MULANJE MOUNTAIN CONSERVATION TRUST

INVENTORY RESULTS OF MULANJE CEDAR RESOURCES ON MULANJE MOUNTAIN.

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SUMMARY

The cedar inventory was carried out to provide quantified information for management planning for sustainable harvest and conservation of the species on Mulanje Mountain. Individual cedar clusters on the mountain were identified and mapped out in a GIS environment. A total area of 845.3 ha has been estimated as currently occupied by cedar clusters on the mountain. The stocking levels of cedar in each site (area) is variable; ranging from 41 stems/ha in Chambe to 136 stems/ha in Chinzama areas. The mountain has a gross standing (cedar) volume overbark of 115,398 m^3, of which 32.27% (37,239 m^3) is from dead cedars. Since the current cedar licensing policy of the Forestry Department allows for utilization of dead cedar trees only, the results present sufficient merchantable volume overbark (22,082 m^3) from dead cedar trees that can be utilized for the next 40 years under the current harvesting regime. The report also proposes measures to protect and conserve the existing live stands of cedar, including replanting of the degraded cedar areas.

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1 BACKGROUND

1.1.1 Mulanje Cedar belongs to a genus of monoecious, African conifers with scale-like leaves and plum-sized woody female cones. The genus is called *Widdringtonia* Endl. Currently four species are recognized in the genus (Pauw & Linder, 1997). These are *Widdringtonia cedarbergensis* Marsh, *W schwarzii* Mast*, W. whytei* and *W. nodiflora*. The Widdringtonias that are found on Mulanje Mountain, which are locally known as Mulanje Cedars, have finally been identified as *Widdringtonia whytei and W. nodiflora* based on the phylogenetic, ecological and biological species concepts (Pauw & Linder, 1997). *Widdringtonia whytei* is a timber tree that is natural and endemic to Mulanje Mountain, whereas *W. nodiflora* is a coppicing species similar to Widdringtonias grown in Zimbabwe, Mozambique and northern South Africa. Detailed morphological differences between the two species have been presented by Pauw & Linder (1997).

1.1.2 The Mulanje cedar (*Widdringtonia whytei*) on Mulanje Mountain can achieve height and diameter growth in excess of 40m+ and 1.0m+, respectively. The importance of Mulanje cedar is not only because of its uniqueness and rareness in growth on the mountain; it is an excellent construction timber, light to moderately heavy, resistant to termites and wood borers, and strongly resistant to fungal attack. The timber is durable and fragrant and has been extensively used for construction work, furniture and paneling (Chapman, 1995). In recognition of its importance, the Malawi government declared the Mulanje cedar as a “Malawi’s National Tree” in 1984.

1.1.3 The species has been exploited for over 100 years on the mountain with the main emphasis on revenue return. It is reported that one large tree might fetch a price of £1000 (Chapman, 1995). The early foresters had some success in re-planting cut-over cedar stands, but plans for an extensive re-afforestation program were not realized (Chapman, 1995). Today the species (Malawi’s National Tree) faces a number of threats leading to possible extinction.

1.1.4 The management of Mulanje Cedar is currently restricted to exploitation as evidenced by the “Open” and “Closed” cedar harvesting seasons cycles by the Forestry Department. The legalized harvesting of cedar is restricted to the dry season between May and October each year. There is, therefore, no deliberate enterprise approach by the Forestry Department to restock the harvested areas. Furthermore, the yearly opening of the “official” cedar harvesting season is not based on the cedar resources currently standing (available) on the mountain at the time of re-opening of the harvesting season. This is evidenced by the fact that the last inventory of cedar resources on Mulanje Mountain was done in 1994 (Lawrence *et al*, 1994) and throughout the years (save for the 2000 to 2003 seasons) the Forestry Department has annually re-opened the cedar harvesting seasons.

1.1.5 This, in addition to a variety of other anthropogenic factors (frequent late fires & illegal logging); invasion of alien species (*Pinus patula)* and infestation of cypress aphids in the late 1980s; have placed the cedar in such a great danger of extinction.

1.1.6 It was on this basis that Mulanje Mountain Conservation Trust (MMCT), an agency dedicated to sustainable management and conservation of Mulanje Mountain, engaged a forest inventory expert to conduct an assessment of the remaining cedar stands on as is basis on the mountain and determine their ecological conservation status in order to inform the decision makers for a possible re-opening of the cedar harvesting season in the year 2004. The results of this study would also form a baseline for an ecological monitoring program for the Core Zone for the Biodiversity Conservation Area of the mountain.

2 TERMS OF REFERENCE (OBJECTIVES)

2.1.1 In close collaboration with the Mulanje Mountain Conservation Trust's Biodiversity Conservation Team based in Mulanje, the forest inventory specialist was responsible for the overall tutelage and supervision of the cedar assessment exercise provided for under the work plan.

2.1.2 Specifically he was mandated to:

- Carry out a complete assessment or inventory of all Mulanje Cedar (*Widdringtonia whyteii*) forests on Mulanje Mountain.
- Determine the amount (harvestable cedar volume) and extent and ecological health status of the live stands at various levels of growth.
- Provide quantified information that would form a bench-mark to inform management planning for sustainable harvest (or no harvest) and conservation of the species.
- Provide a baseline for conducting an ecological monitoring program for the cedar areas in respect of human disturbance, invasive species invasion and general ecological parameters that will form core works on research activities in the MMFR.

3 METHODOLOGY

3.1 Mapping

3.1.1 Using the topographic map sheet 1:40,000 scale of Mulanje Mountain (Department of Surveys, Malawi, 1995), the areas occupied by the cedar were mapped. The possible boundaries of the cedar clusters on the mountain were delineated on the map sheet while in the office. The possible boundaries were delineated with the help of experienced field staff from the Forestry Department and Mulanje Mountain Conservation Trust who have extensive knowledge of the areas occupied by the cedars on the mountain. This was done in a participatory manner to encourage full participation of all local field staff that were involved in the mapping in order to benefit from their diverse local knowledge of the current distribution of the cedars on the mountain.

3.1.2 Sixteen (16) cedar clusters were identified to cover the mountain. The geographic coordinates of the delineated clusters were read and recorded from the topographic map sheet using the Universal Transverse Mercator (UTM) system. These geographic coordinates were loaded onto a Garmin II Global Positioning System (GPS) that were used later to track and verify the cedar cluster boundaries during the field work.

3.1.3 All the sixteen (16) cedar clusters were visited during the field work. In most cedar clusters, boundaries were tracked, verified or new coordinates obtained where the cluster boundaries seemed to differ from those recorded in the office. This was done using a Garmin II GPS. In some clusters, boundaries were observed from the nearest view point because of inaccessibility to get to such areas (very steep slope).

3.1.4 The GPS tracked coordinates of the cluster boundaries were downloaded using Map Source software. Polygons based on the downloaded coordinates were digitized representing cedar clusters on a geo-referenced digital map of Mulanje Mountain Forest Reserve. This was done in ArcView GIS software and saved as a separate shape file. The size of each cedar cluster in terms of area in hectares was calculated using ArcView software to determine the total area covered by the cedar on the mountain.

3.1.5 An overlay of this shape file was done to a geo-referenced shape file of Mulanje Mountain Forest Reserve to show the geographic locations and extent of the Mulanje cedar clusters on the mountain.

3.2 Sampling Design and Tree Data Collection

3.2.1 The delineated cedar clusters were stratified based on the terrain and accessibility of the cedar clusters from the nearest path or firebreak. In each stratum, a systematic sampling technique was used to locate the plots to the stratum. An identifiable starting point on the line (route) of sampling was identified and located on the map sheet. The geographic coordinates in UTM Zone 36L system of the point was recorded and loaded onto a Garmin II GPS. These coordinates were later used to track the starting point of the sampling routes during the field work.

3.2.2 One hundred-metre distance was calculated from the identifiable starting point on the sampling route to the centre of the first plot. The distance from the centre of one plot to another was calculated at 500 metres. The plot centres were marked on the map sheet along the sampling route. The geographic coordinates in UTM system of the plot centres were read from the map sheet, recorded and loaded onto a Garmin II GPS for tracking the plot centre point locations on the ground during the field exercise. The number of plots in each stratum varied with the size of the stratum. A total of 33 plots were laid out in all the cedar clusters.

3.2.3 At each tracked plot centre on the ground, a circular plot was established. The radius of the plot varied from plot to plot depending on the stocking levels of the cluster. It was decided that at least 20 sizable cedar trees should be recorded in a given plot size to give a good representation of the cluster. Therefore, the plot sizes varied from 25 metre- to 60 metre- radii.

3.2.4 In a plot, all cedar trees with diameter at breast height (dbh) equal to or greater than 5 cm were measured for dbh to the nearest centimeter using diameter tapes. Three dominant cedar trees, the 5th tree and every other 10th tree in a plot were selected and measured for height using suunto hypsometer. Young cedar trees of less than 5cm in diameter were regarded as saplings and seedlings. These were only counted in a plot to determine their numbers.

3.2.5 Dead standing trees within the plot were recorded and measured accordingly. This was done to determine the standing volume of the dead cedar trees in relation to the current government policy that allows the logging of only dead cedar trees from the mountain. Other identifiable issues of illegal logging and invasion of alien species (*Pinus patula*) were observed and recorded as the inventory crews navigated the cedar clusters on the mountain. Freshly cut stumps were observed as illegally cut by checking the presence of a Forestry Department stamp on the surface of the cut stump. All the legally felled cedar trees are stumped by the Forestry Personnel.

3.3 Tree Data Analysis

3.3.1 The tree data were summarized in an excel software and statistically analyzed in a Minitab Release 13.3 statistical software. Calculations of the present status of the cedar clusters used a tree list approach in which a list of trees enumerated in each plot during the survey represented the whole growing stock in a cluster. Initially, the following variables were known for every tree of the list:

1. Diameter at breast height (dbh)
2. Quality class,
3. Number of trees per hectare that the tree represents (frequency).

3.3.2 In addition, the data for each tree was complemented with tree heights, stem volume to 5cm top diameter and proportion of volumes (merchantable volume) to 13, 20, and 25 cm top diameters. These additional tree parameters were calculated using the general height and volume models developed by Makungwa & Saramaki (2000) for conifers growing in Malawi.

