

**Forest Health Monitoring in the Eastern Arc Mountains of Kenya and Tanzania: a baseline report on selected forest reserves**

Seif Madoffe, James Mwang'ombe, Barbara O'Connell, Paul Rogers, Gerard Hertel, and Joe Mwangi

Dedicated to three team members, Professor Joe Mwangi, Moi University, Eldoret, Kenya and Forest Department, Nairobi; Mr. Charles Kisen Mabula, Tanzania Forest Research Institute, Lushoto, and Mr. Onesmus Mwangangi, National Museums of Kenya, Nairobi, who passed away shortly after the completion of the field work for this project. They will always be remembered.



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**Forest Health Monitoring in the Eastern Arc Mountains of Kenya and Tanzania: a baseline report on selected forest reserves \***

**Abstract**

This status report presents the results of 43 permanent forest health study plots (3871 trees, saplings, and seedlings) established in 2000 and 2001 in parts of three areas of the Eastern Arc Mountains – the Taita Hills in Kenya (Ngangao and Chawia), the East Usambara Mountains (Amani Nature Reserve) and the Uluguru Mountains (Morogoro Teachers College and Kimboza) in Tanzania. Three main indicators of forest health – mensuration, visual crown ratings, and tree damage – were collected to provide baseline information on the forested areas. In general, the trees measured are considered healthy. There was no attempt to evaluate the variability among plots in a location or to compare locations. The goal was to make the information available to others for continuous study of Eastern Arcs forests. The data have been provided to coordinators for the Critical Ecosystem Partnership Fund in Kenya and Tanzania and to the Tanzania Conservation and Management of the Eastern Arc Mountain Forests Programme. Remeasurement and further analysis of the existing plots will provide interesting trend information, as 35 globally-threatened tree species (1074 trees, saplings, and seedlings) were found on these initial plots.

\* This report was examined by an external reviewer. Discrepancies in identification of a few tree species will be addressed when the permanent plots are revisited and remeasured in 2006.

**Introduction**

The Eastern Arc Mountains are a chain of isolated ancient crystalline mountains (534,000 ha), extending from southeast Tanzania northeast to southeast Kenya (Lovett 1998, Newmark 1998). Climatically influenced by the Indian Ocean, annual rainfall ranges from 3,000 mm/year on the eastern slopes to 600 mm/year in the western rain shadow. This unique combination of moist climate and geographic isolation led to a high degree of endemism in the flora and fauna of these Mountains. Thus, Conservation International recognizes these Mountains as one of the globally important "hot spots" for plant and animal biodiversity (Myers *et al.* 2000). They are also a major source of a wide array of forest-based products, agricultural production, water, and hydropower



for the surrounding villages and distant cities. As the population around the mountains continues to grow, so do the demands for forest resources and habitable land. These increased pressures have ultimately resulted in the rise of forest fragmentation, land degradation, and loss of biodiversity. This has been especially true in the lower, more accessible elevations of the Eastern Arcs, where much of the land has already been cleared for agricultural use. In addition to monitoring the overall change in land use and fragmentation, approaches were needed to monitor the health of the remaining forests.

In 1990, in response to the concerns over the affects of pollution, insects, diseases, climatic change, fragmentation, and other stressors on forests in the United States, the United States Department of Agriculture, Forest Service (USDAFS) and the National Association of State Foresters developed a program of monitoring forest health (Brooks *et al.* 1991). The program involves the use of remote sensing, permanent plots, and special aerial and ground survey techniques. The results have provided status and trend information to a variety of users – scientists, land managers, planners, policy makers, environmental groups, local communities and individuals – who utilize the information for further research, planning, and forest management decisions (Rogers *et al.* 2001).

In February 2000, a forest health monitoring project was established in parts of the Eastern Arc Mountains. This project, funded by the U.S. Agency for International Development (USAID) and the USDAFS, used satellite imagery and permanent forest health monitoring plots to assess land use and

forest health status. Monitoring plots were measured initially (baseline) to gain an understanding of forest tree health. Remeasurement of these same plots will allow comparison over time to assess trends in the measured variables. In addition, a Web site was developed to foster information sharing ([www.easternarc.org](http://www.easternarc.org)). The objective of the program was to determine if forest health monitoring data could be useful to local and national officials and neighboring villagers for making forest policy and management decisions.

This status report presents the results of permanent study plots established in 2000 and 2001 in three areas of the Eastern Arcs – the Taita Hills (Ngangao and Chawia forests) in Kenya, the East Usambaras (Amani Nature Reserve, ANR) and the Uluguru Mountains (selected areas) in Tanzania. In February 2000, a preliminary survey was conducted to test the application of the USDAFS forest health plot protocols in the Eastern Arcs forests. Five plots were established in the Ngangao Forest in the Taita Hills, Kenya, three plots in the ANR, and three in the North Ulugurus above Teachers College in Morogoro. The conclusion of this preliminary survey was that the FHM protocols, with minor adjustments to address the special needs of tropical landscapes, could provide a valuable measure of the Eastern Arcs forests.

In February 2001, the program was expanded to involve more representatives from East African agencies, and to increase the number of baseline plots. The expanded program consisted of one week of training, followed by one week of plot installation, both in the Taita Hills and East Usambaras. More plots were later established in the Ulugurus by previously trained personnel.

The project was led by Gerard Hertel (USDAFS, Northeastern Area, State & Private Forestry – retired), and three representatives from the USDAFS served as trainers and crew leaders. Barbara O'Connell (Northeast Research Station) instructed the Visual Crown Ratings and acted as lead trainer. Kathy Tillman (Northeast Research Station) was the lead Mensuration/Plot Establishment trainer. Paul Rogers (Rocky Mountain Research Station) trained crews in Damage Assessment. Professor Joe Mwangi (deceased), Moi University and the Forest Department, Kenya and Dr. Seif Madoffe, Faculty of Forestry and Nature Conservation, Soikoine University of Agriculture, Tanzania coordinated the crews and fieldwork in their respective countries. Local botanists served as part of the field crews to assist in identification of the tree species in the plots.

Nine Kenyan and six Tanzanian professionals from various East African organizations (Kenya Forest Department; Kenya Wildlife Service-Forest Program; East African Wild Life Society; United Nations Environmental Program/Global Environmental Facility, Cross Borders Biodiversity Project; Forestry & Beekeeping, Tanzania; Commission for Natural Resources, Zanzibar; Tanzania Forest Research Institute) were certified in Forest Health Monitoring techniques. Following the week of training, certified crews installed permanent forest health plots. In addition to those plots established in 2000, twelve plots

were established in the Taita Hills, seventeen plots in the East Usambaras, and three in the Ulugurus (Kimboza Forest).

In June 2002, the crews were trained in data management, analysis, and reporting in Voi, Kenya. With the death of Professor Joe Mwangi, James Mwang'ombe, East African Wild Life Society, took over as Kenyan Lead for the Project.

## **Eastern Arc Forests**

### **Taita Hills, Kenya - Ngangao and Chawia Forests**

The Taita Hills form the northernmost part of the Eastern Arcs. They are located in the Taita-Taveta District, southeast Kenya (03°15' - 3°30'S and 38°15' - 38°30'E), near Voi on the Nairobi-Mombasa Highway, approximately 165 km inland from the Indian Ocean. The altitudinal range of the forested area is from 1500 m to 2,140 m. (Burgess, *et al.* 1998). Annual rainfall ranges from 500 mm in the lower elevations to 1500 mm in the mountains, and can vary widely from year to year. Peak precipitation months are April and November, but moist weather conditions prevail throughout the year (Beentje 1988).

The main economy is agricultural, producing coffee, mango, tomatoes, maize, bananas, beans, vegetables, and cassava for local and commercial trade. To minimize the event of crop failure due to the range in moisture levels, the typical Taita farmer cultivates small plots in the dry lowlands as well as small plots in the upper moist elevations. Forest streams are utilized in simple, small-scale irrigation systems. In addition to agricultural clearing, other human activities, such as planting of exotics, firewood collection and tree poaching, have been integral in the subsistence of the local villagers.

The obvious result of these human activities has been the reduction of forested land area. There are only 12 fragments covering less than 400 ha (Brooks, *et al.* 1998). The remaining forest fragments: Chawia, Fururu, Kichuchenyi, Macha, Mbololo, Mwachora, Ngangao, Ndiwenyi, Ronge, Sagalla, Vuria, and Yale occur in patches across the top elevations, and range in size from less than 1 ha to 220 ha (Beentje 1988).

Forest health plots were established in the relatively-protected but partly-disturbed Ngangao Forest (approximately 92 ha of forest), and the more-disturbed Chawia Forest (approximately 50 ha of forest) (Wilder *et al.* 1998).

### **East Usambara Mountains, Tanzania - Mbomole Hill Trail, Turaco Bird Trail, Kwamkoro Forest Station, and Sigi Trail Forests**

The East Usambara Mountains are located in the Tanga region, in Northeast Tanzania (04°45'-05°20' S, 38°26'-38°48' E), approximately 50 km from the coast. The forested area covers approximately 450 km<sup>2</sup>, and ranges in elevation from 130-1506 m. (Burgess, *et al.* 1998). The majority of the forested area (330 km<sup>2</sup>) is protected in forest reserves. The East Usambaras serve as a water catchment for the nearby city of Tanga. Local villagers harvest the forest for fuel wood and building materials. Cleared land is used for small agricultural plots. Cassava, maize, sweet potato, beans, peanuts and rice are the main crops grown for local consumption. The most important cash crops include cardamom, sugarcane, and other spices such as cinnamon, pepper and clove. Large-scale commercial tea plantations flourish between the reserved forests.

The East Usambara Catchment Forest Project (EUCFP) worked in the East Usambaras mountains since 1990 with the mission to protect these natural forests. The project worked to establish the Amani Nature Reserve (done in 1997), with goals of; protecting water sources, establishing and protecting forest reserves, sustaining villager's benefits from the forest, and rehabilitating the Amani Botanical Garden. The project was implemented by the Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (MNRT) with financial support from the Government of Finland, and implementation support from the Forest and Park Service (FPS). The project successfully ended in 2002.

Forest Health plots were established in four separate parts of the Amani Nature reserve: Mbomole Hill Trail, Turaco Bird Trail, Sigi Trail, and Kwamkoro Forest Station.

### **Uluguru Mountain Region – Morogoro Teachers College Riverine (Uluguru North) and Kimboza Forests**

The Uluguru North Catchment Forest is located in East Central Tanzania (06°51' - 07°01'S, 37°37' - 37°45'E), approximately 180 km from the Indian Ocean. The forested area covers about 8356 ha. at altitudes ranging from 1000 to 2340m. (Burgess *et al.* 1998).

The forests of the Uluguru Mountains serve as water catchment areas for the streams and rivers that feed the Ruvu River, which provides the water supply to the largest city in Tanzania – Dar es Salaam. More than 3 million people and the major industries in Tanzania rely on this water supply.

The Teachers College is located just outside of Morogoro. Located at the northern end of the Ulugurus, the forest strip extends down to 650m behind the Teachers College. Trees were being removed during



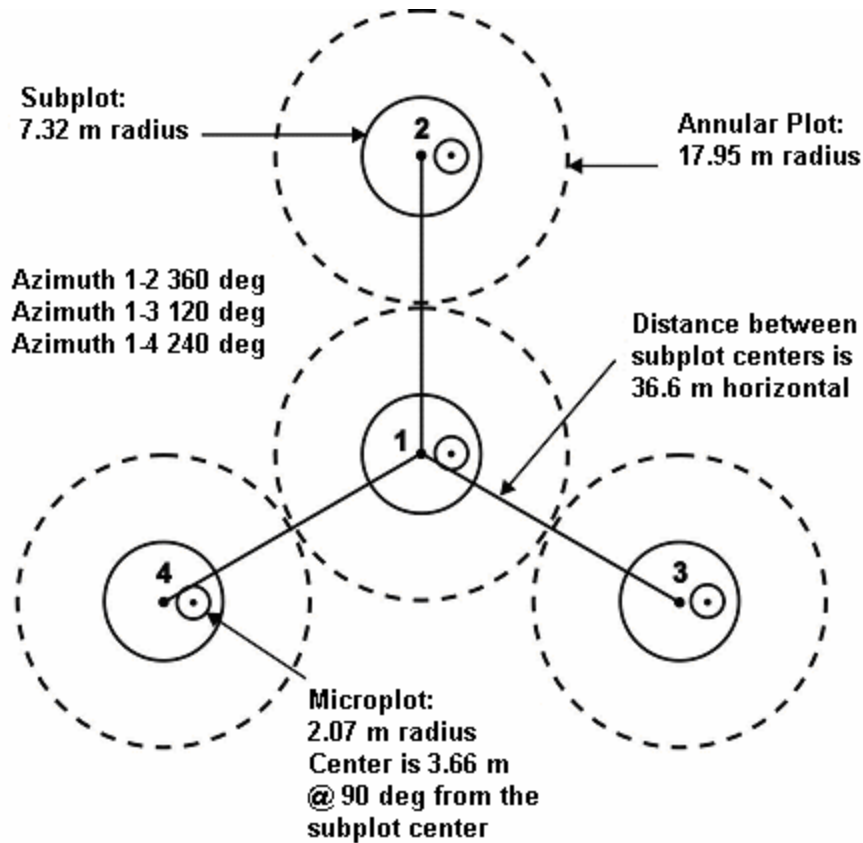
the time of plot establishment. Evidence of human impacts abounds within the forest strip. The Kimboza Catchment Forest Reserve can be accessed from Morogoro to Kisaki Road between Mkuyuni and Matombo villages (06°59' - 07°02'S, 37°47' - 37°49'E). The forested area contains 405 ha. This Catchment Forest Reserve is a seasonal lowland forest in the eastern foothills of the Ulugurus. Estimated annual rainfall is 1700mm. Protruding metamorphosed limestone karsts are a prominent feature within the forest. Logging has almost completely deprived the forest of its tall canopy trees, causing great damage. Minor forest products include building poles and medicines. *Cedrella* plantations are cultivated along the road at the northern edge of the reserve. This species is acting like a non-native invasive.

## **Methods**

In February 2000, the study plots were measured using protocols from the USDA Forest Health Monitoring (FHM) Field Manual (USDA 1999). Shortly thereafter, the USDAFS restructured the FHM Program, and it became a subset of the Forest Inventory and Analysis Program (FIA). This resulted in some minor changes in protocols, but did not affect the overall plot layout and basic tree measurements. In February 2001, the Eastern Arc plots were measured using the new FIA protocols (USDA 2000).

The field plot consists of four subplots approximately 0.017 ha in size with a radius of 7.32 m. The center subplot is subplot 1. Subplots 2, 3, and 4 are located 36.6 m horizontal at azimuths of 360, 120, and 240 degrees, respectively, from the center of subplot 1 (see Figure 1). In the subplots, data are collected on trees with a diameter at breast height (DBH) of 12.7 cm or greater.

Each subplot contains a microplot of approximately 0.0013 ha in size with a radius of 2.07 m. The center of the microplot is offset 90 degrees and 3.66 m horizontal from each subplot center. Microplots are used to select and collect data on saplings (DBH of 2.54 cm to less than 12.7) and seedlings (DBH less than 2.54 cm in diameter and greater than 15 cm in length [conifers] or greater than 30 cm in length [hardwoods]).



**Figure 1. FIA plot diagram.**

**Sampling:**

Plot selection criteria varied between forests, depending upon the level of local knowledge and other current vegetation surveys. In Ngangao, the plots were related to another ongoing study by Kamau Wakanene Mbutia. Dr. Wakanene Mbutia used a stratified random sampling method, whereby the forest was subdivided into six blocks measuring 400 m in width. Random points were established within the blocks to determine the positions of the east to west transects. Sampling points were placed at 100 m along the transect. Beginning at these points, 20 x 50 m plots were established perpendicular to the slope for a total of 29 plots in 6 east-west transects. We randomly selected two plots per transect, and then located the FHM plot centers 30 m west of the SW corner of Wakanene's plots.

Plots in Chawia, Mbomole Hill Trail, Turaco Bird Trail, and Teachers College Riverine Forests were selected after touring the forest fragments with the local foresters or forest guards. The plots were randomly placed in areas that were determined to be representative of the forest types. Plots in Kwamkoro Forest Station, Sigi Trail, and Kimboza Forests were established with little knowledge of the whole area.

**FHM Plots Established in East Africa, 2000 and 2001**

**Kenya**

Mountain Area	Forest Name	Number of Plots
Taita Hills	Ngangao	11
Taita Hills	Chawia	6

**Tanzania**

Mountain Area	Forest Name	Number of Plots
E. Usambaras	Mbomole Hill Trail	5
E. Usambaras	Turaco Bird Trail	6
E. Usambaras	Kwamkoro Forest Station	4
E. Usambaras	Sigi Trail	5
Ulugurus	Teachers College Riverine	3
Ulugurus	Kimboza	3

**Field Measurements:**

Three main indicators of forest health – mensuration, visual crown ratings, and tree damage – were collected to provide baseline information on the forested areas.

**Mensuration:**

Mensuration is tree measurement and sampling to summarize forest conditions. The mensuration indicator is an important descriptor of the forest condition in regard to growth, regeneration, and mortality. Detailed measures of each tree, such as its position on the plot relative to plot center, species identification, DBH, tree height, and relative crown position within the forest canopy were recorded for all trees and saplings on the subplots and microplots, respectively. Microplot seedling numbers were tallied by species.

**Visual Crown Ratings:**

One of the primary indicators of tree health is the condition of the tree crown. The crown indicator takes into account the amount, condition, and distribution of tree foliage, branches, and reproductive structures, and quantitatively describes the visual appearance of the tree crown. All live trees with 12.7 cm DBH or greater are assessed for live crown ratio, crown density, crown dieback, and foliage transparency. All

crown measurements are recorded in 5 percent unit classes, from 0 to 100 percent. Anderson *et al.* (1992) used the following ratings guidelines to determine the health of trees in US forests.

- *Live Crown Ratio* is defined as the proportion of the live tree crown in relation to the total height of the tree. Pruning studies have shown that removal of live branches up to two thirds of tree height will not adversely affect tree growth. Thus, trees with a live crown ratio of at least 35% are considered to be in good health.
- *Crown Density* is the amount of crown foliage, branches, and reproductive structures that block visible light. It is used to assess the expected growth in the near future. Generally, greater density means a healthier tree.
- *Crown Dieback* is the recent mortality of branches with fine twigs, which begins at the outer, upper portions of the tree crown and proceeds toward the tree trunk. Most trees have at least a few dead twigs due to normal environmental stressors. Trees with 5% dieback or less are considered to be in good health.
- *Foliage Transparency* is the amount of light that is visible through the live, normally foliated portion of the crown. "Normal" foliage transparency ratings are relative and vary somewhat between species. Some tree species will exhibit a higher foliage transparency due to their inherent leaf design and branch structure. Without more information on the relative foliage transparency between species, it is generally accepted that trees in good health have a transparency rating of 45% or less.

For saplings with DBH at least 2.54 cm and less than 12.7 cm, the relative health is assessed by crown vigor. Crown vigor is divided into three classes: high, moderate, and low vigor. Sapling vigor class is determined through the combined measures of live crown ratio, percent of normal foliage, and dieback. Ratings in the moderate and high categories indicate more foliage area available for photosynthesis.

#### Tree Damage:

The tree damage indicator assesses the location, type, and severity of natural- and human-caused injury on trees with at least 12.7 cm DBH. Up to two damages are recorded per tree, and only those that are most significant are recorded when multiple damages occur on one tree. Generally, damages that occur in the lower parts of the tree are more significant, so damage location assessment begins at the roots and proceeds up the tree bole to the branch shoots. Damage type describes the form of the injury, and is also recorded in a hierarchal manner when two damages occur in the same location. Damage severity describes the acuteness of the damage, and provides a threshold at which a particular damage should be recorded. In cases of particularly threatening damage types, no threshold is required and the damage is

noted (e.g., conks). The objective of the prioritized listing of damage type, location, and severity threshold is to limit the damage recordings to only those stressors that may severely impact the tree health. In this way, small imperfections that do little to affect tree health, such as small wounds on the bole or dead branches below the live crown are not recorded as damage.

The following lists the damages from most to least significant, and the severity threshold for each type:

<b>Damage Type</b>	<b>Severity</b>
Canker, Gall	20% of bole circumference
Conks, fruiting bodies, and advanced decay	no threshold, all occurrences recorded
Open wounds	20% of bole circumference
Resinosis or gummosis	20% of bole circumference
Cracks and seams	1.5 m in length
Broken bole or roots less than 1 m from the bole	no threshold, all occurrences recorded
Brooms on roots or bole	no threshold, all occurrences recorded
Broken or dead roots beyond 1 m from the bole	20% of bole circumference
Vines in the crown	20% of live crown area
Loss of apical dominance, dead terminal	no threshold, all occurrences recorded
Broken or dead branches	20% of branches within the live crown
Excessive branching or brooms within the live crown	20% of branches within the live crown
Damaged buds, foliage or shoots	30% of buds
Discoloration of foliage	30% of foliage
Other damages not described above	no threshold

What we call serious damage is often part of the ecological-aging processes in these natural forests.

