TANZANIA FOREST CONSERVATION GROUP

TECHNICAL PAPER 3

# An Assessment of the Tanzania Forest Conservation Group Reforestation Programme in the Southern Udzungwa Mountains

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| | |
|---|---|
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# 1 Introduction

The Tanzania Forest Conservation Group (TFCG) is a Tanzanian non-governmental organisation promoting the conservation of high biodiversity forests in Tanzania. TFCG have a number of field based projects in the Eastern Arc and Coastal forests. This includes a project in the Southern Udzungwas where TFCG have been promoting the sustainable management of eight forests since 1993.

One component of this project has been to attempt to restore forest in two areas, Luhunga and Lulanda. The aim of reforesting these areas is to 're-connect' fragments of formerly continuous forest. Restoration of tropical forest in Africa is not well studied. This report attempts to document the process of reforestation in the Southern Udzungwas and to highlight some of the lessons learnt.

## *1.1 Survey Objectives*

This survey aims to assess the success of TFCG's reforestation programme in the southern Udzungwa Mountains, the objectives are:

1. To assess the current status of the Lulanda corridor and Luhunga millennium forest in terms of botanical species composition and vegetation structure.

2. To recommend a management and monitoring strategy for the corridors.

## *1.2 Forest Fragmentation, Edge Effects and Corridors*

'Forest fragmentation' refers to an alteration in the spatial pattern of forests, so that formerly continuous forest areas turn into small forest stands isolated from each other by intensively modified land such as agricultural land, pastures and plantations. The key point is the change from continuous to discontinuous forest stands. Associated with forest fragmentation is forest habitat loss, i.e. the reduction in forest area (Haila, 1999). Although closely related, forest fragmentation and habitat loss can have separate ecological effects. Both forest fragmentation and habitat loss have occurred in Lulanda and Luhunga.

The negative consequences associated with forest fragmentation include: effects on natality; mortality; dispersal; and apparent species impoverishment, which fall into three categories:

a) effects from the reduction in area of the remaining fragment;
b) effects of increasing isolation of the fragments from each other;
c) effects of increasing disturbance from the surroundings.

The exact nature of these effects are highly species and environment specific and no universal rules can be given to mitigate the effects of fragmentation (Haila, 1999).

One of the negative impacts of forest fragmentation is the relative increase in forest edge relative to interior. Forest edge is defined as an 'abrupt transition between two relatively homogenous ecosystems, at least one of which is a forest' (Matlack and Litvaitis, 1999). An area of forest divided into several fragments will have a greater edge length than an equivalent area in a single block. Similarly, complex shaped forest patches will have a greater edge length than uniform shaped forest patches. Forest edges are typically hotter, drier, windier and lighter than undisturbed forest (Matlack and Litvaitis, 1999), which significantly affects plant and animal species assemblages. Historically, the lush plant growth and diversity of animals (particularly grazing animals) at forest edges was considered as beneficial. Now, however, edge habitat is recognised as being incompatible with the requirements of many forest species, and the proliferation of forest edges has threatened the diversity of many forest communities (Matlack and Litvaitis, 1999).

As the total area of natural habitat has reduced and become increasingly fragmented, scientists' understanding of the importance of dispersal and movements between fragments has increased. Conservationists have begun to consider preserving or connecting 'corridors' as a means of conservation. Corridors can be described as 'strips of semi-natural habitat connecting wildlife sanctuaries along which plants and particularly animals can disperse' (Stewart and Hutchings, 1996). The scale of 'corridors' can vary greatly, on a small scale a hedgerow could be considered a corridor allowing the dispersal of small mammal species for example. On a much larger scale, " 'global change corridors' have been proposed to help offset the effects of climatic change by allowing species to move along a north-south axis in response to expected changes in temperature" (Stewart and Hutchings, 1996).

There is considerable debate regarding the effectiveness and usefulness of 'corridors' in conservation. Intuitively, 'corridors' seem to make good ecological sense. Enabling populations to disperse to and from isolated habitat patches should:

1. Maintain or increase species richness in those patches;
2. Augment population size and encourage recolonization, thus reducing the risk of extinction (the rescue effect);
3. Reduce genetic population problems associated with small population size by introducing new genetic material. (Stewart and Hutchings, 1996).

Critics of the 'corridor' idea argue that "corridors may help to spread 'contagious disasters', such as fire, disease, and introduced predators, pests or weeds which may disrupt the existing native plant and animal communities" (Stewart and Hutchings, 1996). Due to the very nature of 'corridors' they are greatly subjected to 'edge effects'. In addition corridors are expensive to create and maintain.

Stewart and Hutchings (1996) conclude that "corridors are potentially hugely expensive to create and maintain, and the resources may be better allocated to maintaining or enlarging existing reserves".

In the defence of 'corridors' as a conservation strategy, it is acknowledged that they may serve as a 'nuclei for restoration and future expansion of the reserve system' (Norton, 1999). When considering the debate about 'corridors' and its relevance to TFCG's afforestation programme it is useful to consider two points.

First, much of the debate regarding the usefulness of corridors considers corridors in the context of 'wildlife corridors', aimed mostly at facilitating the movement of animal species, in particular large mammal species e.g. big cats, elephants, ungulates etc. Due to the present day lack of such large 'wildlife' in the Lulanda, area many of the issues discussed are not of primary importance to our example. However, the potential importance of the 'corridor' for resident primate species is not underestimated. Requirements of 'primate corridors' will undoubtedly differ from the requirements of corridors for larger mammals. Whilst important for management recommendations all such considerations are partially irrelevant now as we are not at the corridor design stage, Luhunga, Lulanda and Ihili 'corridors' exist.

Secondly, although technically many of the areas surveyed are 'corridors', in as much as they connect forest patches, the connected areas are still small fragments of a much wider habitat type. It may be more helpful to consider the reforestation programme in terms of habit extension with improved connectivity, amelioration of negative edge effects along sections of the forest patch borders and the creation of buffer zones. This is particularly the case for Ihili Corridor, where the 'corridor' area surrounds the forest patch, and does not quite link up to other forest patches.

## *1.3 Restoration Ecology*

Restoration ecology has the simple goal of 'returning an ecosystem to a desired, more natural state after human disturbance' (Frelich and Puettmann, 1999). The relatively new science of restoration ecology aims to establish how to achieve that goal, and has progressed since efforts first began about 30 years ago. Initially restoration projects were site-based and areas were restored with little reference to their surroundings (Webb, 1997). Two factors have prompted the shift from a site based to a landscape approach to restoration ecology. Firstly ecological science has highlighted issues of spatial relationships at all scales. Secondly, in some developed nations, the availability of land has increased with the decline in agriculture, forcing the question of 'where' should restoration attempts take place (Webb, 1997).

'The restoration of forest differs in scale – time, breadth, height and depth – from the restoration of most other types of vegetation' (Ashby, 1987). The complex nature of forests, particularly species diverse forests represents a major challenge. Whilst temperate forest and woodland restoration ecology is a relatively well established subject, as demonstrated by the number of texts available on the subject (e.g. Ferris-Kaan, 1995, Frelich & Puettmann, 1999) much less is known about tropical forest restoration. Chapman & Chapman 1996, comment that 'there are still few quantitative data available for tropical forest managers regarding the potential of various management options'.

During the literature search for this study it was found that there are few published examples of tropical forest restoration attempts, and almost no details of indigenous species growth or survival rates relevant to this study. Available information regarding tropical forest restoration attempts are based on work undertaken in the neo-tropics in countries such as Costa Rica, Colombia and Puerto Rico. These studies attempt to identify factors affecting the reforestation of areas that had previously been cleared for grazing or cultivation e.g. Aide *et al* (2000), Aide & Cavelier (1994), Holl *et al* (2000) and Loik & Holl (1999).

The barriers to tropical reforestation identified in these studies include: seed source and dispersal, seed predation, competition with grasses, microclimate and soil limitations on plant growth, fire (Aide & Cavelier, 1994), and photosynthetic responses to habitat change (Loik & Holl, 1999).

More recent studies have investigated ways in which to overcome barriers to forest regeneration, investigating methods such as the use of bird perches; planting native tree seedlings and seeding early successional shrub species (Holl *et al*, 2000). Holl *et al,* (2000), demonstrate that pasture grasses play a major role in limiting the survival of forest seedlings, and that shrubs and remnant trees facilitate the establishment of woody seedlings.

Patterns of natural regeneration have been studied by Aide *et al* 2000 showing that species richness of secondary forests (in Puerto Rico) recovered quite rapidly, but the species composition was quite different in comparison with old growth forest. Enrichment planting was suggested as a strategy for restoring the original composition. This same study also highlights the variability of the impact of exotic species on regenerating forests, depending upon the life history of the exotic species.

Closer to our study site, studies in Uganda have investigated the use of exotic species (*Pinus patula, Pinus caribaea* and *Cupressus lusitanica*) to rehabilitate degraded tropical forests (Finbel & Finbel, 1996, Struhsaker *et al,* 1989 and Chapman & Chapman, 1996). Chapman & Chapman, (1996) recorded relatively high species richness of regenerating species under *Pinus* sp. plantations, but offer cautionary remarks regarding the use of exotics to facilitate regeneration of native species due to damage caused during felling operations. Finbel & Finbel, (1996) show that advanced regeneration beneath plantations is relatively impoverished compared to the levels of tree diversity and stocking characteristic of both logged and unlogged natural forest sites. Perhaps more importantly, Struhsaker *et al,* (1989) reports the dieback of selected forest species which were downslope from conifer plantations (Struhsaker *et al,* 1989). Based on these findings, Struhsaker *et al*, (1989) recommend that conifer plantations should not be planted near natural forest in the tropics. This study is of particular relevance to TFCG's afforestation project, which incorporates areas where exotic species, including *Pinus patula* have been planted.

# 2 Description of Lulanda, Ihili and Luhunga forest corridors.

## 2.1 Lulanda Forest Corridor

### 2.1.1 General Description

| | |
|---|---|
| Name: | Lulanda Forest Corridor<br>Mufindi District, Iringa Region, Tanzania |
| Area: | Magwilwa Forest Patch – 89.3 ha<br>Fufu Forest Patch – 82.6 ha<br>Corridor approx. - 54 ha<br>Total approx. – 235.9 ha |
| Status: | Forests regarded as Local Authority Forest Reserves, but not officially gazetted (Woodcock, 1998). |
| Maps: | East Africa (Tanzania) 1:50 000<br>Series Y742 Sheet 249/1 Edition 1-TSD |
| Year of planting: | Border planted 1996<br>Corridor Planted 1993 – 1999 |

### 2.1.2 Location

| | |
|---|---|
| Latitude/longitude: | 08° 36′ 25″ S 035° 37′ 42″ E |
| Grid Reference: | 36 7 89 300 E 90 47 700 N |
| Elevation: | 1520 m – 1620 m a.s.l. |

### 2.1.3 Topography

Lulanda corridor lies on the edge of a very steep escarpment (which drops from 1600m to 1200 m over less than 1km) and has a complex pattern of steep slopes, ridges and hollows. The central ridge runs approximately southwest to northeast, with an 'arm' extending from the northerly end towards the southwest. A permanent stream flows from the northeast towards the western edge of the corridor, where it enters Fufu forest patch.

### 2.1.4 History

Lulanda corridor is a strip of land between two forest patches, Fufu forest and Magwilwa forest. Formerly these forest patches were part of a much larger contiguous forest encompassing 8 areas. Access to forest resources was controlled by the Hehe leaders and subject to local custom. Clearing of the forest in this area for coffee cultivation began in the 1950's encouraged by the British administration (Woodcock, 1998). The specific area referred to in this report as Lulanda corridor (see Figure 1) was cleared for cultivation in the early 1970's. Maize, beans and vegetables were the principle crops. Farming continued in the corridor area until 1993 when TFCG established its planting programme at the site. The first project manager (Mr Mudemu) began nursery and planting activities. The first nursery was established at the present day nursery site near the road. Many exotic species and some indigenous species were planted prior to 1995, mainly along pathways on ridge tops. A fire swept through the corridor area in 1995, killing most of the planted trees. However the fire did not jump across the Fufu stream to the far north of the corridor (Kiando, pers. comm.). Subsequent project managers have systematically removed surviving exotic planted trees in order to promote indigenous species within the corridor. In making this decision, consideration was given to the negative effects of exotic species found in the corridor such as pine (suppression of understory growth), and eucalyptus (absorbing a lot of water). In addition efforts were made to dissuade villagers from planting the highly invasive black wattle near the corridor borders (Meshack, pers. comm.)

The Lulanda corridor was demarcated and the borders were planted with *Hakea saligna* in 1995 and 1996. In 2000, a survey of Lulanda forest patches (Fufu, Magwilwa and Ihili forest patches) including the corridor areas was conducted by local district authorities with support from TFCG. Numbered concrete markers now mark the border of the corridors and forest patches, although these are not always easy to find.

Planting of indigenous species after the fire in 1995 began under the direction of Mr Charles Meshack. Due to the lack of readily available planting material, little planting was undertaken in 1996 and consisted mostly of seedlings taken directly from the forest and planted in the northwest of the corridor area. It was observed by field staff that many of these saplings died, and this area was replanted in 1997. A second nursery was established on the western border of the corridor adjacent to Fufu forest, this nursery is now abandoned but clearly visible. Planting in 1997 was widespread, covering the northern and western area of the corridor. In 1998, a smaller area was planted in the central southern area of the reserve, followed in 1999 by planting on the eastern side and far southwest corner of the reserve. See Figure 1 for a map showing planted areas. It is worth noting that enrichment planting was carried out in all areas previously planted in all years mentioned.

No precise counts of how many seedlings of each species planted in Ihili and Lulanda corridors were recorded. However TFCG field reports suggest that in total approximately 90,000 seedlings were planted in 1997, 170,000 in 1998 and 83,500 in 1999. Considering the size of the areas planted the figure for 1997 would seem to be an underestimation.

Cutting of the grasses around each planted sapling (clearing) has not been undertaken regularly. Field staff report that in 1997 saplings in the entire planted area of Lulanda corridor were cleared of grasses. Since then clearing has only been undertaken in areas close to paths and at the time of planting. Many areas of the corridor were observed to be overgrown with grasses often reaching 1.5m in height.

## 2.2 Ihili Forest Corridor

### 2.2.1 General Description

| | |
|---|---|
| Name: | Ihili Forest Corridor<br>Mufindi District, Iringa Region, Tanzania |
| Area: | 32 ha (including remaining forest) |
| Status: | Forest regarded as Local Authority Forest Reserves, but not officially gazetted (Woodcock, 1998). |
| Maps: | East Africa (Tanzania) 1:50 000<br>Series Y742 Sheet 249/1 Edition 1-TSD |
| Year of planting: | Border planted– 1996<br>Corridor Planted – 2001 |

### 2.2.2 Location

| | |
|---|---|
| Latitude/longitude: | 08° 36 06 S 35° 36 59 E |
| Grid Reference: | 36 7 88 000 E  90 48 300 N |
| Elevation: | 1500 m – 1620 m a.s.l. |

### 2.2.3 Topography

Ihili corridor lies approximately 300m to the north of Lulanda corridor, it surrounds Ihili forest patch that straddles a gully running from the southwest to the northwest. A distinct peak reaching 1620m a.s.l. lies on the northern side of the gully, the planted corridor includes the southern slope of this peak. A stream runs through the gully in a westerly direction originating in the forest.

### 2.2.4 Ihili Forest Corridor

Ihili corridor surrounds Ihili forest patch. The history of deforestation in Ihili corridor is the same as the pattern of deforestation in Lulanda corridor. Ihili corridor was demarcated and the borders planted with *Hakea saligna* in 1995 and 1996 at the same time as Lulanda corridor. All indigenous tree seedling planting was undertaken in 2001. No post planting clearing had been undertaken prior to this survey. TFCG have been considering linking Ihili with Fufu-Magwilwa by planting the areas up to the road. These plans are still under review.

