean values for the 21-trees method, the Tree centered quarter method and the Disturbance index transects are summarized in table 4.12, table 4.13, table 4.14 and table 4.15.

Methods	Bigwa	Bunduki	Choma	Tegetero
21-trees	N.S.	**P < 0.05**	**P < 0.05**	N.S.
Quarter	N.S.	N.S.	N.S.	**P < 0.05**
Disturbance index	N.S.	**P < 0.05**	N.S.	N.S.

Table 4.12 Summary of the results of the Mann-Whitney U-test, which test locally collected data in comparison to data collected by us

Methods	Bigwa	Bunduki	Choma	Tegetero
21-trees	**P < 0.01**	P < 0.71	P < 0.52	**P < 0.05**
Quarter	**P < 0.01**	P < 0.11	P < 0.51	P < 1.00
Disturbance index	P < 0.22	P < 0.43	P < 0.08	**P < 0.02**

Table 4.13 Summary of the results of the Monte Carlo test, which test whether locally collected data can be considered statistically identical to our data.

Considering the results from tables 4.12 and 4.13, it is important to note that the Tegetero field team had received one additional day of training in comparison with the other field teams, and that the Bigwa field team received supervision from a local forest officer during their data collecting using the 21-trees method and the Tree centered quarter method.

	21-trees			**Tree centered Quarter**			**Disturbance index transect**		
Location	**Local**	**Us**	**P <**	**Local**	**Us**	**P <**	**Local**	**Us**	**P <**
Bigwa	14.6 ± 4.5	16.1 ± 3.9	N.S.	356 ± 171	356 ± 156	N.S.	5.5 ± 1.6	3.3 ± 1.5	N.S.
Bunduki	33.5 ± 21.5	47.7 ± 30.8	N.S.	1249 ± 870	1940 ± 203	N.S.	11.6 ± 0.9	7.8 ± 0.5	0.05
Choma	10.4 ± 5.0	36.00 ± 18.0	0.05	620 ± 200	1165 ± 718	N.S.	10.4 ± 1.1	10.2 ± 0.8	N.S.
Tegetero	36.1 ± 21.8	66.0 ± 39.5	N.S.	334 ± 195	980 ± 400	0.05	12.1 ± 0.9	12.0 ± 0.6	N.S.

Table 4.14 A comparison for the mean values and standard deviation between data collected by us and by the local field assistants. P < is indicating whether there is a significant difference between the two mean values.

	Log 21-trees			**Log Tree centered Quarter**		
Location	Local	Us	P	Local	Us	P
Bigwa	1.16 ± 0.65	1.21 ± 0.59	N.S.	2.55 ± 2.23	2.55 ± 2.19	N.S.
Bunduki	1.52 ± 1.33	1.68 ± 1.49	N.S.	3.10 ± 2.94	3.29 ± 2.31	N.S.
Choma	1.02 ± 0.70	1.56 ± 1.25	N.S.	2.79 ± 2.30	3.07 ± 2.86	N.S.
Tegetero	1.56 ± 1.34	1.82 ± 1.60	N.S.	2.52 ± 2.29	2.99 ± 2.60	N.S.

Table 4.15 A comparison for the logarithmic transformed mean values and standard deviation between data collected by us and by the local field assistants. P < is indicating whether there is a significant difference between the two mean values.

4.3.4. Bitterlich gauge method

A Mann-Whitney U-test found no significant differences between the Bitterlich score collected by us and the local participants from Tegetero and Bunduki. However, half of the local participants from Bigwa and all of the local participants from Choma got significantly different ($P < 0.05$) results in comparison with our data, when using the Bitterlich method (table 4.16).

Of the 15 local participants only one managed to get Bitterlich score results, which could be considered statistical identical ($P < 0.05$) to our data, when tested by a Monte Carlo randomization test (table 4.16).

However, table 4.16 shows that the field team from Tegetero, which had received the most training, also was the field team that in general got the best results. These results signify that local participants are able to improve their performance in the use of the Bitterlich method, if they receive an accurate amount of training in collecting data.

Person	Monte Carlo	Mann-Whitney
Teg 1	P < 0.26	N.S.
Teg 2	P < 0.17	N.S.
Teg 3	P < 0.15	N.S.
Bun 1	P < 0.18	N.S.
Bun 2	**P < 0.05**	N.S.
Bun 3	P < 0.51	N.S.
Bun 4	P < 0.61	N.S.
Cho 1	P < 0.68	P < 0.05
Cho 2	P < 0.69	P < 0.05
Cho 3	P < 0.69	P < 0.05
Cho 4	P < 0.68	P < 0.05
Big 1	P < 0.66	P < 0.05
Big 2	P < 0.83	P < 0.05
Big 3	P < 0.76	P < 0.05
Big 4	P < 0.96	P < 0.05

Table 4.16 The results of the statistical test between our Bitterlich results and the results of the local participants, The Monte Carlo test if the results are significantly identical, while the non-parametric Mann-whiney U-test test whether the results can be considered significantly difference. .