**Analysis:**

Due to the small number of plots and trees recorded in these early surveys, analysis is limited to basic estimations of status. Tree count by forest name, tree type (tree, sapling, or seedling), and species is calculated, and only the most common species are reported. A listing of all tree, sapling and seedling species (total number – 3871) at each location is found in Appendix A. The average DBH of the most common species is calculated and reported. Appendix B lists the average DBH (for trees >12.7cm) for all species by forest. (Note, in some cases, it was impossible to accurately physically measure DBH due to vines around tree bole and/or buttressing. In those instances, DBH was estimated. Although normally omitted for growth calculations, estimated values are included here for full representation of the base-line data.) Distributions of visual crown ratings by forest are provided in Appendix C.

**BASELINE RESULTS**

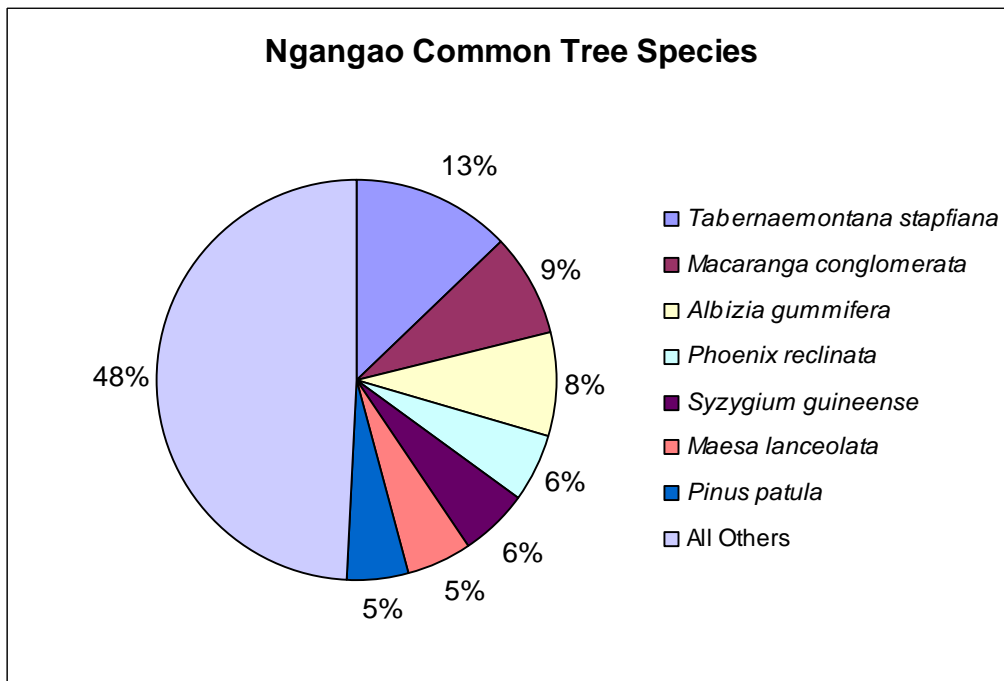
**Ngangao Forest, Taita Hills, Kenya**

Eleven forested FHM plots were established and measured in the Ngangao Forest in the Taita Hills Mountain Area.

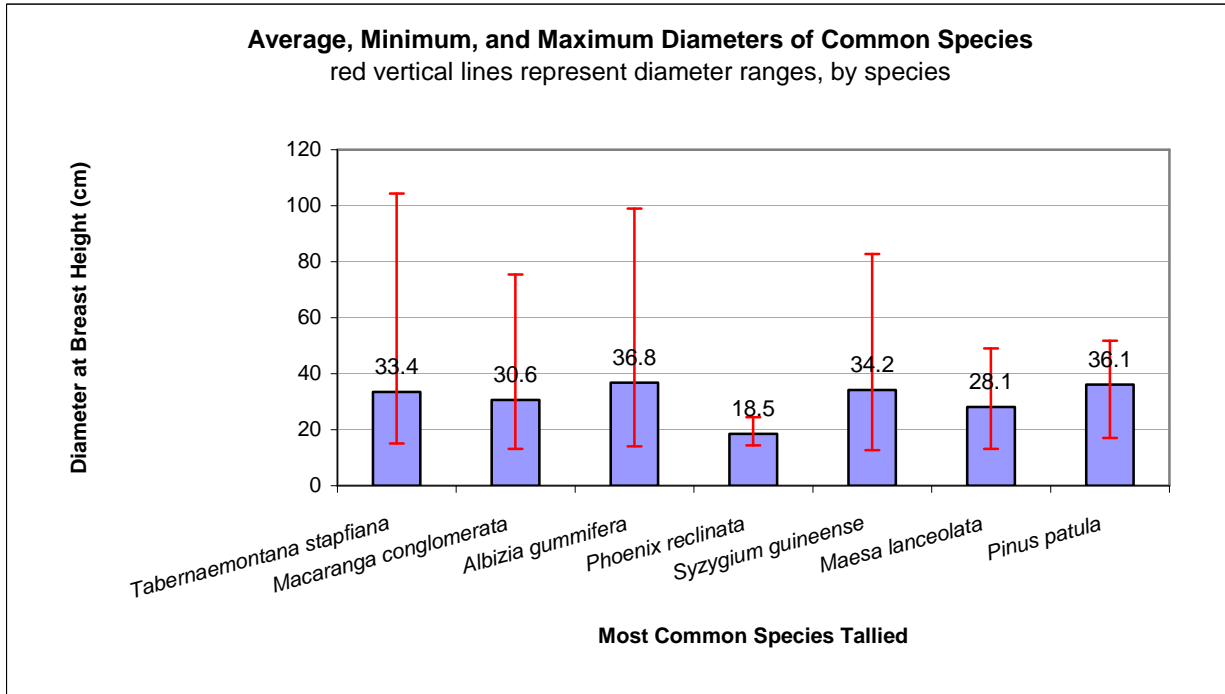
Ngangao Forest Trees:

There were a total of 47 species and 363 live trees. The most common were *Tabernaemontana stapfiana* Britten, *Macaranga conglomerata* Brenan, *Albizia gummifera* (J.F. Gmel.) C.A. Sm., *Phoenix reclinata* Jacq., *Syzygium guineense* (Willd.) DC, *Maesa lanceolata* Forssk., and *Pinus patula* Schiede ex Schltdl. & Cham.

The significant number of *P. patula* is the result of a plot randomly falling in a plantation located near the summit of Ngangao. The plantation was established to control erosion caused by previous clearing of the forest.

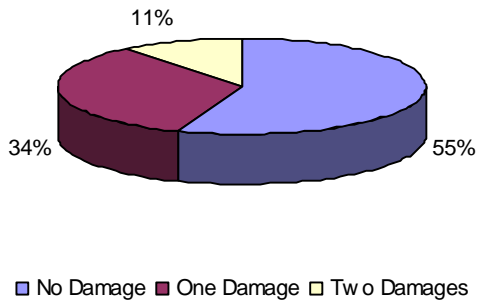


Of the most common tree species, the average DBH ranged between 18.5 cm for *P. reclinata* and 36.8 cm for *A. gummifera*.

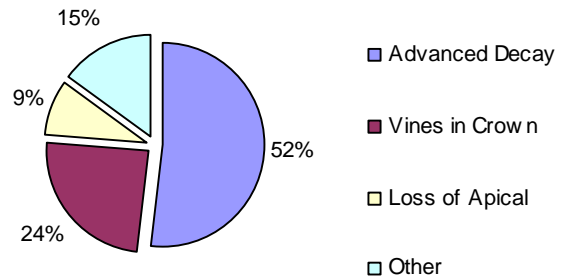


No damage was observed on 202 trees, one damage was observed on 122 trees, and 39 trees had two damages. Of the 200 damages noted on 161 trees, advanced decay and vines in crowns were the most common types.

**Number of Tree Damages**

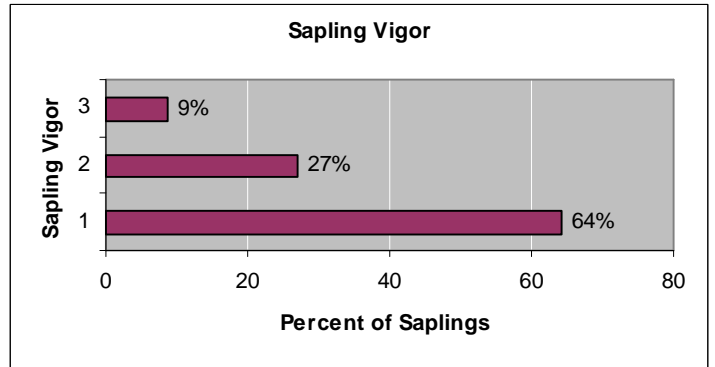
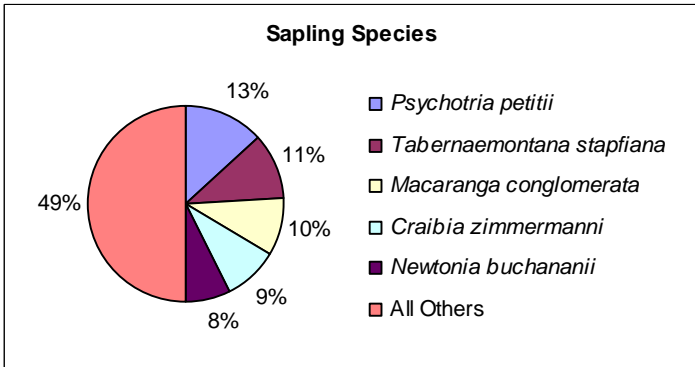


**Tree Damage Types**



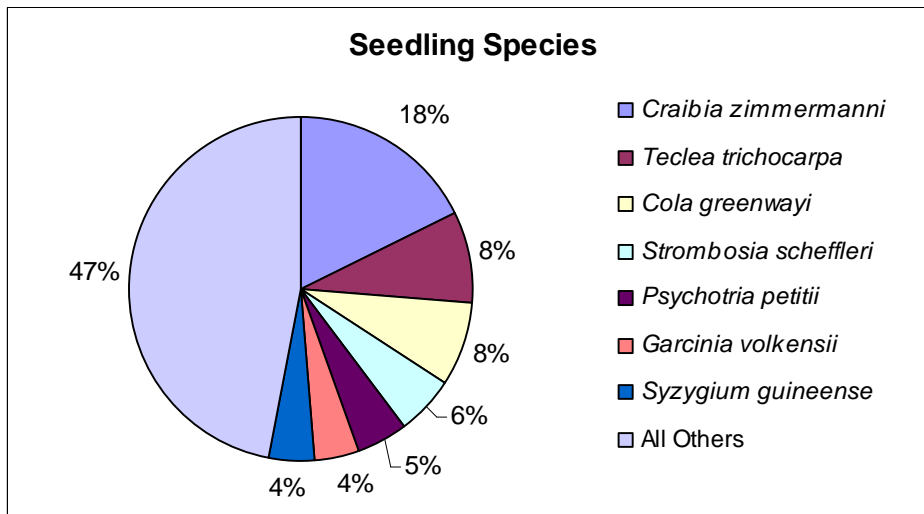
Ngangao Saplings

There were 30 species among the 92 saplings sampled. The most common species (50% of all saplings sampled) were *Psychotria petiti* Verdc., *T. stapfiana*, *M. conglomerata*, *Craibia zimmermanni* (Hams) Dunn, and *Newtonia buchananii* (Baker) Gilb. & Boutique. Ninety-one percent of the saplings had average to good vigor.



Ngangao Seedlings:

There were a total of 51 species and 487 seedlings in the sample. *C. zimmermanni*, *Teclea trichocarpa* Engl., *Cola greenwayi* Brenan, *Strombosia scheffleri* Engl., *P. petiti*, *Garcinia volkensii* Engl., and *S. guineense* were the most common species, making up 53% of the total seedlings surveyed.



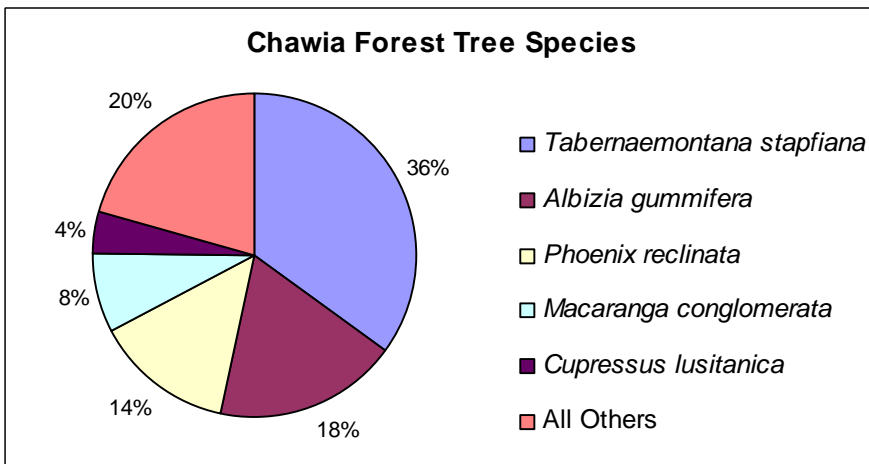


**Chawia Forest, Taita Hills, Kenya**

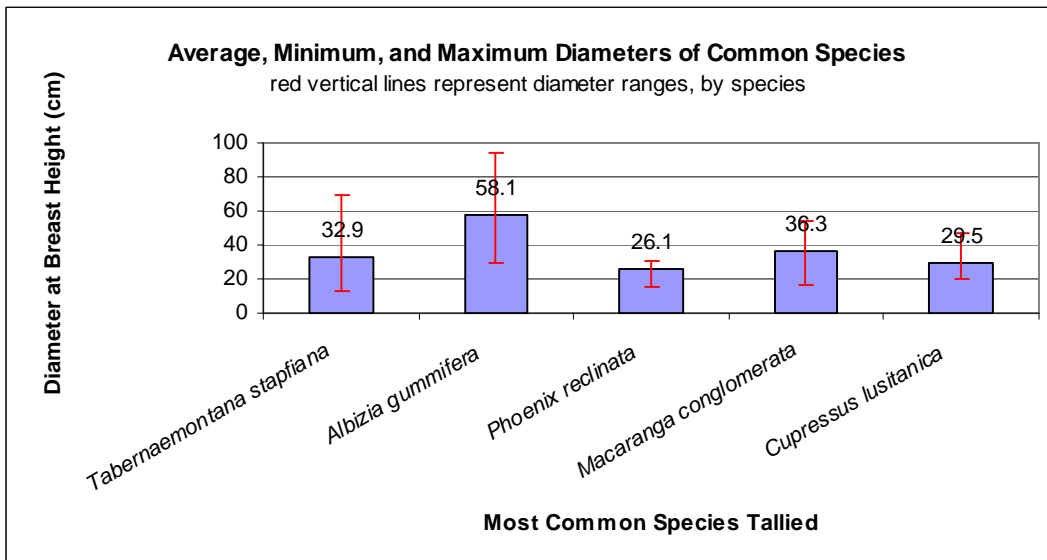
A total of six forested FHM plots were established and measured in Chawia Forest in the Taita Hills Mountain Area.

**Chawia Forest Trees:**

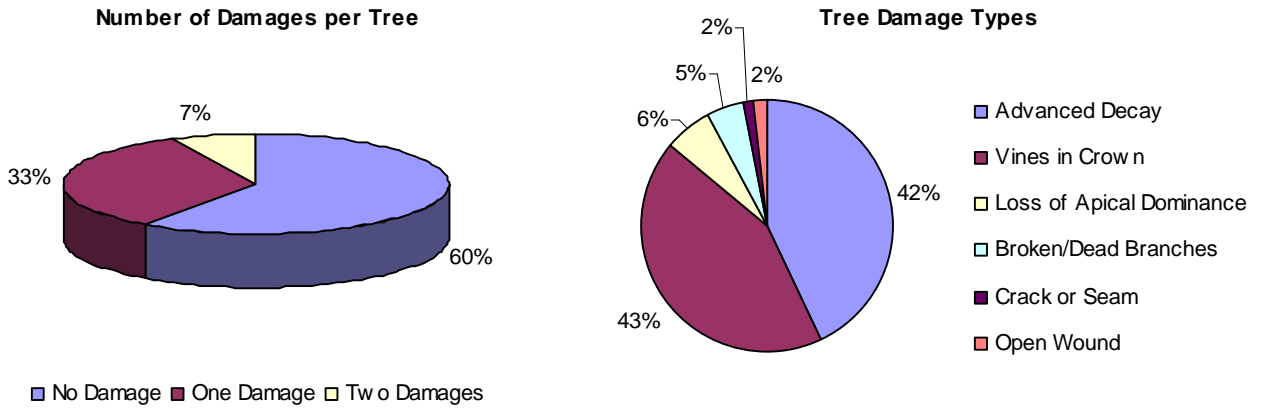
There were 19 species and 137 live trees measured, of which, 80% were species *T. stapfiana*, *A. gummifera*, *P. reclinata*, *M. conglomerata*, and *Cupressus lusitanica* Mill.



The average DBH for the most common species ranged from 26.1 cm for *P. reclinata* to 58.1 cm for *A. gummifera*.



Of all live trees, 82 trees had no damage, while 45 trees had one damage, and 10 had two damages. Of the 65 damage types observed on 55 trees, the most common damages were advanced decay and vines in crown.



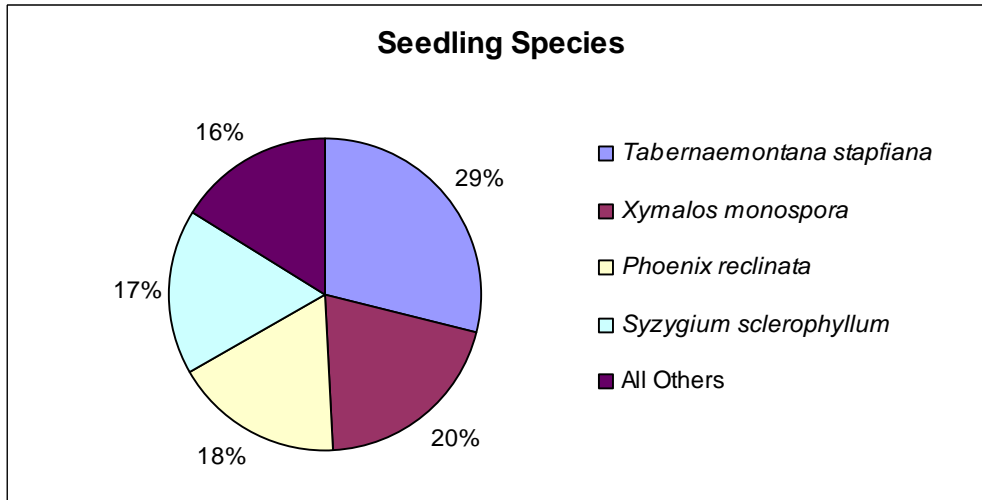
**Chawia Forest Saplings:**

A total of 7 species and 12 saplings were measured. The most common species found were *T. stapfiana* and *Pleiocarpa pycnantha* (K. Schum.) Stapf. All 12 saplings were rated crown vigor 1 (good).

Sapling Species	Count	Vigor
<i>T. stapfiana</i>	5	1
<i>P. pycnantha</i>	2	1
<i>Leptonychia usambarensis</i> K. Schym.	1	1
<i>Ouratea scheffleri</i> Gilg	1	1
<i>Polyscias fulva</i> (Hiern) Harms	1	1
<i>Syzygium sclerophyllum</i> Brenen	1	1
<i>Xymalos monospora</i> (Harv.) Warb.	1	1

Chawia Forest Seedlings:

Of the 16 species and 228 seedlings measured, 84% were species *T. stapfiana*, *X. monospora*, *P. reclinata*, and *S. sclerophyllum*.