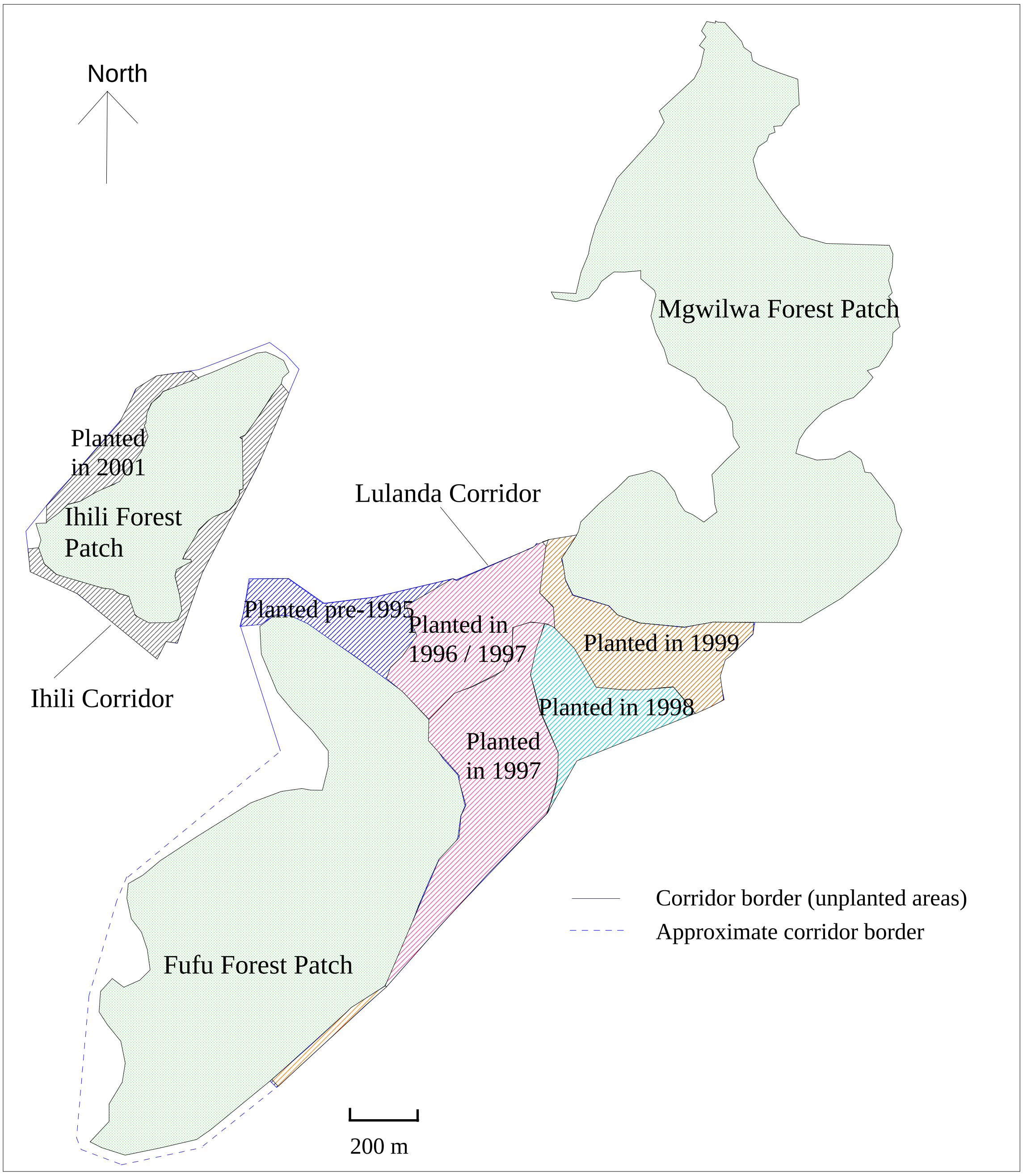


**Figure 1** Map showing Lulanda and Ihili corridors, three forest patches and the year each area was planted.

## 2.3 Luhunga Forest Corridor

### 2.3.1 General Description

| | |
|---|---|
| Name: | Luhunga Forest Corridor<br>Mufindi District, Iringa Region, Tanzania |
| Area: | Corridor approximately 7.5 ha (of which 1.5 ha is planted)<br>Luhunga forest approximately 150 ha |
| Status: | Forest regarded as Local Authority Forest Reserves, but not officially gazetted (Woodcock, 1998). |
| Maps: | East Africa (Tanzania) 1:50 000<br>Series Y742 Sheet 248/1 Edition 1-TSD |
| Year of planting: | Planted 2000 |

### 2.3.2 Location

| | |
|---|---|
| Latitude/longitude: | 08° 33′ 48″ S 35° 27′ 33″ E |
| Grid Reference: | 36 7 70700 E 90 52 650 N |
| Elevation: | 1824 – 1848 m a.s.l. |

### 2.3.3 Topography

Luhunga corridor slopes gently downhill from the planted area in the northwest towards the east and southern borders. A stream runs along the eastern border of the corridor.

### 2.3.4 History

Luhunga forest and corridor lie approximately 18.5 km to the north west of Lulanda. Luhunga corridor is a strip of land between a large forest block and a small patch of forest and several remnant trees. Luhunga corridor was forested as recently as 1996, when the area was cleared for cultivation. The main crops were maize and beans. The last crops were planted in 1999, since then no crops have been planted or harvested in the area (Ngassa. pers. comm.).

Luhunga Corridor is also known as the Millennium Forest, and owes its existence partly to TFCG and the District Natural Resource Office, but also to the very enthusiastic local community. The Lugoda – Lutali forests (into which Luhunga falls) were recommended to TFCG as a potential project site by the District Natural Resources Office (DNRO). After TFCG implemented initial project activities, the local ward committee requested assistance to establish a corridor (like Lulanda), to mark the new millennium. The DNRO supported the idea and the local community with assistance from the DNRO and TFCG established Luhunga corridor. In February 2000, 6400 seedlings of four indigenous species (*Macaranga kilimandscharia, Bridelia micrantha, Syzygium cordatum,* and *Aphloia theiformis*) were planted on a 2m x 2m grid. Tree seedlings were provided by the TFCG nursery in Lulanda, which was the only source of indigenous seedlings in the area. Additional areas in the corridor are due to be planted in 2002 and 2003 with support from the DNRO and TFCG.

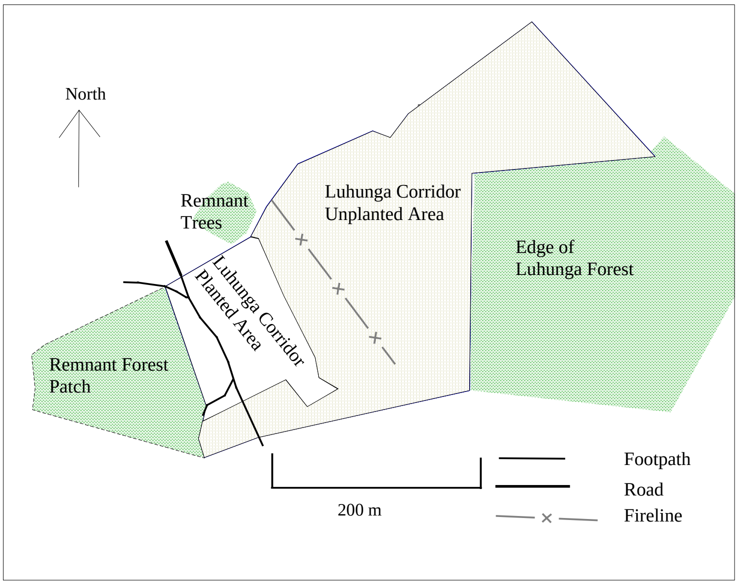


**Figure 2** Sketch map showing Luhunga Corridor and forest patches.

Please note the large difference in scale between Figure 1 and 2.

## 2.4 Seedlings

The indigenous seedling planting stock came from three sources. The majority of seedlings (particularly in the earlier years) came from seedlings or 'wildings' collected from adjacent forest patches after the heavy rains when seeds in the seed bank have germinated. These seedlings were then placed in the nursery for approximately six months, where they were watered and protected from infestation, a process known as 'hardening'.

The second but minimal source of planting material was seedlings or 'wildings' taken from the forest and planted directly in the corridor, without 'hardening' in the nursery.

The third seedling source consisted of seeds collected from the forest but germinated in the nursery and then allowed to develop in the same way as seedlings collected from the forest. The success of seed germination in the nursery varied between species. No figures exist to compare actual success rates however observations by project staff suggest that *Parinari* sp. was particularly difficult to make germinate; *Syzygium cordatum* seeds required drying prior to germination; *Craibia brevicaudata* germinated easily in the nursery but many died when seedlings were planted out into the corridor; *Bridelia micrantha, Macaranga kilimandscharia,* *Trema orientalis* and *Nuxia floribunda* grew well around the nursery. An effort was made to concentrate efforts on those species that were observed to perform well.

Having grown to about 30 centimetres (cm) tall and having roughly five leaves the seedlings were planted out in the corridor. Each seedling was planted in a shallow hole approximately 50 cm in diameter and five – ten cm deep. The holes were approximately two metres apart. Seedlings were not planted in waterlogged areas, under trees, or in areas that had many regenerating stems.

Clearing of the planting lines was undertaken in January and February of each year, followed by digging holes during March. The tree-planting season took place early in the year just prior to the heavy rains in April and May. Clearing of vegetation around seedlings (when it was undertaken) took place during July to December.

### 2.5 Fire line

Following the fire in 1995, a fire line 9 m wide was cut in 1997 along the southern border of the Lulanda forests and corridor (see Figure 3). TFCG staff and the Lulanda villagers clear the fire line in the months preceding the dry season (August) each year. In March/April 1998, 5400 fire resistant species seedlings were planted along the fire line. In September 1998 vulnerable areas of the fire line were widened. By August 1999 the fire line had been widened to approximately 15 metres.

The observation tower on the corridor provides an opportunity to monitor the threat of any fire on the escarpment south of the reserve. In 2001, the fire line proved its worth by enabling the Lulanda community to successfully protect the corridor and forests from a long lasting fire threat from lower down the escarpment. It is notable that individuals were 'patrolling' the fire line 24 hours a day for over a week in the month of September. Due to the efforts of the Lulanda community the fire encroached only a very small area into the corridor.

# 3 Methodology

The vegetation in Lulanda, Ihili and Luhunga corridors was sampled systematically. The corridor areas were divided into a grid (200m x 200m), this grid was not marked in the field. The vegetation sample plots were located in the southeast corner of each of the grid squares. Two nested sample plots were established at each point located.

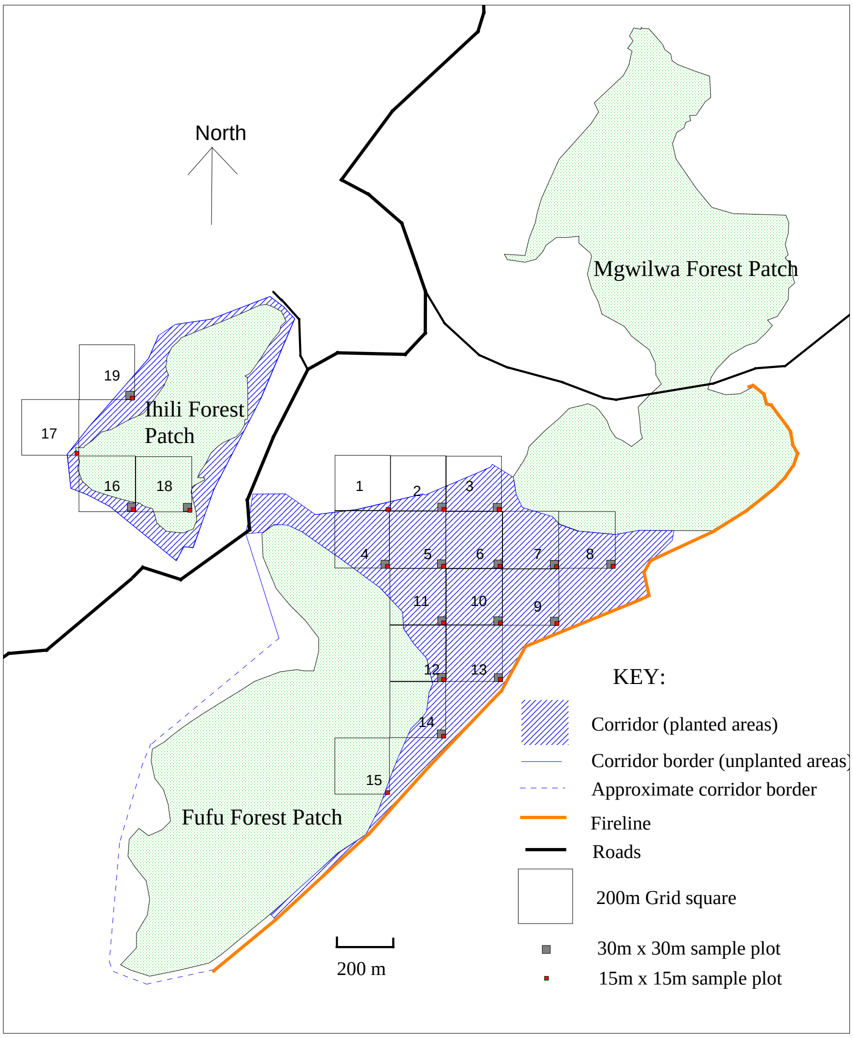


**Figure 3** Map showing location of fire line and vegetation sample plots in Lulanda and Ihili forest corridors.


Figure 4 Map showing location of vegetation sample plots in Luhunga corridor.

## *3.1 Location of sampling plots*

Each of the sample plot start points were located using a GPS. A Magellan GPS 315, using the UTM coordinate system and ARC 60 map datum was used. Care was taken to enable the GPS to make an accurate fix by allowing time for the readings to fix properly.

Once located each point was marked by placing a red 45cm metal rod into the ground approximately 30 cm was left protruding above ground (see Figure 5). These markers were located in the southeast corner of each of sample plot, providing a permanent mark of the plot start location.

**Figure 5** Red metal rod marking the southeast corner of each sample plot.

**Figure 6** Tag labelled with plot and tree number.

## 3.2 Sampling plots

Regeneration and seedling growth rates were measured in a 15m x 15m sample plot nested within a larger 30m x 30m sample plot in which seedling survivorship was measured.

### 3.2.1 Tree seedling growth rates and regeneration (15m x 15m plot)

A 15m x 15m sample plot was used to:

1. assess the growth rates of each planted tree seedling
2. record the number of regenerating species and stems

The 15m x 15m plots were established as follows. Starting at the plot marker (red metal stake), 'person one' cut a straight line 15m in length to the north, guided by 'person two' who ensured the right direction using a compass. A rope was tied between the end points, thus delineating the eastern border of the plot. This process was repeated to demarcate the other three borders of the plot. Care was taken to follow exactly the correct bearing (e.g. north, west etc.) to ensure the plot was square.

Within each 15m x 15m sample plot every naturally regenerating stem (larger than 1cm diameter at breast height (DBH)) and planted tree seedling was identified, and measured. The height of the top of the crown was recorded in meters (m). The DBH and basal diameter (BD) were recorded in centimetres (cm). DBH was measured at a height of 1.3m on the main trunk, where a regenerating sample tree had multiple stems the DBH was measured and recorded for each and every stem. Basal diameter was recorded at ground level, above the root stem.

In addition the general health of each measured tree was assessed qualitatively. Trees (including planted seedlings) were described as either:

**Thriving** – tree in good health and growing well.

**Satisfactory** – tree in reasonable health, this included trees that had dropped some leaves due to lack of water but were in no danger of dying.