3.3.3 The tree height model (function) used in calculating the individual tree heights of the trees enumerated in a plot was of a form;

$$Ln\_ (h-1.3) = \beta_0 + \beta_1 * H_{dom} + \{\beta_2 * H_{dom} / (dbh + 5)\} – \{\beta_3 / (dbh + 5)\}$$

Where:

Ln_ = natural logarithm of height (h) in meters

H_{dom} = dominant height (m)

dbh = diameter at breast height (cm)

$\beta_0, \beta_1, \beta_2, \beta_3$ = regression coefficients with the following values;

β_0	= 2.911;	β_1	= 0.01362;
β_2	= 0.761;	β_3	= 25.386.
R^2	= 0.972		

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3.3.4 The calculation of the stem volume to 5 cm top diameter of individual trees in a plot was done using a volume function to 5 cm top diameter of the form;

$$V = 10^{**}(\beta_0+\beta_1*\log_{10}\_dbh+\beta_2* \log_{10}\_ht)$$

Where:

V = Standing volume per tree (m^3) from stump height (15cm) to 5 cm top diameter over bark.

$\log_{10}$_dbh = logarithm to base 10 of diameter at breast height (dbh) (cm) over bark.

$\log_{10}$_ht = logarithm to base 10 of height to 5 cm top diameter (m)

$\beta_0, \beta_1, \beta_2$ = regression coefficients with the following values;

β_0 = -4.318; β_1 = 1.887;

β_2 = 1.021. R^2 = 0.976

3.3.5 The calculation of the proportions of volumes (merchantable volumes) of individual trees to 13, 20, and 25 cm top diameters were done using merchantable volume functions of the form;

$$V_m/V_{5cm} = \beta_0 * \{[1 - \exp(\beta_1 * dbh)] ** \beta_2\}.$$

Where:

V_m = merchantable volume to top diameter limit (m^3)

V_{5cm} = volume to 5cm top diameter (m^3)

dbh = diameter at breast height over bark (cm)

$\beta_0, \beta_1, \beta_2$ = regression coefficients with the following values;

	β_0	β_1	β_2	R^2
V_{13cm}	0.942	-0.288	53.358	0.920
V_{20cm}	0.855	-0.248	202.375	0.930
V_{25cm}	0.827	-0.222	399.521	0.950

3.3.6 From these characteristics, a set of stand (cluster) level results were calculated. All the stand characteristics were calculated for different size (dbh) and quality classes in terms of stocking, total standing volumes and merchantable volumes. The results are presented in both tabular and graphical forms.

4 RESULTS

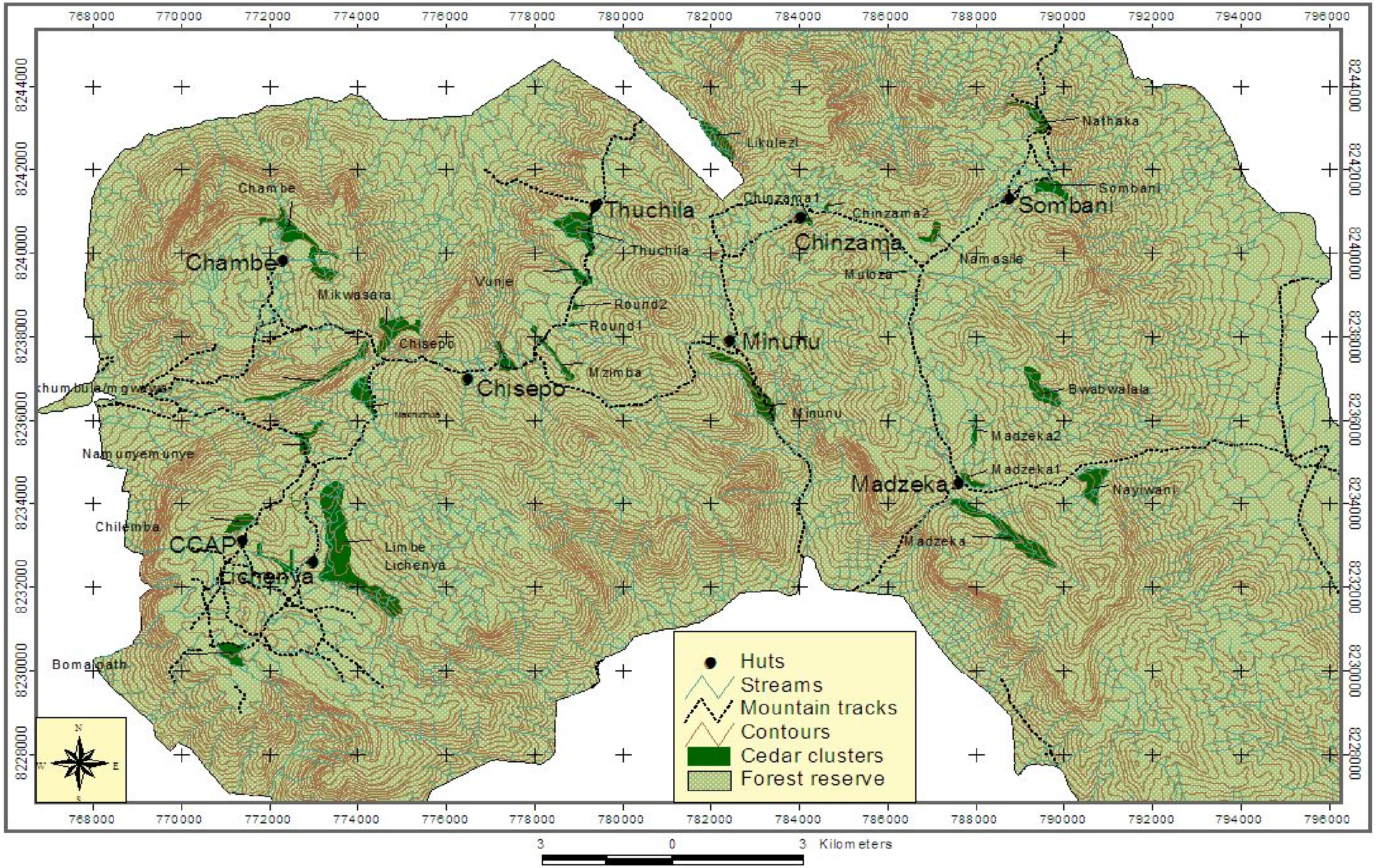
4.1 Spatial Distribution of Cedar Clusters

4.1.1 Map 1 presents the spatial distribution and geographic locations of cedar clusters on Mulanje Mountain as at July 2004. The current cedar clusters are mostly confined to areas around the base of steep gorges as evidenced by the closeness of the contours in areas confined by the cedar clusters on the map. The cedar clusters are currently restricted to these relatively inaccessible areas because the terrain affords some protection from anthropogenic pressures like human-induced forest fires and unsustainable logging systems that the mountain plateaux had experienced over the years.

4.1.2 There are some cedar clusters that are confined to ravines and hollows on the plateaux (e.g. Chambe and Sombani basins; Namunyemunye cluster). The cedar clusters on these basins are as a result of early replanting program as evidenced by the spatial linear arrangements of the standing trees observed on the ground during the survey. However, most of these stands are currently heavily degraded e.g. Namunyemunye cluster, because they are accessible and subjected to fierce wildfires and illegal harvesting from nearby communities.

4.1.3 In general terms, from the accounts of Whyte (1891& 1894) and Sclater (1893) as reported by Chapman (1995) the landscape of the spatial distribution of Mulanje cedar a century ago appeared much the same as now, the cedar confined to the ravines and hollows on the plateaux, below cliffs and in the gorges, where the terrain affords some protection from fire. The current study supports that observation. This shows that these are the original (natural) sites where the species had been growing naturally and therefore the current afforestation program by MMCT should be concentrated on the same sites.

4.1.4 The path network and construction of huts on the mountain seemed to follow the pattern of the occurrence and distribution of cedar clusters on the mountain. This is evidenced by the path and hut networks in relation to the residual standing cedar clusters as observed on Map 1. The path network and huts must have been constructed to ease access to cedar clusters during the early days of cedar harvesting over 100 years ago (Chapman, 1995). This confirms the early spatial distribution of the cedar stands (clusters) on the mountain.



Map 1. Mulanje Cedar Clusters on Mulanje Mountain as at July 2004

4.2 Area Distribution and Stocking Levels of Cedar Clusters

Table 1. Forest Area (ha) covered by Mulanje Cedar as at July 2004.

Charge name	Cluster name	Area (ha)	Area/charge (ha)
Chambe	Chambe Likhubula Makhutula	63.8 39.9 29.9	133.5
Chinzama	Chinzama1 Chinzama2 Minunu1 Minunu2	3.1 2.3 1.7 53.0	60.1
Lichenya	Boma path Chilemba Lichenya1 Limbe Mtayamoyo Muloza Namunyemunye	23.7 17.8 3.4 177.8 14.1 0.8 18.5	256.1
Madzeka	Bwabwalala Madzeka Madzeka1 Madzeka2 Nayiwani	34.5 74.2 9.4 8.7 36.6	163.4
Sombani	Namasile Nathaka Sombani	9.7 21.3 22.6	53.6
Thuchila	Chisepo Likulezi Mikwasala Mvunje Mzimba Raundi1 Raundi2 Thuchila	17.8 29.1 39.2 15.8 18.9 1.3 2.1 54.4	178.6
TOTAL		**845.3**	**845.3**

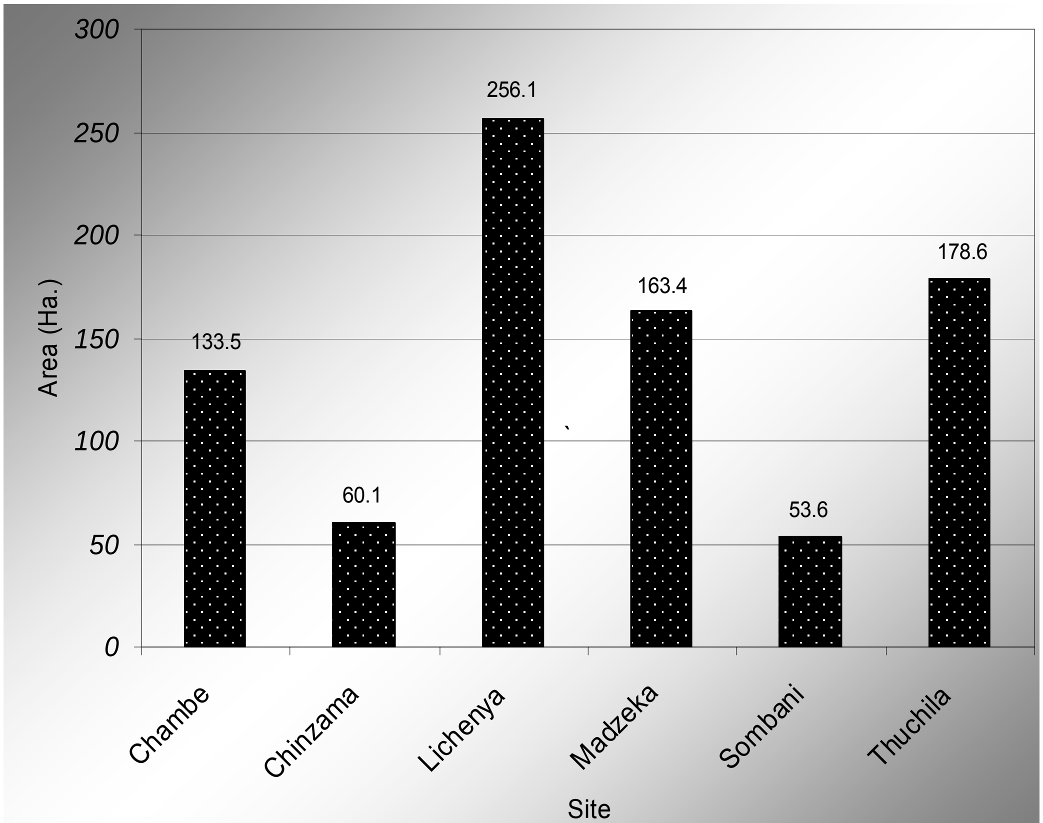


Figure 1: Area distribution (ha) of Mulanje cedar on Mulanje Mountain as at July 2004.