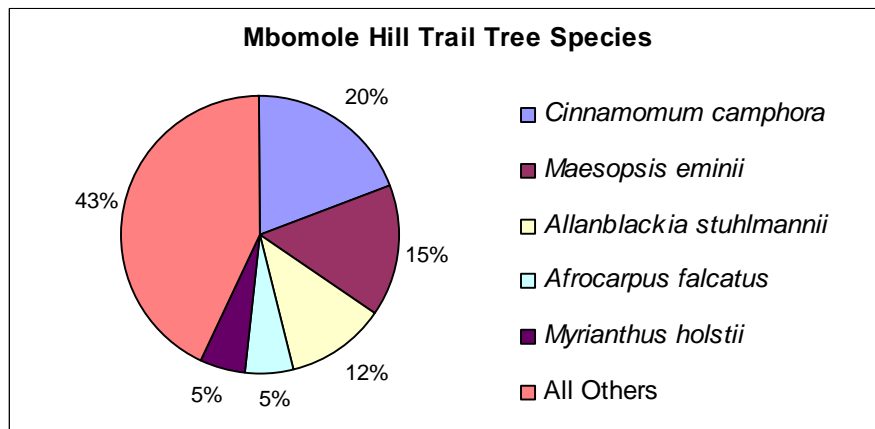
**Amani Nature Reserve, Tanzania**

**Mbomole Hill Trail**

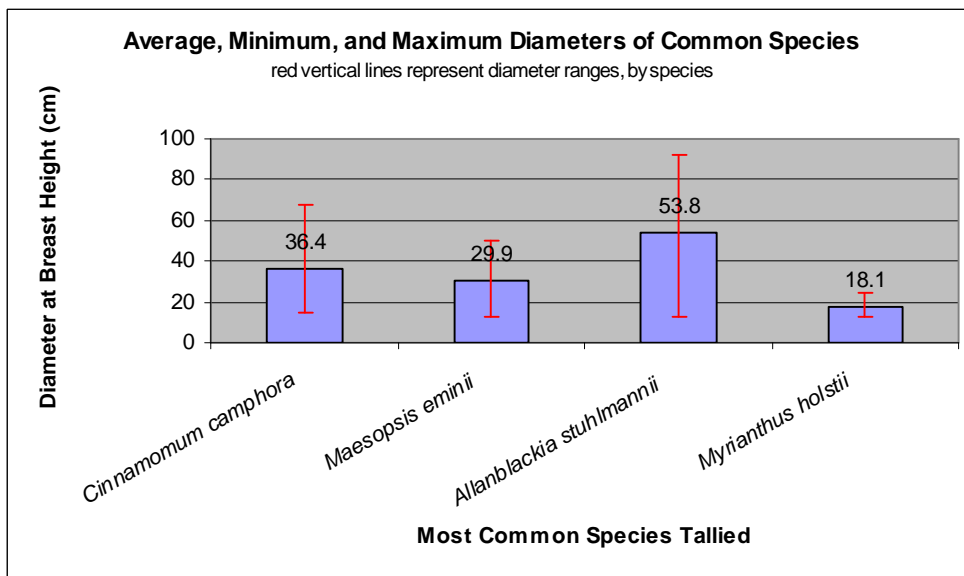
A total of five forested FHM plots were established and measured in the Mbomole Hill Trail Forest.

Mbomole Hill Trail Trees:

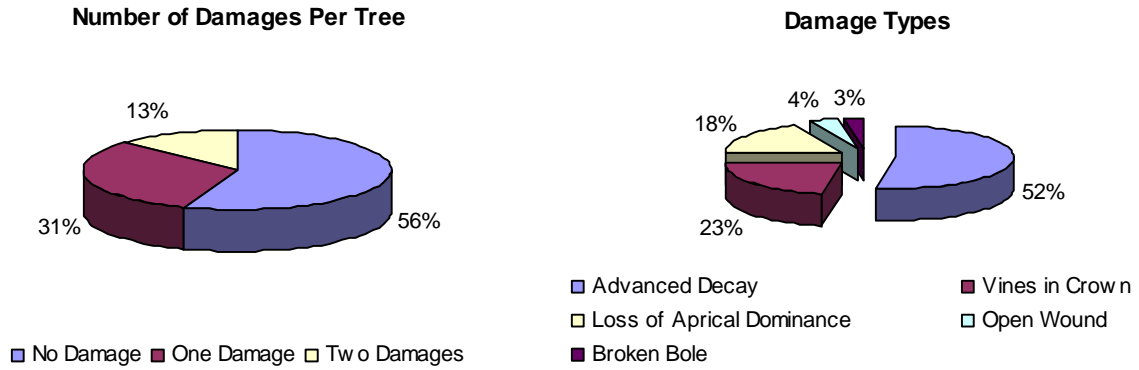
There were 37 species and 128 live trees sampled. Of these, 57% were species *Cinnamomum camphora* (L.) J. Presl. (non-native invasive), *Maesopsis eminii* Engl. (non-native invasive), *Allanblackia stuhlmannii* (Engl.) Wngl., *Afrocarpus falcatus* Pilger, and *Myrianthus holstii* Engl.



Average DBH for most common species ranged from 18.1 cm for *Myrianthus holstii* to 53.8 cm for *Allanblackia stuhlmannii*.

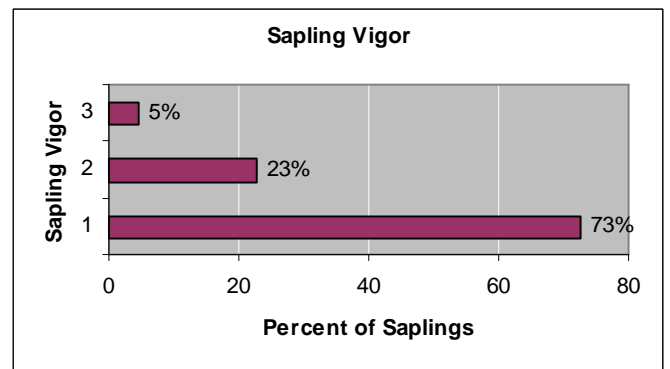
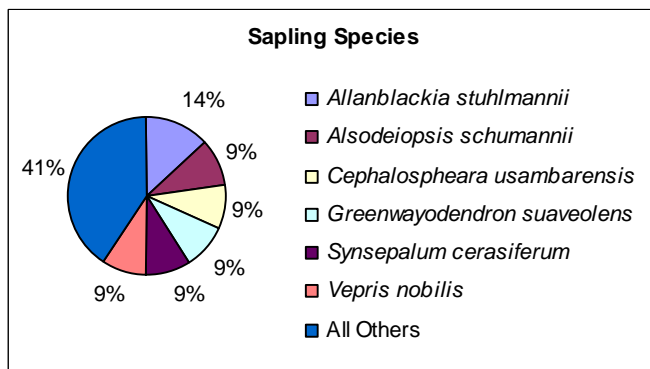


Of all trees measured, 71 had no damage, while 40 had one damage and 17 had two damages. Of the 74 damages found on 57 trees, the most frequently noted types were advanced decay, vines in crown, and loss of apical dominance.



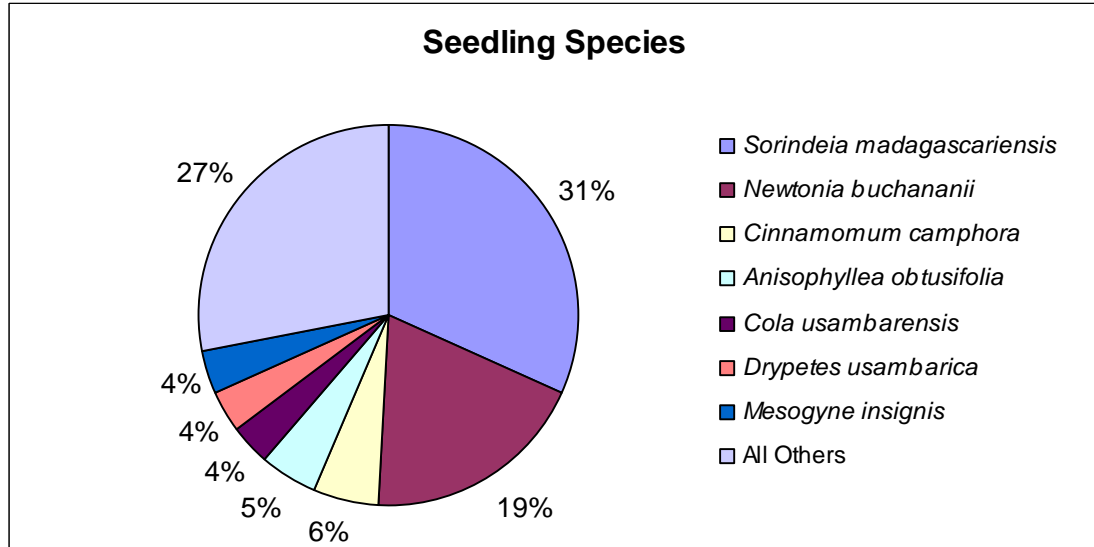
Mbomole Hill Trail Saplings:

There were 22 saplings and 15 species measured. Of those, 59% were species *A. stuhlmannii*, *Alsodeiopsis schumannii* (Engl.) Engl., *Cephalospheara usambarensis* (Warb.) Warb., *Greenwayodendron suaveolens* (Engl. & Diels) Verdc., *Synsepalum cerasiferum* (Welwitsch), and *Vepris nobilis* (Delile) W. Mziray. Most (96%) of the saplings had average to good vigor.



Mbomole Hill Trail Seedlings

There were 142 seedlings and 33 species measured. Of those, 73% were *Sorindeia madagascariensis* Thouars ex DC, *Newtonia buchananii* (Baker) Gilb. & Boutique, *C. camphora*, *Anisophyllea obtusifolia* Engl. & Brehmer, *Cola usambarensis* Engl., *Drypetes usambarica* (Pax) Hutch., and *Mesogyne insignis* Engl.

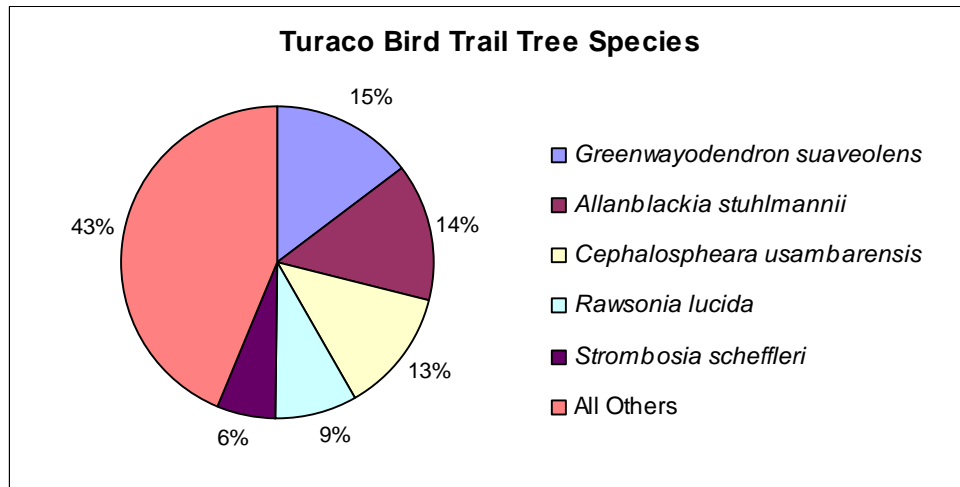


**Turaco Bird Trail, East Usambaras**

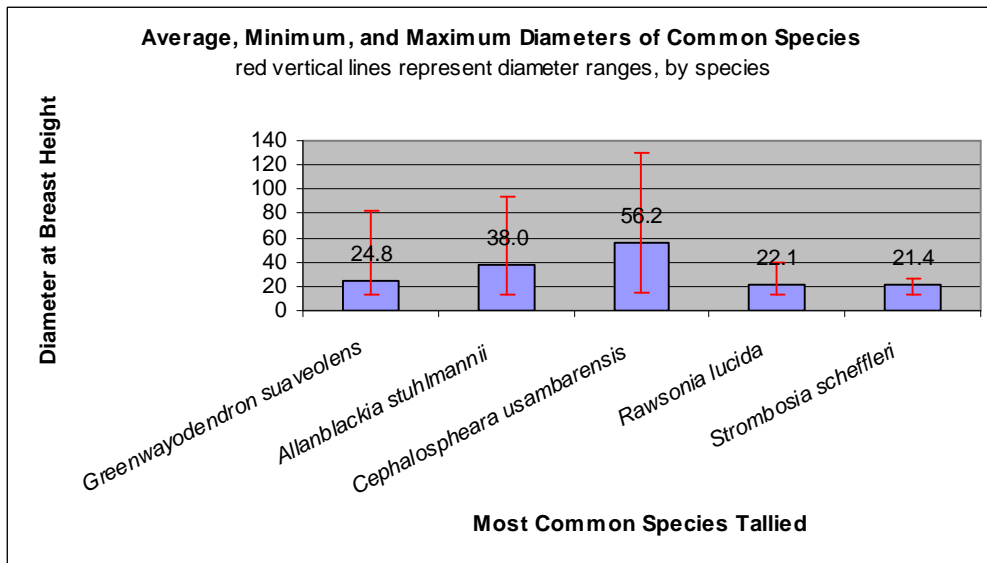
A total of six plots were established in the Turaco Bird Trail Forest area.

Turaco Bird Trail Forest Trees:

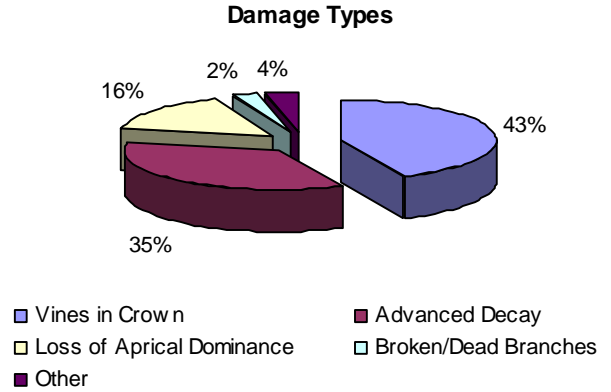
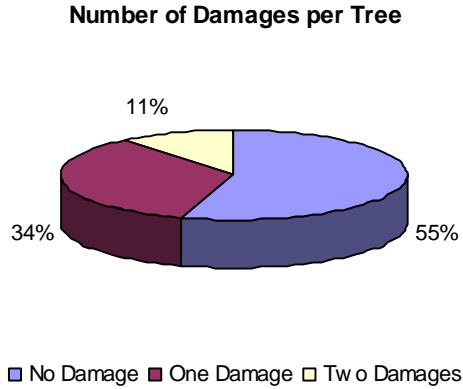
There were 149 live trees and 29 species measured in Turaco Bird Trail Forest. Of those, 56% were species *G. suaveolens*, *A. stuhlmannii*, *C. usambarensis*, *Rawsonia lucida* Harv. & Sond., and *Strombosia scheffleri* Engl.



The average DBH for the most common species ranged from 21.4 cm for *S. scheffleri* to 56.2 cm for *C. usambarensis*.

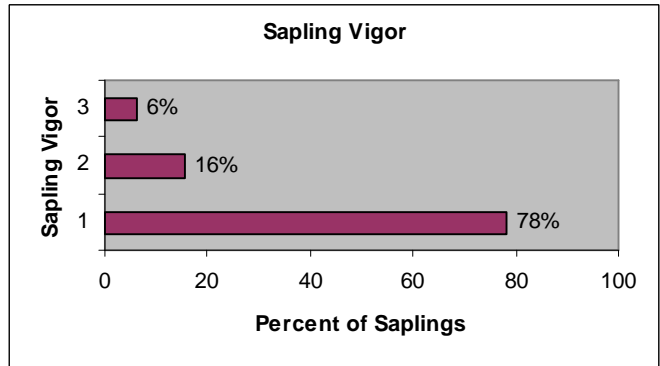
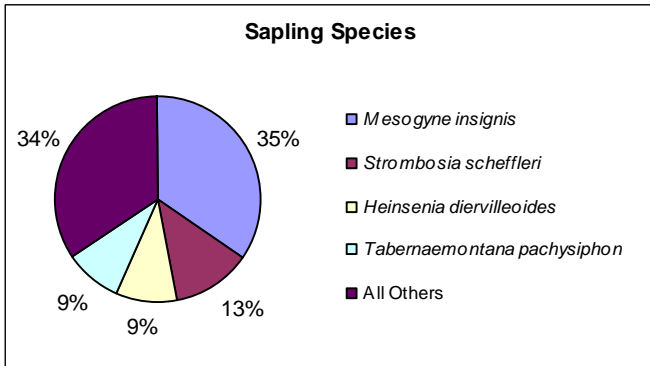


No damage was observed on 82 trees, while 51 had one damage and 16 had two damages. Of the 83 damages noted, the most common damages were vines in crown, advanced decay, and loss of apical dominance.



**Turaco Bird Trail Forest Saplings:**

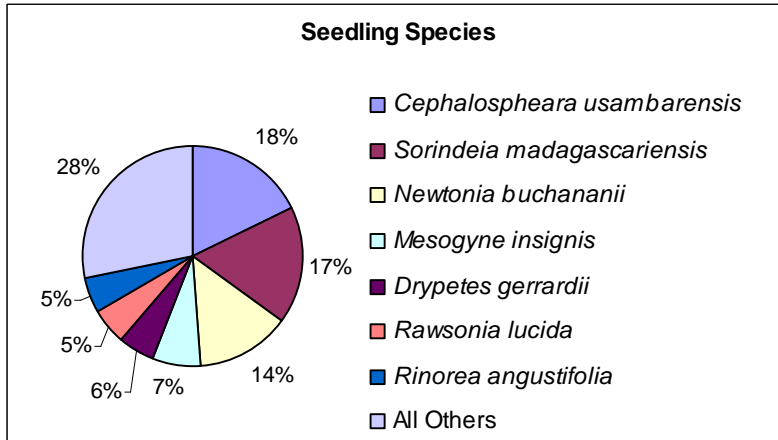
There were 32 saplings and 13 species measured in Turaco Bird Trail Forest. Of those, 66% were species *Mesogyne insignis* Engl., *S. scheffleri*, *Heinsenia diervilleoides* K. Schum., and *Tabernaemontana pachysiphon* Stapf. Ninety-four percent of the saplings had average to good vigor.





Turaco Bird Trail Forest Seedlings:

There were 392 seedlings and 38 species measured in Turaco Bird Trail. Of those, 61% were species *C. usambarensis*, *S. madagascariensis*, *N. buchananii*, *M. insignis*, *D. gerrardii*, *R. lucida*, and *Rinorea angustifolia* (Thouars) Baill.

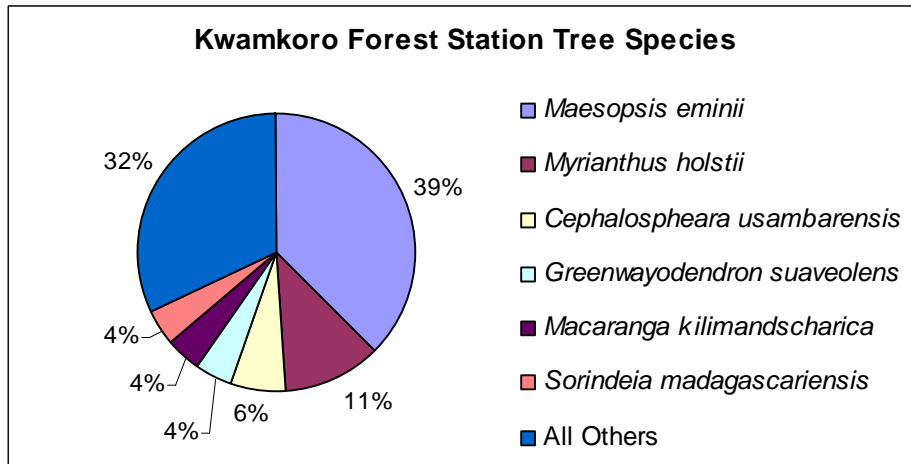


**Kwamkoro Forest Station, East Usambaras, Tanzania**

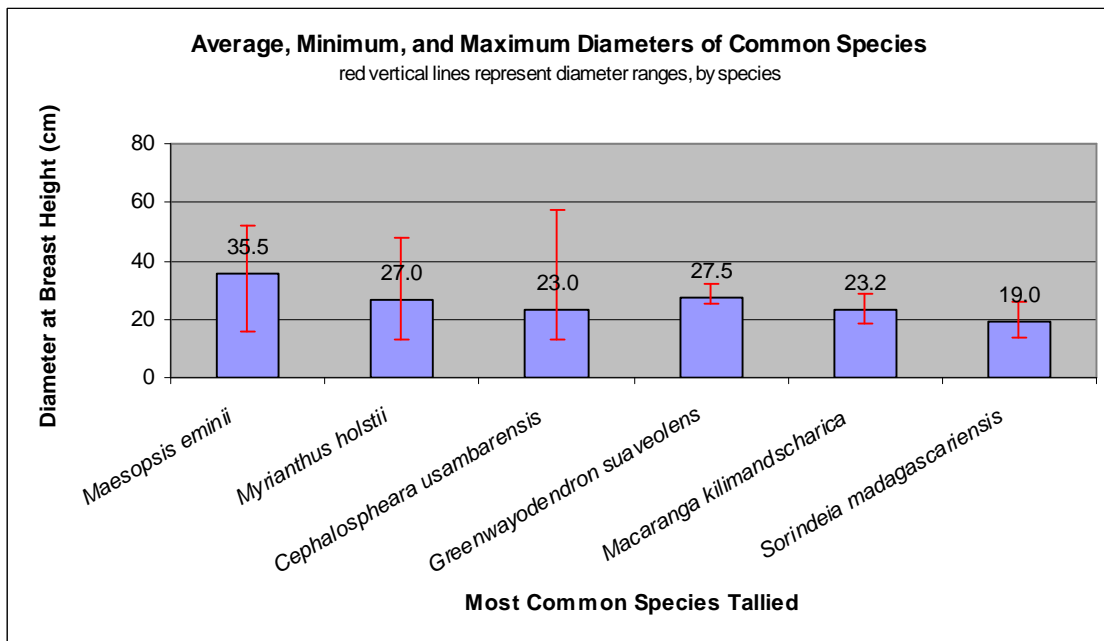
There were four plots established in Kwamkoro Forest Station.