The mean values of the observation done by the local participants show that the data collected by every one on the Choma field team and two from Bigwa significantly differ ($P < 0.05$) from our matching results, while there is no difference between mean values of data collected by the other assistants and us (Figure 4.14).

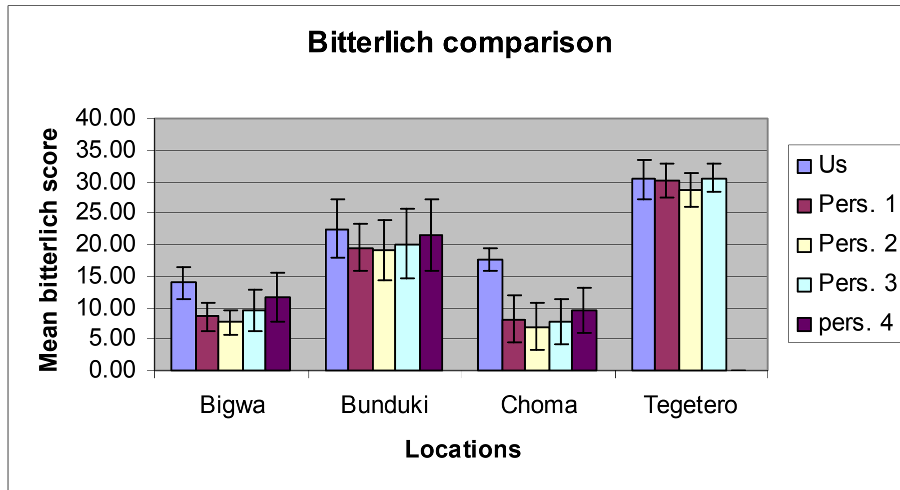

Figure 4.14 shows the mean Bitterlich score with standard deviation for every field assistant compared to the mean score with standard deviation for our observation on the same test grounds.

If the data from the field assistants that had a significantly different result in from ours are removed from the survey. Then the two participants from the disturbed areas had the significantly lowest mean values, and the participants from the undisturbed location generally had the significantly highest mean values, with the exception of person 2 from Tegetero, whose mean value slightly overlapped with person 4 from Bunduki (table 4.17).

	Bigwa			Bunduki		
Person	**Local**	**Us**	**P**	**Local**	**Us**	**P**
Pers. 1	8.6 ± 2.3	13.9 ± 2.5	0.05	19.4 ± 3.7	22.5 ± 4.6	N.S.
Pers. 2	7.7± 1.8	13.9 ± 2.5	0.05	19.1 ± 4.8	22.5 ± 4.6	N.S.
Pers. 3	9.5 ± 3.2	13.9 ± 2.5	N.S.	20.1 ± 5.5	22.5 ± 4.6	N.S.
Pers. 4	11.7± 3.9	13.9 ± 2.5	N.S.	21.6 ± 5.7	22.5 ± 4.6	N.S.

	Choma			Tegetero		
Person	**Local**	**Us**	**P**	**Local**	**Us**	**P**
Pers. 1	8.1 ± 3.8	17.6 ± 1.8	0.05	30.1 ± 2.6	30.3 ± 3.1	N.S.
Pers. 2	7 ± 3.7	17.6 ± 1.8	0.05	28.6 ± 2.7	30.3 ± 3.1	N.S.
Pers. 3	7.8 ± 3.6	17.6 ± 1.8	0.05	30.5 ± 2.2	30.3 ± 3.1	N.S.
Pers. 4	9.5 ± 3.7	17.6 ± 1.8	0.05			

Table 4.17 A comparison for the mean values and standard deviation between Bitterlich data collected by us and by the local field assistants. P < is indicating whether there is a significant difference between the two mean values.

The results shown in table 4.17 indicate that the Bitterlich method is suitable for locally based monitoring. Even with an extremely limited amount of training those local participants who understood the method were able to collect meaningful data. This indicates that if the local

participants receive further training in use of this method, then with time they will be able to provide useful information for the future management of forest reserve.

5. Discussion

5.1 Monitoring

It is widely recognized that there is a global need for extended monitoring and development in developing countries in the tropics, if the world's biodiversity is to be preserved for future generations (Balmford et al. 2005, CBD 1992, UN 2002, Birdlife 2005, Workshop 1997, Howard et al. 1998, Margules and Pressey 2000). Monitoring is essential for providing information on many levels: where conservation efforts should be concentrated, detecting changes over time and space, enabling management to evaluate their conservation efforts and influence decision makers to take action (Howard et al. 1998, Yoccoz et al. 2001, Danielsen et al. 2005). Most of the world's countries are as parties to the Convention of Biodiversity obligated to monitor biodiversity according to article 7 in the convention (CBD 1992). Most of the developed countries have fulfilled this obligation, but the majority of the developing countries still have major problems in establishing monitoring programs, as the funds are extremely limited (Uychiaoco et al. 2005). There is an ongoing discussion on what, how, and who is going to do the monitoring.