4.2.1 Table 1 presents the current estimated areas (hectares) occupied by cedar clusters on Mulanje Mountain. Similarly, the same results are presented in graphical form in Figure 1. The results show that Mulanje cedar on Mulanje Mountain (excluding Michesi Mountain) cover 845.3 ha or 1.3% of the total area of Mulanje Forest Reserve (64,250 ha), including Michesi Mountain (Forestry Department).

4.2.2 As can be seen from the results, Lichenya plateau contributes the highest proportion of cedar (in terms of area in hectares occupied by cedar) on the mountain. Lichenya plateau alone contributes 30.3% (256.1 ha) of the total area occupied by the cedars (845.3 ha) on the mountain. Much (69.4%) of this cedar on Lichenya is concentrated on Limbe Cluster, located to the east of the Lichenya Hut (Map 1). The trend in terms of contribution of Limbe cluster (69.4%) on Lichenya cedars is consistent with the findings of Sakai (1989) who found Limbe cluster alone contributing 75.3% of total cedar on Lichenya.

4.2.3 However, Sakai (1989) found that Sombani basin (site) contributed the highest area (ha) to the total area occupied by cedar on the mountain (28.7%). This is contrary to our findings in the current study whereby Sombani basin contributes the least area with only 6.3% (53.6 ha) of the total area occupied by the species on the mountain. In Sombani, the only cedar clusters currently remaining are at Namasile, Nathaka and Sombani. The other 10 clusters that were identified and quantified by Sakai (1989) had completely been degraded in the past 16 years.

4.2.4 In other words, the cedar forest area in Sombani has transgressed from 419 ha to 53.6 ha giving an average deforestation rate of 22.8 ha per year for the past 16 years. This is followed by Thuchila area that has transited from 328 ha (Sakai, 1989) to the current 178.6 ha giving an average deforestation rate of 9.3 ha per year for the past 16 years. Surprisingly, both these areas are currently under the management of Phalombe District Forestry Office. There is need therefore to review, audit and monitor how the District Forestry Office (Phalombe) manages the yearly cedar harvesting season, let alone the possibility of illegal harvesting in the district.

4.2.5 Although area distribution of the Mulanje cedar and the deforestation rates can be used to frame discussions about the current state of the Malawi's National Tree on the mountain, perhaps of greater significance are the condition of the cedars and their ability to provide a range of goods and services demanded of them. Tables 2 & 3 therefore provide the current stocking levels of Mulanje cedar in different sites (areas) and of different size (diameter) classes on each site, including their healthy conditions, respectively, on the mountain. Similar results are presented in graphical forms in Figures 2, 3, 4, & 5.

Table 2. Stocking levels of Mulanje Cedar as at July 2004.

Site name	Stocking		
	Stem/ha	Live (%)	Dead (%)
Chambe	47	87.2	12.8
Chinzama	131	58.8	41.2
Lichenya	91	61.5	38.5
Madzeka	88	55.7	44.3
Sombani	126	78.6	21.4
Thuchila	91	62.6	37.4

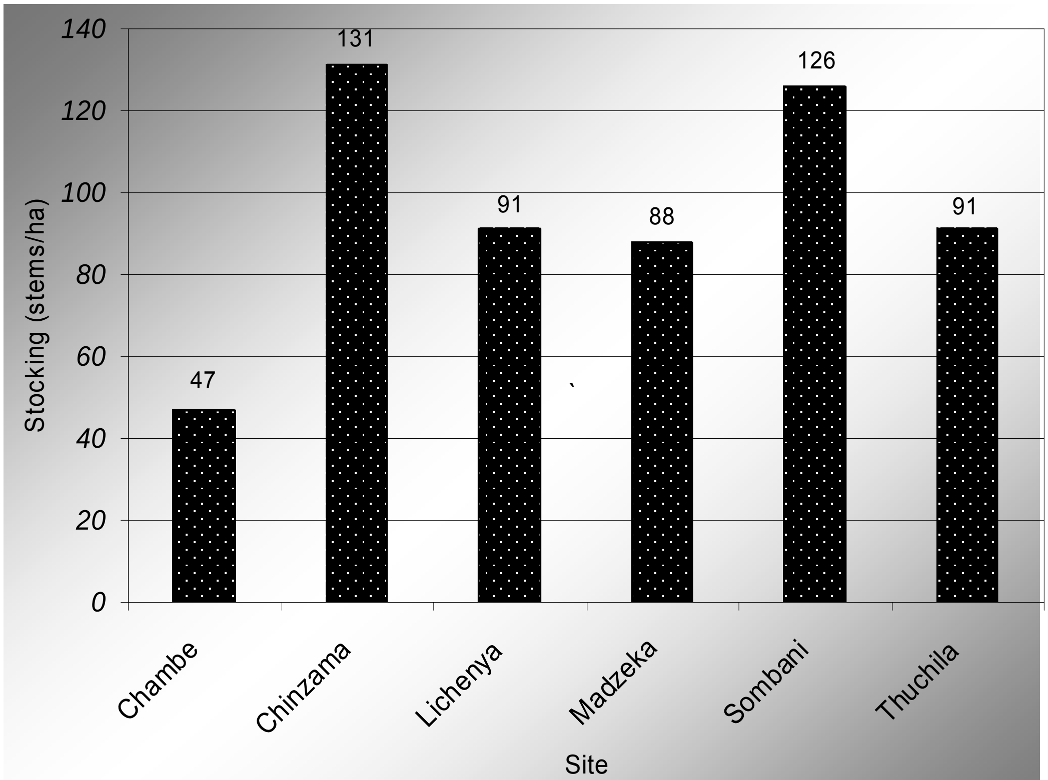


Figure 2: Stocking levels (stems/ha) of Mulanje cedar on Mulanje Mountain as at July 2004.

4.2.6 Figure 2 shows that Chinzama and Sombani areas have the highest stocking levels with 131 stems/ha and 126 stems/ha, respectively, and are not significantly different from each other ($p > 0.05$). Chambe basin has the least stocking levels per ha (47 stems/ha), whereas the stocking levels of Lichenya, Thuchila and Madzeka are not significantly different from one another ($p > 0.05$). The overall stocking rates of Mulanje cedar in all areas (sites) on the mountain are very low. The average area occupied by individual cedar tree on the mountain ranges from 76 m^2 in Chinzama to 217 m^2 in Chambe. Compare this with the final acceptable felling stocking level of mature *Pinus* species in Malawi of 250 stems/ha, giving the average area occupied by individual mature *Pinus* tree of 40 m^2.

4.2.7 These results reflect how heavily degraded the cedar forests are on Mulanje Mountain, with Chambe being the most degraded cedar area. On Chambe basin, you can only see individual scattered cedar trees sparsely located. The relatively high mean stocking level in Chinzama area is mostly contributed by a cedar stand to the east of the Chinzama Hut (Map 1), which has a stocking level of about 260 stems/ha. Similarly, for the stocking level of Sombani area is mostly contributed by the cedar stand (cluster) located to the east of Sombani Hut, near the Forest compound. These stands (clusters) appear to be as a result of an early cedar replanting program as evidenced by the spatial regular (linear) arrangements of the standing trees observed on the ground during the survey. Records could not be traced to determine when these stands were replanted. The closeness of the stands to the living compounds afforded some form of protection from severe wildfires and illegal harvesting. This shows that if the replanted cedars are well protected from these human-induced pressures, the degradation of its stock will be reduced.

4.2.8 Table 3 presents the density distribution of cedar trees across size classes on the mountain. The graphical presentation of the density distribution across different size classes on the mountain is presented in Figure 3. Similarly, the graphical presentations of the density distribution across different size classes for each site are presented in appendix 1.

Table 3. Density (stems/ha) distribution of Mulanje Cedar as at July 2004.

Size (dbh) class (cm)	Chambe		Chinzama		Lichenya		Madzeka		Sombani		Thuchila	
	Dead	Total	Dead	Total	Dead	Total	Dead	Total	Dead	Total	Dead	Total
5- 14.9	4	63	0	43	4	13	0	0	0	59	4	68
15- 24.9	4	77	0	17	55	115	0	0	4	68	63	81
25- 34.9	0	5	13	47	89	178	26	26	4	1 23	106	162
35- 44.9	0	0	4	43	78	209	21	26	26	119	55	106
45- 54.9	0	17	8	51	41	97	8	13	8	73	30	115
≥ 55	0	18	38	98	20	145	43	154	0	63	21	221

4.2.9 The results in Table 3 indicate that Chambe and Sombani have no or few mature, old cedar trees that are currently dead. Since the current licensing policy for cedar sawing allows only the dead cedar trees to be harvested, this means that Chambe and Sombani areas will currently be excluded from pit-sawing once the sawing season is opened up. Cedar sawing will have to be concentrated in the other four areas (sites) that have reasonable number of dead cedars.

4.2.10 The results also show that the density distribution of cedars across different size classes on the mountain is nearly normally distributed, with the exception of the largest size class. Most of the cedar trees are concentrated in the size classes between 25 and 45 cm. This is contrary to a J-shaped type of size (diameter) distribution observed by Lawrence *et al* (1994). In Lawrence's (1994) report, the largest number of stems was observed in diameter classes of 15 and 25 cm. These classes have now moved to larger diameter classes while the number of smaller trees remains relatively the same, giving approximately normal distribution as has been observed in the current study. It can be observed from the results that there are few smaller trees, which gives a clear indication of how little recent regeneration is surviving.