**Struggling** - tree not in good health, struggling to survive, this included trees that had fallen over.

Information regarding the year of planting was collected through interviews with the former project managers (Mr Charles Meshack and Mr Adrian Kahemela), the current project manager (Mr Gerard Ngassa) and project field assistants (Mr Niblet Kiando and Mr Nicholas Kisonga).

Each tree measured was given a 'tree number' (starting from 1 in each plot), this 'tree number' together with the plot number was written in indelible ink onto a red plastic tag and tied to the tree. For regenerating trees the tag was tied at approximately the point the DBH was measured, for planted tree seedlings the tag was tied loosely at the base of the tree so as not to restrict growth of the seedling (see Figure 6).

All information was recorded in a field notebook, and then written up on to a plot vegetation form. Finally all data was entered into a Microsoft Excel file (submitted to TFCG with this report).

Most plant species were identified by the TFCG botanical collector Moses Mwangoka in the field. 117 representative specimens of species (mostly regenerating species) encountered were taken, where possible five or six duplicate specimens of each species were collected and prepared. Each specimen was given a 'MM' number, all location and habitat notes were recorded in Moses Mwangoka's note book. A list of MM numbers and current identifications is given in Appendix 1.

Collected specimens were identified by Moses Mwangoka at the National Herbarium in Arusha. Roy Gereau (from the Missouri Botanical Gardens, USA) provided species confirmation of a limited number of specimens. Some of the collected specimens have been entered into a field herbarium held by TFCG, the remainder have been deposited at the National Herbarium in Arusha and at the Missouri Botanical Gardens.

### *3.2.2 Survivorship sampling plots (30m x 30m).*

Starting at the plot marker, 'person one' cut a straight line 30m in length to the north, guided by 'person two' who ensured the right direction using a compass. A rope was tied between the end points, thus delineating the eastern border of the plot. This process was repeated to demarcate the other three borders of the plot. Care was taken to follow exactly the correct bearing (e.g. north, west etc.) to ensure the plot was square. This plot incorporated the 15m x 15m plot to form nested plots (see Figure 3).

The whole plot was thoroughly searched for evidence of tree seedling planting. Where planting had taken place it was assumed that each hole had a tree seedling planted in it at the time of planting. Each hole was recorded as either:

**Hole** – indicating the planted tree seedling had died.

or

**Tree** – indicating the planted tree seedling was still alive.

Where it was not possible to establish a 30m x 30m plot within the boundaries of the corridor area, survivorship was calculated from the number of holes and trees within the 15m x 15m plot alone.

### 3.3 Photography

At each plot marker a photograph was taken with a Pentax Equina camera, set on 23mm zoom using Kodak Advanced Photo System 200 asa film. At most plots a photograph was taken facing north, east, south, west and northwest (across the plot) from the plot marker. Due to a shortage of film, at some of the later plots photographs were taken facing north and west only.

### 3.4 Field survey period

Fieldwork was undertaken between the 6$^{th}$ November 2001 and the 30$^{th}$ November 2001 for a total of 25 days. The consultant worked in the field with Moses Mwangoka who provided identifications of plant material and collected a reference herbarium collection, we were assisted by up to three TFCG field assistants.

# 4 Results

## 4.1 Plot information

A total of 22 plots were surveyed, 15 in Lulanda corridor, four in Ihili corridor and three in Luhunga corridor. The GPS co-ordinates for each vegetation plot are given in Appendix 4. Due to the systematic location of plots not all the plots fell in areas where planting had been undertaken. Plot 1 (Lulanda), Plot 17 (Ihili), Plot 21 and 22 (Luhunga) were not planted with seedlings therefore it is not possible to calculate a value for percentage seedling survival for these plots (see Table 1).

A summary of physical characteristics and findings for each plot is presented in Appendix 4.

In total 1082 stems were recorded, of which 282 were planted individuals. Each stem was measured and identified. Their species, frequency and distribution are given in Appendix 3. A total of 800 regenerating individuals were measured and identified, their species, frequency and distribution are given in Appendix 2.

## 4.2 Seedling survivorship

Table 1 below, shows the % survivorship of planted tree seedlings per plot. Percentage survivorship was calculated as follows:

$$\frac{\textbf{Number of trees (surviving seedlings)}}{\textbf{Number of holes + Number of trees}} \times 100$$

Figures in Table 1 are based on counts obtained from 30m x 30m plots except where indicated with an asterisk *, these are based on data from 15m x 15m plots. These exceptions are due to the close proximity of the sample plots to the corridor border, making it impossible to establish a 30m x 30m plot. Figure 7 below shows the pattern of survivorship across Lulanda and Ihili corridor.

**Table 1** Percentage survivorship per plot.

| Location | Plot Number | % Survivorship | Location | Plot Number | % Survivorship |
|---|---|---|---|---|---|
| Lulanda | 1 | - | Lulanda | 12 | 37 |
| Lulanda | 2 | 60 | Lulanda | 13 | 53 |
| Lulanda | 3 | 67 | Lulanda | 14 | 33 |
| Lulanda | 4 | 75 | Lulanda | 15 | 45* |
| Lulanda | 5 | 69 | Ihili | 16 | 44 |
| Lulanda | 6 | 16 | Ihili | 17 | - |
| Lulanda | 7 | 30 | Ihili | 18 | 24 |
| Lulanda | 8 | 72 | Ihili | 19 | 54 |
| Lulanda | 9 | 81 | Luhunga | 20 | 93 |
| Lulanda | 10 | 66 | Luhunga | 21 | - |
| Lulanda | 11 | 75 | Luhunga | 22 | - |

* % survival calculation based on 15m x 15m plot
\- = no planting in that area

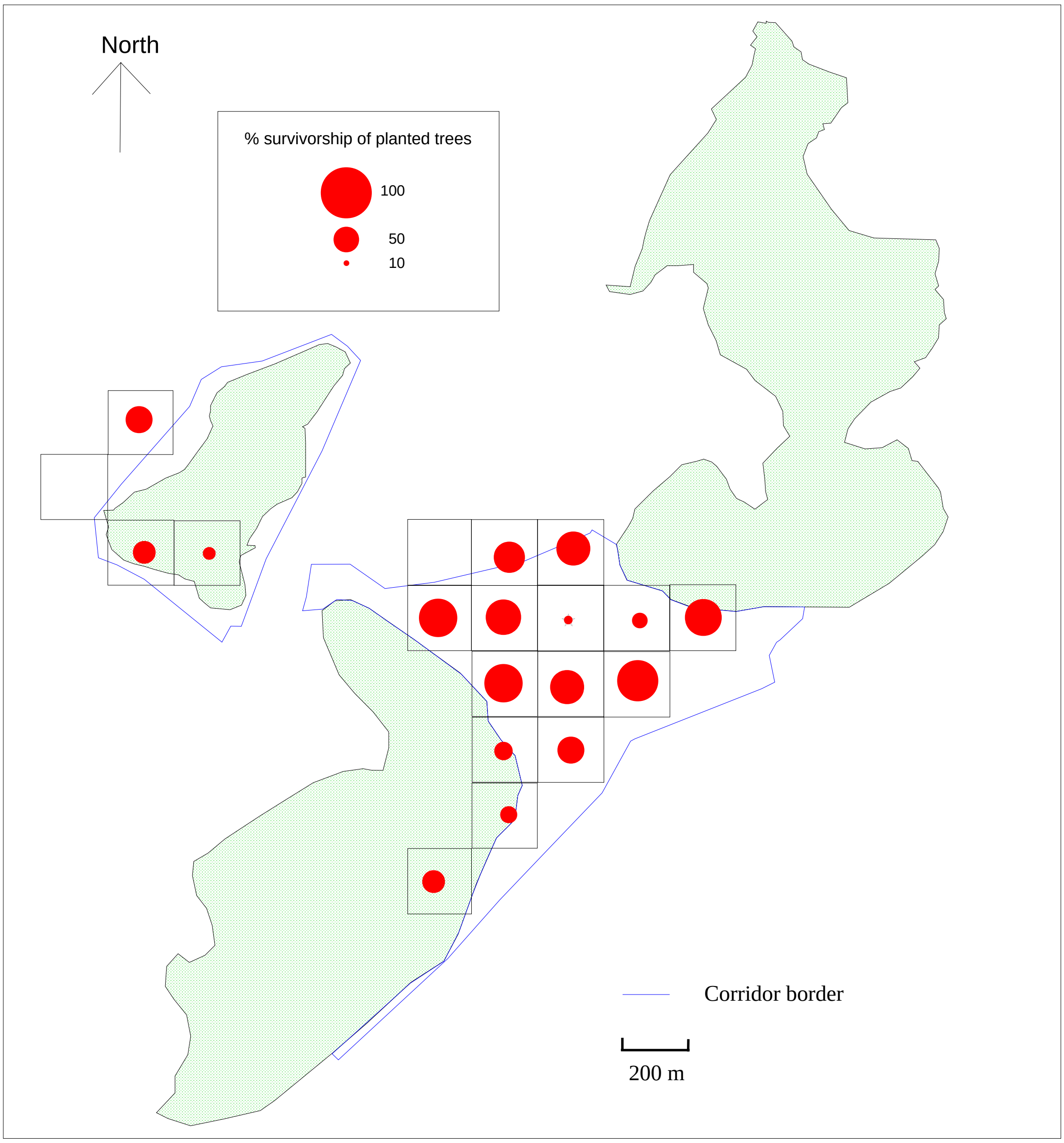


**Figure 7** Map showing percentage survival of planted tree seedlings in Lulanda and Ihili corridors.

Table 1 and Figure 7 show that seedling survival varied greatly across the sample plots and between corridor areas.

- Lulanda area has a wide range of survival rates varying from 81% to 16%, with an average survival rate of 55%.
- Ihili area had a generally lower seedling survival rate ranging from 24% to 54 % with an average of seedling survival 41%.
- Ihili and Lulanda area combined have an average seedling survival rate of 53%
- Luhunga has the highest seedling survival rate (93%), but this is only recorded from a single plot.

### *4.2.1 Correlation analysis*

Spearman's Rank Correlation ($r_s$) was used to assess the relationship between percentage seedling survival and various other factors (see below), using the equation given in Kent & Coker, 1994. The significance of the correlation coefficient ($r_s$) was then tested by calculating the students t-test value and comparing to critical t-test values printed in Zar, 1984. Equations for both of these statistical tests are given in Appendix 5.

Statistical analysis revealed that there is **no** significant correlation ($P > 0.05$) between the percentage seedling survival per plot and: slope; age; canopy cover; ground vegetation cover; canopy height; number of planted tree species and the number of regenerating species. There is no clear relationship between the percentage seedling survival per plot and the aspect of the plot, (as this is a non-numerical measure it was not tested statistically).

**Figure 8** below shows percentage survival plotted against total number of stems per plot together with the linear trend line showing the line of best fit and the $R^2$ value of the regression line.

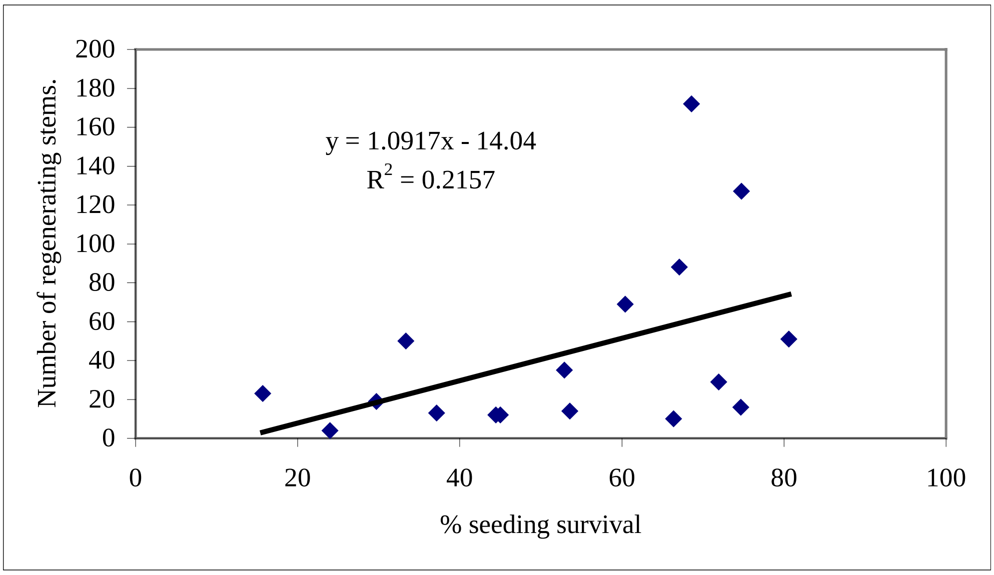


Figure 8 Chart showing percentage seedling survival per plot plotted against the number of regenerating stems per plot.

There is a significant correlation ($P < 0.05$) between percentage survival per plot and number of regenerating stems. Statistical test values are given in Appendix 6.

Figure 9 below shows percentage seedling survival plotted against shrub layer vegetation cover together with the linear trend line showing the line of best fit and the $R^2$ value of the regression line.

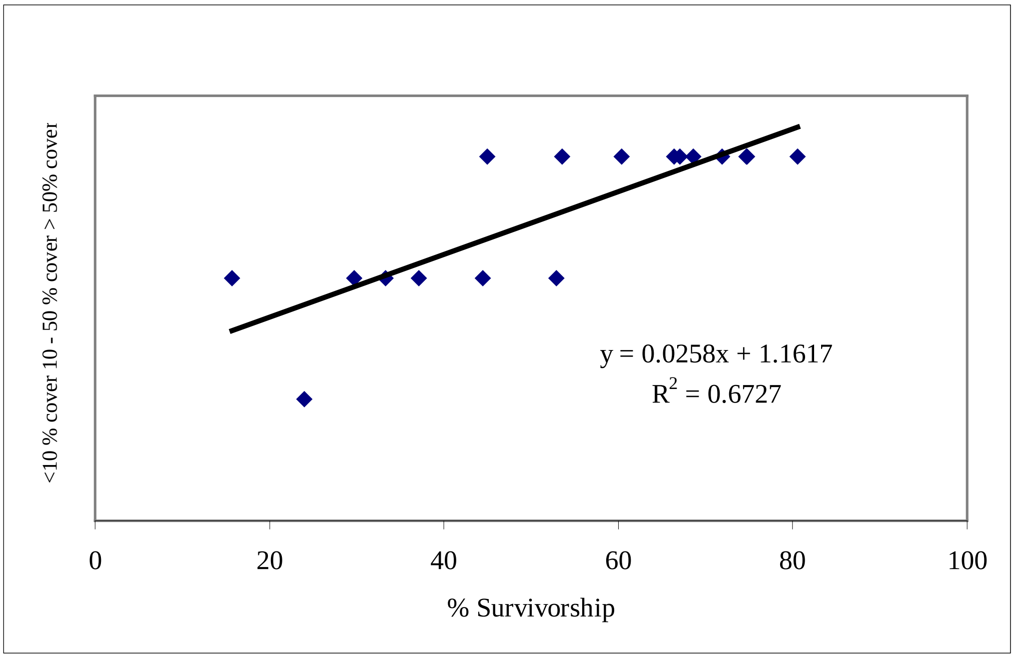


**Figure 9** Chart showing percentage seedling survival plotted against shrub layer vegetation cover.

There is a significant relationship ($P < 0.0005$) between percentage survival per plot and shrub layer vegetation cover. Statistical test values are given in Appendix 6.

### 4.3 Current species composition

In total, 121 plant species from 52 families were recorded in this survey. A complete species list is given in Appendix .

Of this total, 51 species from 29 families were recorded in the systematic survey (i.e. within vegetation plots).