5.1.1. Perspectives on what to monitor

Many have argued that strong emphasis should be put on the occurrence of endemic species. They argues that endemic species are the most important targets for management planning, since they depend entirely on a single area for survival, (Mittermeier et al. 1998, Johansson et al. 1998, Dinesen 1998, Myers et al. 2000, Brooks et al. 2001, Olson et al. 1998). However, the monitoring of populations of endemic species is often very expensive and can be difficult to apply for locally based monitoring schemes. Studies from Cameroon have showed that species richness generally decline with increasing disturbance (Lawton et al. 1998). In some places species richness may however increase at a local scale as a result of disturbance due to an increase in disturbance tolerant species, while the forests-dependent, endemic and threatened species often decline (Connell 1978, Huston 1979, Bernard 2002). This survey found no relation between species richness and abundance of endemic species (table 4.4). This indicates that species richness might not be the best indicator of forest disturbance and threats towards endemic species.

The results in this project showed that the less disturbed locations had the highest abundance of endemic tree species (table 4.3). Therefore, this locally based monitoring survey focuses on disturbance and forest structure. The forest structure and disturbance may generally be good indicators for many taxa, as high vertebrate diversity and endemism in general follows the global trends of plant diversity (Mittermeier et al. 1998). A study from Laos concluded, that locally

collected fauna monitoring data can reveal trends, only if the data is collected repeatedly under the same condition. This is due to the fact that fauna activities largely depend on daily, seasonal and weather variations (Poulsen and Luanglath 2005). Therefore trees may be the best functional group for locally based monitoring, since their appearance does not dependent as much on time, weather or seasonal changes. Furthermore, the linkage between plants and fauna in forest ecosystems means that disturbance and clearance of the plant community often will affect the faunal biodiversity, especially endemic and forest depending species.

Originally it was the intention to develop a list of animal indicator species to include fauna observations in this survey. However, it proved to be an impossible task given the available time and resources. Therefore it was decided only to focus on vegetation, which we found much easier to handle also for the local participants. In earlier studies molluscs have been suggested as indicator species for forest disturbance in the Eastern Arc Mountains. They have several advantages in comparison with other fauna: they are simple and rapid to sample, they can be surveyed year round, they are relatively robust and easy to store, and they are very sensible to forest disturbance, because of the increase in solar radiation following forest clearance (Tattersfield et al. 1998). Also savannah and woodland grasshoppers have been suggested, as they capable of immigrate quickly to the mountains following deforestation, and therefore they can be good indicators for forest disturbance (Hochkirch 1998). However, both of these faunal groups are indirect indicators of changes in the forest structure, hence it might be easier and more reliable to monitor the forest structure directly.

In a monitoring scheme, it can be useful to focus on animals that are hunted by locals. This will benefit the conservation work, because it will be obvious for the local people what to gain from the program. Additionally, there will be a large local knowledge of the abundance, which can provide useful information in the detecting of changes in a relatively easy and cost-effective manner. However, since the majority of the large forest dependent species already has been pushed close to extinction in many places e.g. the Uluguru Mountains (Kristiansen 1995), the use of this approach can be problematic. Furthermore, monitoring schemes based on interview of local people may vary in quality, as villagers sometimes have reasons for not telling the truth out of fear of further restrictions (Poulsen and Luanglath 2005, Van Rijsoort and Jinfeng 2005, Townsend et al. 2005).

5.1.2. Focus on how to monitor

Systematic biological field surveys are the best monitoring solution from a biological point of view. However, it is very expensive and time consuming (Margules and Pressey 2000, Jayasuriya et al. 1997, Van Rijsoort and Jinfeng 2005, Hockley et al. 2005). Designs for monitoring in developed countries are often not practicable in developing countries, where the conditions are quite different. Most monitoring programmes in developing countries are too large and too expensive in be sustained by locally available resources. For example, Danielsen et al. (2005) found that the median

cost of a locally-based monitoring scheme was about 0.08 $/ha/year, while the median cost for a conventional monitoring scheme was roughly 20.5 times greater (1.7 $/ha/year). The expenses cause many programmes to collapse when donor funds stops (Danielsen et al. 2003).

Another problem is the fact that taxonomical identification relies on educated national or international taxonomists. In most developing countries such national experts are very limited (Jayasuriya et al. 1997, Johansson et al 1998). This means that systematic biological surveys in developing countries often rely on international experts, and that solution is often not very cost-effective. Furthermore, professional monitoring methods often focus on long-term trends in species composition, for instance permanent vegetation plots. Permanent plot are often used in developing countries. This approach yields valuable scientific data, but because of the limited amount of data it rarely provides the necessary input for day to day management (Danielsen et al. 2000).

In this light some have argued that the aim of a monitoring system should be to ensure better management and involvement of local people, since the management of biological resources on a day to day bases often relies on poor rural people in developing countries (Getz et al. 1999, Danielsen et al. 2000, Sheil 2001, Danielsen et al. 2003, Hockley et al. 2005). Research and monitoring needs be sensitive to local priorities and limitations to be successful, especially when local resources are involved. Usually scientific biodiversity data-collection approaches are not suitable for local conservation requirements, as they are far to complex and often extremely expensive (Sheil 2001, Danielsen et al. 2005).