Kwamkoro Forest Station Trees:

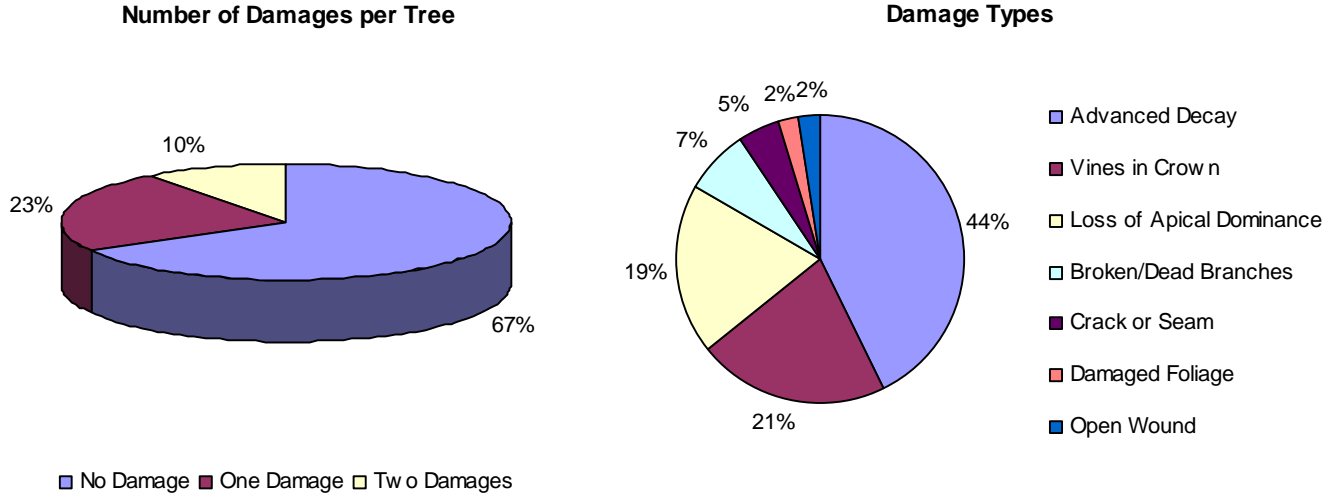
Of the 96 live trees and 29 species measured in Kwamkoro Forest Station, 68% were species *M. eminii* (non-native invasive), *Myrianthus holstii* Engl., *C. usambarensis*, *G. suaveolens*, *Macaranga kilimandscharica* Pax., and *S. madagascariensis*.



Of the most common species measured, the average DBH ranged from 19.0 cm for *S. madagascariensis* to 35.5 cm for *M. eminii*.

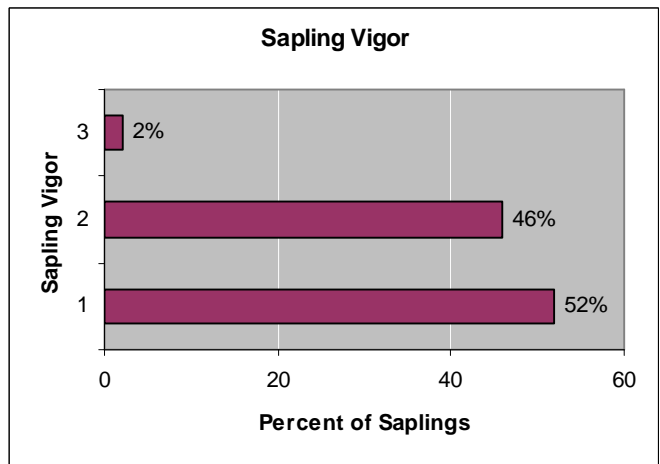
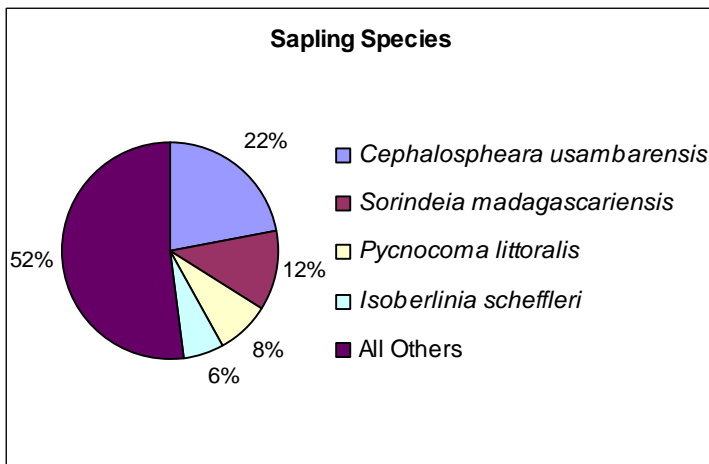


Of all live trees surveyed, 64 had no damage, while 22 had one damage and 10 had two damages. Of the 42 damages noted on 32 trees, the most common types were advanced decay, vines in crown, and loss of apical dominance.



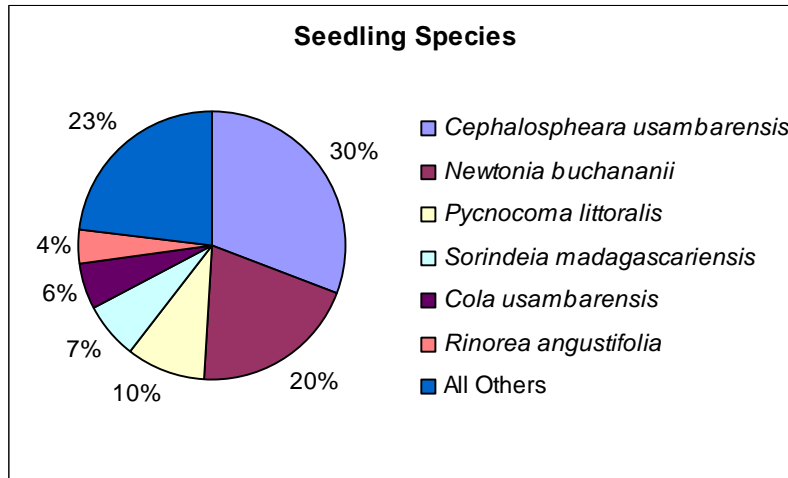
**Kwamkoro Forest Station Saplings:**

There were a total of 24 species and 50 saplings measured in Kwamkoro Forest Station. Of those, 72% were species *C. usambarensis*, *S. madagascariensis*, *Pycnocoma littoralis* Pax., *Isoberlinia scheffleri* (Harms) Greenway, *A. stuhlmannii*, *Macaranga capensis* (Baill.) Sim., *M. kilimandscharica*, *Millettia sacleuxii* Dunn, *Myrianthus holstii* Engl., and *Tabernaemontana pachysiphon* Staph. Ninety-eight percent of the saplings had average to good vigor.



Kwamkoro Forest Station Seedlings:

A total of 29 species and 195 seedlings were sampled. Of those, 77% were species *C. usambarensis*, *N. buchananii*, *P. littoralis*, *S. madagascariensis*, *Cola usambarensis* Engl., and *Rinorea angustifolia* (Thouars) Baill.

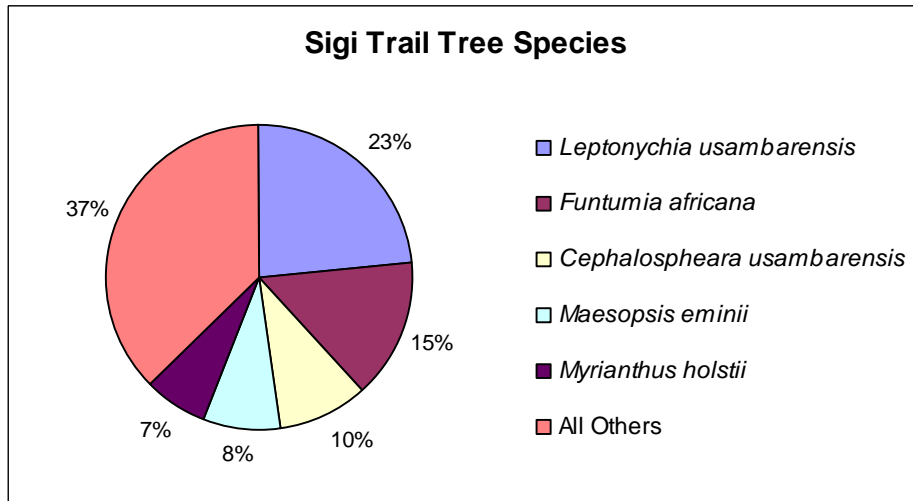


**Sigi Trail, East Usambaras, Tanzania**

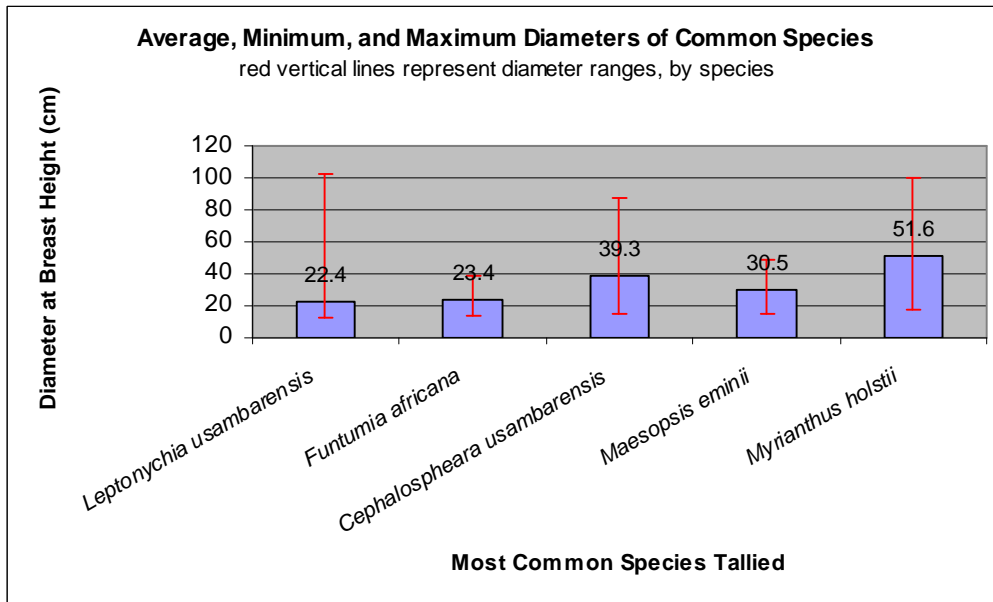
A total of five plots were established in Sigi Trail Forest.

Sigi Trail Forest Trees:

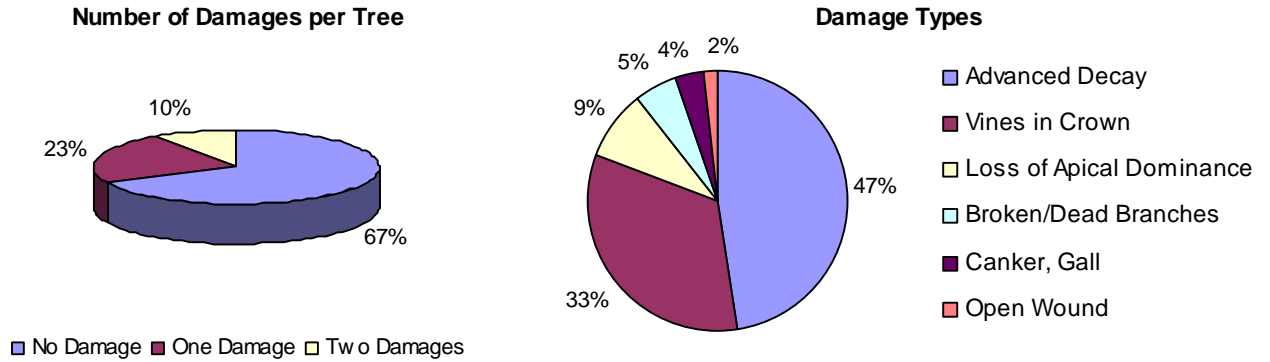
There were 136 live trees and 29 species sampled. The most common species (63%) were *Leptonychia usambarensis* K. Schum., *Funtumia africana* (Benth.) Stapf, *C. usambarensis*, *M. eminii*, and *Myrianthus holstii* Engl.



The average DBH for the most common species ranged from 22.4 cm for *L. usambarensis* to 51.6 cm for *M. holstii*.

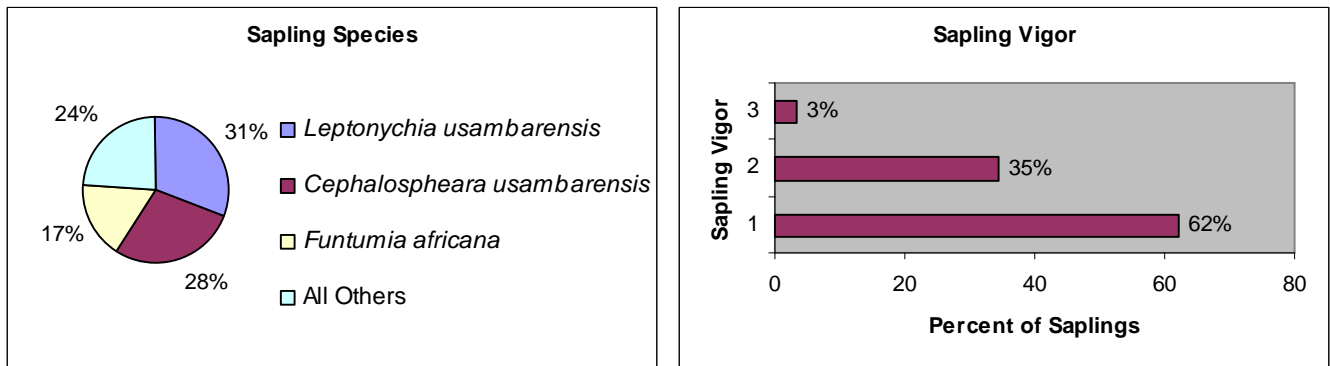


Ninety-two trees had no observable damages, 31 had one damage, and 13 trees had two damages. The most common damage types of the 57 damages measured were advanced decay, vines in crown and loss of apical dominance.



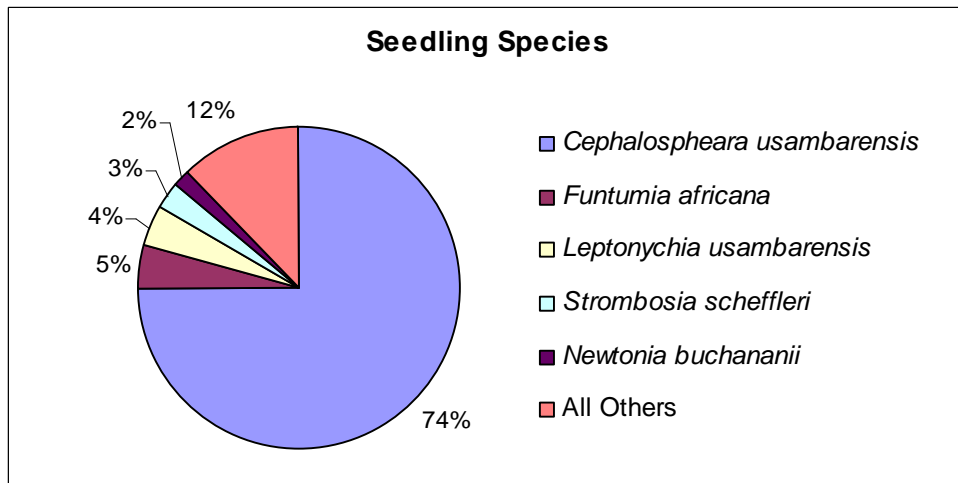
Sigi Trail Forest Saplings

There were 29 saplings and 9 species measured. Seventy-six percent were species *L. usambarensis*, *C. usambarensis*, and *F. africana*. Ninety-seven percent of the saplings had average to good vigor.



### Sigi Trail Forest Seedlings

There were 33 species and 603 seedlings surveyed. Of those, 88% were species *C. usambarensis*, *F. africana*, *L. usambarensis*, *S. scheffleri*, and *N. buchananii*.

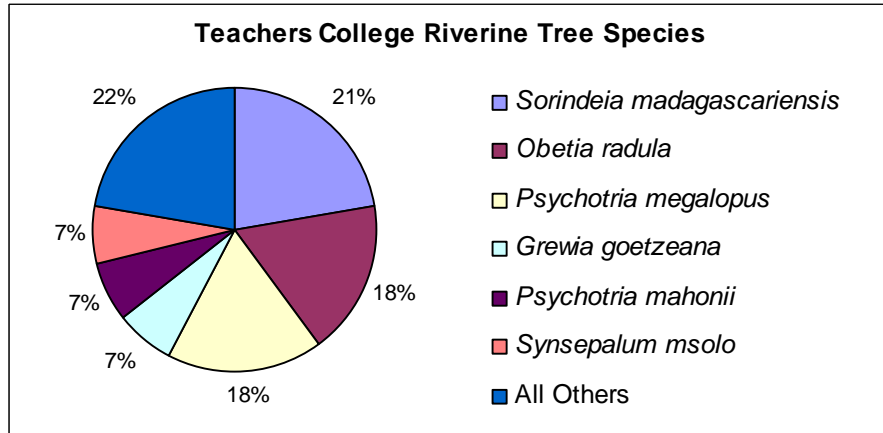


**Morogoro Teachers College Riverine Forest, Ulugurus, Tanzania**

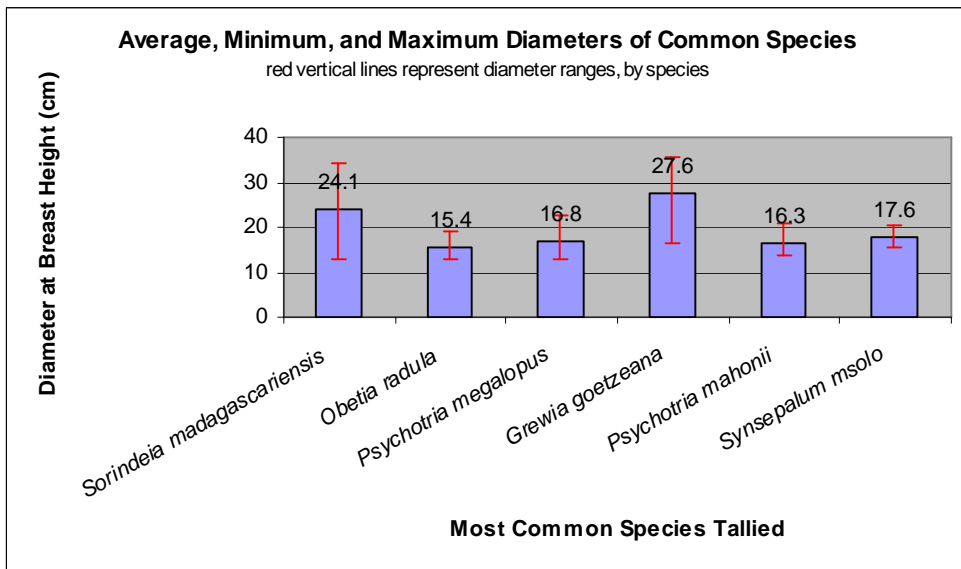
A total of three plots were established in Teachers College Riverine Forest.