The additional 70 species were recorded casually in and around the survey areas. All data analysis and calculation is based on species listed in Table 2.

**Table 2 Tree and shrub species recorded in the systematic survey of Lulanda, Ihili and Luhunga corridors.**

| Family, Genus and Species | Author | Life form | Endemic | Habitat | Location | |
|---|---|---|---|---|---|---|
| | | | | | Regenerating | Planted |
| **Anacardiaceae** | | | | | | |
| *Rhus longipes* var. *shinoides* | Engl. | T | No | Riverine forest, forest margins, wooded grasslands.* | Lu Ih Lul | |
| **Apocynaceae** | | | | | | |
| *Rauvolfia caffra* | Sond. | | No | Riverine forest/thicket less often in forest away from water* | Luh | Lul Ihi |
| *Rauvolfia manii* | Stapf | T | No | Moist forest, especially at margins and in disturbed areas.* | Luh | |
| **Bignoniaceae** | | | | | | |
| *Tecoma nyassae* | Oliv. Ex Hook. | | No | | Lul | |
| **Cecropiaceae** | | | | | | |
| *Myrianthus holstii* | Engl. | T | No | | Lul | |
| **Compositae** | | | | | | |
| *Bidens magnifolia* | Sherff | | No | | Lul Ihi | |
| *Solanecio mannii* | (Hook. F) C. Jeffery* | T* | No | Dry evergreen forest edges, degraded secondary forest, riverine rocky slopes in bushland.* | Lul | |
| **Ebenaceae** | | | | | | |
| *Diospyros squarrosa* | Klotzsch | T* | No | Woodland/bushland or thicket, occaisionally forest margins.* | Luh | |
| *Euclea* sp. | | | | | Ihi | |
| **Ericaceae** | | | | | | |
| *Agarista salicifolia* | (Lam.) Oliv. | T | No | Forest edge, secondary forest, high altitude bushland.* | Lul Ihi | |
| **Euphorbiaceae** | | | | | | |
| *Bridelia micrantha* | (Hochst.) Baill. | S | No | Riverine forest margins, less often in bushland/wooded grassland.* | | Lul Ihi Luh |
| *Macaranga kilimandscharia* | Pax | T | No | Moist upland forest, abundant at forest edges.* | Luh | Lul Luh |
| **Flacourtiaceae** | | | | | | |
| *Aphloia theiformis* | (Vahl) Benn. | S | No | Upland moist forest.* | Lul Luh | Lul Ihi Luh |
| **Guttiferae** | | | | | | |
| *Psorospermum febrifugum* var. *ferrugineum* | Spach | S | No | Wooded grassland.* | Lul | |

| Family, Genus and Species | Author | Life form | Endemic | Habitat | Location | |
|---|---|---|---|---|---|---|
| | | | | | Regenerating | Planted |
| **Labiatae** | | | | | | |
| *Iboza multiflora* | (Benth.) E.A.Bruce | S* | No | Bushland on rocky slopes.* | Lul | |
| *Plectranthus* sp. | | | | | Lul | |
| **Lauraceae** | | | | | | |
| *Cryptocarya liebertiana* | Engl. | S | No | Moist forest.* | | Lul Ihi |
| **Leguminosae - Mimosoideae** | | | | | | |
| *Albizia gummifera* var. *gummifera* | (J.F.Gmel.) C.A.Sm. | T | No | Dry or wet, upland or lowland forest edges, riverine forest.* | Lul Ihi | Lul |
| **Leguminosae – Papilionoideae** | | | | | | |
| *Craibia brevicaudata* subsp. *schliebenii* | (Vatke) Dunn | T | No | | | Lul Ihi |
| *Dalbergia lactea* | Vatke | S | No | Riverine.* | Lul Luh | |
| *Kotschya aeschynomerioides* | (Baker) Dewit & P.A.Duvign. | S | No | Upland grassland and evergreen bushland, often in shallow soil pockets in rocks then in dense stands.* | Lul Ihi | |
| *Kotschya carsonii* | (Baker) Dewit & P.A.Duvign. | S | No | | Lul | |
| *Millettia oblata* subsp. *intermedia* | Dunn | T | Yes | | Ihi Luh | Lul |
| *Tephrosia elata* | Deflers | H | No | | Lul | |
| **Loganiaceae** | | | | | | |
| *Buddleja salviifolia* | (L.) Lam. | S | No | | Lul | |
| *Nuxia floribunda* | Benth. | T | No | Forest (remnants).* | | Lul |
| **Malvaceae** | | | | | | |
| *Hibiscus fuscus* | Garcke | S | No | | Lul Ihi | |
| *Hibiscus diversifolius* | Jacq. | S | No | | Lul | |
| **Melastomataceae** | | | | | | |
| *Dissotis speciosa* | Taub. | H | No | | Lul | |
| **Melianthaceae** | | | | | | |
| *Bersama abyssinica* subsp. *abyssinica* var. *abyssinica* | Fresen. | T | No | Upland grassland, dry and wet montane and riparian forest glades and edges.* | Luh | Lul |
| **Myricaceae** | | | | | | |
| *Myrica salicifolia* | Hochst. ex A.Rich. | | No | Dry rocky bushland and eroded slopes.* | Lul Ihi | |
| **Myrsinaceae** | | | | | | |
| *Embelia schimperi* | Vatke | S | No | Upland evergreen forest.* | Ihi | |
| *Maesa lanceolata* | Forssk. | S | No | Secondary forest pioneer, in forest margins.* | Lul Ihi | |
| **Myrtaceae** | | | | | | |
| *Syzygium cordatum* | Hochst. | | No | Riverine.* | Lul | Lul Luh |
| **Oleaceae** | | | | | | |
| *Schrebera alata* | (Hochst.) Welw. | T* | No | Dry forest (edges and remnants), evergreen (secondary) bush and less often in scattered tree grassland.* | Lul | |
| **Pinus** | | | | | | |
| *Pinus patula* | | | | | Ihi | |

| Family, Genus and Species | Author | Life form | Endemic | Habitat | Location | |
|---|---|---|---|---|---|---|
| | | | | | Regenerating | Planted |
| **Proteaceae** | | | | | | |
| *Faurea wentzeliana* | Engl. | T | No | | Lul | |
| **Rubiaceae** | | | | | | |
| *Hallea rubrostipulata* | (K.Schum.) J.-F.Leroy | T | No | | Lul Ihi | |
| *Keetia gueinzii* | (Sond.) Bridson | S | No | Moist forest (margins), secondary bushland, riverine forest. | | Lul Ihi |
| *Keetia lulandensis* | Bridson | C | Yes | | Luh | |
| *Pentas schimperana* subsp. *schimperana* | (A.Rich.) Vatke | S | No | Forest clearings.* | Lul | |
| *Psychotria goetzei* | | | | | | Lul |
| **Rutaceae** | | | | | | |
| *Teclea nobilis* | Delile | S | No | Moist forest.* | Luh | Lul |
| *Clausena anisata* | (Willd.) Benth. | S | No | Moist or dry forest margins, secondary bushland, riverine sometimes woolded grassland.* | Luh | |
| **Sapindaceae** | | | | | | |
| *Dodonaea viscosa* | (L.) Jacq. | S* | No | Sand near high water mark, dunes.* | Lul Luh | |
| **Solanaceae** | | | | | | |
| *Solanum anguivi* | Lam. | | No | | Lul Ihi | |
| **Tiliaceae** | | | | | | |
| *Sparrmannia ricinocarpa* | (Eckl. & Zeyh.) Kuntze | | No | Forest margins or clearings, riverine secondary bushland where forest has disapeared, extends into Hagenia and Bamboo zones.* | Ihi | |
| *Triumfetta brachyceras* | K. Schum. | | No | | Lul | |
| **Verbenaceae** | | | | | | |
| *Lippia javanica* | (Burm.f.) Spreng. | S | No | Secondary bushland or grassland, less often in wooded grassland.* | Lul Ihi | |
| *Vernonia lasiopus* | O.Hoffm.* | S* | No | Common in disturbed vegetation, (bushed) grassland and riverine woodland or forest.* | Lul | |
| *Vernonia myriantha* | Hook.f. | S* | No | Forest edges and ruderal places.* | Lul Ihi | |

Key: Life forms: H = Herb. T = Tree. S = Shrub. C = Climber. TF = Treefern.
* indicates details taken from Beentje, 1994, all other information is taken from the List of East African Plants, (LEAP).
Regions in Tz, refer to those regions used in the Flora of Tropical East Africa, Region 7 = Southern highlands of Tanzania including the Udzungwa Mountains. For a map showing these regions please refer to Schulman, 1998.
Lul = recorded in Lulanda corridor. Ihi = recorded in Ihili corridor. Luh = recorded in Luhunga corridor.

#### *4.3.1 Endemism*

A total of five Tanzanian endemic species were recorded; *Millettia oblata* subsp. *intermedia*, *Pavetta lynesii, Aframomum alpinum, Psychotria megalopus* and *Keetia lulandensis*. All were naturally regenerating and found casually (with the exception of *Millettia oblata* subsp. *intermedia*, which occurred in the systematic survey).

Two of the species endemic to Tanzania, *Millettia oblata* subsp. *intermedia* and *Pavetta lynesii,* are tree species. *Millettia oblata* subsp. *intermedia,* is known from only three regions in Tanzania (3,6&7), its range is restricted to the Eastern Arc Mountains. This species is widespread in the East Usambara Mountains where the subspecies has been recorded in Amani Nature Reserve (Frontier Tanzania, 2001a), Segoma Forest Reserve (Frontier Tanzania, 2001b), and Semdoe Forest Reserve (Frontier Tanzania, 2001c).

*Psychotria megalopus* is a shrub only known from two regions in Tanzania (6&7). *Aframomum alpinum* known only from one region in Tanzania (3) is a herb.

The climber *Keetia lulandensis* is a species endemic to the Udzungwa Mountains.

In addition the shrub, *Rubus keniensis,* a species endemic to Kenya (Mt. Kenya and Nyandarua, Beentje, 1994) was recorded frequently in Lulanda and Ihili corridors. It should be noted that at present this is a provisional identification and awaits verification by the Missouri Botanical Gardens. This may represent a range extension. This species was not recorded by Frontier Tanzania in New Dabaga/Ulangambi Forest Reserve, (Frontier, 2000d).

## 4.4 Vegetation structure

### 4.4.1 Distribution and density of planted species - Lulanda and Ihili corridor.

A total of 15 planted species were recorded in Lulanda corridor, six of these were recorded in Ihili corridor. The number of surviving planted species per plot varied from a maximum of six to a minimum of one (see Figure 10 and Table 3 below). Zero represents those plots where no seedlings were planted. Unfortunately no record exists of how many species were originally planted in each area.

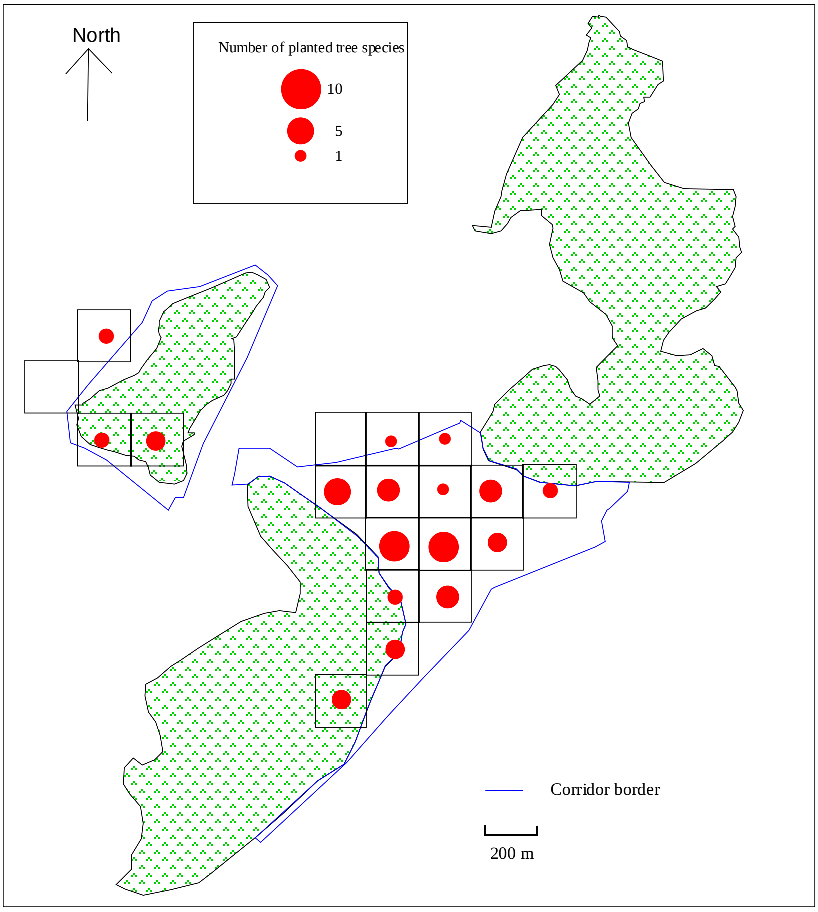


Figure 10 Map showing the number of planted species per plot in Lulanda and Ihili corridor.

**Table 3** Number of planted species surviving per plot.

| **Plot number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No. of planted sp.** | 0 | 1 | 1 | 5 | 4 | 1 | 4 | 2 | 3 | 6 | 6 | 2 | 4 | 3 | 3 | 2 | 0 | 3 | 2 | 4 | 0 | 0 |

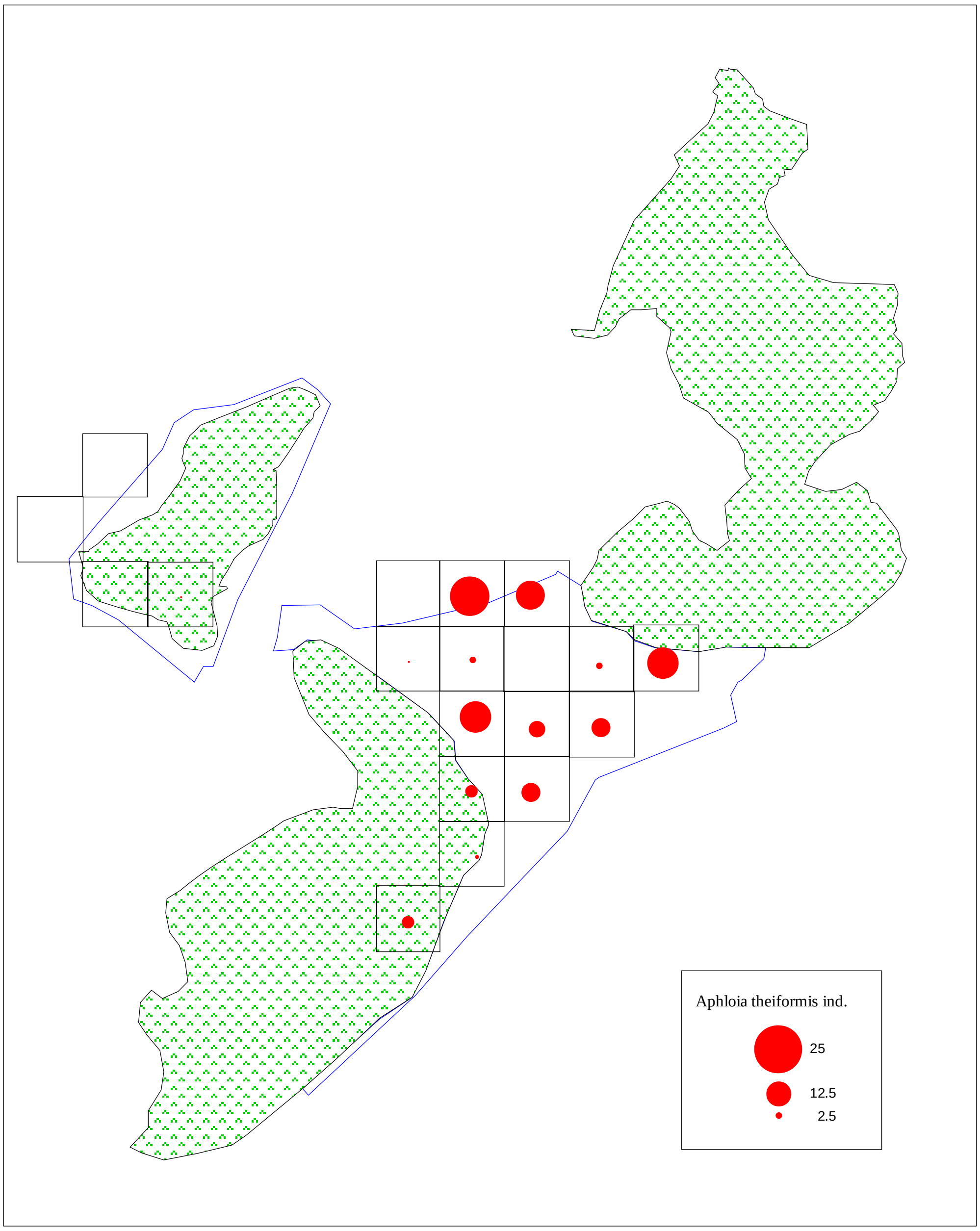


**Figure 11** Map showing the distribution of *Aphloia theiformis* in Lulanda and Ihili corridor.

*Aphloia theiformis* is the most numerous (120 individuals) and widely distributed planted tree species, occurring in 14 of a possible 17 plots in Lulanda and Ihili.