There are several advantages of locally based monitoring in comparison with scientific monitoring: it provides much cheaper monitoring, the local involvement increases the local ownership towards the reserve and extends the monitoring coverage by involving more people. Furthermore, by identifying the threats or changes locally, action can be taken more quickly. Additionally, involving local people in the monitoring process often leads to more effective conservation, because it raises awareness and pride among the local people. This often encourages the local communities to take part in the protection and conservation efforts, and thereby reduce the threats (Becker et. 2005, Danielsen et al. 2005, Van Rijsoort and Jinfeng 2005).

Locally based monitoring can provide cheap and meaningful data on condition of habitats and changes in local ecosystem benefits (Danielsen et al. 2005). However, for local people to be involved, the methods used must be very simple (Danielsen et al. 2003, Hockley et al. 2005). Some have argued that the involvement of villagers in monitoring may compromise with data accuracy (Brandon et al. 2003, Rodriguez 2003). Furthermore, it has been argued that since volunteers and local people are not experts, the variation of the collected data will be greater compared to data collected by educated biologists (Firehock and West 1995, Genet and Sargent 2003, Danielsen et al. 2005).

Studies of the effectiveness of locally based monitoring in Laos and the Philippines showed that data collected by local participants had a higher variance in comparison to data collected by biologists (Uychiaoco et al. 2005, Poulsen and Luanglath 2005). However, the introduction of some errors does not necessarily mean that the data are not useful for its intended purpose (Firehock and West 1995). For example, studies from Mexico and Laos have indicated that locally based monitoring may provide useful and rapid information about trends in biodiversity (Hellier et al. 1999, Poulsen and Luanglath 2005). However, concerns are still being raised that many programmes are not paying enough attention to their efficiency (Yoccoz et al. 2001). Before testing the efficiency of a monitoring scheme, it is very important to clarify, for what purpose the data is being collected. If the data is collected for scientific purpose, precision is very important, while data collected for management purposes focus on reliability rather than precision of the data. However, the reproducibility of the methods is extremely important for both purposes. Since monitoring is a study of changes over time, the methods will need to be repeated many times and not necessarily by the same people. It is a valid point that the efficiency of the method used for the monitoring should be tested, hence so priorities and conservation actions are not taken on a wrong basis. It is however important to stress that it is often impossible to use a scientific approach in developing countries, where monitoring budgets are generally very limited. Thus, locally-based monitoring is often the only sustainable approach, as it is much cheaper than conventional biodiversity monitoring (Danielsen et al. 2005). However, there is a need to test the reliability and reproducibility of locally based monitoring schemes ensures the quality of the data (Danielsen et al. 2003, Danielsen et al. 2005, Rodriguez 2003, Kremen et al. 1994). Because poor monitoring and evaluations on biased data can lead to the acceptance of wrong conclusions, and thereby do more harm than good (Sutherland et al. 2004).

This project has focused on testing the reliability and the local reproducibility of the developed monitoring methods, while the precision of the data has been compromised in order to simplify the methods, so they are applicable to use by local people. The reliability of the data is tested in relation to different degrees of forest disturbance, whereas the local reproducibility is tested by statistically comparing data collected by trained biologists with data collected by local participants.

5.1.3. Sustainability

Locally based monitoring is generally much more cost-effective than scientific monitoring, which makes them easier to sustain for local government and local communities once the donors have disappeared. On the other hand, a monitoring system can not be expected to sustain, if the local communities do not benefit in some way for their involvement (Poulsen and Luanglath 2005, Topp-Jørgensen et al. 2005). In order to be sustainable, a locally based monitoring scheme must incorporate benefits for the local communities. Because local people often are poor and busy, it

maybe necessary to pay local participants some sort of allowance for their monitoring tasks (Van Rijsoort and Jinfeng 2005). Furthermore, studies have shown that there is a significant correlation between conservation effectiveness and compensation to local communities (Bruner et al. 2001). Another important aspect for the sustainable conservation is, that projects if possible should build on existing institutions, so data can be collected, stored, analyzed and remain accessible locally, even if this results in a decline of data quality (Danielsen et al. 2005).

5.2 The monitoring methods

5.2.1. The developed monitoring methods

The monitoring approaches used in this project have focused on forest structure and habitat disturbance as measurements of biodiversity quality. The methods are relatively simple to use, and they are only depending on low cost techniques with a minimum of equipment. Therefore they can all be locally implemented without depending on outside experts. The implementation of the methods are institutionalised under the existing systems - Catchment Forest office, local WCST groups and village environmental committees - as recommended in Danielsen et al. (2000). All of the developed methods can in principle be used for locally based monitoring, since they are simple and cost-effective. The only equipment needed are compasses, measuring tapes, ropes, pen and paper, which are all more or less accessible locally. Furthermore, neither of the methods are very time consuming in comparison with comprehensive scientific methods.