Teachers College Riverine Forest Trees:

There were 45 live trees and 14 species sampled. The most common species (78%) were *Sorindeia madagascariensis* Thouars ex DC, *Obetia radula* (Baker) Baker ex B.D. Jacks., *Psychotria megalopus* Verdc., *Grewia goetzeana* K. Schum., *Psychotria mahonii* C.H. Wright, and *Synsepalum msolo* (Engl.) Pennington.

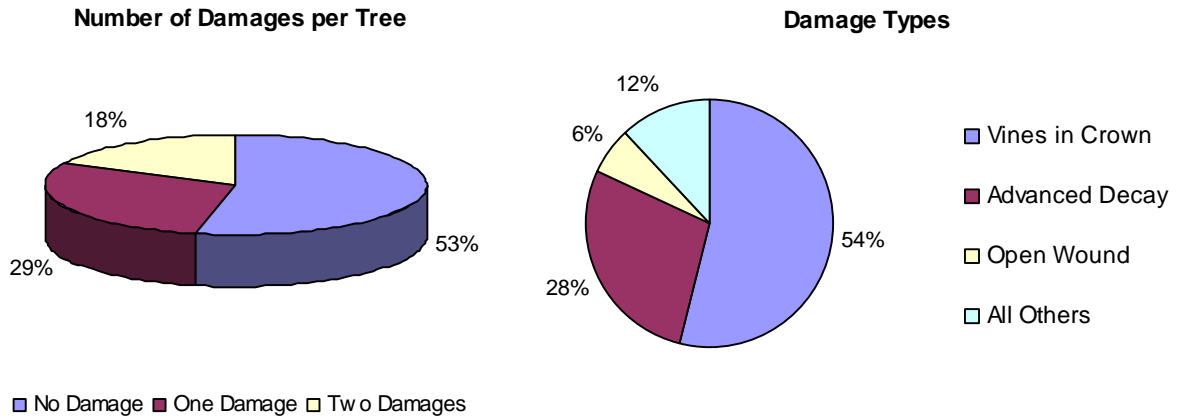


The average DBH of the most common species ranged from 15.4 cm for *O. radula* to 27.6 cm for *G. goetzeana*.



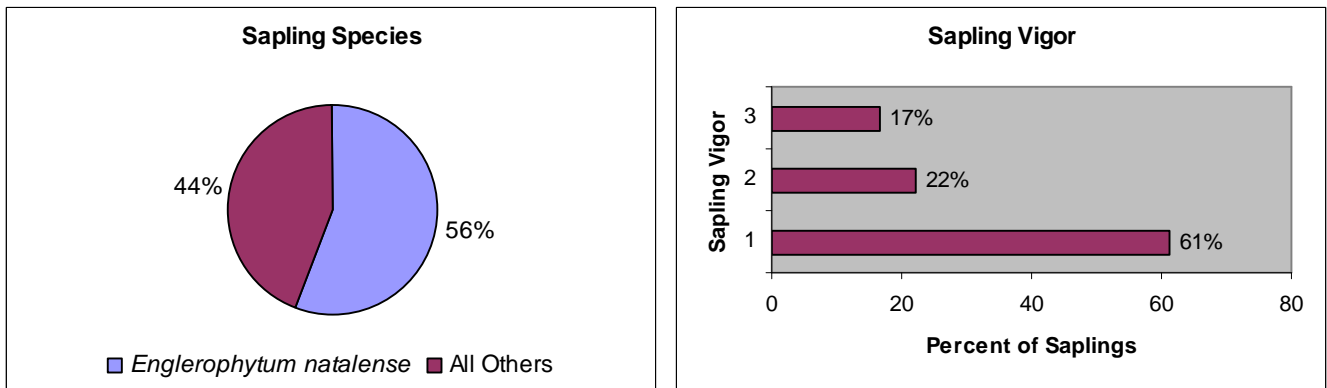


Eight trees had no damage, while 24 had one damage and 13 trees had two damages. Of the 50 damage types noted on 37 trees, the most common were vines in crown and advanced decay.



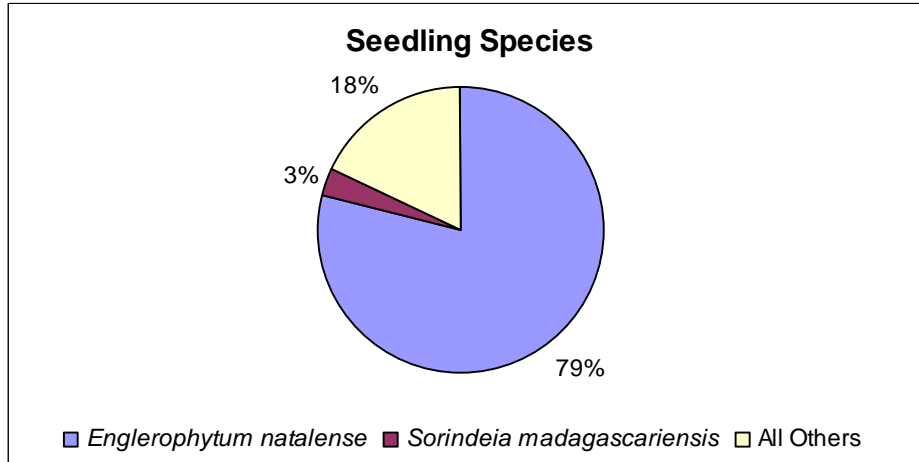
Teachers College Riverine Forest Saplings:

There were a total of 18 saplings and 9 species measured in the sample. These species were *Englerophytum natalense* (Sonder) Pennington, *Albizia gummifera* (J.F. Gmel.) C.A. Smith, *Blighia unijugata* Baker, *Carpolobia goetzei* Gürke, *Deinbollia kilimandscharica* Taub., *Diospyros whyteana* (Hiern) F. White, *O. radula*, *S. madagascariensis*, and *S. msolo*. Eighty-three percent of the saplings had average to good vigor.



Teachers College Riverine Forest Seedlings:

There were 100 seedlings and 14 species measured in the sample. Ninety-four percent of the seedlings were species *E. natalense*, *S. madagascariensis*, *Clausena anisata* (Willd.) Hook. f. ex Benth., *D. kilimandscharica*, *D. whyteana*, *Oxyanthus speciosus* DC, *P. mahonii*, *S. msolo*.

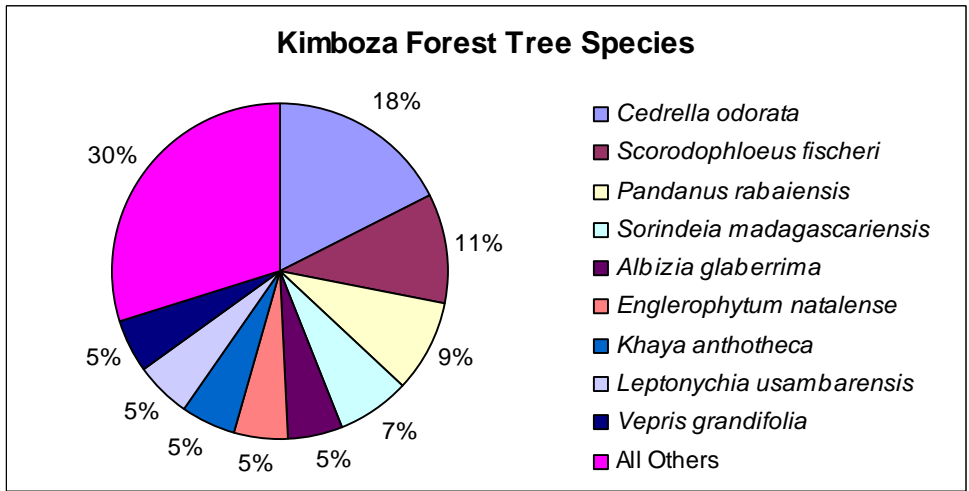


**Kimboza Forest, Tanzania**

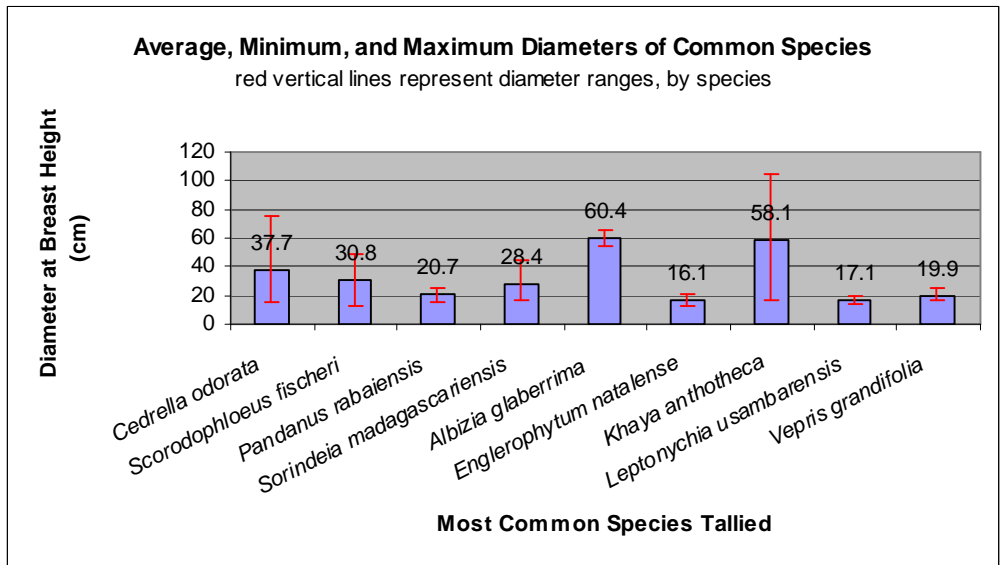
A total of three plots were established in Kimboza Forest.

Kimboza Forest Trees:

A total of 24 species and 57 live trees were measured. Seventy percent of the live trees were species *Cedrella odorata* L (non-native invasive), *Scorodophloeus fischeri* (Taubert) J. Léonard, *Pandanus rabaiensis* Rendle, *Sorindeia madagascariensis* DC, *Albizia glaberrima* (Schum. & Thonn.) Benth., *Englerophytum natalense* (Sonder) Pennington, *Khaya anthothea* (Welw.) C. DC, *Leptonychia usambarensis* K. Schum., and *Vepris grandifolia* Engl.

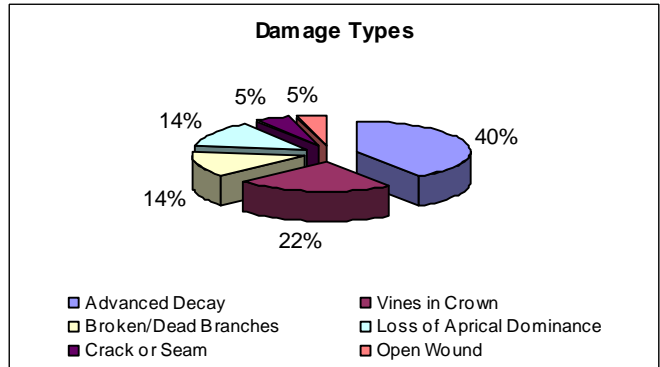
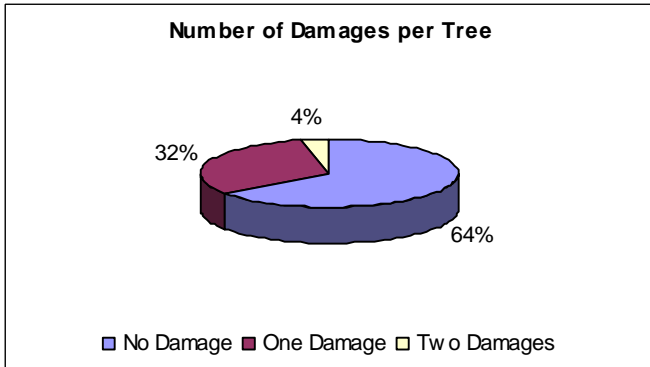


The average DBH for the most common species ranged from 17.1 cm for *L. usambarensis* to 60.4 cm for *A. glaberrima*.



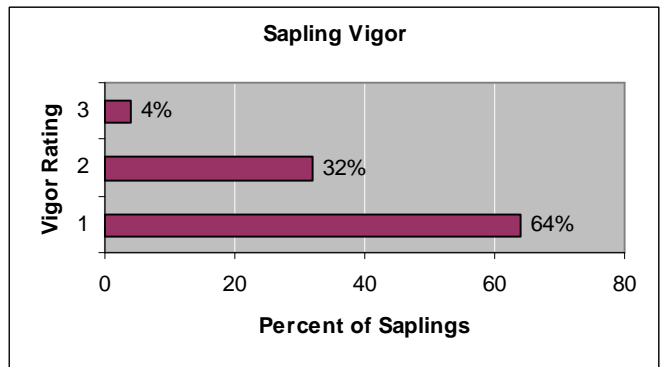
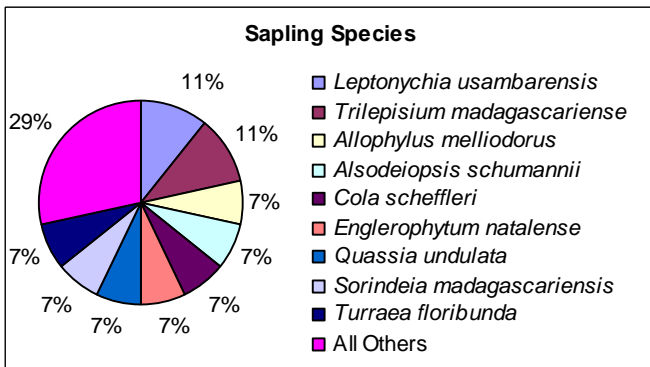
Tree Damage:

There was no observable damage on 37 trees, 18 trees had one damage and 2 trees had two damages. Of the 22 damages found on 20 trees, the most frequent types were advanced decay and vines in crown.



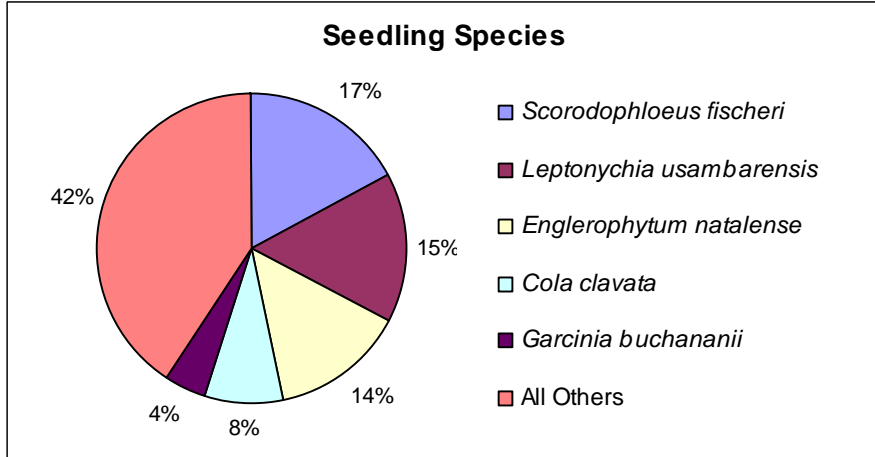
Kimboza Forest Saplings

There were 17 species and 28 saplings in the sample. Of those, 71% were species *L. usambarensis*, *Trilepisium madagascariense* DC, *Allophylus melliodorus* Radlk., *Alsodeiopsis schumannii* (Engl.) Engl., *Cola scheffleri* K. Schum., *E. natalense*, *Quassia undulate* (Guill. & Perr.) D. Dietr., *S. madagascariensis*, and *Turraea floribunda* Hochst.. Ninety-six percent of the saplings had average to good vigor.



Kimboza Forest Seedlings

There were 50 species and 330 seedlings measured in the sample. Of those, 59% were species *S. fischeri*, *L. usambarensis*, *E. natalense*, *Cola clavata* Mast., and *Garcinia buchananii* Baker.



## Conclusions & Recommendations

This report summarizes baseline data collected in the 2000 and 2001 Forest Health Monitoring field efforts in Kenya and Tanzania, East Africa. Forty-three field plots were established on eight separate forests in the Eastern Arc Mountains spanning these two countries. We tallied a total of 1152 trees (1111 live trees and 41 dead standing), 283 saplings (2.54 cm to <12.7 cm), and 2477 (<2.54 cm and >15 cm in length) seedlings in this initial field effort. Though individual tree tallies may appear large, plots are few, and we have not yet remeasured baseline plots. Nonetheless, this report gives the status of conditions, in a limited fashion, for these forest areas and for these particular plots. We will rely on future remeasurement of baseline conditions to assess trends in forest health.

Some preliminary conclusions are that a few tree species often make up the majority of forest cover in a given region of the Eastern Arc Mountains. Does this assessment signal a loss of diversity, or are some species naturally generalists in these regions? Could a given forest's proximity to human disturbance – for example, road building, land clearing, or illegal tree felling – increase the survivorship of generalist, or weedy species, in addition to the scarcity of certain valuable timber species (such as *Ocotea usambarensis* in the Taita Hills).

Because species have widely different crown forms it is more difficult to assess cumulative crown conditions. Once we amass a large enough tree sample, we may zero in on particular species values. However, this preliminary analysis shows that most trees tallied on these plots have healthy crown conditions.

An average of 57 percent of trees 12.7 cm diameter and greater had no damage at all. This figure is comparable to forest damage assessments published in the United States (Stolte 1997, Rogers *et al.* 2001). The most common tree damages were “advanced decay” and “vines in crown.” While these damages may cause debilitating, or life threatening, damage to North American trees (where the damage system was developed) it is unclear exactly how they affect East African species. In some instances, investigative or follow-up work will be needed to interpret the meaning of certain baseline measures.

In summary, we have taken a tree-based approach to our preliminary assessment of forest health in parts of these select East African mountain ranges. As an overall statement, we have found predominantly healthy conditions among the trees of this area. However, we must stress the preliminary and small sample-size nature of this status report. It is clear that plot remeasurement and installment of a greater number of baseline plots will yield statistically stronger results.

So, in the end, we see that a true forest health assessment will include a multi-layered sample approach that combines the non-biased aerial coverage of remote sensing with the detailed systematic measurement of ground plots over time. In this way, we recommend continued work with regional agencies and local villagers to apply the most up-to-date forest health assessments to dynamic contemporary forest issues in Kenya and Tanzania.