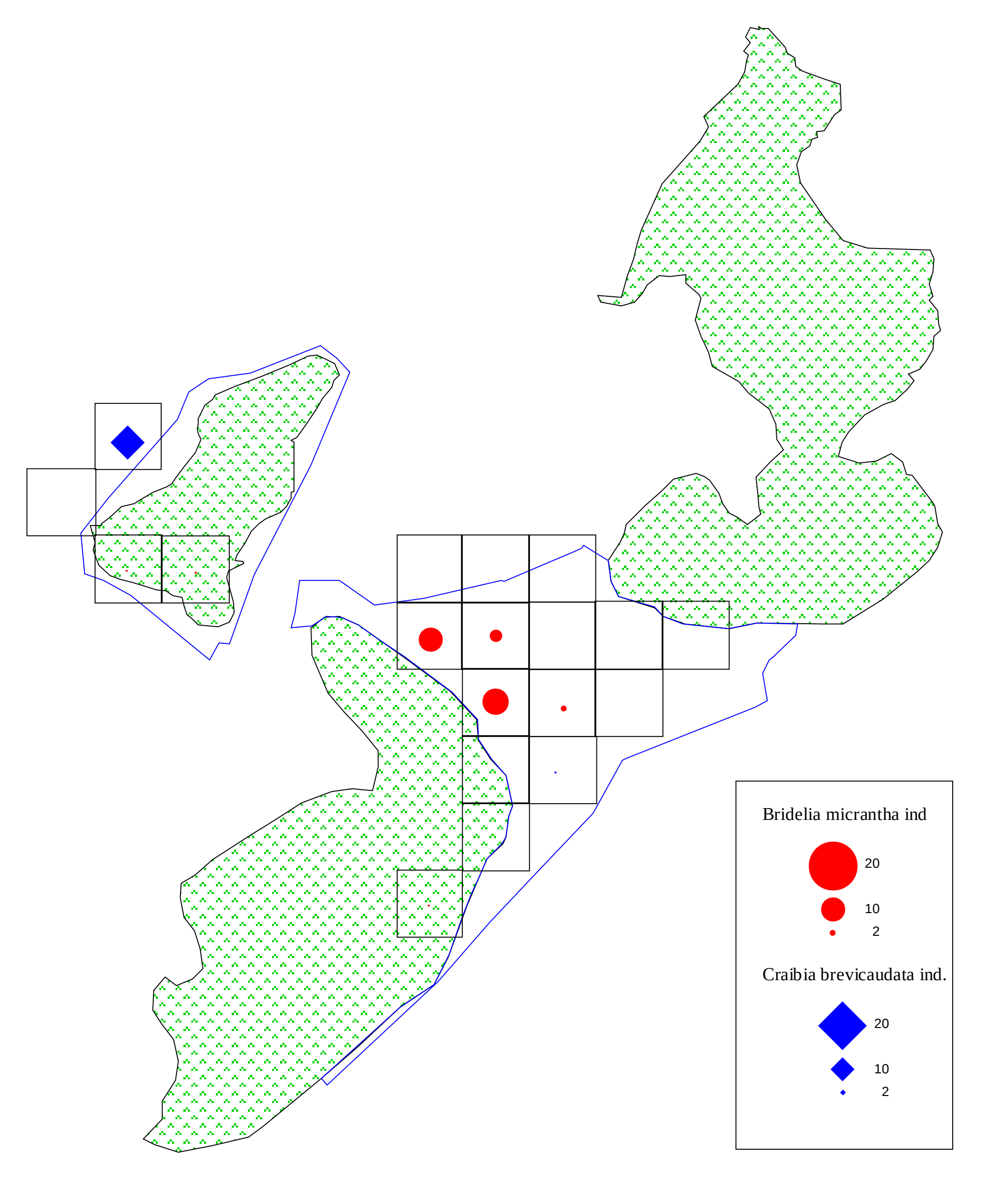


**Figure 12** Map showing the distribution of *Bridelia micrantha* and *Craibia brevicaudata* in Lulanda and Ihili corridor.

*Bridelia micrantha* is the second most numerous (31 individuals) and widespread species occurring in 7 of a possible 17 plots in Lulanda and Ihili corridor. *Craibia brevicaudata* occurs only in two plots. In Ihili corridor it is the most numerous species (14 individuals) but in Lulanda it was recorded only once.

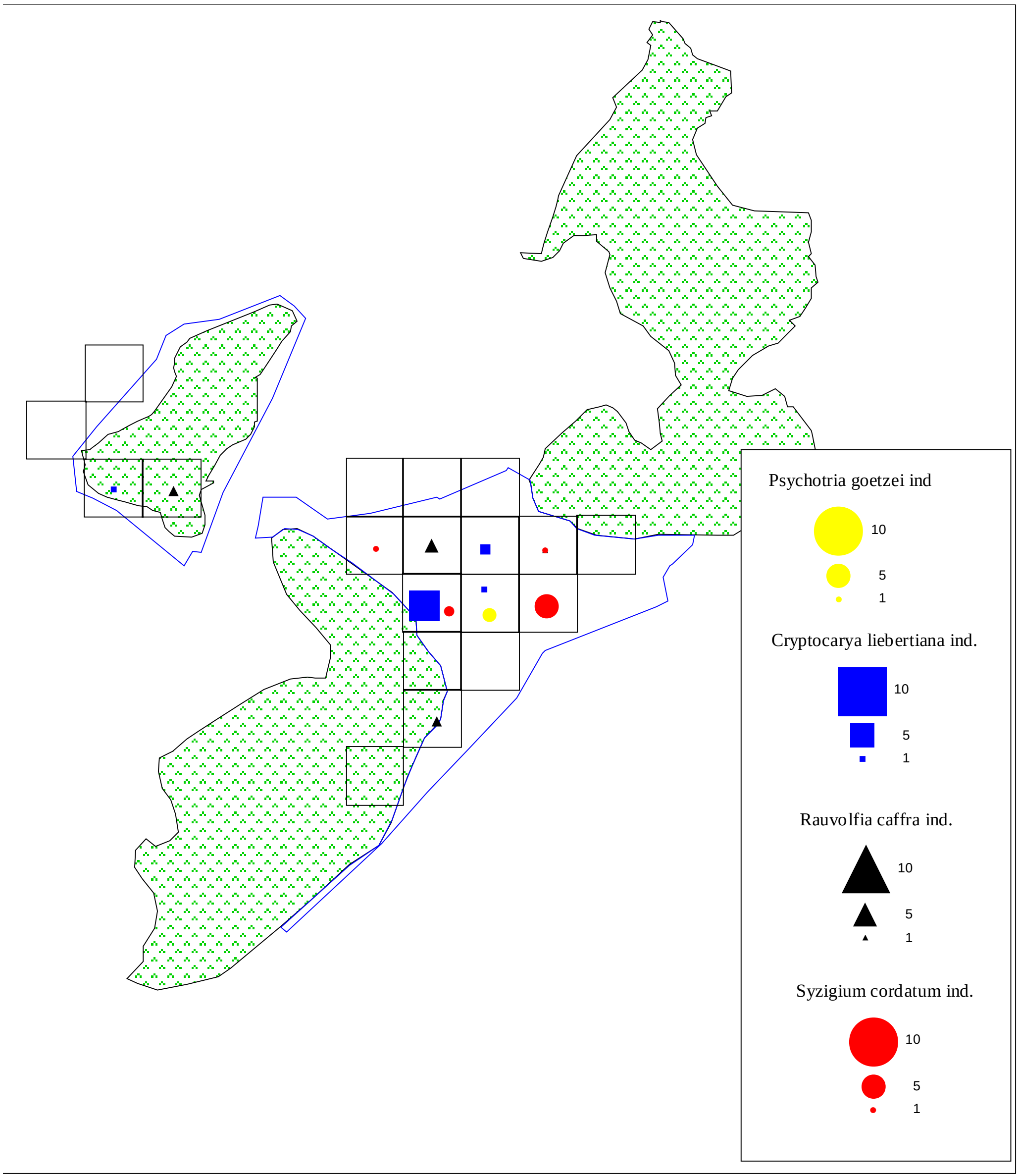


**Figure 13** Map showing distribution of *Psychotria goetzei, Cryptocarya liebertiana, Rauvolfia caffra* and *Syzygium cordatum* in Lulanda and Ihili corridor.

*Psychotria goetzei* is not widespread in the corridor, three individuals occurred in one plot. *Cryptocarya liebertiana, Rauvolfia caffra* and *Syzygium cordatum* are all reasonably numerous (represented by between eight and ten individuals) but not very widespread, each recorded in only four of a possible 17 plots.

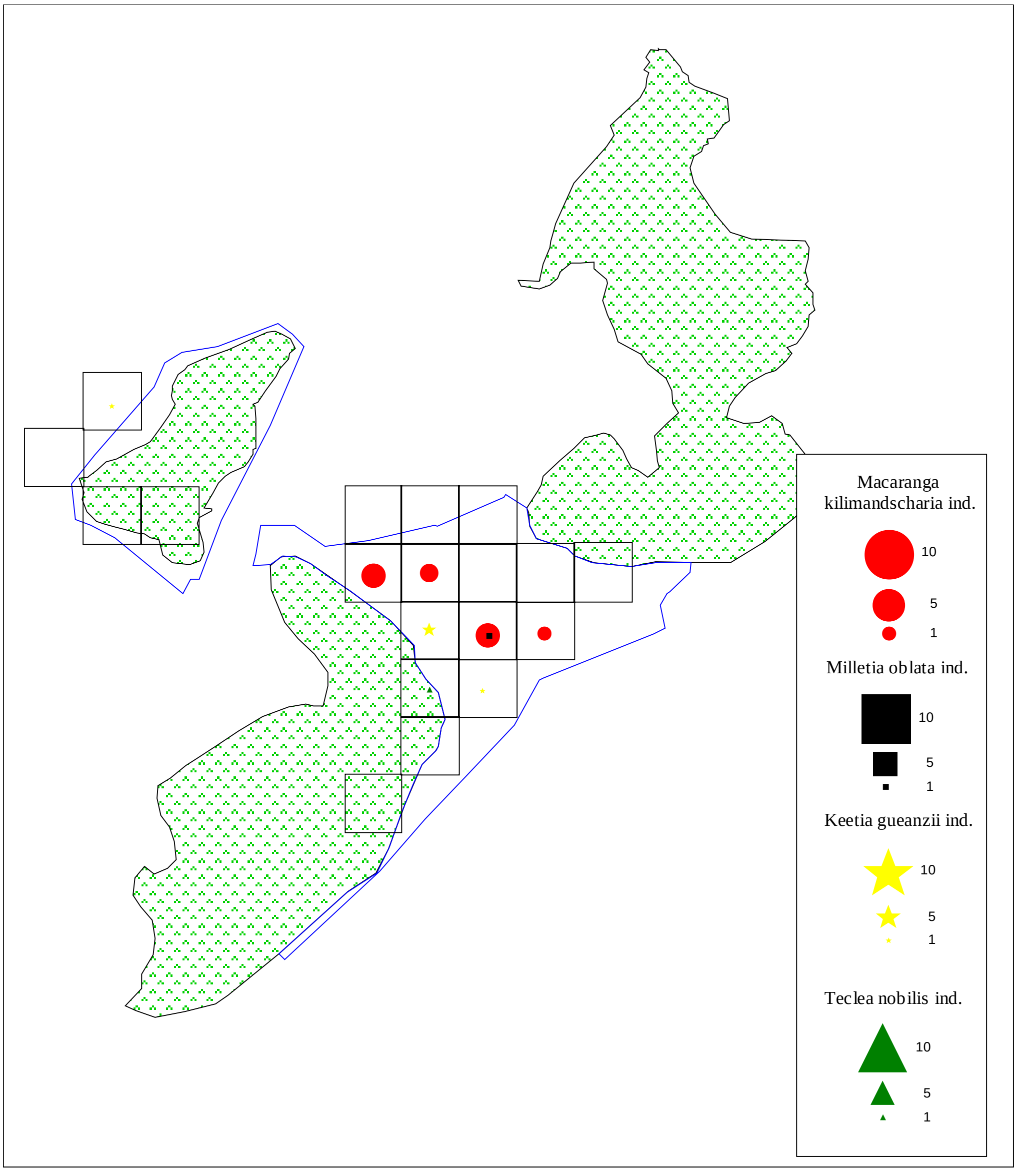


**Figure 14** Map showing the distribution of *Macaranga kilimandscharia, Millettia oblata, Keetia gueinzii* and *Teclea nobilis* in Lulanda and Ihili corridor.

*Macaranga kilimandscharia* is reasonably numerous (represented by nine individuals) but not very widespread occurring in only four plots. *Keetia gueinzii* is not very numerous (five individuals) and was only recorded in three plots. *Millettia oblata* and *Teclea nobilis* were both only recorded once.