However, only data from the Bitterlich method (table 4.10) and the Disturbance index transect (table 4.9) could be used to statistically distinguish between the different levels of disturbance represented by the four study sites. The 21-trees method could only be used to statistically differentiate between the very disturbed and the undisturbed locations (table 4.5). Finally, the Tree centered quarter method was not able to distinguish between any of the four locations (table 4.8).

Other studies have earlier used basal area based methods similar to the 21-trees method to describe the level of forest disturbance (Cottam and Curtis 1956, Wilder et al. 1998). Cottam and Curtis (1956) showed that the true basal area is dependent on the number of trees used in a survey, which indicates that the results for the 21-trees method might have been more unambiguous, if more samples had been taken. Using a point centered quarter method in North American forests, Cottam and Curtis (1956) found that it required between 26 and 38 samples to achieve a standard deviation below 5 %. The point centered quarter method was also used in a survey of the vegetation structure and composition in Taita hills forests in Kenya. Here 40 sampling points were taken and only trees with DBH higher than 15 cm were included (Wilder et al. 1998). These studies indicate that the results of this survey using the Tree centered quarter method might also have been better, if the number of samples had been increased, and if the DBH limit had been higher than 5 cm. This would

have eliminated a lot of the fern trees, which had enormous effect on the tree density in the Bunduki area.

	21 trees method	Tree centered quarter method	Bitterlich	Disturbance index	Permanent plot
Equipment					
	Measuring tapes, pen and paper	Measuring tapes, compass, pen and paper	Bitterlich gauge, pen and paper	Rope, strings, pen and paper	Measuring tapes, pen and paper
Frequency					
	Every 3-4 month	Every 3-4 month	Every 3-4 month	Every 3-4 month	Every 2-3 year
Human resources	Minimum 2-3 persons	Minimum 2 persons	Minimum 1 person	Minimum 3-4 persons	Minimum 2-3 persons
Pros					
	Easy to take on	Easy to take on	Easy to take on	Easy to take on	Provide scientifically good data
	Cost-effective	Cost-effective	Cost-effective	Cost-effective	Can be used in establishing biodiversity baselines
			Equipment are locally available	Equipment are locally available	Good for detecting long term changes
			Provide useful data on disturbance on short term scale	Provide useful data on disturbance on short term scale	
Cons					
	Less accuracy in the data	Less accuracy in the data	Less accuracy in the data	Less accuracy in the data	
	More time consuming than the other simple methods	Have not been shown capable to describe disturbance	Require some training of local participants	Require some training of local participants	Needs expert for identification
	Needs many samples to provide unambiguous conclusions		Results may to some extent rely on individual estimates	Require at least 3 persons at the same time for sampling	Relatively expensive
	Measuring tapes may not be locally available	Measuring tapes and compasses may not be locally available		The index might need adjustments	Very time consuming
	Have not been shown capable to describe disturbance				Not suitable of short term disturbance monitoring

Table 5.1 provides a quick overview of the methods used in this survey

The key element for the monitoring program in Uluguru North is that management officials on the basis of the collected data are able to evaluate results of conservation efforts, and to detect systematic disturbance in the area. On the basis of this survey, the Bitterlich method and the Disturbance index transect are recommended as the most suitable for future monitoring. The advantages with these two approaches are that they are sensitive to changes over short period of time, they are cost-effective, and that they are relatively simple to use. The major disadvantages are less focus on biodiversity directly and less data accuracy in comparison with scientific monitoring. Table 5.1 gives a quick comparison between all of the methods used in this survey, including permanent plots. The great variation between the individual samples from all of the four methods indicates that the best result will be achieved by analysis the mean values, rather than the individual samples.

Even though the Bitterlich method and the Disturbance index transects have been recommended for future monitoring, some adjustments of the methods might be needed. For example, studies from Ethiopia and Malaysia suggested that the abundance of lianas is greatest in the intermediate disturbed forests (Senbeta et al 2005, Bernard 2002). Although lianas with a diameter greater than 20 cm in general are restricted to undisturbed forest (Budowski 1970), it should be considered to remove the liana parameter from the disturbance index. The biggest problem with Bitterlich method is that it requires a certain amount of training and do to a certain extent rely on individual estimations (table 5.1.). We experienced one field team that moved to areas with more trees to please us, because they thought it would give the best results. This less lack of randomness is a potential problem for any monitoring program, and can only be solved through further education and training.

5.2.2. Local participants

The local field teams' ability to collect data using the developed methods was tested by comparing their data to data collected by us. In general the Tegetero field team, which had received the most training, provided the most accurate data using the Bitterlich method (table 4.16) and the Disturbance index (table 4.13). Using the 21-trees method and the Tree centered quarter method (table 4.13) the field team from Bigwa provided the most accurate data, although also the Tegetero field team collected data statistically identical to ours using the 21-trees method. During these exercises they received supervising from local forest officer Mr. Mazengo, who answered question during their data collecting. This indicates that the field teams will be able to use these methods provided that they receive more practice and training.