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## Appendix A - Number of Live Seedling, Sapling and Tree Species by Forest

Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza	Total
<i>Afrocarpus falcatus</i>	0	0	9	0	0	0	0	0	9
<i>Alangium chinense</i>	0	0	0	0	0	1	0	0	1
<i>Albizia adianthifolia</i>	0	0	0	0	0	1	0	0	1
<i>Albizia glaberrima</i>	0	0	0	0	0	0	0	4	4
<i>Albizia grandibracteata</i>	0	0	0	0	0	0	2	2	4
<i>Albizia gummifera</i>	35	29	0	3	1	3	1	0	72
<i>Allanblackia stuhlmannii</i> *	0	0	20	22	5	0	0	0	47
<i>Allophylus abyssinicus</i>	1	0	0	0	0	0	0	0	1
<i>Allophylus melliodorus</i>	0	0	0	0	1	0	0	2	3
<i>Alsodeiopsis schumannii</i> *	0	0	3	5	0	0	0	6	14
<i>Angylocalyx braunii</i> *	0	0	2	0	0	0	0	2	4
<i>Anisophyllea obtusifolia</i>	0	0	10	10	0	0	0	0	20
<i>Annickia kummeriae</i> *	0	0	0	0	0	2	0	0	2
<i>Anthocleista grandiflora</i>	0	0	3	1	3	0	0	0	7
<i>Antiaris toxicaria</i>	0	0	0	0	0	6	0	0	6
<i>Aphloia theiformis</i>	4	0	0	0	0	0	0	0	4
<i>Beilschmiedia kweo</i> *	0	0	0	2	0	0	0	0	2
<i>Bersama abyssinica</i>	2	0	0	0	1	1	0	10	14
<i>Blighia unijugata</i>	0	0	1	4	0	8	3	11	27
<i>Bridelia brideliifolia</i>	0	0	0	0	0	0	1	0	1
<i>Brucea antidysenterica</i>	2	0	0	0	0	0	0	0	2
<i>Canthium oligocarpum</i>	5	0	0	0	0	0	0	0	5
<i>Carpolobia goetzei</i>	0	0	0	0	0	0	1	0	1
<i>Casearia battiscombei</i>	0	0	0	0	0	0	0	2	2
<i>Cassipourea gummiflua</i>	0	0	0	1	0	0	0	0	1
<i>Cassipourea malosana</i>	0	0	0	0	1	0	0	0	1
<i>Castilla elastica</i>	0	0	0	0	0	10	0	0	10
<i>Cedrella odorata</i>	0	0	0	0	0	0	0	15	15
<i>Celtis africana</i>	0	0	0	0	1	0	0	0	1
<i>Celtis gomphophylla</i>	0	0	0	0	2	0	0	0	2
<i>Celtis mildbraedii</i>	0	0	0	1	0	0	0	0	1
<i>Cephalosphaera usambarensis</i> *	0	0	6	89	77	471	0	0	643
<i>Chrysophyllum gorungosanum</i>	1	0	0	1	0	0	0	0	2
<i>Chrysophyllum perpulchrum</i>	0	0	1	2	2	2	0	0	7
<i>Cinnamomum camphora</i>	0	0	35	0	0	0	0	0	35
<i>Clausena anisata</i>	1	0	0	0	0	0	2	0	3
<i>Coffea fadenii</i> *	4	0	0	0	0	0	0	0	4
<i>Cola clavata</i>	0	0	0	0	0	0	1	27	28
<i>Cola greenwayi</i>	50	0	2	12	1	0	0	0	65
<i>Cola scheffleri</i> *	0	0	0	0	0	0	0	8	8
<i>Cola usambarensis</i>	0	0	8	3	12	0	0	0	23
<i>Combretum schumannii</i>	0	0	0	0	0	0	0	5	5
<i>Cordia africana</i>	0	0	0	0	0	0	1	0	1
<i>Craibia zimmermanni</i>	109	0	0	0	0	0	0	0	109
<i>Croton megalocarpus</i>	4	0	0	0	0	0	0	0	4
<i>Croton sylvaticus</i>	0	0	0	0	0	0	0	1	1
<i>Cryptocarya liebertiana</i>	0	0	0	0	2	0	0	0	2
<i>Cupressus lusitanica</i>	11	6	0	0	0	0	0	0	17

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Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza	Total
<i>Cussonia spicata</i>	12	1	0	0	0	0	0	0	13
<i>Cylicomorpha parviflora</i>	0	0	0	0	0	0	0	1	1
<i>Cynometra brachyrrachis</i> *	0	0	0	1	0	0	0	0	1
<i>Cynometra sp.</i>	0	0	0	1	0	0	0	0	1
<i>Cynometra suaheliensis</i> *	0	0	0	0	0	2	0	0	2
<i>Dasylepis integra</i> *	23	0	0	0	0	0	0	0	23
<i>Deinbollia kilimandscharica</i>	0	0	2	0	1	0	3	3	9
<i>Diospyros abyssinica</i>	4	0	0	0	0	0	0	0	4
<i>Diospyros amaniensis</i> *	0	0	1	1	0	0	0	0	2
<i>Diospyros greenwayi</i> *	0	0	0	0	0	0	1	0	1
<i>Diospyros whyteana</i>	0	0	0	0	0	0	4	0	4
<i>Dracaena laxissima</i>	7	0	0	0	0	0	0	0	7
<i>Dregea abyssinica</i>	0	0	0	0	0	0	0	1	1
<i>Drypetes gerrardinooides</i>	12	0	1	26	3	0	0	6	48
<i>Drypetes natalensis</i>	0	0	3	0	0	0	0	4	7
<i>Drypetes usambarica</i>	0	0	6	7	0	0	0	0	13
<i>Ehretia cymosa</i>	0	2	0	0	0	0	0	0	2
<i>Ekebergia capensis</i>	5	0	0	0	0	0	0	0	5
<i>Enantia kummeriae</i>	0	0	2	0	0	1	0	0	3
<i>Englerodendron usambarense</i> *	0	0	9	3	0	0	0	0	12
<i>Englerophytum natalense</i>	0	0	0	0	0	0	89	51	140
<i>Erica arborea</i>	1	0	0	0	0	0	0	0	1
<i>Erythrococca usambarica</i>	3	0	0	0	0	0	0	0	3
<i>Erythrophleum suaveolens</i>	0	0	0	0	0	1	0	0	1
<i>Erythroxyllum emarginatum</i>	0	0	0	0	0	0	0	1	1
<i>Eucalyptus saligna</i>	0	3	0	0	0	0	0	0	3
<i>Ficus exasperata</i>	0	0	0	0	0	1	1	0	2
<i>Ficus sur</i>	0	0	0	0	1	1	0	0	2
<i>Ficus thonningii</i>	0	1	0	0	0	0	0	0	1
<i>Ficus vallis-choudae</i>	0	0	0	0	0	5	2	0	7
<i>Funtumia africana</i>	0	0	2	0	0	53	0	0	55
<i>Garcinia buchananii</i>	0	0	0	0	0	0	0	14	14
<i>Garcinia smeathmannii</i>	0	0	0	0	0	0	0	3	3
<i>Garcinia volkensii</i>	24	0	0	0	0	0	0	0	24
<i>Greenwayodendron suaveolens</i>	0	0	6	32	6	0	0	0	44
<i>Grevillea robusta</i>	0	1	0	0	0	0	0	0	1
<i>Grewia goetzeana</i>	0	0	0	0	0	0	3	1	4
<i>Heinsenia diervilleoides</i>	1	0	1	16	0	2	0	0	20
<i>Isobertinia scheffleri</i> *	0	0	0	1	6	0	0	2	9
<i>Jambosa jambos</i>	0	0	0	0	0	7	0	0	7
<i>Khaya anthotheca</i> *	0	0	0	0	0	0	0	3	3
<i>Lepidiotrichilia volkensii</i>	0	1	0	0	0	0	0	0	1
<i>Leptonychia usambarenensis</i>	14	12	2	9	0	66	0	57	160
<i>Macaranga capensis</i>	0	0	0	2	3	0	0	0	5
<i>Macaranga conglomerata</i> *	47	15	0	0	0	0	0	0	62
<i>Macaranga kilimandscharica</i>	0	0	3	0	6	0	0	0	9
<i>Maesa lanceolata</i>	21	1	0	0	1	0	0	0	23
<i>Maesopsis eminii</i>	0	0	19	2	37	13	0	0	71
<i>Mangifera indica</i>	0	0	0	0	0	0	0	2	2
<i>Manilkara mochisia</i>	1	0	0	0	0	0	0	0	1

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Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza	Total
<i>Manilkara obovata</i>	0	0	0	0	0	0	0	1	1
<i>Manilkara sulcata</i>	2	0	0	0	0	0	0	1	3
<i>Maranthes goetzeniana</i>	0	0	2	0	0	0	0	0	2
<i>Margaritaria discoidea</i>	0	0	0	0	0	1	0	0	1
<i>Maytenus acuminata</i>	0	0	0	1	0	0	0	1	2
<i>Melanodiscus oblongus</i>	3	0	0	0	0	0	0	0	3
<i>Memecylon teitense</i> *	1	0	0	0	0	0	0	0	1
<i>Mesogyne insignis</i> *	0	0	7	38	5	3	0	0	53
<i>Milicia excelsa</i>	0	0	0	0	0	1	0	0	1
<i>Millettia oblata</i>	28	3	0	0	0	0	0	0	31
<i>Millettia sacleuxii</i> *	0	0	0	0	6	0	0	0	6
<i>Mimusops kummel</i>	0	0	0	0	0	0	0	2	2
<i>Morinda asteroscepa</i> *	0	0	1	0	0	0	0	0	1
<i>Myrianthus holstii</i>	0	0	8	10	15	12	0	1	46
<i>Myrsine melanophloeos</i>	16	4	0	0	0	0	0	0	20
<i>Mystrolyon aethiopicum</i>	2	0	0	0	0	0	0	0	2
<i>Neoboutonia macrocalyx</i>	0	1	0	0	0	0	0	0	1
<i>Newtonia buchananii</i>	34	0	28	59	41	10	0	0	172
<i>Nuxia congesta</i>	1	0	0	0	0	0	0	0	1
<i>Obetia radula</i>	0	0	0	0	0	0	9	0	9
<i>Ochna holstii</i>	21	0	2	0	0	0	0	7	30
<i>Ochna insculpta</i>	3	0	0	0	0	0	0	0	3
<i>Ocotea usambarensis</i>	1	0	0	0	0	0	0	0	1
<i>Ouratea scheffleri</i> *	1	3	0	0	0	0	0	0	4
<i>Oxyanthus speciosus</i>	16	0	0	5	0	2	2	2	27
<i>Pancovia golungensis</i>	0	0	0	0	0	0	0	1	1
<i>Pandanus rabaiensis</i>	0	0	0	0	0	0	0	5	5
<i>Parinari excelsa</i>	0	0	6	2	3	2	0	0	13
<i>Pauridiantha paucinervis</i>	2	0	0	0	0	0	0	0	2
<i>Pavetta hymenophylla</i>	0	0	0	0	0	0	0	1	1
<i>Peddiea fischeri</i>	0	0	0	0	0	0	0	1	1
<i>Phoenix reclinata</i>	35	59	0	0	0	0	0	0	94
<i>Pinus patula</i>	19	0	0	0	0	0	0	0	19
<i>Placodiscus pedicellatus</i>	0	0	0	0	0	0	0	2	2
<i>Pleiocarpa pycnantha</i>	2	8	0	0	0	0	0	0	10
<i>Podocarpus latifolius</i>	8	0	0	0	0	0	0	0	8
<i>Polyscias fulva</i>	7	5	2	0	1	0	0	0	15
<i>Polyscias stuhlmannii</i>	8	0	0	0	0	0	0	0	8
<i>Polysphaeria macrantha</i> *	0	0	0	0	0	0	0	2	2
<i>Pouteria adolfi-friedericii</i>	10	0	4	7	5	2	0	0	28
<i>Pouteria alnifolia</i>	0	0	0	0	0	0	0	3	3
<i>Premna schliebenii</i> *	0	0	0	0	1	0	0	0	1
<i>Prunus africana</i> *	0	1	0	0	0	0	0	0	1
<i>Psychotria alsophila</i> *	21	0	0	0	0	0	0	0	21
<i>Psychotria crassipetala</i> *	12	0	0	0	0	0	0	0	12
<i>Psychotria goetzei</i>	0	0	0	0	0	0	0	1	1
<i>Psychotria mahonii</i>	0	0	0	0	0	0	5	0	5
<i>Psychotria megalopus</i> *	0	0	0	0	0	0	9	1	10
<i>Psychotria orophila</i>	5	0	0	0	0	0	0	0	5
<i>Psychotria petiti</i> *	35	0	0	0	0	0	0	0	35
<i>Psychotria pseudoplatyphylla</i> *	9	0	0	0	0	0	0	0	9

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Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza	Total
<i>Psydrax parviflora</i>	0	0	0	1	0	0	1	3	5
<i>Psydrax schimperiana</i>	0	0	0	0	0	0	0	1	1
<i>Pterocarpus tinctorius</i>	0	0	1	0	0	0	0	0	1
<i>Pycnocomma littoralis</i> *	0	0	0	0	23	0	0	0	23
<i>Quassia undulata</i>	0	0	2	5	4	7	0	5	23
<i>Rawsonia lucida</i>	0	0	1	35	2	0	0	0	38
<i>Rawsonia reticulata</i>	0	0	0	7	0	0	0	0	7
<i>Rhamnus prinoides</i>	0	0	0	0	0	0	0	1	1
<i>Ricinodendron heudelotii</i>	0	0	0	0	0	1	0	2	3
<i>Rinorea angustifolia</i>	0	0	0	21	8	4	0	0	33
<i>Ritchiea albersii</i>	0	1	0	0	0	0	0	0	1
<i>Rytigynia eickii</i> *	1	0	0	0	0	0	0	0	1
<i>Rytigynia uhligii</i>	7	0	0	0	0	0	0	0	7
<i>Sapium ellipticum</i>	0	0	2	0	2	0	0	0	4
<i>Schefflerodendron usambarense</i>	0	0	1	5	0	0	0	0	6
<i>Scorodophloeus fischeri</i>	0	0	0	0	0	0	0	64	64
<i>Solanecio mannii</i>	0	0	0	0	0	0	0	4	4
<i>Sorindeia madagascariensis</i>	0	0	48	77	23	11	14	16	189
<i>Spathoclea companulata</i>	0	0	0	0	1	0	0	0	1
<i>Stadmania oppositifolia</i>	0	0	0	0	0	0	0	1	1
<i>Sterculia appendiculata</i>	0	0	0	0	0	2	0	0	2
<i>Strombosia scheffleri</i>	37	4	1	18	1	20	0	1	82
<i>Strychnos stuhlmanii</i>	0	0	0	0	0	1	0	0	1
<i>Suregada procera</i>	0	0	0	1	0	0	0	0	1
<i>Suregada zanzibariensis</i>	0	0	0	4	0	0	0	0	4
<i>Synsepalum cerasiferum</i>	0	0	7	7	5	1	0	0	20
<i>Synsepalum msolo</i>	0	0	0	0	0	14	6	0	20
<i>Syzygium guineense</i>	44	3	1	1	0	0	0	0	49
<i>Syzygium micklethwaitii</i>	0	43	0	0	0	0	0	0	43
<i>Tabernaemontana pachysiphon</i>	0	0	0	8	9	1	0	0	18
<i>Tabernaemontana stapfiana</i>	60	119	0	0	0	0	0	2	181
<i>Tarrenna pavetoides</i>	0	0	0	0	0	1	0	0	1
<i>Tarrenna nigrenscens</i>	0	0	1	0	0	0	0	0	1
<i>Teclea nobilis</i>	1	0	0	0	0	0	0	0	1
<i>Teclea trichocarpa</i>	44	0	0	0	0	0	0	0	44
<i>Tricalysia pallens</i>	0	0	0	0	7	0	0	3	10
<i>Trichillia dregeana</i>	0	0	1	1	0	10	0	0	12
<i>Trilepisium madagascariense</i>	0	0	0	1	0	2	0	4	7
<i>Trimeria grandifolia</i>	1	0	0	0	0	0	0	0	1
<i>Turraea floribunda</i>	0	0	0	0	0	0	1	3	4
<i>Turraea holstii</i>	2	0	0	0	0	0	0	0	2
Unknown1	0	0	0	0	0	1	0	0	1
Unknown2	0	0	0	0	0	1	0	0	1
Unknown3	0	0	0	0	0	0	0	1	1
Unknown4	3	0	0	0	0	0	0	0	3
Unknown5	4	0	0	0	0	0	0	0	4
<i>Uvariadendron usambarense</i> *	0	0	0	0	0	0	0	6	6
<i>Vangueria volkensii</i>	10	0	0	0	0	0	0	0	10

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Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza	Total
<i>Vepris grandifolia</i>	0	0	0	0	2	0	0	3	5
<i>Vepris nobilis</i>	0	0	2	1	0	0	0	13	16
<i>Vepris simplicifolia</i>	0	0	0	0	0	0	0	4	4
<i>Vernonia schimperi</i>	0	0	0	0	0	0	0	2	2
<i>Vitex keniensis</i>	2	0	0	0	0	0	0	0	2
<i>Xylopia parviflora</i>	0	0	1	0	0	0	1	0	2
<i>Xymalos monospora</i>	20	51	6	0	3	0	0	0	80
<i>Zanha golungensis</i>	0	0	0	0	0	1	0	0	1
<i>Zanthoxylum gillettii</i>	0	0	0	0	1	0	0	0	1
<i>Zenkerella egregia</i> *	0	0	0	1	0	0	0	0	1
Total	942	377	292	573	341	768	163	415	3871

\* Globally threatened tree species from 2002 IUCN Red List of Threatened Species ([www.redlist.org](http://www.redlist.org))

## Appendix B - Average DBH of All Live Trees &gt;12.7cm DBH

Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza
<i>Alangium chinense</i>	.	.	.	.	.	85.2	.	.
<i>Albizia adianthifolia</i>	.	.	.	.	.	29.5	.	.
<i>Albizia glaberrima</i>	.	.	.	.	.	.	.	60.4
<i>Albizia grandibracteata</i>	.	.	.	.	.	.	32.8	.
<i>Albizia gummifera</i>	36.8	58.1	.	37.4	.	60.1	.	.
<i>Allanblackia stuhlmannii</i>	.	.	53.8	38.0	29.5	.	.	.
<i>Allophylus abyssinicus</i>	25.0	.	.	.	.	.	.	.
<i>Allophylus melliodorus</i>	.	.	.	.	14.8	.	.	.
<i>Alsodeiopsis schumannii</i>	.	.	13.3	.	.	.	.	.
<i>Angylocalyx braunii</i>	.	.	.	.	.	.	.	25.0
<i>Anisophyllea obtusifolia</i>	.	.	50.0	50.5	.	.	.	.
<i>Anthocleista grandiflora</i>	.	.	91.5	102	30	.	.	.
<i>Antiaris toxicaria</i>	.	.	.	.	.	22.4	.	.
<i>Aphloia theiformis</i>	23.0	.	.	.	.	.	.	.
<i>Blighia unijugata</i>	.	.	.	.	.	.	26.0	.
<i>Bridelia brideliifolia</i>	.	.	.	.	.	.	25.5	.
<i>Canthium oligocarpum</i>	17.9	.	.	.	.	.	.	.
<i>Cassipourea gummiflora</i>	.	.	.	46.0	.	.	.	.
<i>Castilla elastica</i>	.	.	.	.	.	22.2	.	.
<i>Cedrella odorata</i>	.	.	.	.	.	.	.	37.7
<i>Celtis africana</i>	.	.	.	.	41.1	.	.	.
<i>Celtis mildbraedii</i>	.	.	.	30.2	.	.	.	.
<i>Cephalosphera usambarensis</i>	.	.	17.8	56.2	23.0	39.4	.	.
<i>Chrysophyllum gorungosanum</i>	13.9	.	.	18.3	.	.	.	.
<i>Chrysophyllum perpulchrum</i>	.	.	22.5	28.6	41.5	75	.	.
<i>Cinnamomum camphora</i>	.	.	36.4	.	.	.	.	.
<i>Cola greenwayi</i>	33.8	.	20.1	17.8	.	.	.	.
<i>Cola usambarensis</i>	.	.	23.9	.	.	.	.	.
<i>Combretum schumannii</i>	.	.	.	.	.	.	.	16.4
<i>Cordia africana</i>	.	.	.	.	.	.	16.1	.
<i>Craibia zimmermanni</i>	36.0	.	.	.	.	.	.	.
<i>Croton megalocarpus</i>	21.9	.	.	.	.	.	.	.
<i>Cryptocarya liebertiana</i>	.	.	.	.	25.8	.	.	.
<i>Cupressus lusitanica</i>	25.4	29.5	.	.	.	.	.	.
<i>Cussonia spicata</i>	21.1	12.7	.	.	.	.	.	.
<i>Cynometra suaheliensis</i>	.	.	.	.	.	41.0	.	.
<i>Dasylepis integra</i>	28.5	.	.	.	.	.	.	.
<i>Deinbollia kilimandscharica</i>	.	.	13.8	.	.	.	.	.
<i>Diospyros abyssinica</i>	16.3	.	.	.	.	.	.	.
<i>Diospyros greenwayi</i>	.	.	.	.	.	.	25.4	.
<i>Diospyros whyteana</i>	.	.	.	.	.	.	30.7	.
<i>Drypetes gerrardii</i>	31.8	.	.	24.3	14.1	.	.	.
<i>Drypetes natalensis</i>	.	.	24.4	.	.	.	.	30.5
<i>Ehretia cymosa</i>	.	21.2	.	.	.	.	.	.
<i>Ekebergia capensis</i>	17.8	.	.	.	.	.	.	.
<i>Enantia kummeriae</i>	.	.	19.6	.	.	.	.	.
<i>Englerodendron usambarensense</i>	.	.	30.8	23.1	.	.	.	.
<i>Englerophytum natalense</i>	.	.	.	.	.	.	.	16.1
<i>Erica arborea</i>	15.5	.	.	.	.	.	.	.