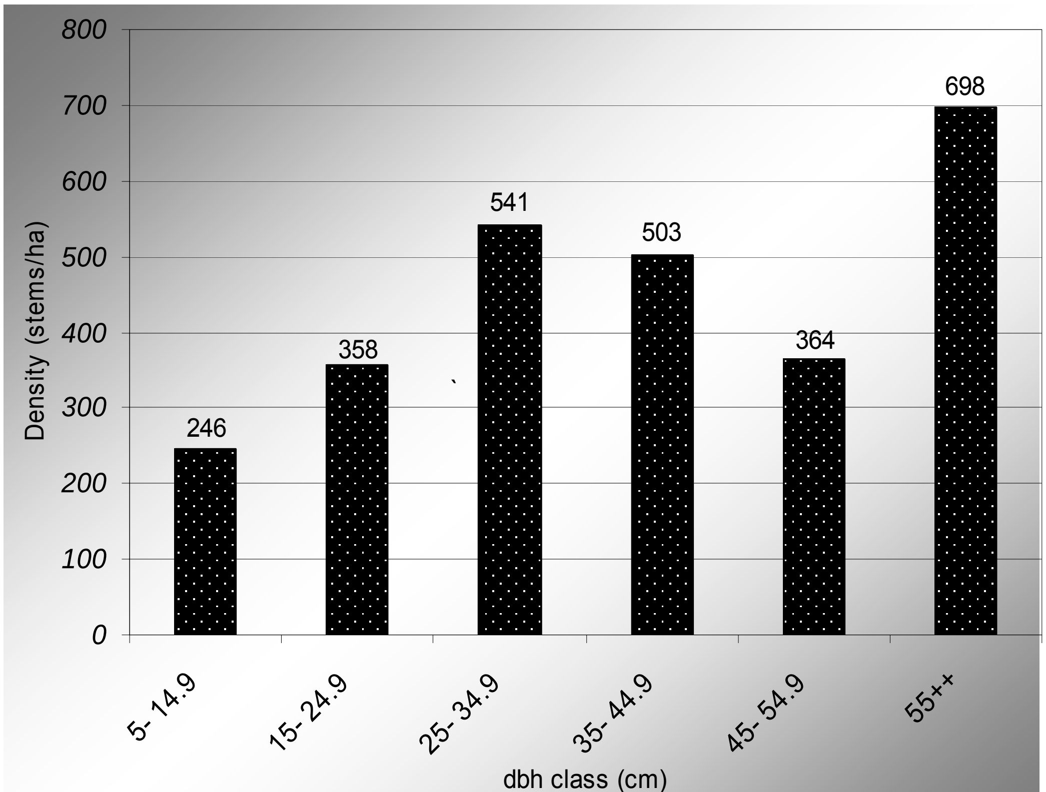


Figure 3: Density distibution of cedar across different size classes on Mulanje Mountain as at July 2004.

4.2.11 Figure 4 presents the average proportions of live and dead cedars distributed over each site (area) on the mountain. The values are presented as average proportions of live and dead cedars in a given unit area (ha) expressed as a percent (%) of the total number of stems present at that unit area (ha). For instance, from the results approximately 13% of the total cedar present in Chambe area is dead (87% of it is live cedar).

4.2.12 It should be noted from the results that Chambe and Sombani areas have the least proportions of dead cedars, whereas Madzeka, Chinzama, Lichenya and Thuchila areas have relatively higher dead cedars, in that order. In terms of distribution of dead cedar across size (diameter) classes, the results of Figure 5 shows that the distribution of dead cedars across size classes is approximately closer to normal, with many dead trees located in the middle sizes (25-34.9 & 35-44.9cm dbh). These results show that the death of cedar is randomly distributed in which every tree of any size has an equal chance of dying. In other words, the death of cedar trees on Mulanje Mountain was observed in all size classes (young, medium and old trees).

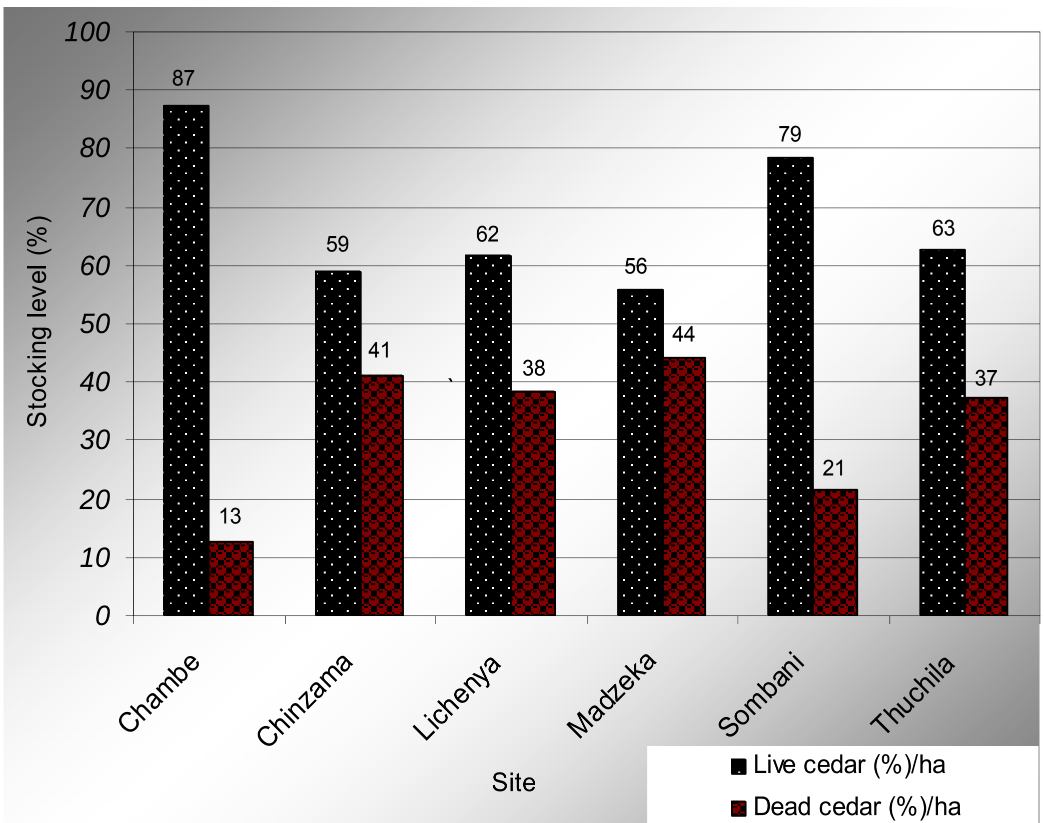


Figure 4: Proportional stocking levels (%) of live & dead cedar at each site on Mulanje Mountain as at July 2004.

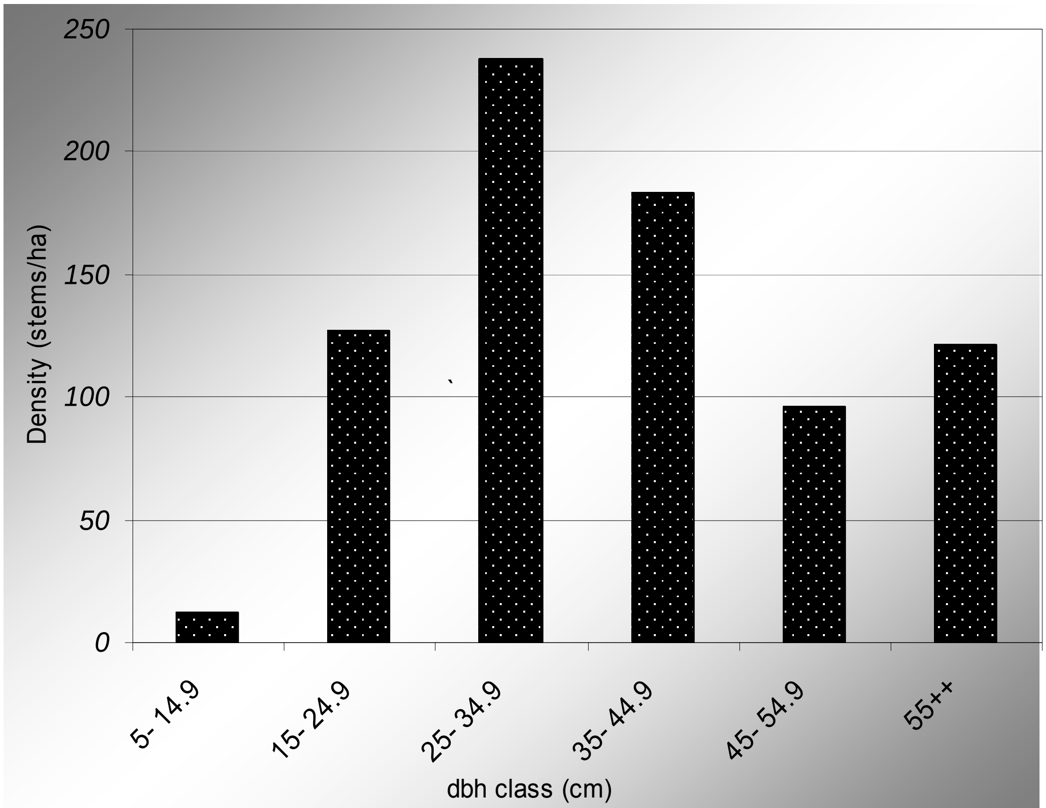


Figure 5: Density distibution of dead cedar across different size classes on Mulanje Mountain as at July 2004.

4.2.13 Dead cedar on Mulanje Mountain was first reported over 100 years ago. The following is an extract from the first report of 1896 of McClounie (Government Forester) to Commissioner Johnston in Zomba, as presented by Chapman (1995): "… Up to the present I have cut out nothing but **DEAD** wood, which in most cases is in good seasonable condition. The supply of timber yearly might be considerable and not materially affect the forests for many years…" In addition, in the recent past, Edwards (1982), Sakai (1989), Lawrence *et al* (1994), Chapman (1995), Pauw & Linder (1997) and FORINDECO (2000), all have reported about the dead and dying cedars on the mountain.

4.2.14 However, the causes of the death of the cedars on the mountain have not been explicitly established. Some authors speculate the following as the causes of the death of cedars on the mountain.