Andrianadrasana et al. (2005) found in their study on Madagascar that less educated people tend to be nervous, which can lead to inaccurate estimates of numbers. We did not examine the educational background of the local participants in this survey, but it was clear that the best data were collected by the most devoted persons. The importance of the dedication towards the project from the local participants must not be underestimated. In order to ensure this commitment, it is important that the local people see some incentives to participate in the monitoring.

The financial security in the communities living around the Uluguru North Forest Reserve is generally not very high. The population growth is high, and the people are poor. It is difficult to argue that poor local people should be responsible for the monitoring of the world's biodiversity and other resources of national and global importance without any benefits. Thus, for the monitoring program to succeed, it probably will be necessary to incorporate per diems or other benefits for the local participants. The incentives for the local people that participated in this monitoring survey were partly related to the prestige of knowledge and being consulted by project staff and foreigners, but they also received financial compensation for the time spend in the field by the project.

5.2.3. The role of simple cost-effective monitoring

It is very important to realize that both locally based monitoring and scientific monitoring have forces and weaknesses. The scientific biodiversity surveys play many very important roles. They establish baseline knowledge of biodiversity, they are capable of influencing national and global policies, and they increase international funds for conservation and development efforts (Danielsen et al. 2005). However, in many developing countries they are far too expensive and time consuming to be a sustainable solution for continual monitoring. Permanent vegetation plots are designed to create biodiversity baselines and study long term effects, as global warming, large scale human disturbance or other major changes.

The methods used in this survey are designed to detect changes in disturbance of a forest area, which can be used by local project management in their effort to priorities the conservation funds and actions. These methods are much more cost-effective, as they are carried out by local villagers. Furthermore, they are much less time consuming, which is important, as it is unrealistic to expect that local people will be able to use more than a few days a year on such monitoring scheme, unless they receive payment for the work. Therefore, the aim is that the villagers will spend the maximum of one day in the field every 3-4 month collecting the data. Finally, since these methods are plotless, they might have an advantage in quickly detecting disturbances in comparison with permanent vegetation plots. Because local people will tend to perform illegal activities, as pole cutting and timber extraction, outside a well defined and appropriately marked permanent plot.

The scientific and the locally based approaches shall not be seen as substitutes, but rather as supplements for each other. The permanent vegetation plots are useful for establishing the necessary biodiversity baselines, which can identify important biodiversity areas (Johansson et al. 1998) and provide information on long term changes and trends. The locally based monitoring methods on the other hand can be used to detect changes in disturbance and forest structure on a short term bases enabling management to quickly take action if necessary.

5.3 Conservation perspectives

The need to conserve the forests of the Eastern Arc Mountains has been on the agenda since the 19th century. Many of today's forest reserves were established during the German and British colonial periods (Chachage 1998). However, the colonialism was an outside authority that denied the Africans the right to use and manage their natural resources (Hackel 1999). Furthermore, the management historically has failed to provide benefits for the local communities, and conservation efforts have often resulted in restrictions towards local people's use of forest resources (Schildkrout 1996, Newmark and Hough 2000). This along with the lack of local involvement has in some places led to hostility from local people towards conservation efforts.

To face this problem conservationists in Africa are struggling to develop new approaches to protect the natural heritage of the continent (Newmark and Hough 2000, Brooks et al. 2001). During the last couple of decades conservation strategies have aimed at involving local people and integrating conservation and development projects. In the Eastern Arc the deforestation rates have declined for the past 10 years. This is partly a result of the changed conservation strategy, and partly because most of the forest outside of the reserves have already been cleared (Mbilyni and Kashaigili *in press*).

Today the importance of the Eastern Arc Mountains forests is broadly recognised in Tanzania. However, the country suffers from extreme economic problems, thus the conservation of the Eastern Arc is largely depending on foreign aid assistance. This situation is not likely to change within the coming decades (Rodgers 1993). The current levels of resource extraction are still unsustainable in the longer term (Hartley and Kaare 2001), and the protection and management of the forests are generally inadequate.

5.3.1. Economical perspectives

Global perspectives

The conservation of the world's ecosystems, their biodiversity and the services they provide are essential for humans in the future (Balmford et al. 2005). The services provided by the world's

biosphere include atmospheric gas balance, climate regulation, disturbance regulation, water balance, water supply, erosion control, sediment retention, soil formation, nutrient cycling, livelihood for millions of people, pollination, biological control, refugia, food production, raw materials, genetic resources, recreation, cultural uses and there is still much to learn about these ecosystems' potential benefits to humankind (Costanza et al. 1997, Balmford et al. 2002, Bawa et al. 2004). All these services do not fit into the traditional commercial markets. Thus, they are often wrongly regarded as free services from the political decision makers.

A review based on more than 300 case studies shows that the overall global economy benefits from protecting the world's ecosystems. The benefits are up to 100 times greater than the estimated costs of the protection, including compensation to local stakeholders (Balmford et al. 2002). Other scientists argue that the value of the ecosystem services are in the range of 16-54 trillion USD$/year globally. The tropical rainforests alone provide services estimated to be around 2000 USD$/ha (Costanza et al. 1997). In comparison a surveys from Zambia has estimated that the protection of the country's forest would cost 2 USD$/ha/per year, a price that very few developing countries can afford (Newmark and Hough 2000).