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Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza
<i>Erythrophleum suaveolens</i>	.	.	.	.	.	27.7	.	.
<i>Eucalyptus saligna</i>	.	40.5	.	.	.	.	.	.
<i>Ficus exasperata</i>	.	.	.	.	.	45.0	.	.
<i>Ficus sur</i>	.	.	.	.	.	43.2	.	.
<i>Ficus vallis-choudae</i>	.	.	.	.	.	89.8	104	.
<i>Funtumia africana</i>	.	.	19.4	.	.	23.4	.	.
<i>Garcinia volkensii</i>	17.8	.	.	.	.	.	.	.
<i>Greenwayodendron suaveolens</i>	.	.	40.0	24.8	27.5	.	.	.
<i>Grevillea robusta</i>	.	18	.	.	.	.	.	.
<i>Grewia goetzeana</i>	.	.	.	.	.	.	27.6	.
<i>Heinsenia diervilleoides</i>	.	.	17.9	19	.	.	.	.
<i>Isobertlinia scheffleri</i>	.	.	.	.	.	.	.	13.8
<i>Khaya anthotheca</i>	.	.	.	.	.	.	.	58.1
<i>Leptonychia usambarensis</i>	20.7	17.8	18.2	20.3	.	22.4	.	17.1
<i>Macaranga capensis</i>	.	.	.	23.6	13	.	.	.
<i>Macaranga conglomerata</i>	30.6	36.3	.	.	.	.	.	.
<i>Macaranga kilimandscharica</i>	.	.	16	.	23.2	.	.	.
<i>Maesa lanceolata</i>	28.1	.	.	.	15.8	.	.	.
<i>Maesopsis eminii</i>	.	.	29.9	32.1	35.5	30.5	.	.
<i>Mangifera indica</i>	.	.	.	.	.	.	.	24.1
<i>Manilkara sulcata</i>	17.5	.	.	.	.	.	.	.
<i>Maranthes goetzeniana</i>	.	.	36	.	.	.	.	.
<i>Margaritaria discoidea</i>	.	.	.	.	.	53	.	.
<i>Mesogyne insignis</i>	.	.	13.6	.	.	29.9	.	.
<i>Milicia excelsa</i>	.	.	.	.	.	67	.	.
<i>Millettia oblata</i>	23.3	17.7	.	.	.	.	.	.
<i>Millettia sacleuxii</i>	.	.	.	.	16.3	.	.	.
<i>Mimusops kummel</i>	.	.	.	.	.	.	.	44.6
<i>Morinda asteroscepa</i>	.	.	72.3	.	.	.	.	.
<i>Myrianthus holstii</i>	.	.	18.1	32.7	27	51.6	.	100.9
<i>Myrsine melanophloeos</i>	22.8	.	.	.	.	.	.	.
<i>Neoboutonia macrocalyx</i>	.	23.4	.	.	.	.	.	.
<i>Newtonia buchananii</i>	31.0	.	24.1	66.8	65.3	.	.	.
<i>Nuxia congesta</i>	88.9	.	.	.	.	.	.	.
<i>Obetia radula</i>	.	.	.	.	.	.	15.4	.
<i>Ochna holstii</i>	24.5	.	14.6	.	.	.	.	.
<i>Ocotea usambarensis</i>	46.9	.	.	.	.	.	.	.
<i>Odyenda zimmermannii</i>	.	.	70.3	.	.	.	.	.
<i>Ouratea scheffleri</i>	25.7	17.2	.	.	.	.	.	.
<i>Oxyanthus speciosus</i>	14.9	.	.	.	.	.	.	.
<i>Pandanus rabaiensis</i>	.	.	.	.	.	.	.	20.7
<i>Parinari excelsa</i>	.	.	17.6	64.7	22.4	.	.	.
<i>Phoenix reclinata</i>	18.5	26.1	.	.	.	.	.	.
<i>Pinus patula</i>	36.1	.	.	.	.	.	.	.
<i>Podocarpus latifolius</i>	37.7	.	.	.	.	.	.	.
<i>Afrocarpus falcatus</i>	.	.	27.4	.	.	.	.	.
<i>Polyscias fulva</i>	32.1	43.3	18.6	.	16.3	.	.	.
<i>Polyscias stuhlmannii</i>	32.6	.	.	.	.	.	.	.
<i>Polysphaeria macrantha</i>	.	.	.	.	.	.	.	13.9
<i>Pouteria adolfi-friedericii</i>	58.9	.	97.5	27.6	27.7	.	.	.
<i>Prunus africana</i>	.	28.3	.	.	.	.	.	.
<i>Psychotria alsophila</i>	15.7	.	.	.	.	.	.	.



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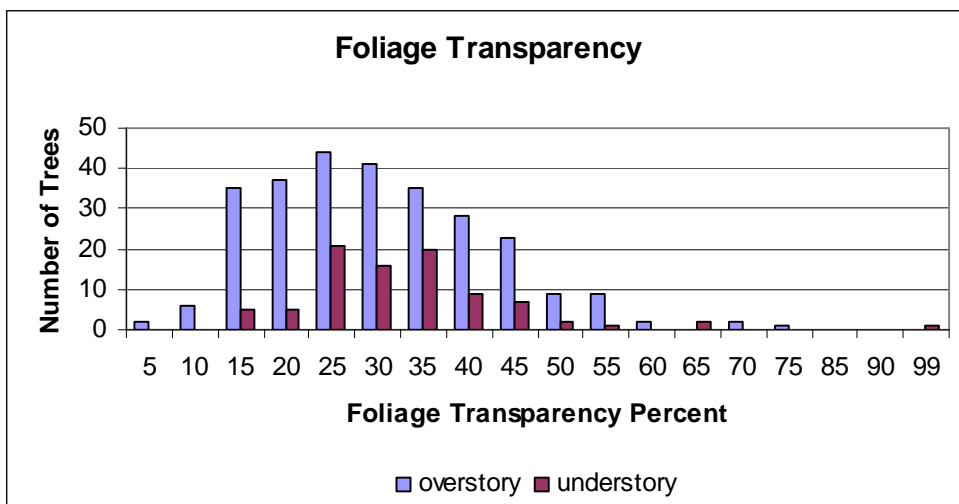
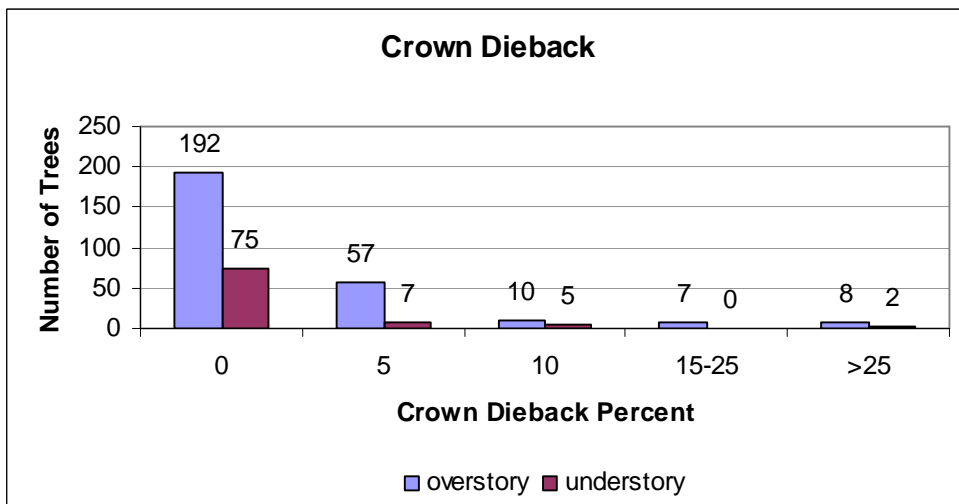
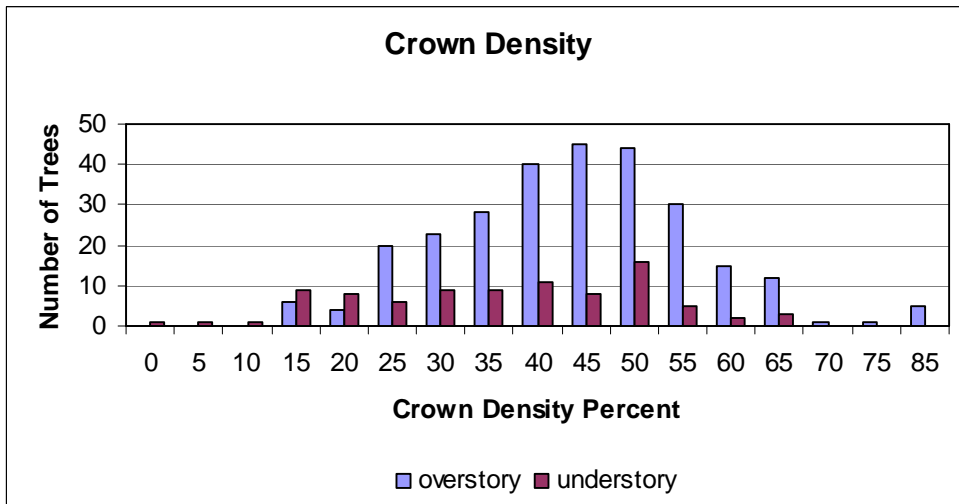
Species	Ngangao	Chawia	Mbomole Hill Trail	Turaco Bird Trail	Kwamkoro Forest Station	Sigi Trail	Teachers College Riverine	Kimboza
<i>Psychotria crassipetala</i>	15.3	.	.	.	.	.	.	.
<i>Psychotria mahonii</i>	.	.	.	.	.	.	16.3	.
<i>Psychotria megalopus</i>	.	.	.	.	.	.	16.8	.
<i>Psychotria petiti</i>	16.2	.	.	.	.	.	.	.
<i>Pterocarpus tinctorius</i>	.	.	67.7	.	.	.	.	.
<i>Quassia undulata</i>	.	.	.	24.4	38.2	106.5	.	16.0
<i>Rawsonia lucida</i>	.	.	15	22.1	.	.	.	.
<i>Ricinodendron heudelotii</i>	.	.	.	.	.	20.3	.	67.9
<i>Ritchiea albersii</i>	.	24.9	.	.	.	.	.	.
<i>Rytigynia eickii</i>	27	.	.	.	.	.	.	.
<i>Rytigynia uhligii</i>	16.1	.	.	.	.	.	.	.
<i>Sapium ellipticum</i>	.	.	27.1	.	17.4	.	.	.
<i>Schefflerodendron usambarensense</i>	.	.	.	22.1	.	.	.	.
<i>Scorodophloeus fischeri</i>	.	.	.	.	.	.	.	30.8
<i>Solanecio manni</i>	.	.	.	.	.	.	.	16.6
<i>Sorindeia madagascariensis</i>	.	.	23.3	21.1	19.0	14.1	24.1	28.4
<i>Spathoclea companulata</i>	.	.	.	.	17.5	.	.	.
<i>Sterculia appendiculata</i>	.	.	.	.	.	75	.	.
<i>Strombosia scheffleri</i>	45.2	51.9	.	21.4	21.5	38.5	.	.
<i>Synsepalum cerasiferum</i>	.	.	24.6	19.9	39.3	.	.	.
<i>Pachystela msolo</i>	.	.	.	.	.	37.0	.	.
<i>Synsepalum msolo</i>	.	.	.	.	.	40.4	17.6	.
<i>Syzygium guineense</i>	34.2	.	.	.	.	.	.	.
<i>Syzygium micklethwaitii</i>	.	53.1	.	.	.	.	.	.
<i>Tabernaemontana pachysiphon</i>	.	.	.	.	14.5	.	.	.
<i>Tabernaemontana stapfiana</i>	33.4	32.9	.	.	.	.	.	13
<i>Teclea trichocarpa</i>	27.9	.	.	.	.	.	.	.
<i>Tricalysia pallens</i>	.	.	.	.	14.6	.	.	.
<i>Trichilia dregeana</i>	.	.	.	27.1	.	40.9	.	.
<i>Trilepisium madagascariense</i>	.	.	.	.	.	15.2	.	27.1
<i>Turraea holstii</i>	17.7	.	.	.	.	.	.	.
Unknown1	.	.	.	.	.	40	.	.
Unknown3	.	.	.	.	.	.	.	66.7
<i>Vepris grandifolia</i>	.	.	.	.	.	.	.	19.9
<i>Xylopia parviflora</i>	.	.	.	.	.	.	15.1	.
<i>Xymalos monospora</i>	29.9	52.5	28.7	.	28	.	.	.
<i>Zenkerella egregia</i>	.	.	.	25	.	.	.	.

### Appendix C - Visual Crown Ratings:

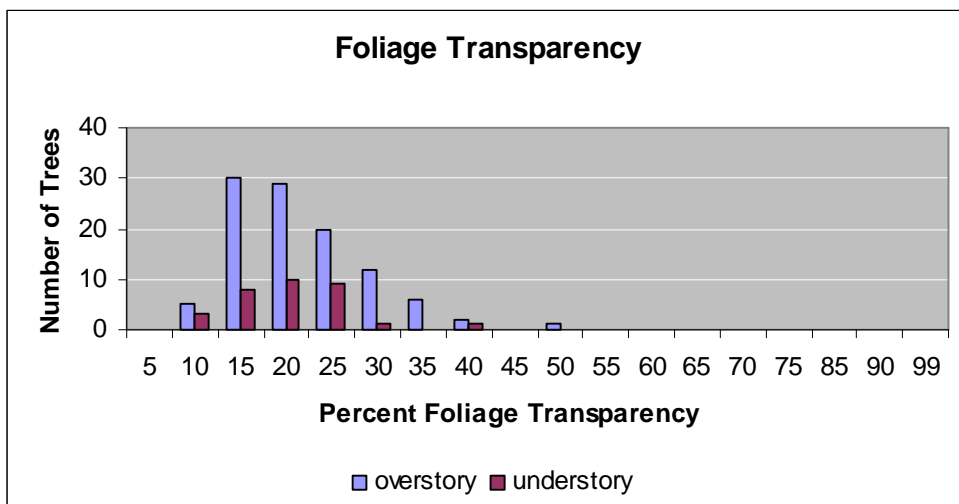
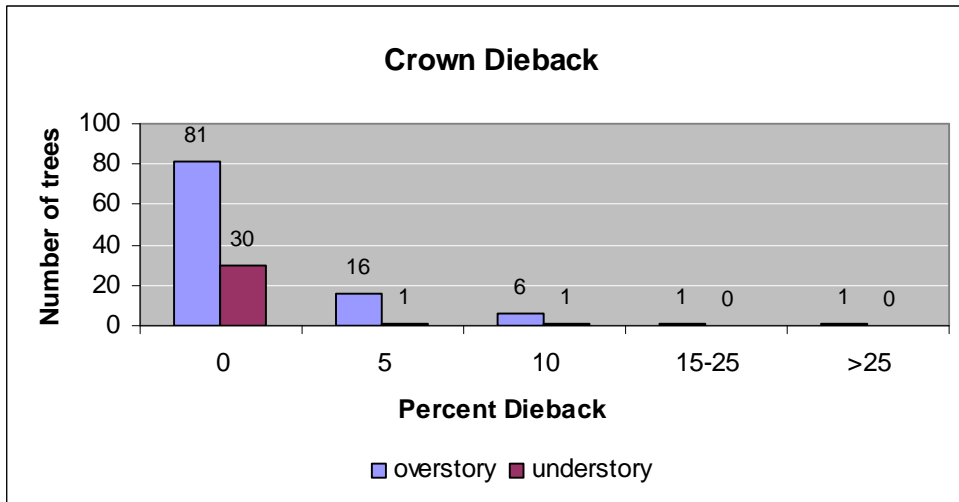
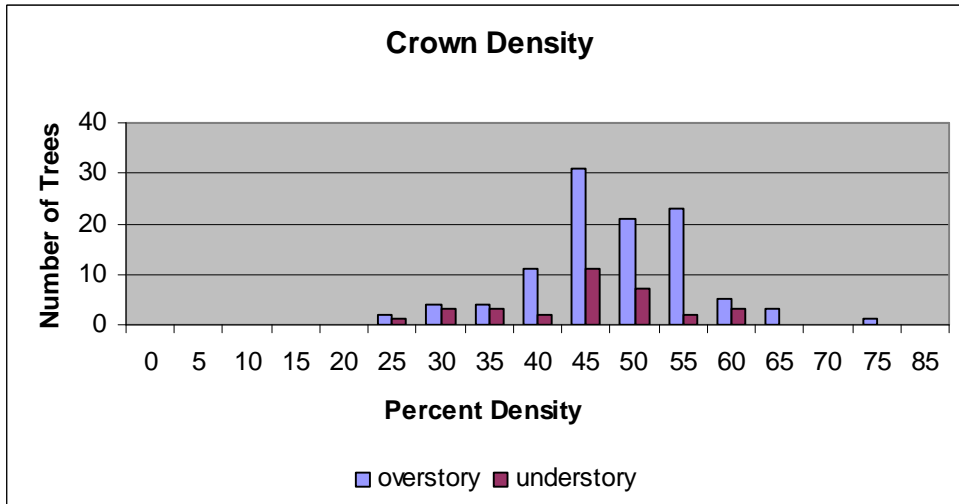
One of the primary indicators of tree health is the condition of the tree crown. The crown indicator takes into account the amount, condition, and distribution of tree foliage, branches, and reproductive structures, and quantitatively describes the visual appearance of the tree crown. All live trees with 12.7 cm DBH or greater are assessed for live crown ratio, crown density, crown dieback, and foliage transparency. All crown measurements are recorded in 5 percent unit classes, from 0 to 100 percent. Anderson et al. (1992) used the following ratings guidelines to determine the health of trees in US forests.

- *Live Crown Ratio* is defined as the proportion of the live tree crown in relation to the total height of the tree. Pruning studies have shown that removal of live branches up to two thirds of tree height will not adversely affect tree growth. Thus, trees with a live crown ratio of at least 35% are considered to be in good health.
- *Crown Density* is the amount of crown foliage, branches, and reproductive structures that block visible light. It is used to assess the expected growth in the near future. Generally, greater density means a healthier tree.
- *Crown Dieback* is the recent mortality of branches with fine twigs, which begins at the outer, upper portions of the tree crown and proceeds toward the tree trunk. Most trees have at least a few dead twigs due to normal environmental stressors. Trees with 5% dieback or less are considered to be in good health.
- *Foliage Transparency* is the amount of light that is visible through the live, normally foliated portion of the crown. "Normal" foliage transparency ratings are relative and vary somewhat between species. Some tree species will exhibit a higher foliage transparency due to their inherent leaf design and branch structure. Without more information on the relative foliage transparency between species, it is generally accepted that trees in good health have a transparency rating of 45% or less.