- Frequent wildfire damage
- Cypress aphid (*Cinara cupressi*) attack
- Invasion by alien species e.g. *Pinus patula*
- Deliberate damage (ring barking) of trees by man

- Effects of Climate Change: The meteorological data at the Tea Research Foundation seems to reveal an increase in temperatures and other climatic factors over the past twenty years.
- Natural process: It is believed that some primitive members of the cedar family have become extinct, as such it is speculated that the Mulanje cedar might also be in transition to extinction.
- A combination of two or more of the above factors.

4.2.15 Despite all these speculations and calls for research to establish the real cause of massive death of cedar, not much has so far been carried out by the Forestry Department, in particular the nation's forestry research center (Forestry Research Institute of Malawi – FRIM).

4.2.16 FRIM's research agenda on Mulanje cedar concentrated on introduction and monitoring of biological agent to control *Cinara cupressi* on the mountain. It is not yet known whether the natural enemy was established and what has been its impact on the aphid. However, during the survey it was crystal clear that the cedars are still dying and fresh dead cedars were being observed. Even before the aphid attack was first reported in Malawi in late 1980s, massive dead cedars were reported. It is therefore difficult to establish whether the massive death of the cedars is explicitly due to aphid attack. A comprehensive and in-depth research programme is therefore recommended to establish all possible causes of death and develop a mitigation and management programme to save the National Tree from extinction.

4.3 Standing Tree Volume of Mulanje Cedar

4.3.1 Table 4 presents the total standing volume (m^3) of all the cedar stands (clusters) on the mountain. The same table also presents the proportions of the total standing volume provided by live and dead standing cedars on the mountain. The determination of the standing volume of the dead cedars is to provide the estimate (volume) of the dead cedars that the Forestry Department can base the opening of this year's cedar sawing season. The current government policy on cedar licensing on Mulanje Mountain is to allow private sawyers (Pit Sawyers) to harvest ONLY the dead standing cedar trees.

4.3.2 In this report, the total standing tree volume is defined as the estimated standing volume to a minimum top limit of 5 cm diameter of individual trees calculated using formula 2. These results presented in a tabular form are also provided in graphical forms in Figures 6 & 7.

4.3.3 The results show that 115,398 (m^3) of cedar volume is currently standing on Mulanje Mountain. Approximately 32.27% (37,239 m^3) of this volume is from dead cedar while the remaining is from the live cedar. These results are relatively higher than the findings of Lawrence *et al* (1994) who estimated the total standing volume of 110,000 m^3. Lawrence's volume equation was formulated from volume data taken with Spiegel relascope whose top diameter limit of each tree was not specified. Realizing the average height of a mature cedar tree, it could be practically difficult to take the measurements with a Spiegel relascope to the minimum top limit of 5 cm diameter. As such there are possibilities that Lawrence's equation tends to underestimate the total standing volume of the cedars on the mountain.

Table 4. Total standing volume distribution (m^3) of Mulanje Cedar on Mulanje Mountain as at July 2004 at each site.

Site	Volume (m^3)		
	Total	Live	Dead
Chambe	7,231	5,407	1,825
Lichenya	43,753	27,702	16,051
Thuchila	28,933	20,033	8,900
Chinzama	5,653	3,819	1,834
Madzeka	20,479	14,434	6,048
Sombani	9,348	6,764	2,584
Total	115,398	78,158	37,239

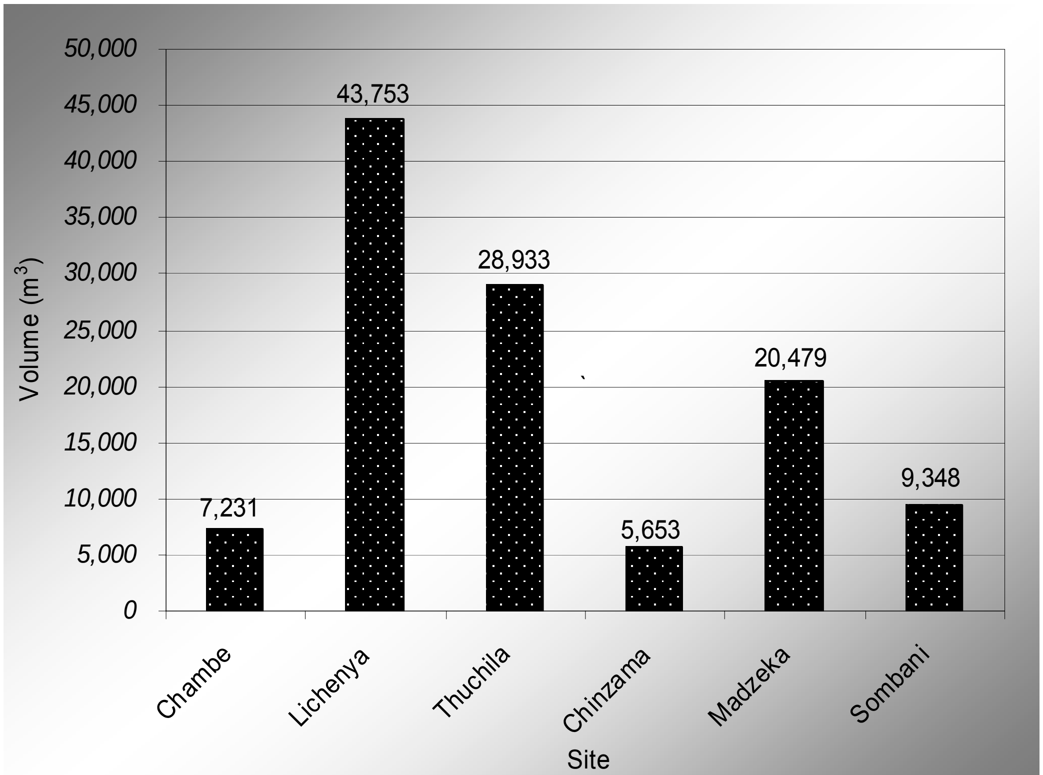


Figure 6: Volume distribution (m^3) of Mulanje Cedar as at July 2004.

4.3.4 The results also show that Lichenya plateau contributes the highest proportion (37.9%) of the total cedar volume standing on the mountain. This is followed by Thuchila, which contributes 25.1% of the total standing volume. Chinzama contributes the least (4.9%). During the survey, it was observed that most of the cedars dominating Lichenya (especially Limbe cluster) and Thuchila (Mikwasala & Mvunje clusters) were of the species *Widdringtonia whytei*. Lawrence *et al* (1994) called *W. whytei* as atypical cedar and estimated its mean clear bole as 62% of its total height, thereby contributing significantly to the large volume proportions on the mountain. The greater bole length and the smaller branching habit of *W. whytei* provide a greater amount of readily utilizable timber as observed in the study.

4.3.5 Figure 7 presents the volume proportions of dead and live cedars across all sites on the mountain expressed as a percent of the total standing volume in each site. Lichenya has the highest proportion (36.7%) of the dead cedar followed by Chinzama (32.4%) and Thuchila (30.8). On average 32.27% of the total volume standing on the mountain is from dead cedar trees. Lawrence *et al* (1994) found 30% of the total standing volume coming from dead cedar trees. The death has increased by 2.27% over the past 10 years, despite that the dead trees have been harvested yearly from the mountain as stipulated by the cedar licensing policy in Malawi. This shows that in real sense the increase in volume of the dead trees has been much more than this value, which is a worrying situation.

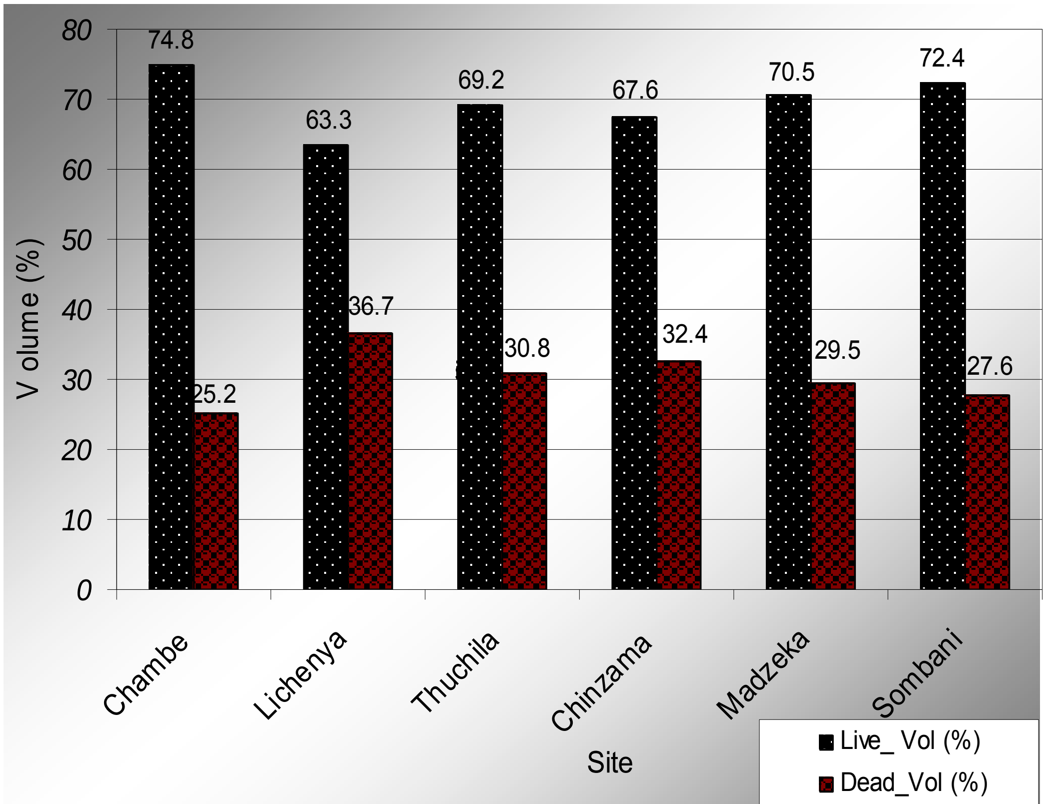


Figure 7: Proportional volume (%) of live & dead Mulanje Cedar at each site as at July 2004.

4.3.6 Since the cedar licensing policy in Malawi allows the utilization of ONLY dead cedar trees, the total standing volume of the dead cedar trees was then partitioned to various minimum top diameter limits corresponding to minimum economic (merchantable) sawing timber limits. Until recently the Forestry Department has been allowing the pit sawyers on the mountain to utilize the cedar for timber to a minimum top diameter limit of 30 cm. This is an extremely wasteful venture. The tops and lops that are left on the ground could as well be utilized for timber.