Despite their tremendous social and scientific importance, tropical ecosystems are rapidly disappearing. Establishment of park and reserves can be part of the solution. As an example, Bruner et al. (2001) found that 83 % of tropical parks fully hold their borders against land clearings for a median funding of 1.18 USD$/ha/year. In comparison the world spends roughly 6.5 billion USD$/year on existing reserves, but half of this is spent in USA alone (Balmford et al. 2002). As a consequence of the imbalance in the distribution of funds, 88 % of the total area in developed countries is under management. This only applies to 6 % in the developing countries (FAO 2003). If the tropical ecosystems are to be preserved in the future, the developed countries in the western world need to invest more money in conservation and development in the developing countries. This viewpoint was also accentuated by a bloc of developing countries, which at the 11th annual United Nations summit on climate change in Montreal 2005 propose that the developed countries should pay the developing countries to preserve their rain forests, since the whole world benefits from their services without sharing the cost.

Eastern Arc perspectives

The Eastern Arc Mountains also provide a number of valuable services, such as climate stabilization, carbon storage, protection of hydrological functions, erosion and nutrient cycling and biodiversity conservation. The economical value of the services provided by the Eastern Arc Mountain forests are estimated to be as much as 621.4 million USD$/year (Pfliegner and Burgess *in press*). For comparison the Tanzanian government has 320 staff costing a total of 400.000 USD$/year, to manage the more than 150 forest sites around the Eastern Arc Mountains. This

emphasizes the need for further investment in the management and the protection of these forests (Burgess and Kilahama *in press*).

The most important resource provided by the Eastern Arc forests is the water supply for millions of people. For example, the Uluguru Mountains function as the water catchment for Dar es Salaam. Thus, most economic activities in the city and the livelihood of 3-4 million people depend on the water from the Uluguru Mountain forest, hence the water supply account for millions of USD$/year. If the forest of the Uluguru Mountains becomes deforested, all these activities will be jeopardized. The alternative water supply for Dar es Salaam are the construction of a 300 million USD$ dam on the Ruvu River to store water collected during the rainy season to use in the dry season (Baker and Baker 2002). However, there is no doubt that the best solution for the future is: further investment in conservation of the Uluguru Mountain forest.

5.3.2. Conservation in the future

For conservation to be successful it is essential that local communities are involved and that socioeconomic are integrated in the project (Brooks and Thomson 2001, Bawa et al. 2004). Hence, well planned rural development will automatically lead to successful conservation (Kremen et al. 1994). Development of local rural communities is necessary to provide alternative subsistence and economic opportunities for local the people, so they rely less on illegal exploitation of natural resources (Noss 1997). Thus, conservation problems associated with high human population can only be overcome by providing economic security for the poor rural population (Hackel 1999).

Nevertheless, local people are generally willing to contribute in conservation efforts, if they benefit from them. The benefit can be economical, but also benefits such as social prestige may help engage local people in a project. For example, we found that involving the local participants in the establishment of the permanent plots and educating them in species identification using local names, both inspired and gave them pride in their participation in this project. Other benefits such as higher availability of natural resources can also be used as incentives for the local communities to participate in a project, but as shown in figure 4.5 the availability of natural resources used by the local people does not always correlated with intensity of forest disturbance.

One of the problems for forest conservation is that it operates with a certain time lag. It will usually take some time, before the effects of conservation actions are visible to the local people in their daily life. Benefits such water supply, erosion protection and fertilization of agriculture land will probably not be recognized, before the forest has disappeared, and the damage is irretrievable. For example, the fact that deforestation leads to a decrease in soil fertility in the surrounding agriculture land (for further details see 1.2.2. and 1.5.3.) presents a potential vicious spiral, because low fertility causes a decrease in yield. The response from poor uneducated farmers will often be clearing of

more forest for agriculture land. Thus, attention needs to be directed at alternative income and education schemes for local communities, if conservation is to succeed. For an education scheme of local communities to be effective, it is essential that the local staff fully understand the purpose of each step in the project (Margules and Pressey 2000, Sheil 2001). The knowledge level of the field staff is extremely important, since they are the ones, who communicate with and inspire the local communities to participate in the project. Therefore their level of knowledge and dedication often determine whether a project will succeed or fail. The motivation and inspiration shown by the WCST staff working in the Uluguru Mountains is outstanding. However, the number of staff is insufficient and the understanding of processes, such as monitoring purposes, is sometimes inadequate.

However, conservation can only succeed, if it is seen as part of a larger agenda. The conservation responsibilities are not only a subject for the poor rural population in the developing countries, everyone needs to contribute. Slowing human caused extinction of biodiversity and destruction of the world's ecosystems depends on a combination of local, regional, national and international efforts with special focus on developing countries in the tropics (Becker et al. 2005). Many international donors are already working in the Eastern Arc Mountains, and between January 2004 and December 2008 Critical Ecosystem Partnership Fund (CEPF) is investing 7 million USD$ in conservation of the Eastern Arc and coastal forests of Tanzania and Kenya. However, foreign aid can not solve the problems alone. This has been illustrated by an IUCN project in West Usambara with focus on forest conservation and local community development, it ran for 10 year, but 5 years after it ended all activities had stopped. Because there was no structure or organisation to sustain the work, after the funding had stopped (Workshop 1997).