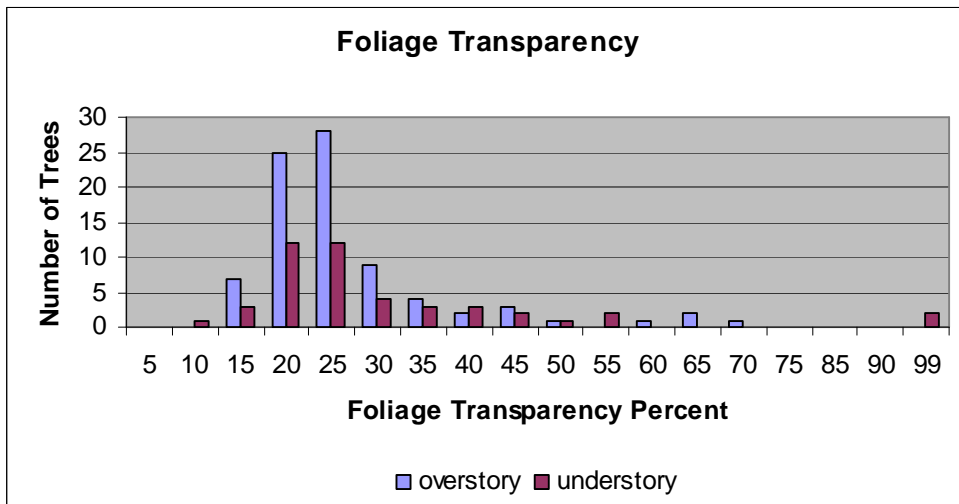
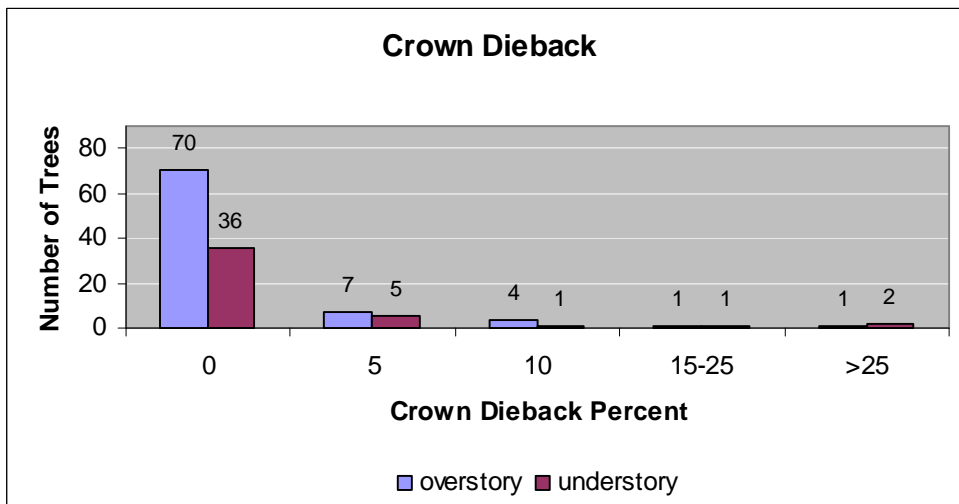
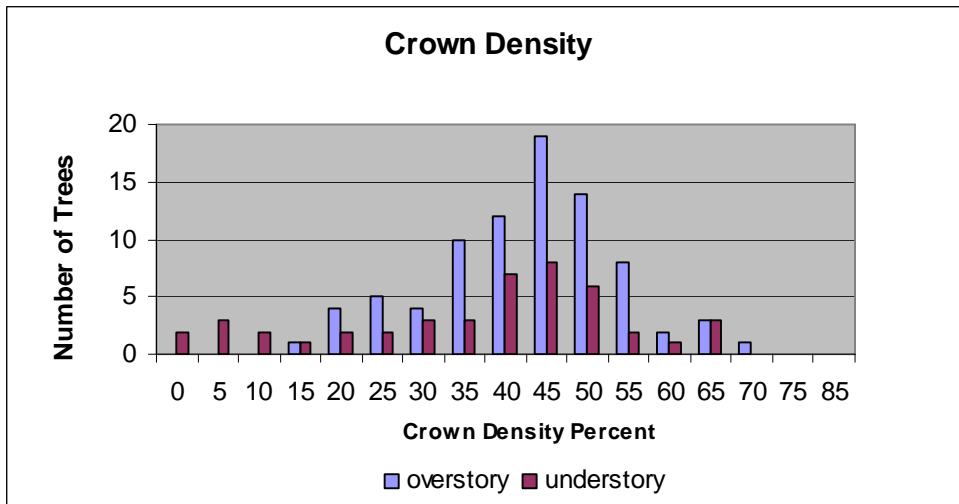
Ngangao Forest, Taita Hills, Kenya



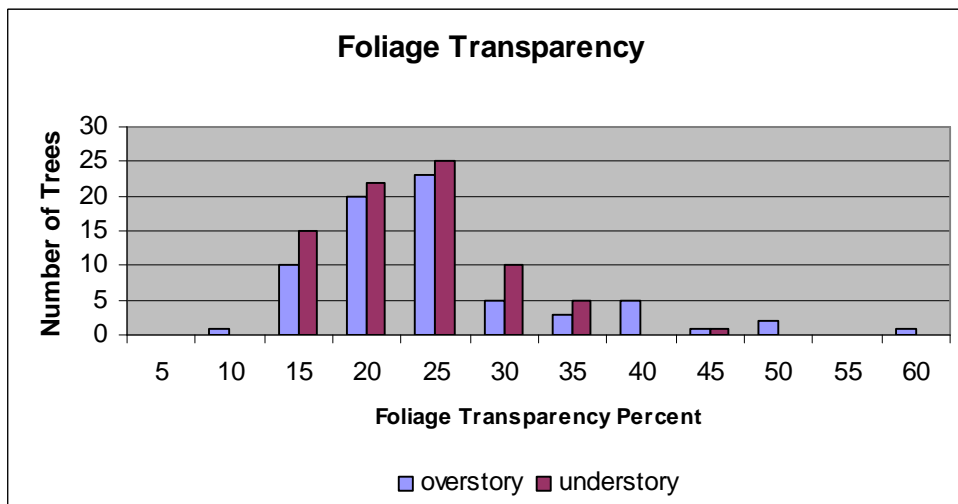
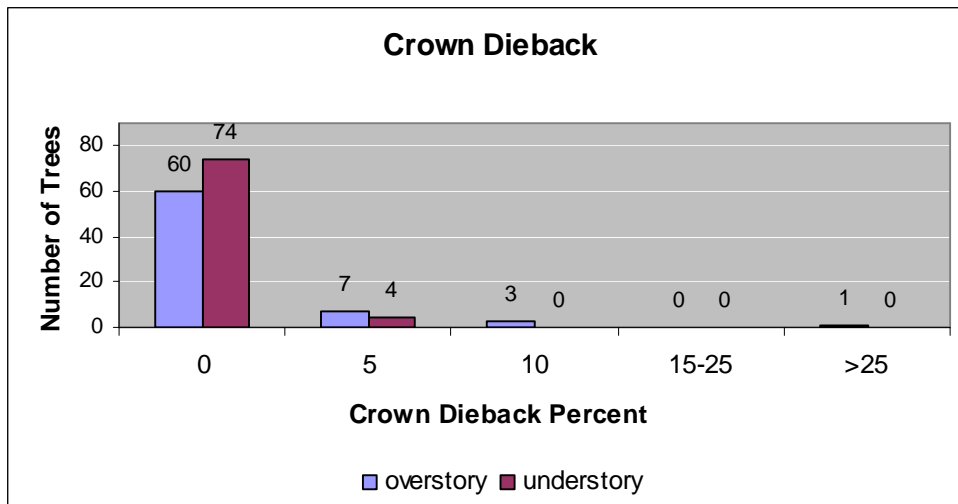
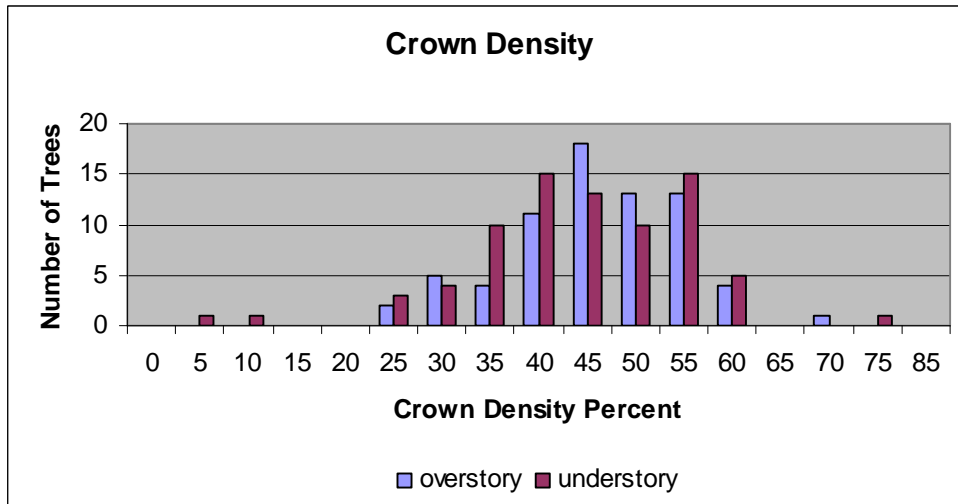
Chawia Forest, Taita Hills, Kenya



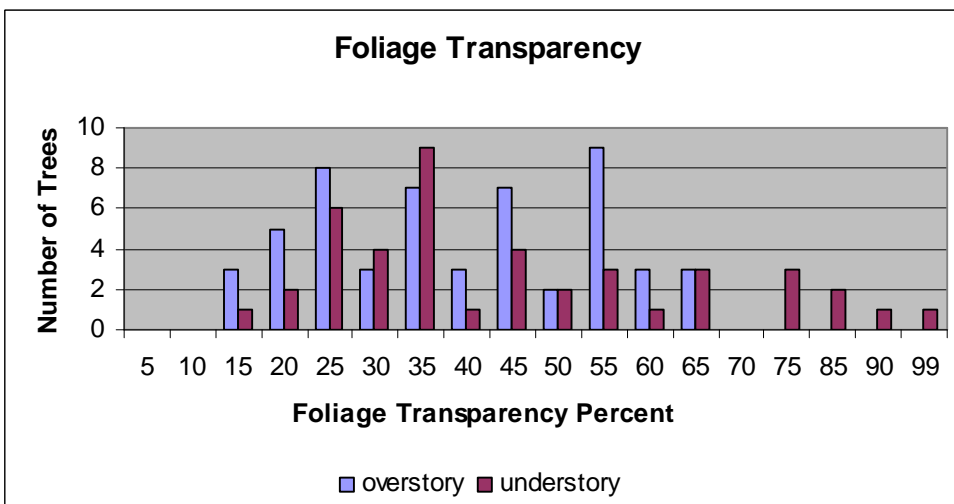
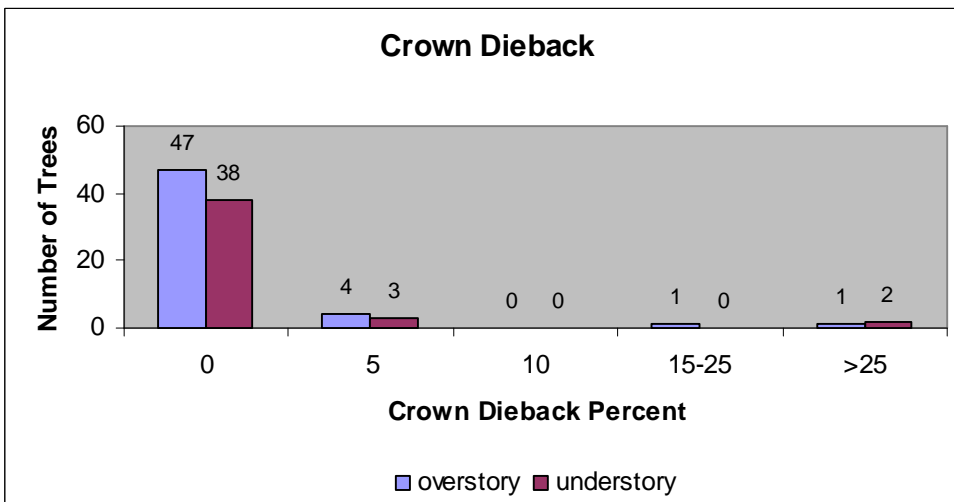
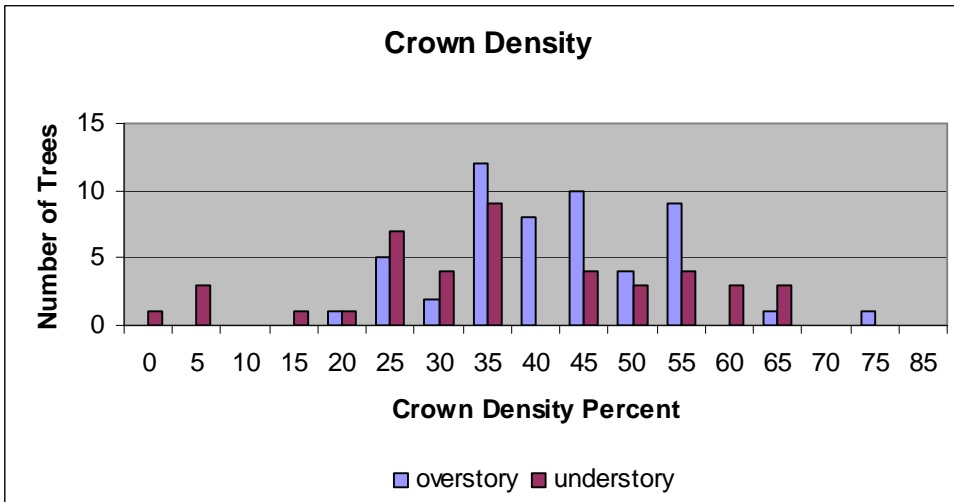
Mbomole Hill Trail, East Usambara Mountains, Tanzania



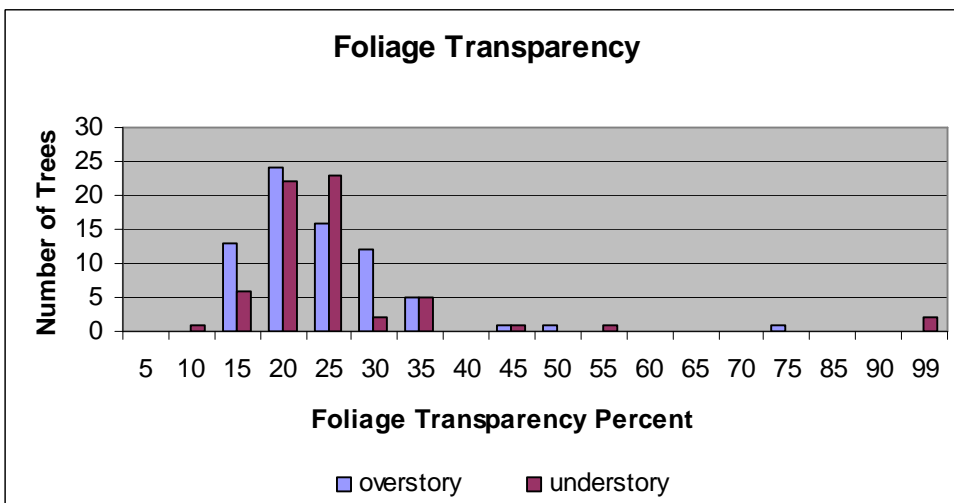
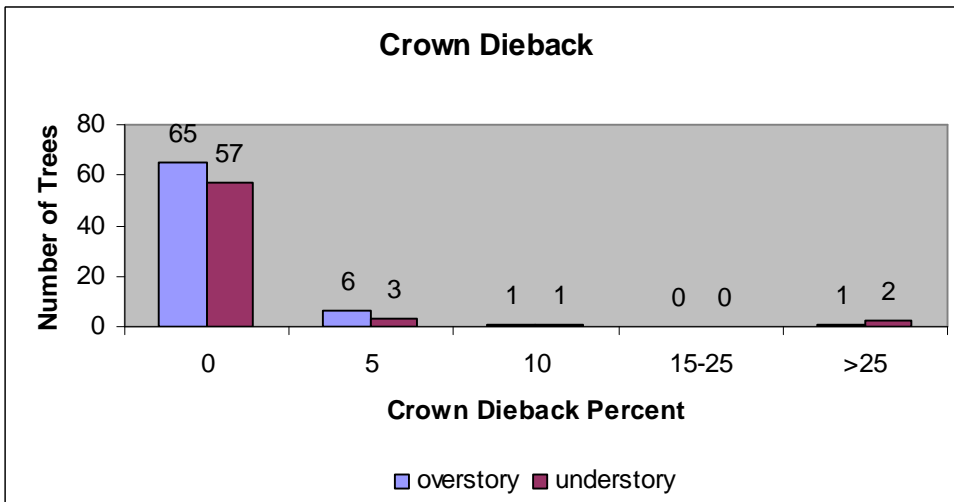
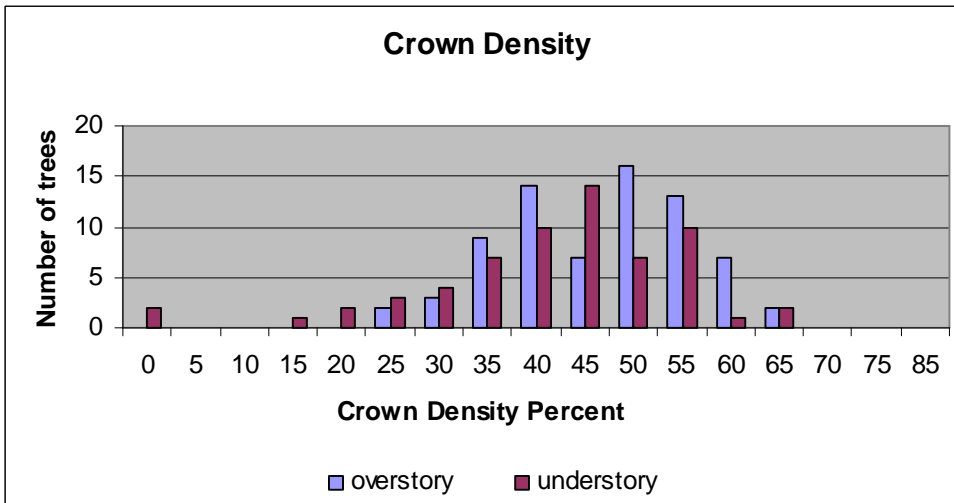
Turaco Bird Trail, East Usambara Mountains, Tanzania



**Kwamkoro Forest Station, East Usambara Mountains, Tanzania**

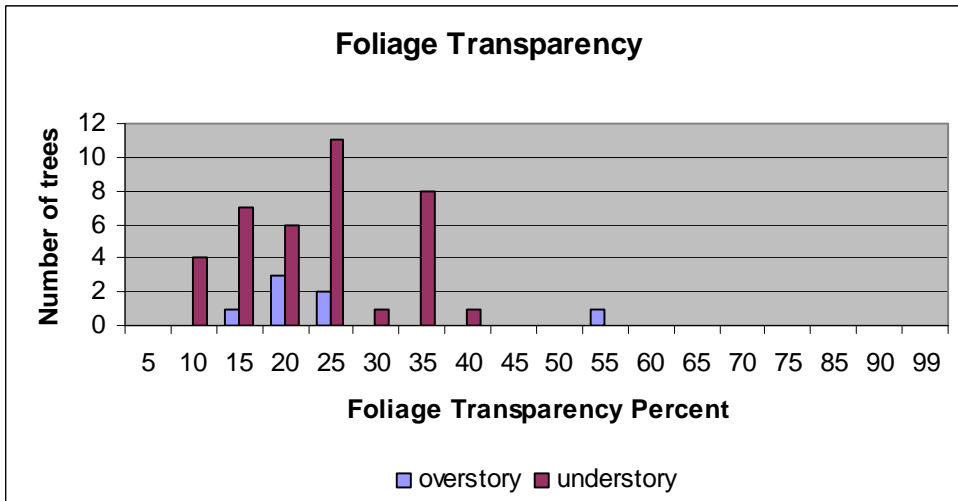
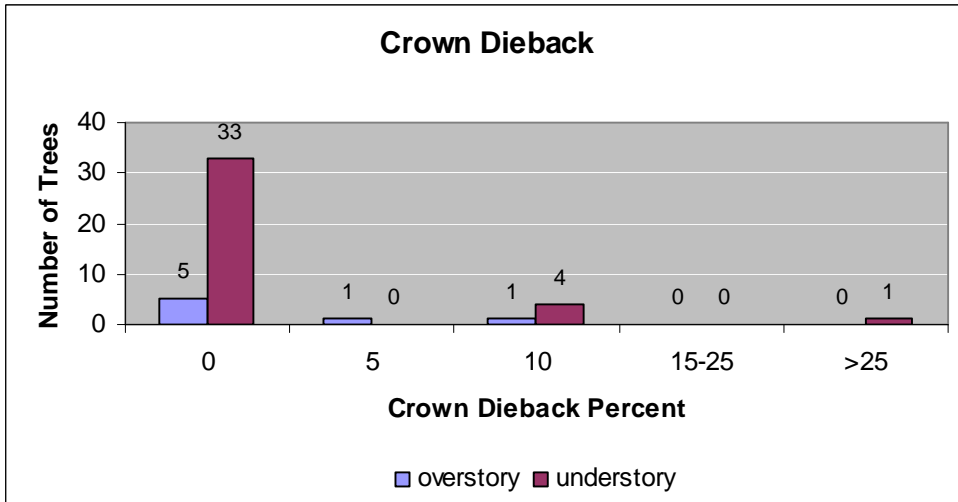
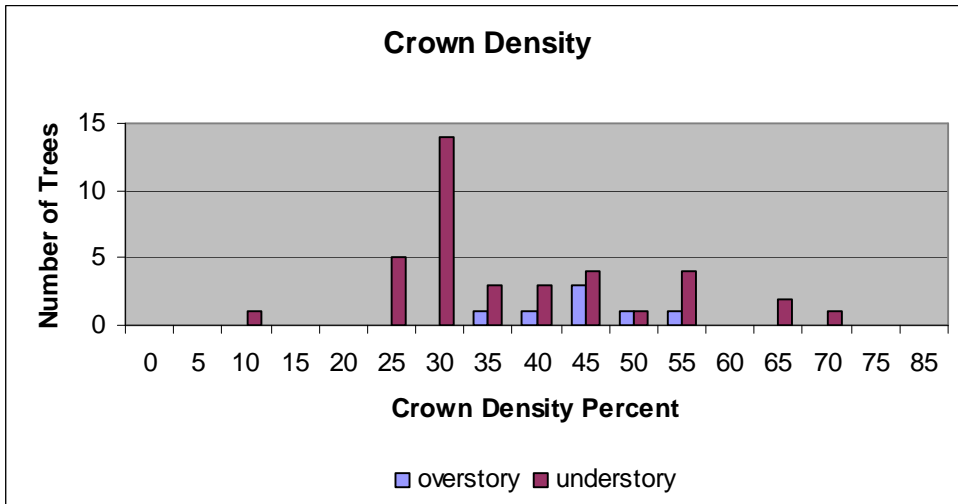


Sigi Trail, East Usambara Mountains, Tanzania





Teachers College Riverine, Uluguru Mountains, Tanzania



Kimboza, Uluguru Mountains, Tanzania