4.3.7 Most pit sawyers in pine plantations in Malawi have been utilizing wood to 20cm top diameter. This has also been regarded as wasteful and these pit sawyers are being encouraged to utilize the wood to as lower as 13cm top diameter as is the case with most wood processing industries. If pine trees, which are regarded as less superior to cedar in terms of physical, chemical and aesthetical wood properties, are utilized efficiently, what will stop the cedar tree from being efficiently utilized?

4.3.8 In this regard, three minimum top diameters that have been extensively utilized in pine plantations in Malawi are proposed. These minimum top diameters are 13 cm, 20 cm and 25 cm. The logs of 25-cm top diameter are regarded as the large-sized logs. The standing volumes to these minimum top diameters have been calculated and presented in Table 5. The same results are presented in graphical form in Figure 8.

Table 5. Merchantable volume distribution (m^3) of dead cedar on Mulanje Mountain as at July 2004 at each site.

Top diameter limit	Volume (m^3)
Vol_5cm	37,239
Vol_13cm	31,239
Vol_20cm	26,922
Vol_26cm	22,082

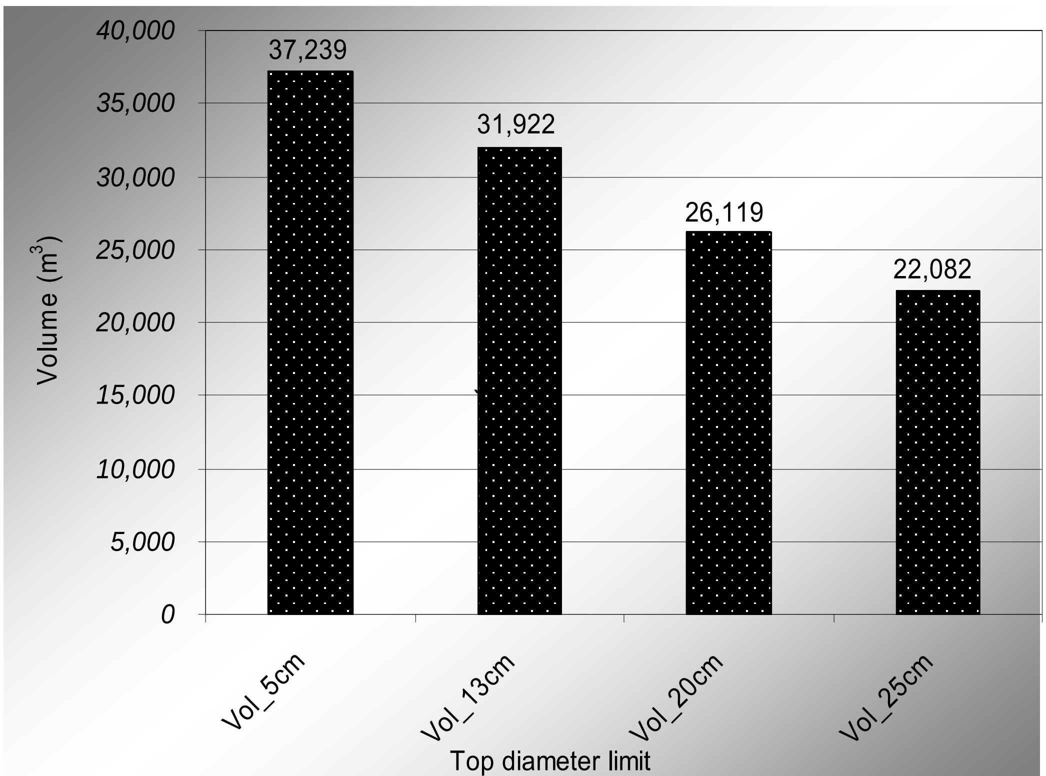


Figure 8: Merchantable volume distribution of dead cedar to various top diameter limits.

4.3.9 The results show that there is 31,239 m^3 of merchantable volume to 13-cm top diameter that can be harvested from dead cedar trees on the mountain. However, if the market requires large-sized logs then the mountain can currently supply 22,082 m^3 of merchantable volume from dead trees alone. It is calculated that 59.3% of the total merchantable volume from the dead cedar trees is of the large-sized logs.

4.3.10 The mean yield (volume) of an individual pit sawyer in one cedar sawing season on Mulanje Mountain is estimated at 20 m^3. The last 5 cedar sawing seasons, the Forestry Department engaged an average number of 20 pit sawyers in each sawing season, thereby harvesting an average of 400 m^3 yearly. Realizing that most of the trees are in very inaccessible areas (supposing 40%) as such cannot be reached for harvesting. This translates into 33 sawing seasons to utilize the currently standing volume of large-sized logs from dead cedar trees standing in accessible areas. In other words, the volume from dead cedar trees which are currently standing on the mountain can last for over 33 years, if utilized at the current rate with proper supervision and monitoring.

4.4 Regeneration

4.4.1 This study defined regeneration as those cedar saplings and seedlings that were less than 5cm in diameter at breast height. The saplings and seedlings were very scarce and wherever they occurred, they were in small clumps or as sporadic individuals. For instance no regenerant was observed in all the plots measured in Madzeka area, a few regenerants were observed in clumps in only one plot in Chambe and Sombani areas, respectively. Sporadic individual regenerants were observed along the fringe of the cedar cluster in just a single plot in Limbe cluster of Lichenya. In general, the number of regenerants counted in all the areas was too small to provide meaningful analysis. Therefore, no tabular results are presented.

4.5 Illegal Harvesting

4.5.1 Illegal harvesting of cedar was observed nearly in all the areas but varied in their degree of the problem. For instance in Lichenya (Limbe cluster), pole sized cedars with a mean stump diameter of 23cm had recently been illegally cut. In a single plot it was observed that 10 cedar trees in a 17m radius circular plot were cut and all of them were dead trees.

4.5.2 In Thuchila, illegal tree harvesting is prominent. Nearly in all the clusters visited, freshly cut stumps and lops & tops of cedar trees were observed. The mean stump diameter of the cut trees was 67cm and all of them were cut from live trees. In all these stumps there was no Forestry Department stamp on the upper surface of the stump to signify legally harvested tree, let alone the current cedar sawing season had not yet been opened.

Surprisingly, a team of 11 cedar poachers were seen in one afternoon carrying peeled logs descending through the Mvunje cluster.

4.5.3 In Madzeka, freshly cut logs were being sawn right in the forest. The inventory crew confiscated two saws from illegal tree poachers who had run away when the crew was approaching the sawing place. These saws were left under the custody of a watchman at Madzeka Hut.

4.5.4 This shows the magnitude of the illegal cedar harvesting on the mountain. However, throughout the two-week stay on top of the mountain no single Forestry Patrolman, Forest Guard or any other Forestry Official was seen to patrol the cedars. The only people who were on the mountain were the casual labourers hired by MMCT to clear and maintain firebreaks in readiness for the fire season.

4.6 Eradication of *Pinus patula*

4.6.1 *Pinus patula*, which is regarded as an alien invasive tree species on the mountain, is currently being eradicated from the Sombani and Chambe basins. These are the two basins that were planted with *Pinus patula* in 1946 with the original objective of acting as a nurse crop for the frost-tender Mulanje cedar (Edwards, 1982). The species had become established and naturalized and therefore threatens the survival of the cedars on the mountain.

4.6.2 The *Pinus patula* at Sombani basin had been completely cut, but burning of the cut trees was done while the survey team was on the mountain. At Chambe the cutting (eradication) of the pine trees was still going on, and some of the cut areas had been burnt off. Currently, extensive areas of pine trees have been cut and it is unlikely that the areas cut in both basins will be replanted within the next rainy season, thereby posing threats to soil and water degradation. This also contravenes the Kyoto Protocol (in which Malawi is signatory) of cutting down ozone depleting gases (e.g. carbon monoxide from incomplete combustion of biomass fuel) and leaving the ground under forest cover for the purpose of carbon sequestration.

4.6.3 The cutting of pine stands at Chambe includes cutting down of well-tendered, nearly mature stands of pines which would have been ready for economic harvesting in few years to come. Some of the pine stands were being thinned from above by pit sawyers and utilized for timber sawing. One wonders whether these were official pit sawyers registered by the Forestry Department (since the sawing season for pines had already been closed by 30th May). Otherwise, this is a real economic and monetary loss to the Government's investment in the establishment and management of the Chambe pine plantation.

4.6.4 Progress has been made on the cedar replanting program on Chambe on those areas that were cleared last year. The seedlings are establishing well and are well protected from wildfires which are a major threat to growth and development of cedar seedlings under natural environments. However, from our discussion with MMCT staff it became apparent that the ultimate goal of the replanting programme of cedar was not well articulated – whether it was for economic or biodiversity conservation purposes. If the ultimate goal was for future economic utilization of the cedars, then the current replanting approach was sufficient with extra emphasis on seed sources to avoid mixing up of *W. whytei* and *W. nodiflora* which have different characters for economic purposes. Also elite mother trees would need to be properly selected.

4.6.5 However, if the purpose was for biological conservation, then planting of cedar in pure stands (sole planting) might not be the best approach. Inclusion of cedar with *Prunus africanus* or other known species associated with cedar in the natural environment would be recommended. This will safeguard the species from some of the speculative insect pests, climatic or environmental factors that may wipe out the species if planted in sole stands.

4.7 Wildfire Management on Cedar Clusters

4.7.1 The devastating effects of wildfires on Mulanje cedar were first reported in 1891 by Alexander Whyte when he visited cedar forest on Lichenya. Since then, there have been subsequent reports on effects of fires by a number of authors (Manning 1894 and Chapman1961, 1962 as reported by Edwards 1982; Edwards 1981, 1982; Sakai, 1989). Efforts to protect the young stands of cedar by early burning the grasslands were started in 1901 and a firebreak network was first introduced on the mountain in 1949 (Edwards 1982).

4.7.2 The current fire management systems being implemented at the mountain involves maintenance of fire breaks, controlled early burning which is done in July; and mobilization of stand-by fire fighting teams. A two-tier system of firebreaks is currently being implemented on the mountain. The first tier consists of major firebreak network, including those on the plateau lip and constitutes the main pathways. The second tier consists of a minor firebreak around each cedar cluster and is placed at a reasonable distance from the edge, to provide a peripheral strip in which regeneration is promoted. The clearing of the second tier of minor firebreaks is still in progress in some clusters. MMCT is encouraged to continue facilitating this process until all the clusters are covered with the second tier of minor firebreaks.

4.7.3 While carrying out the survey, MMCT made arrangements to invite the fire fighting team from Chileka Airport to train the stand-by fire fighting teams in readiness for the fire season on the mountain. One would wonder whether inviting the team from Chileka was appropriate, realizing that their area of fire fighting specialization is not really on bush or forest wildfires. Fire fighting trainers with forest background would have been most appropriate as the spread characteristics of such forest fires are unique. This uniqueness determines the fire fighting control approaches to be used depending on the fire characteristics.