This shows that conservation efforts only can be sustainable, if there is support from the local communities and a motivated forest department. Foreign aid can help this process, but not drive it. For conservation to be successful in the Eastern Arc Mountains, it will require compensation to private and local economies. Since the people that gain the most of forest services seldom are the same people, who are depending on agriculture land, fire wood, building poles from the forests to obtain their livelihood. One of the major problems for the future investment in water catchment is that water generally is considered a free good without any economical value. This perception will have to change in the future. The economical benefits of the water must be shared, to create incentive and the economical security for the local communities living around the catchment forest reserves. Otherwise the population growth and the poverty will force local people to keep on over-exploiting of the forests, and the decline in forest area will continue.

The conservation of the Eastern Arc Mountains requires money for the management of the forest, and development for the local people living around it. To create a sustainable solution the money for this could come from the industries and the breweries in the urban areas that use much of the

cities water supply. This money could be generated either through taxes on water or voluntary contributions. Alternative income scheme such as ecotourism could also be considered. However this can not be expected to cover more than a small proportion of the total conservation costs.

5.4 Recommendations for the project

5.4.1. Organizational recommendations

The project will benefit, if the communication between the centralized office and the Morogoro regional office is strengthened further in the future. The relatively low level of communication between the Dar es Salaam office and the Morogoro office sometimes results in misunderstandings, and that the different levels in the project are not always on the same page. Also it should be considered to further educate the field management staff about the perspectives and uses of monitoring systems. It will strengthen the future monitoring scheme, if the educational level among the field management staff is raised on subject of monitoring purposes, and how to use the collected information.

5.4.2. Recommendation for future monitoring

The only two methods from our survey found consistent enough for monitoring of changes in disturbance level were the Bitterlich method and Disturbance index transects, the local field teams should use these two methods to collect monitoring data one day every 3-4 month, while the permanent plots only need to be attended every 2-3 years intervals. For the data to be accurate enough to be use by the management personnel in the future, the local participants will need further training in use of the methods. Mr. Mazengo is fully capable of performing these necessary training sessions for the local field teams. To gain the best results, the project should consider to economically compensating the local participants, at least for the time used in the coming training sessions. When the local participants have reached a satisfying level of capacity, they should be encouraged to hold training sessions in use of the monitoring methods for the other local villagers. This will increase the social prestige benefits for the local participants, increase the awareness on conservation importance in the local communities and spread out expertise and build capacity for more people. If the expertise is not spread out around the local communities, there will be no one to take over, if the current participants move or stop their involvement, and the whole scheme will fall. Regarding the analysis of the monitoring data Mr. Mazengo have received training and is competent to analyse the collected data. This knowledge should be passed on by Mr. Mazengo to the rest of the management staff at the WCST office in Morogoro, to ensure that the analysis task can be taken over by others, if he should be engage in other assignments.

6. Conclusion

Today it is broadly recognized that the way forward for conservation of ecosystems in developing countries is through local participation. However, involving local people in monitoring process is often a balance between the benefits of local involvement and the reliability of the collected data. Hence, for locally based monitoring to be successful the methods used must be as simple as possible. This will lower the quality of the collected data, but so far only few studies have tested, if such monitoring schemes can provide reliable information for conservation management. In this study the efficiency of four different simple and cost-effective monitoring methods was tested. Of these methods only the Bitterlich method and the Disturbance index transects applied to local use and were capable of providing reliable data on forest disturbance.

This study concludes that local people to a certain degree are capable of collecting reliable data on habitat loss and disturbance. If the monitoring methods are simple and the local participants are provided with sufficient training. These aspects are critical for the sustainability of any locally based monitoring design. If scientists fail to provide locals with the sufficient training, or the methods are not simple and cost-effective enough, the whole scheme are likely to collapse, when the project ends. Nowadays almost every conservation or development project strongly emphasis involvement of local people in participatory management and monitoring, but the efficiency of such projects have rarely been tested. Further studies on this area need to be conducted, in order to enable project designs to optimize the results of local involvement and still make priorities on the basis of reliable information.

The sustainability of the monitoring project in the Uluguru North Forest Reserve will almost certainly continue to rely on subsidizes from the Tanzanian government, industries or foreign development agencies for many years. It can not be expected that poor local villagers will work without some sort of compensation on monitoring and conservation of an area of both national and international importance. Consequently, if the local participants are not financially compensated for the time they use on the scheme, fewer people will get involved, and it will be more difficult to keep people involved over longer periods of time. This will require money for training of new participants. Alternatively per diems might help to keep the participants and their expertise involved in the project for a longer period of time. For this reason this study recommends that the local participants are paid some sort of per diem for their training and work sessions at least for the first year until the program are up and running.

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