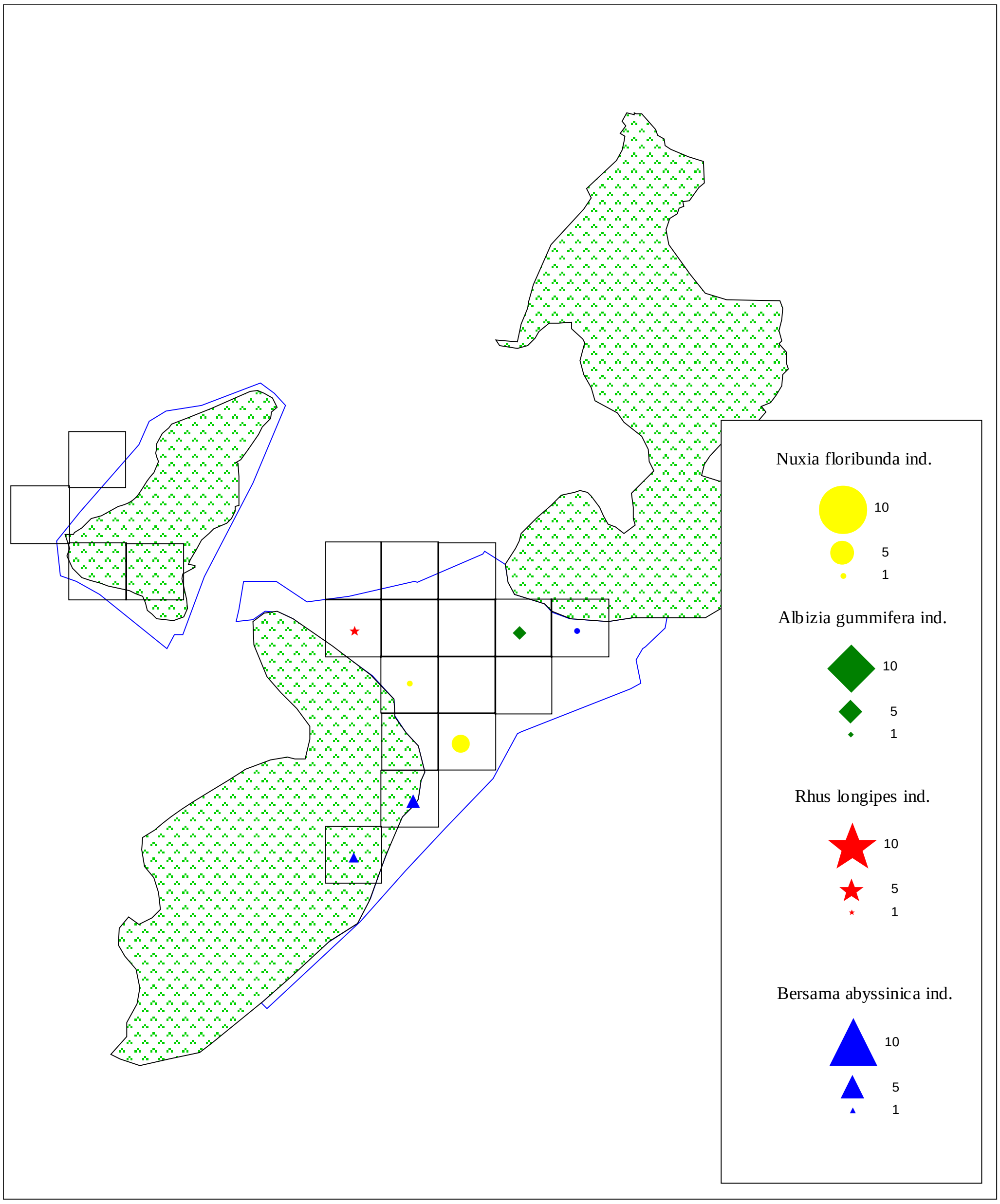


**Figure 15** Map showing the distribution of *Nuxia floribunda, Albizia gummifera, Rhus longipes* and *Bersama abyssinica* in Lulanda and Ihili corridor.

*Rhus longipes* had a very limited distribution of only one individual; *Nuxia floribunda* is represented by five individuals in two plots and *Bersama abyssinica* is represented by six individuals in three plots. Planted *Albizia gummifera* occurred in only one plot represented by three individuals.

### *4.4.2 Regenerating species density*

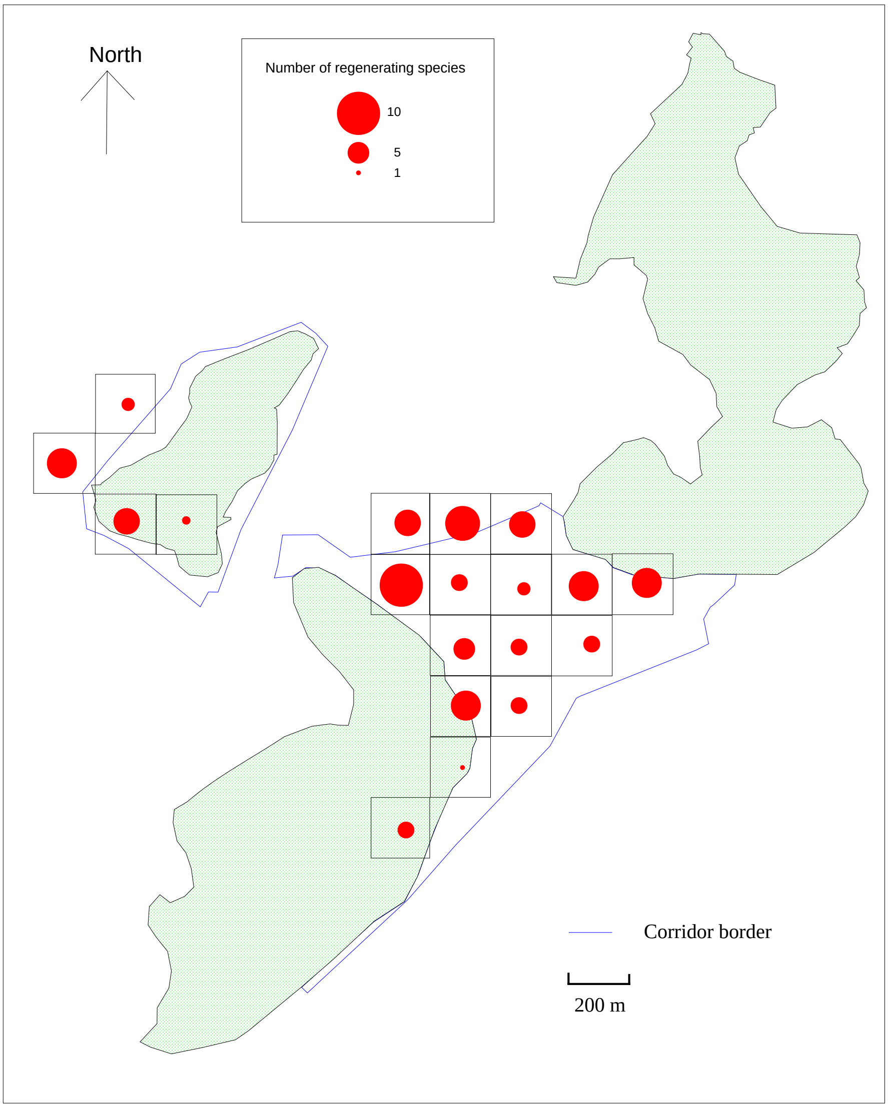


**Figure 16** Map showing the number of regenerating species per plot in Lulanda and Ihili corridor.

Plot 22 (Luhunga) and plot 4 have the highest regenerating species richness, whilst plot 21 (Luhunga), plot 14 and 18 have the lowest (see Table 4).

**Table 4** Number of regenerating species per plot.

***All regenerating stems in Plot 20 were cleared to prevent competition with planted species.**

| Plot number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No. of regenerating sp.** | 6 | 8 | 6 | 10 | 4 | 3 | 7 | 7 | 4 | 4 | 5 | 7 | 4 | 1 | 4 | 6 | 7 | 2 | 3 | 0* | 0 | 11 |

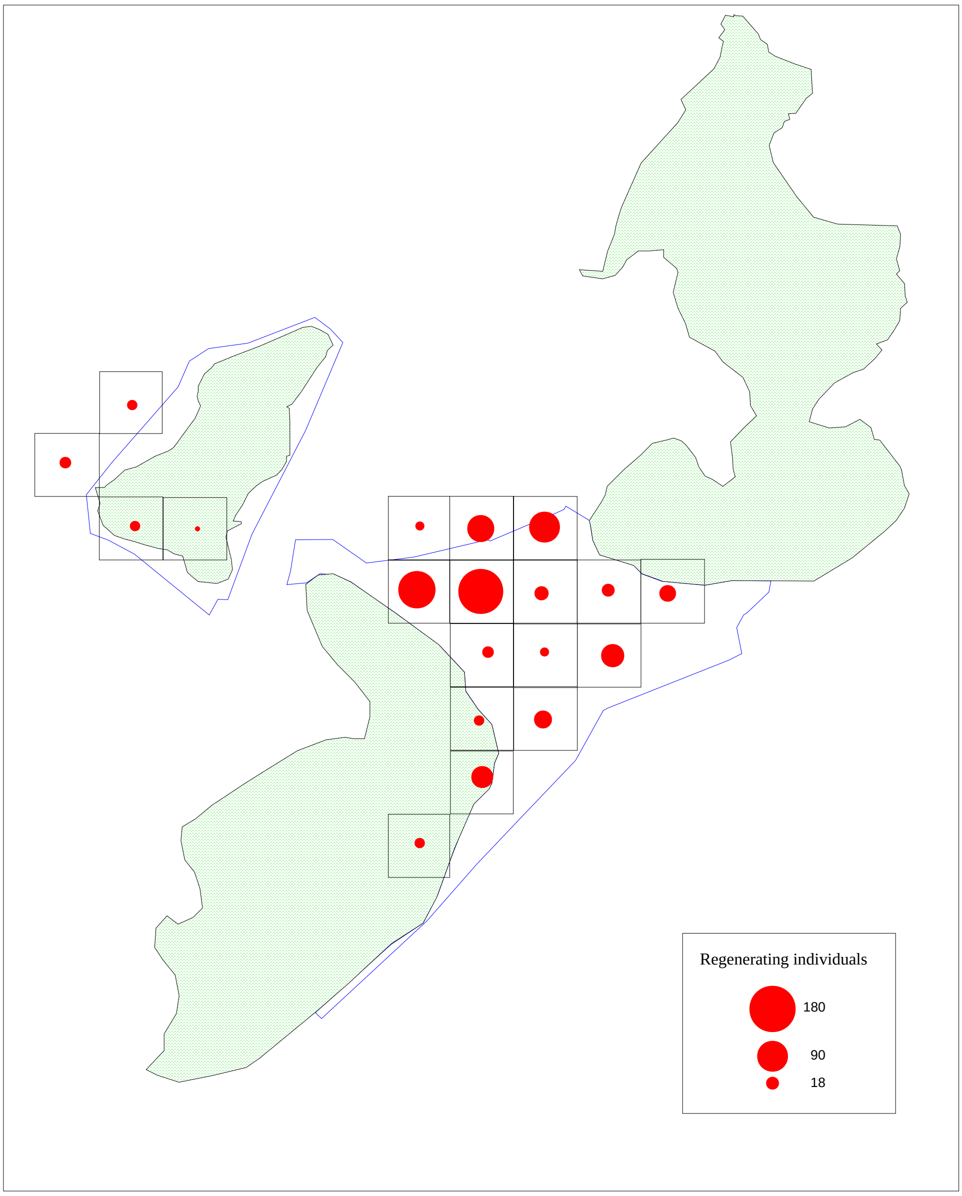


**Figure 17** Map showing the number of regenerating stems per plot in Lulanda and Ihili corridor.

The pattern of regeneration displayed in Figure 17 is closely related to the distribution of *Kotschya spp.*. *Kotschya spp.* is by far the most numerous regenerating genus in the corridors, accounting for 65 % of regenerating stems. It is clear from Figure 18 below that its distribution is uneven across the corridors. *Kotschya spp.* was not recorded in Luhunga.

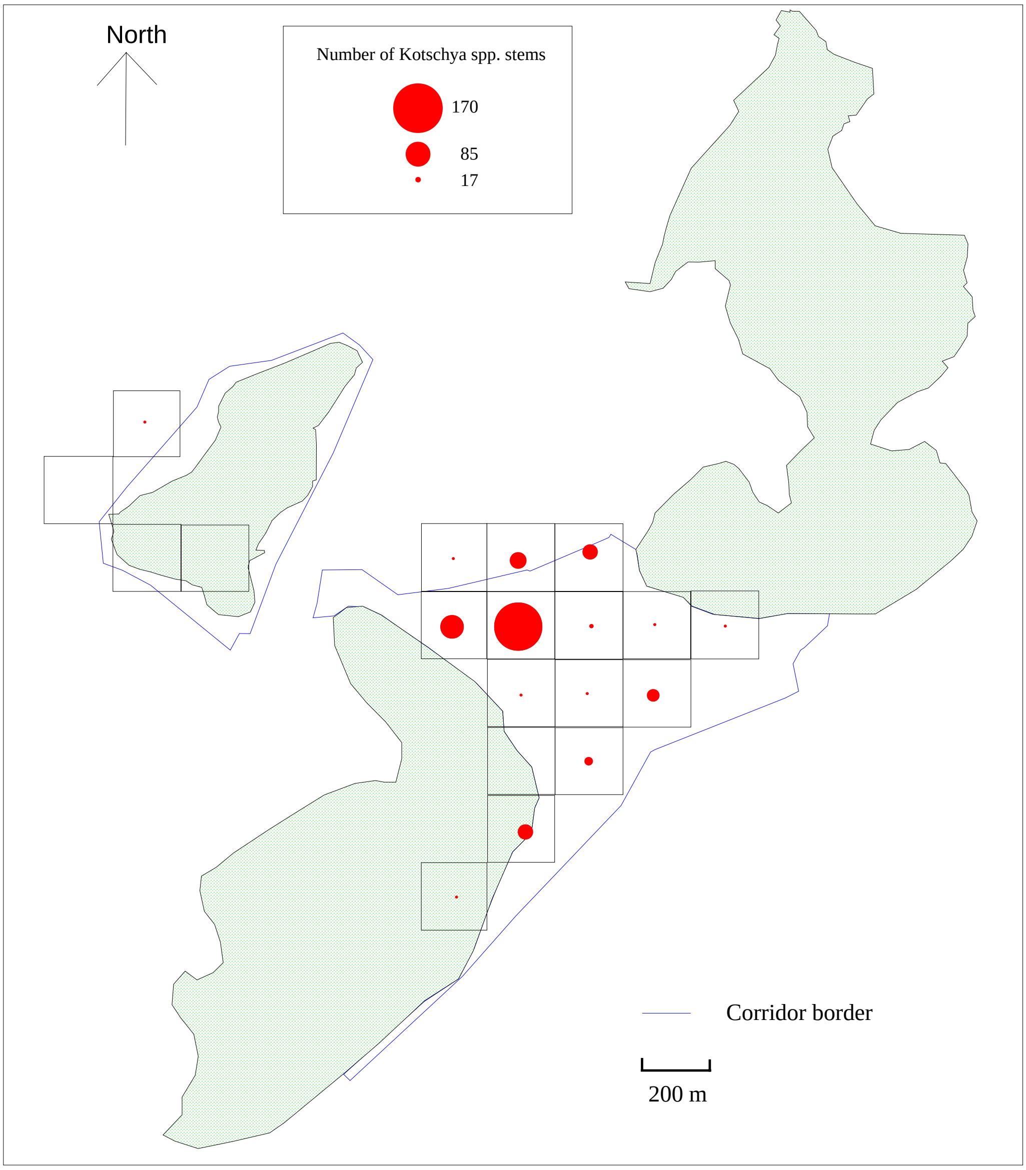


Figure 18 Map showing number of *Kotschya* spp. stems per plot in Lulanda and Ihili corridor.

Figure 18 shows a concentration of Kotschya spp. around plot 4 and 5 and to a lesser extent around plots 2 and 3.

### *4.4.3 Luhunga corridor*

Of the three plots located in Luhunga corridor, only one (plot 20) fell into an area that had been planted. Only four species were planted in Luhunga corridor, all four were represented in plot 20, *Aphloia theiformis* (20 individuals) *and Macaranga kilimandscharia* (19 individuals) being the most numerous, followed by *Syzygium cordatum* (9 individuals) and then *Bridelia micrantha* (6 individuals).

As all regenerating plants were slashed to limit competition with planted trees it is not possible to compare the regeneration in Luhunga with the regeneration in Lulanda and Ihili. It is noteworthy that regeneration was very different in the two plots located in areas with no planting (and therefore no slashing). Plot 21, had no regenerating species >1cm dbh. Plot 22 however had a total of 29 regenerating individuals from 11 species, including three of the species chosen for planting. Many (79%) of the regenerating stems in Plot 22 were shooting from old cut stumps. No old stumps were observed in plot 21.