5 RECOMMENDATIONS

5.1.1 From the preceding chapters, it is clear that the first priority for the management of Mulanje cedar on the mountain is the protection of the cedar forest against wildfires, invasive alien species such as *Pinus patula* and *Rubus ellipticus* and wood poachers. However, the eradication programme for the invasive alien species, in particular *Pinus patula* is in progress in Chambe and Sombani basins. There were some individual or small clumps of *Pinus patula* near CCAP Hut and on the grassland of Limbe cluster on Lichenya plateau, for example. Similar situations also appear to occur in other areas. These may, when the cones are mature, be spread to the nearest cedar clusters. It is recommended that these individual or small clumps of *P. patula* be eradicated before they spread out.

5.1.2 The present two-tier firebreak system is inadequate in most areas to completely protect the cedar clusters from wildfires. These should continue to be complemented by controlled early burning, yearly firebreak maintenance and stand-by fire fighting teams. It is also recommended that fire warning placards be prepared and posted on strategic points on the mountain to alert the people about the dangers of wildfires on the mountain. Since most of the wildfires are human-induced, public awareness campaigns about the dangers of starting fires need to be carried out by the Education and Communication Department of the MMCT in conjunction with both Mulanje and Phalombe DFOs.

5.1.3 For long-term strategic approach to fire management on the mountain, a comprehensive study needs to be carried out to establish people's attitudes and perception towards wildfires. This will highlight deep-rooted indigenous knowledge towards wildfires and any future fire management proposition will be responsive to such challenges. It is also proposed that fire monitoring strategies be put in place to monitor the occurrence and spread of wildfires on the mountain. There are now opportunities to monitor wildfires by use of satellites. Malawi has an opportunity to receive free e-mail alerts of near-real time occurrence of wildfires in specified areas through Air-borne Fire Information System (AFIS) based at CSIR in South Africa. Therefore, AFIS capacity can be accessed to enhance fire monitoring. For details about AFIS, contact the author at Bunda College.

5.1.4 The present system of sporadic patrols on the mountain to curb illegal cedar exploitation is not adequate. The patrol teams are resident at the base of the mountain and as such wood poachers monitor their movements in terms of when they ascend the mountain for patrols. It is therefore recommended that the proposed patrol programme developed by FORINDECO (2000) be implemented. However, with the current situation on the mountain, 4 patrol teams are proposed to be resident on the mountain as follows:

1 patrol team based at Lichenya Hut cover the Lichenya clusters.
1 patrol team based at Thuchila Hut to cover the Thuchila clusters.
1 patrol team based at Madzeka Hut to the Madzeka clusters.
1 patrol team resident at Chinzama hut to cover Chinzama, Minunu and Sombani clusters.

These patrol teams should include those patrolmen that were recently sent for wildlife military training at Liwonde National Park. The team patrolling Thuchila clusters should not segregate between clusters that belong to Mulanje or Phalombe DFOs, as is currently the case.

5.1.5 The study revealed massive death of the cedars on the mountain. However, most of the causes of the death are speculative. A number of authors (Edwards 1982, Sakai 1989) had called for research to establish the real causes of death but not much has currently been done except the monitoring of aphid populations. A comprehensive and interdisciplinary research involving pathologists, entomologists, ecologists is therefore proposed. Bunda College of the University of Malawi has the capacity to carry out such research program. Some of the research activities can be done by post-graduate students at Bunda College as part of their research theses, thereby MMCT contributing to capacity building of Malawians and at the same time research questions are dealt with within a specified time period. It is therefore proposed that a joint research program between MMCT and Bunda College be developed soonest.

5.1.6 The study has also revealed that there is low natural regeneration of cedars on the mountain. This was in agreement with the findings of Edwards (1982), Sakai (1989) and Lawrence *et al* (1994). It is believed that the absence of regenerants in most areas might be as a result of frequent annual fires (Chapman 1996). However, there has been no quantified data to show the correlation between fire frequencies and survival, growth and development of cedar regenerants. It is therefore proposed that fire research trials need to be established on the mountain to determine its impacts on survival, growth and development of cedar seedlings and trees.

5.1.7 Presently, in areas with a good number of regenerants, these should be well protected from severe wildfires. In order to initiate increased number of seedlings, the emphasis should be on artificial regeneration of the cedar stands through replanting as opposed to natural regeneration. There are some old planted cedar stands on the mountain (e.g. Sombani near Forestry compound) that show very good growth, indicating that the mountain has a great potential for establishment and good growth of cedars. The efforts being currently taken by MMCT in replanting the cedars on the mountain are commendable and need to be continued.

5.1.8 As the cedar re-aforestation exercise is underway on the mountain, issues related to sources and quality of cedar seed material need to be seriously considered. As much as community seed collection might be a viable option for economic community empowerment, this might have far-reaching consequences in future in terms of timber quality. The chances that communities can mix *W. whytei* (the recommended type) and *W. nodiflora* (the dwarf types) or collect seed only from the dwarf cedar type are very high. The dwarf cedar type (*W. nodiflora*) has relatively short bole and heavy branching system thereby providing easiness for seed collection by communities. It is therefore recommended that the National Tree Seed Centre (NTSC) at Forestry Research Institute of Malawi (FRIM) be sub-contracted to collect cedar seed on behalf of MMCT for the replanting exercise. NTSC at FRIM has the professional capacity and modern equipment for seed collection, processing, testing and storage.

5.1.9 The study has revealed that most important cedar stands with reasonable amounts of dead cedar trees that can be harvested are located within the biodiversity conservation zones as demarcated by FORINDECO (2000) e.g. Lichenya area. In these biodiversity conservation zones, FORINDECO (2000) recommended that no exploitation of cedar would be allowed. However, in biodiversity conservation management, some form of monitored low impact exploitation of the resource is allowed. There are tools and techniques that have been developed to exploit the resources in such areas. Therefore, it is recommended that low impact harvesting/logging systems be employed to utilize the dead cedar trees in the conservation areas of the mountain. This should be done under close supervision by the field forestry staff. If the old dead trees are left unutilized, they may fall off at a later stage, thereby destroying the ecosystem and becoming fire hazard.

5.1.10 In some of the biodiversity conservation areas, the cedar population is already degraded, e.g. Linje-Lauderdale Crater on Lichenya plateau and Minunu – Madzeka area. In such areas it is recommended that enrichment planting with cedar seedlings be explored. Realizing that cedar is a pioneer species, it is recommended that in areas where canopy closure of other species is very high, opening the canopy (gap creation) is essential to allow light penetration that will facilitate establishment and development of the seedlings. The study on enrichment planting can as well be incorporated with the proposed comprehensive research program.

5.1.11 It has also been observed that there is a lot of wastage by pit sawyers when sawying the wood. It is therefore recommended to allow the pit sawyers to fully utilize the whole tree. The tops and lops can be sold to craftsmen who make cedar boxes. Currently, the cedar licensing policy only allows the private sawyers to purchase the trees and there are no provisions for small scale craftsmen to purchase and own a full cedar tree on the mountain. Some cedar trees (*W.nodiflora*) can best be utilized by such purposes as opposed to timber production because of its heavy branchness and short sawable log (bole). There are many dead cedar trees of this type that pit sawyers may not be interested to buy. It is recommended that Forestry Department regulates the cedar licensing policy to include small scale craftsmen.

5.1.12 There is need to undertake detailed research to assess cedar losses due to diseases and pests and underpin the factors that promote natural and rapid regeneration, which can be mimicked for artificial propagation of planting materials for replanting on a wider scale. Other studies should also focus on ecological aspects of cedar and other associated communities including growth and development behaviour under the prevailing conditions. It is therefore recommended that permanent sampling plots (PSPs) in specific cedar clusters be established to study these variables. During the field work the following cedar clusters were identified to provide appropriate sites for such monitoring plots (PSPs). The clusters were Chambe, Mikwasara, Limbe, Vunje, Chinsepo, and Namasile. The selection of these sites were based on a number of factors including the prevalence of cedar seedlings, association of cedar with other plant/tree communities, cedar growth behavior and other unique biophysical characteristics of the sites.

5.1.13 Finally, it was observed that there has been no an encompassing cedar management and utilization policy in Malawi, despite it being a very important National Tree. All activities related to cedar are done on an ad hoc basis except the licensing of the opening of the cedar sawing season. The policy should include all aspects of management including marketing of timber from cedar trees. MMCT is well suited to mobilize and provide advocacy for such policy formulation and implementation.

6 CONCLUSION

6.1.1 The findings of this study have established the ecological conservation status of Mulanje Cedar on the mountain; and therefore management and research recommendations to enhance and improve sustainable conservation and utilization of the cedars on the mountain have been proposed for implementation. In addition, based on the analytical assessment of quantities of the harvestable and merchantable volumes of dead cedars available on the mountain, the Forestry Department and Mulanje Mountain Conservation Trust (MMCT) are advised to open the sawing season this year and subsequent years, as long as the recommendations that have put in this paper are adhered to and implemented. The current cedar volumes from dead cedar trees can last for over 33 years (harvesting seasons) at the current utilization rate.

7 REFERENCES

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8 APPENDIX 1.

Tree Density Graphical Presentation.

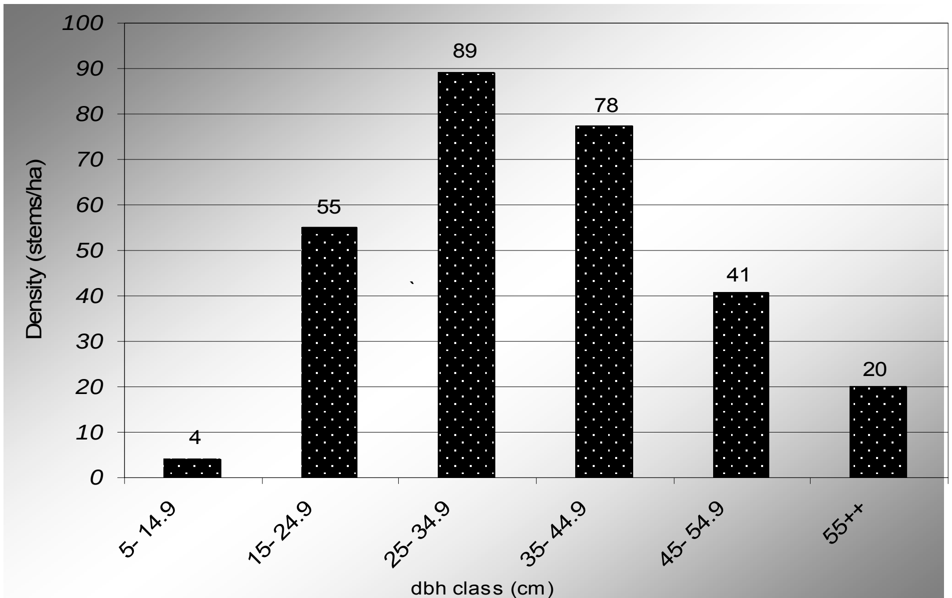

Figure 1: Density distibution of dead cedar across different size classes at Lichenya as at July 2004.

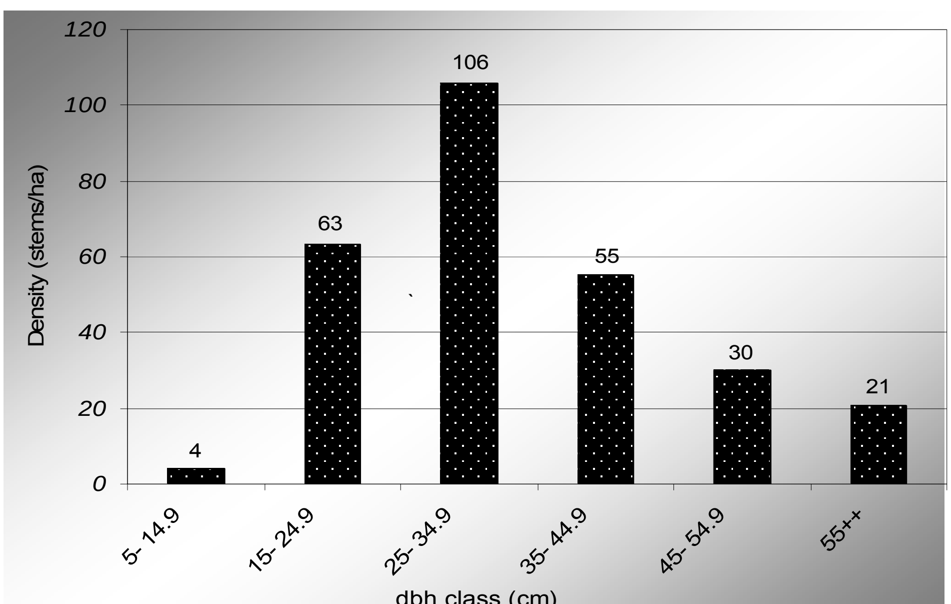

Figure 2: Density distibution of dead cedar across different size classes at Thuchila as at July 2004.

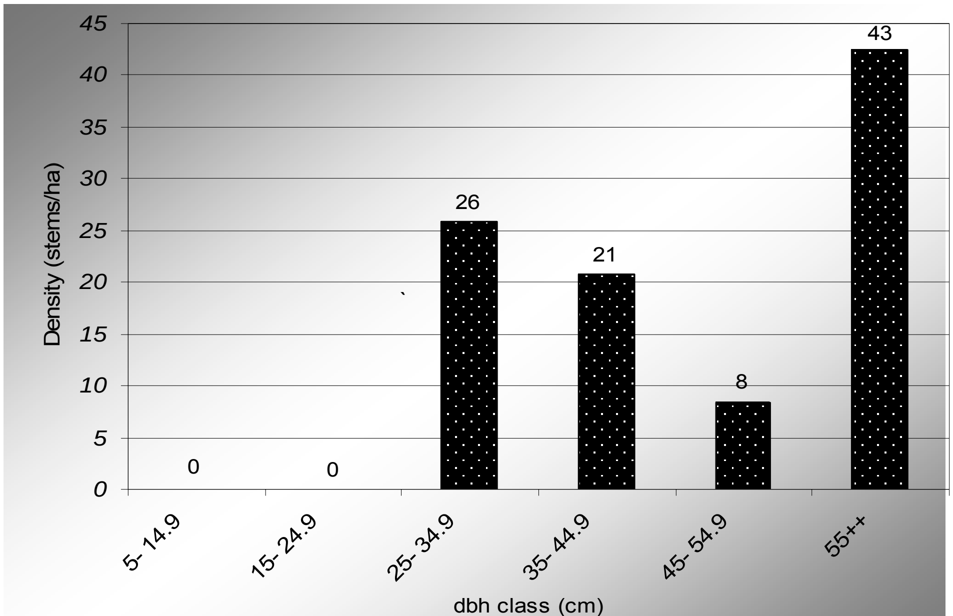

Figure 3: Density distibution of dead cedar across different size classes at Madzeka as at July 2004.

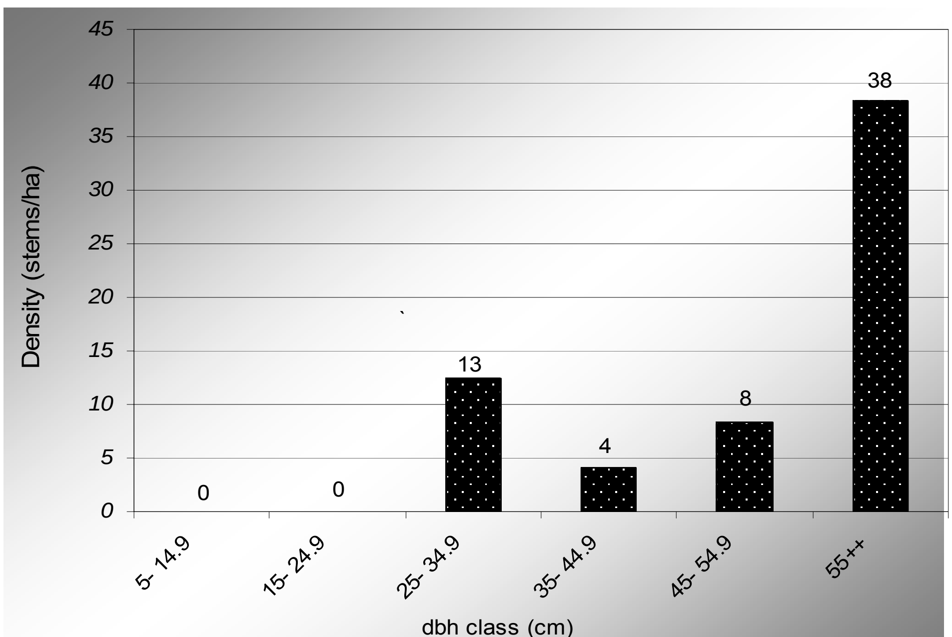

Figure 4: Density distibution of dead cedar across different size classes at Chinzama as at July 2004.

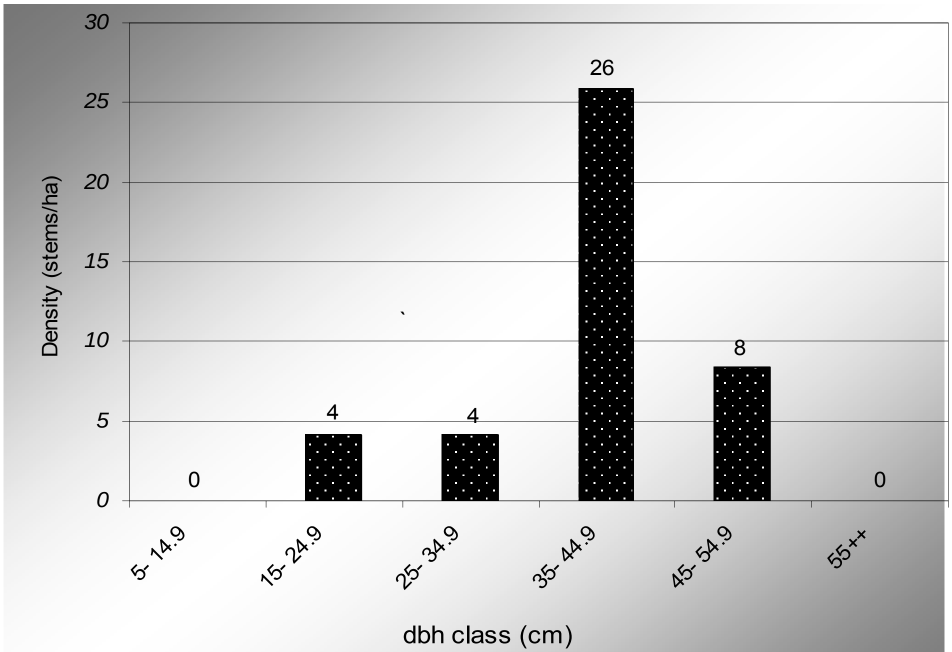

Figure 5: Density distibution of dead cedar across different size classes at Sombani as at July 2004.

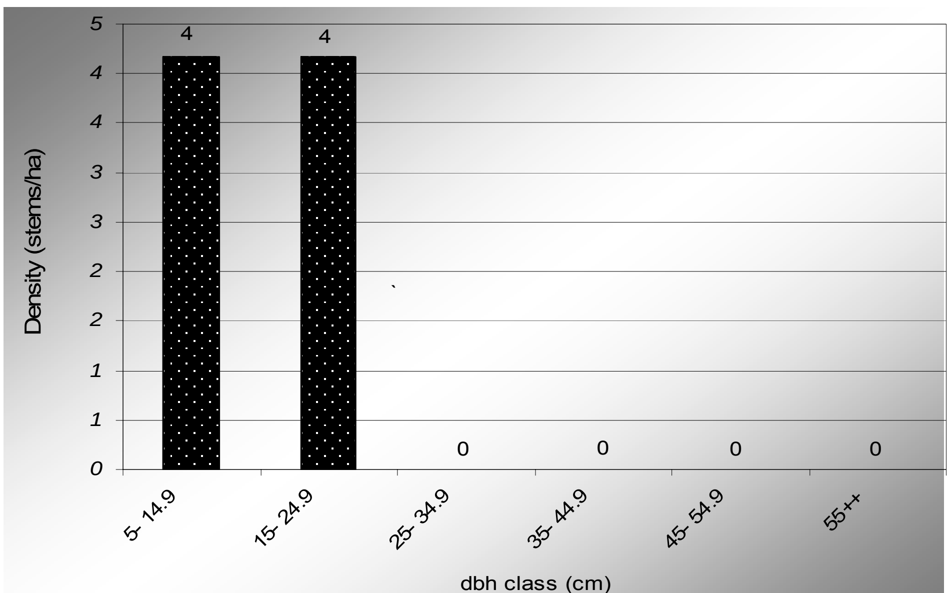

Figure 6: Density distibution of dead cedar across different size classes at Chambe as at July 2004.