### *4.4.4 Average height of vegetation.*

Figure 19 below shows that the average height of regenerating vegetation in all plots is greater than the average height of planted trees.

There is no significant relationship (P> 0.05) between the average regenerating vegetation height and the average height of planted trees.

Figure 19 below shows that the average height of regenerating vegetation varies across the corridors. Generally speaking the vegetation is taller in Lulanda (plots 1-15) than Ihili (plots 16-19), which is in turn taller than Luhunga, (note that the regenerating vegetation in Luhunga was cleared in plot 20, that there was no planting in plot 21 & 22, and no regeneration >1cm dbh in plot 21).

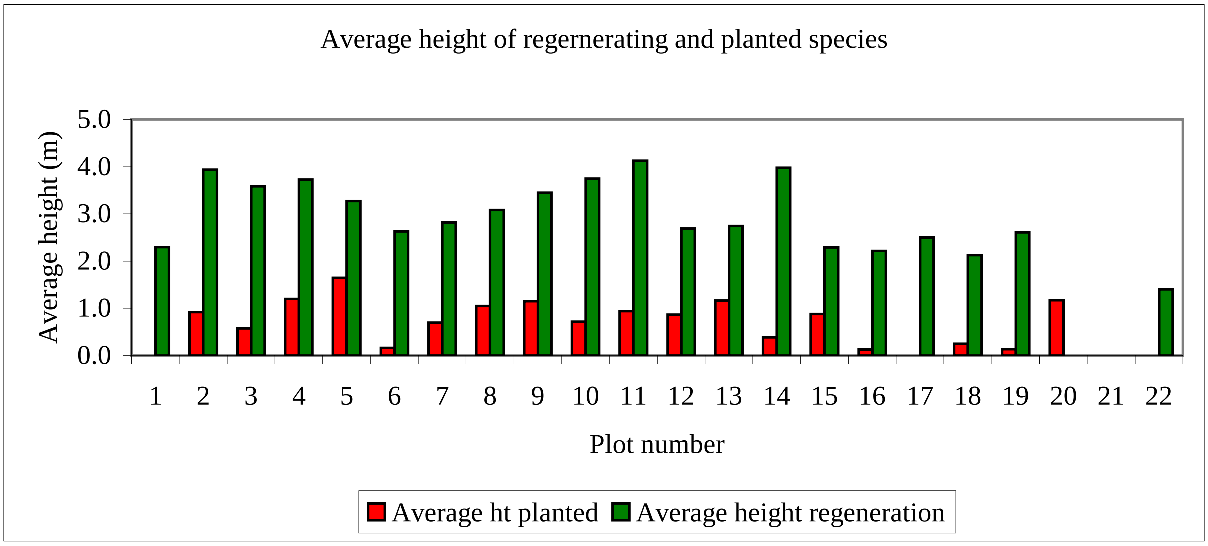


Figure 19 Chart showing the average height of planted and regenerating trees and shrubs in Lulanda, Ihili and Luhunga corridor.

Figure 20 below shows that seedlings planted in Lulanda are tallest, followed by Luhunga and then Ihili. This result is as expected as the Lulanda seedlings were planted first (1996 – 1999), followed by Luhunga seedlings (2000), followed lastly by Ihili seedlings (2001).

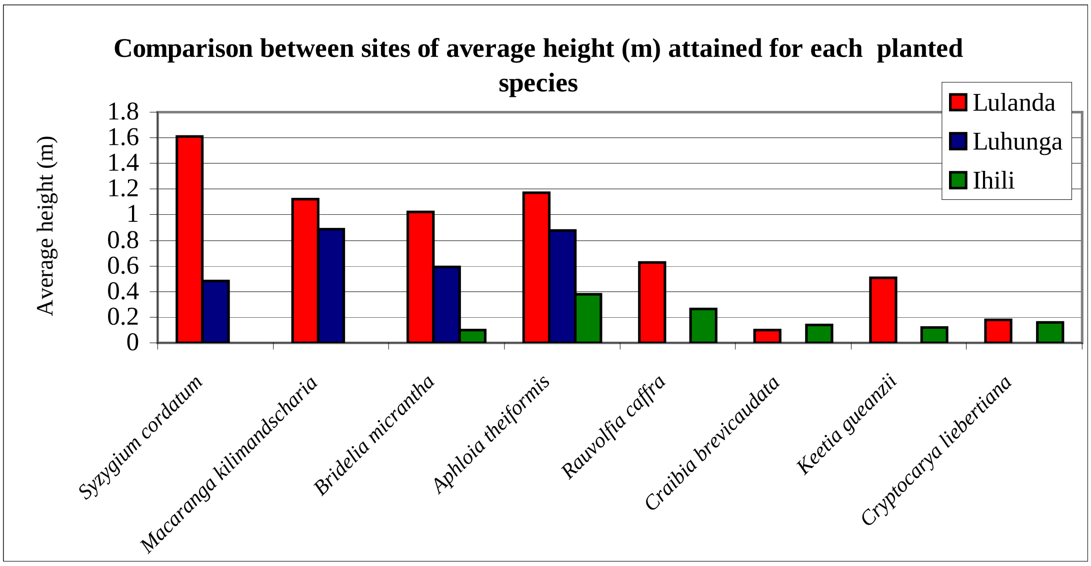


**Figure 20** Chart comparing the actual average height of planted tree species between sites.

Figure 21 below shows that the actual basal diameter of most species is larger at Lulanda corridor than Luhunga and Ihili, (with the exception of *Macaranga kilimandscharia*), and larger at Luhunga than Ihili. This result is as expected as the Lulanda seedlings were planted first (1996 – 1999), followed by Luhunga seedlings (2000), followed lastly by Ihili seedlings (2001).

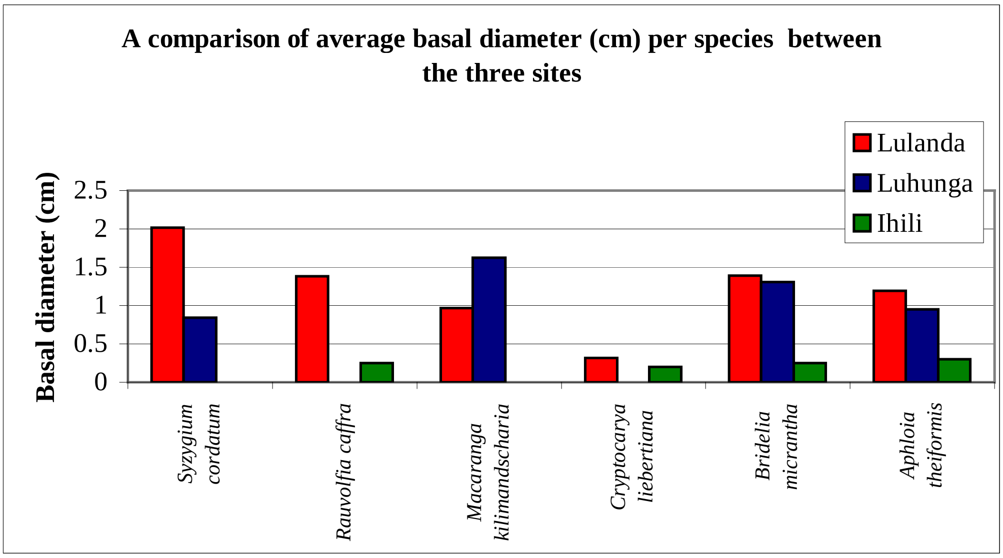


**Figure 21** A graph comparing the actual average basal diameter of planted tree species between sites.

## 4.5 Growth rates

Figure 22 below shows the annual growth rates of all the surviving planted tree species in Lulanda corridor.

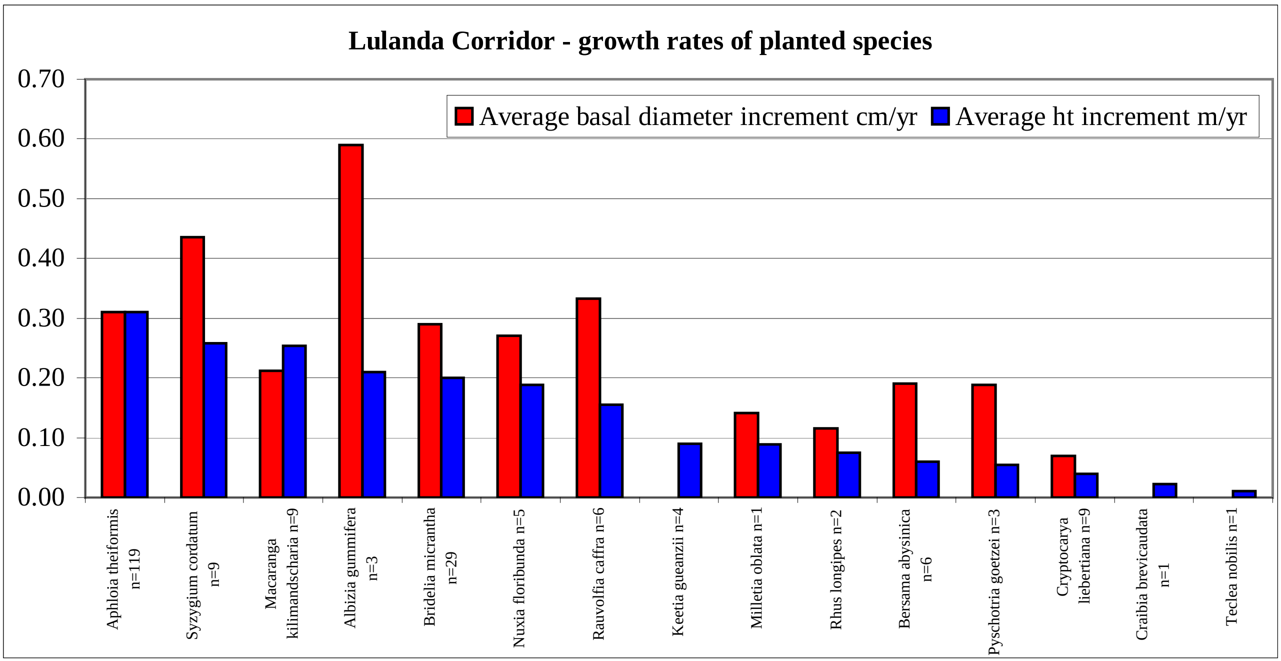


**Figure 22** Chart showing average annual height and basal diameter increment of planted tree species in Lulanda Corridor

Figure 22 shows clearly that two species (*Craibia brevicaudata*, and *Teclea nobilis*) have not performed well in Lulanda corridor.

Those species with both high basal increment and height increment rates such as *Aphloia theiformis, Syzygium cordatum, Macaranga kilimandscharia, Bridelia micrantha, Nuxia floribunda* and *Rauvolfia caffra* seem to the most successful species in Lulanda corridor.

Figure 23 below shows the annual growth rates of all the surviving planted tree species in Ihili corridor.

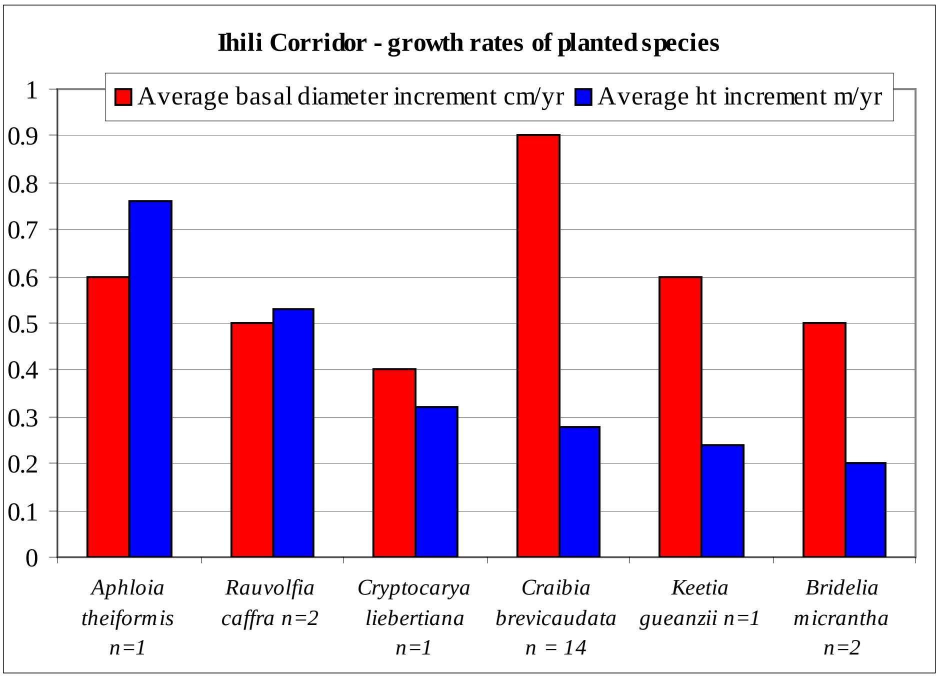


**Figure 23** Growth rates of planted tree species in Ihili corridor.

Figure 23 shows that in Ihili corridor *Aphloia theiformis* and *Rauvolfia caffra* performed well in terms of average height increment, whereas *Craibia brevicaudata* exceeded all other species in terms of basal diameter increment. This is surprising considering the poor performance of *Craibia brevicaudata* in Lulanda corridor.

Figure 24 below shows the annual growth rates of planted tree species in Luhunga corridor.

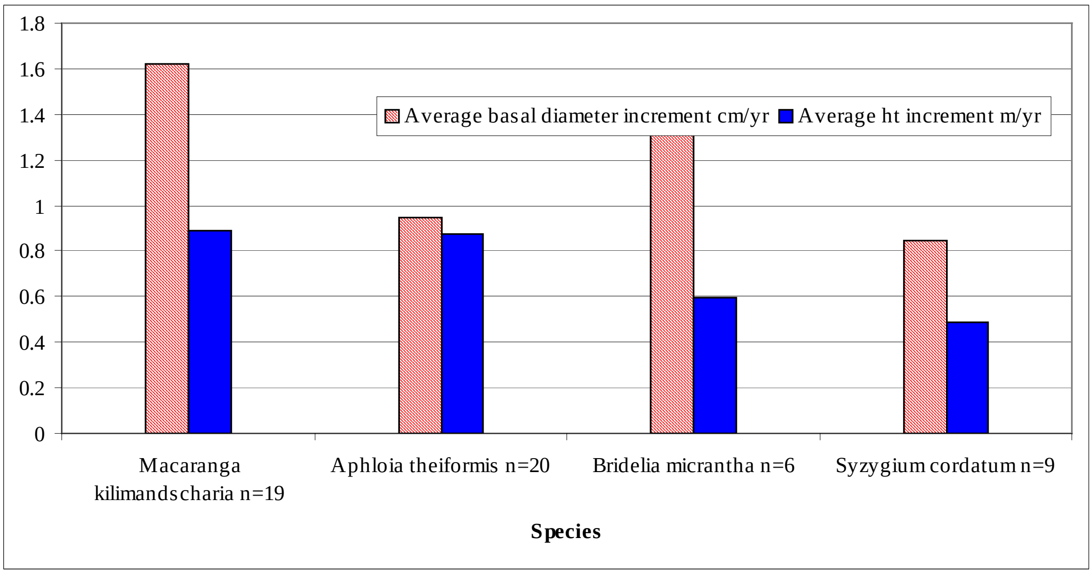


**Figure 24** Growth rates of planted tree species in Luhunga corridor.

Figure 24 shows that all four species performed well in Luhunga corridor, in particular *Macaranga kilimandscharia* seems to grow well.

Figure 25 and Figure 26 below compare the average annual growth rates of each species between each site.

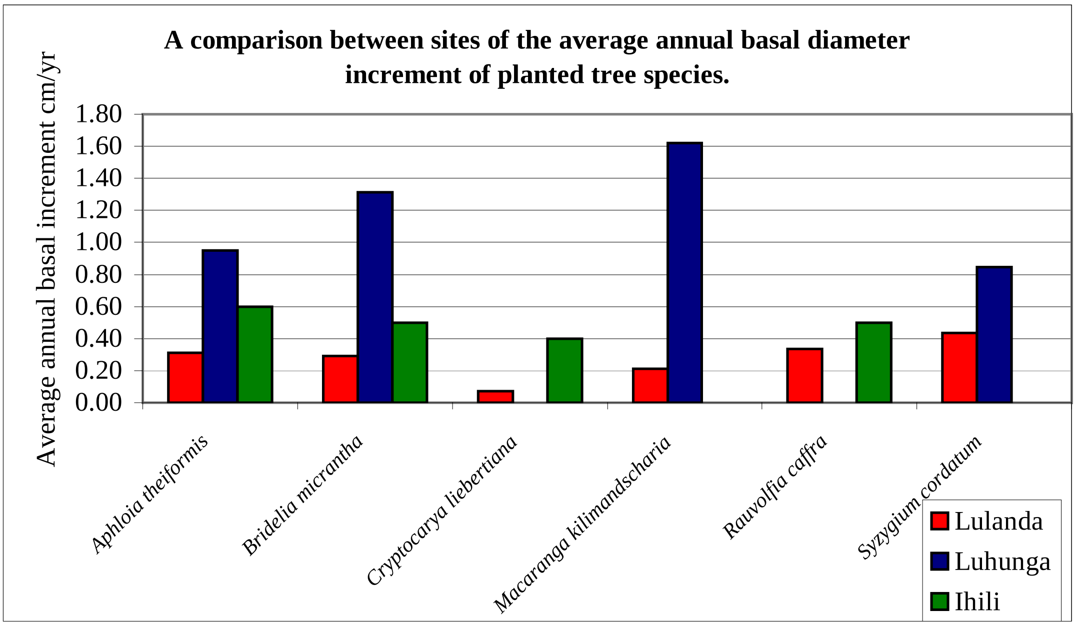


**Figure 25** Graph comparing average annual basal increment of planted tree species at each corridor.

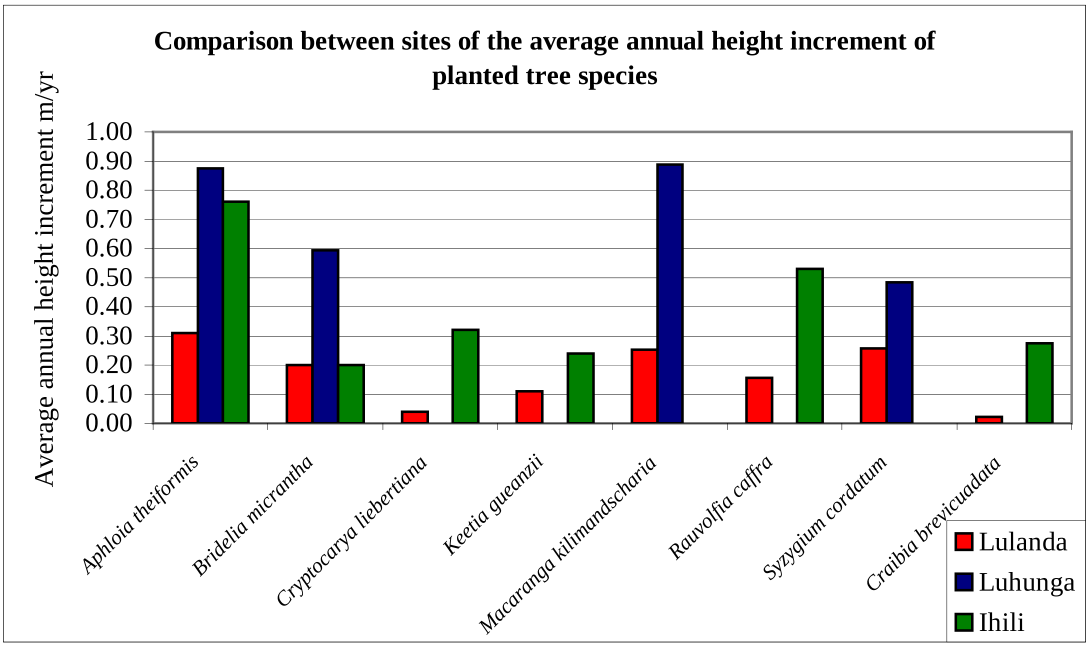


**Figure 26** Graph comparing the average annual height increment of planted tree species at each site.

Figure 25 and Figure 26 clearly show that growth rates at Luhunga corridor are highest, followed by Ihili, the lowest growth rates were recorded at Lulanda corridor.

### 4.6 Photographs

Photographs taken in vegetation plots are presented in albums available from TFCG.

## 5 Discussion

The discussion of the findings of this survey will focus on several key themes and issues and is divided into subsections accordingly.

## 5.1 *Which are the best performing species?*

There are two important factors to consider when assessing which species are the most successful: **survival**, and **growth rate.** Due to the small number of planted species and plots in Luhunga and Ihili the best performing species will be assessed using data from Lulanda corridor only.

**Survival**

TFCG former project managers listed 24 species that were planted (see Table 5 below). It is not possible to calculate an exact percentage seedling survival rate for each species, as the original number of individuals per species planted is unknown. However using 'local knowledge' of roughly how many of each species were planted (Table 5) and looking at the current frequency of each species in the corridor (Figure 27) it is possible to get a rough idea of those species that survive well and those that do not.

**Table 5** Species planted in Lulanda Corridor.

| **Kihehe** | **Latin Name** | **How many planted?** Source: TFCG field staff including former project managers |
|---|---|---|
| Muheyelo | *Aphloia theiformis* | Many |
| Muhapi | *Bridelia micrantha* | Many |
| Mpongolo | *Macaranga kilimandscharia* | Many |
| Matawe (Kiswahili) | *Phoenix reclinata* | Many (Ihili) |
| Mpande | *Craibia brevicaudata* | Some |
| Mguluka | *Cryptocarya liebertiana* | Some |
| Mkombaluiko | *Nuxia floribunda* | Some |
| Mvelevele | *Rauvolfia caffra* | Some |
| Kitunumbi | *Rhus longipes* | Some |
| Muvengi | *Syzygium cordatum* | Some |
| Mtanga | *Albizia gummifera* | Few |
| Mpeme | *Bersama abyssinica* | Few |
| Mujembi | *Hallea rubosticulata* | Few |
| Mfusa | *Myrianthus holstii* | Few |
| Mkufwa | *Myrica salicifolia* | Few |
| Msombe | *Teclea nobilis* | Few |
| Libevu | *Trema orientalis* | Few |
| Mkanzaule | *Parinari excelsa* | Few – but most died |
| Mfudu | *Vitex sp.* | Few – near nursery |
| Mdetema | *Dracena sp.* | Few - on fire line only |
| Mkungugu | *Milletia oblata* | Few |
| Mrungurungu | *Zanthophylum sp.* | None – all died in nursery due to insects |
| Litagamba ? | *Keetia gueinzii* | ? |
| ? | *Psychotria goetzei* | ? |

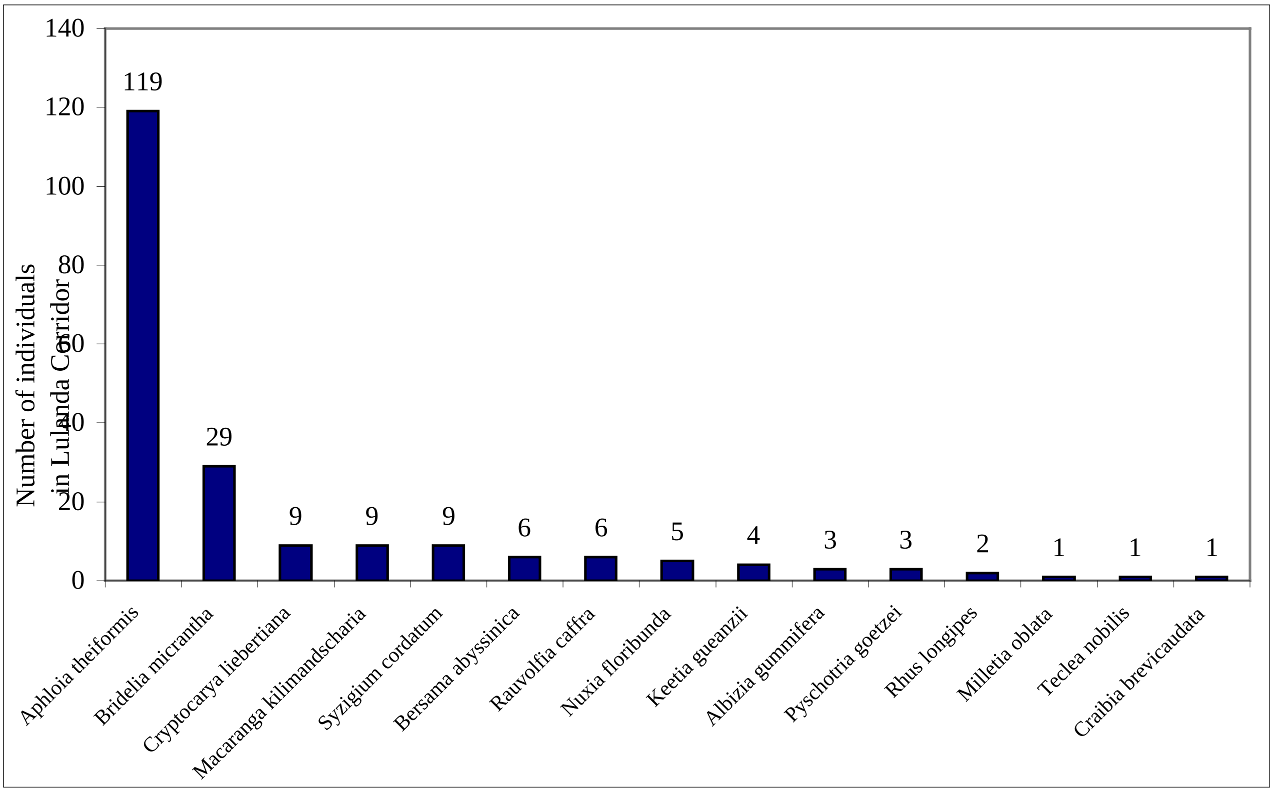


**Figure 27** Chart showing the number of individuals of each surviving planted species in Lulanda Corridor.

Of the 24 species listed in Table 5 only 15 were sampled in the corridor in this study. Of the nine species originally planted but not recorded, six (*Hallea rubosticulata, Myrianthus holstii, Myrica salicifolia, Trema orientalis, Vitex sp.,* and *Dracena sp.*) were represented at planting by only a 'few' individuals. It is impossible to conclude whether these six species were simply at too low densities to be recorded or whether they had died.

The remaining three species *Phoenix reclinata, Parinari excelsa* and *Zanthophylum sp.* we can deduce have low survival rates. *Parinari excelsa* and *Zanthophylum sp.* were observed not to survive well and were not recorded in the Lulanda sample. *Phoenix reclinata* was reportedly represented by many individuals in Ihili, so it is reasonable to expect this species to be represented in the Ihili sample, however none were recorded. In addition to this, low survival rates (therefore high rates of mortality) were encountered in the plots in Ihili corridor (see Table 1).

*Aphloia theiformis* was reportedly represented by many individuals at planting, and it is the most frequent species in the Lulanda sample, suggesting that individuals of this species have survived very well.

Similarly, *Bridelia micrantha* was numerous at planting and is numerous in the sample plots suggesting this species too survives well.

*Macaranga kilimandscharia, Cryptocarya liebertiana,* and *Syzygium cordatum* although not very numerous in the sample were observed frequently outside the sample plots, this combined with the fact that not as many of these species were planted (recorded as 'some') suggest that species survive well.

Evidence suggests that the survival of *Craibia brevicaudata* is mixed. This species was recorded only once in Lulanda corridor, however only a 'few' individuals were planted, therefore a low frequency is to be expected. However TFCG field staff reported that many *Craibia brevicaudata* individuals had died. In contrast this species was the most frequent species in Ihili suggesting a reasonable survival rate at least over the first sixth months.

*Nuxia floribunda* and *Rauvolfia caffra* were both present in the Lulanda sample, 'some' were planted suggesting that these species have a reasonable survival.

Fewer *Rhus longipes* were recorded than the previous two species, despite similar planting numbers, suggesting *Rhus longipes* does not survive as well.

Only a few *Albizia gummifera* were planted, yet this species was recorded quite frequently, suggesting this species survives reasonably well. In addition many *Albizia gummifera* were seen regenerating in and out of the sample plots.

Two species *Bersama abyssinica* and *Milletia oblata,* were recorded at low densities but planted at low densities also, it therefore seems they survive reasonably well.

Only one individual of *Teclea nobilis* was recorded, as this species was planted at low densities it is difficult to determine whether this species is simply occurring at very low densities not detected by this survey or has not survived well

Planting density of the final two species *Keetia gueinzii* and *Psychotria goetzei* is unknown therefore it is not possible to establish any idea of their survival rates.

The 24 species listed in Table 5 can be divided into four broad categories as follows.

| **Survives 'well'** | **Survives 'reasonably well'** | **'Poor' survival** | **Unknown** |
|---|---|---|---|
| *Aphloia theiformis* | *Nuxia floribunda* | *Phoenix reclinata* | *Hallea rubosticulata* |
| *Bridelia micrantha* | *Rauvolfia caffra* | *Parinari excelsa* | *Myrianthus holstii* |
| *Macaranga kilimandscharia* | *Albizia gummifera* | *Zanthophylum sp.* | *Myrica salicifolia* |
| *Cryptocarya liebertiana* | *Bersama abyssinica* | *Rhus longipes* | *Trema orientalis* |
| *Syzygium cordatum* | *Milletia oblata* | | *Teclea nobilis* |
| | | | *Vitex sp.* |
| | | | *Dracena sp.* |
| | | | *Keetia gueinzii* |
| | | | *Psychotria goetzei* |
| | | | *?Craibia brevicaudata?* |

**Growth rates**

The best performing species in terms of growth rates (see Figure 22) are:

| | |
|---|---|
| *Aphloia theiformis* | *Nuxia floribunda* |
| *Bridelia micrantha* | *Rauvolfia caffra* |
| *Macaranga kilimandscharia* | *Albizia gummifera* |
| *Syzygium cordatum* | |

Whilst there is no clear cut off point between 'successful' and 'unsuccessful' species there does seem to be a group of seven species (listed above) that have both higher basal diameter and height growth rates. These seven species all had a height growth rate > 15 cm per year and a basal diameter growth rate > 2 mm per year.

When taking into consideration growth rates and survival the following species seem to be the 'best performing' species in Lulanda, i.e. they are good 'survivors' and the fastest growing species.

| | |
|---|---|
| *Aphloia theiformis* | (Shrub) |
| *Bridelia micrantha* | (Shrub) |
| *Macaranga kilimandscharia* | (Tree) |
| *Syzygium cordatum* | (Tree ) |

The following species also grow quickly but have a lower survival rate.

| | |
|---|---|
| *Nuxia floribunda* | (Tree) |
| *Rauvolfia caffra* | (Tree |
| *Albizia gummifera* | (Tree) |

The following species although slower growing, have been shown to have reasonable survival rates, so could be considered for planting.

| | |
|---|---|
| *Bersama abyssinica* | (Tree) |
| *Milletia oblata* | (Tree) |

### 5.2 Differences between Lulanda and Luhunga.

On visiting Luhunga the rapid success of planted seedlings is very striking. Figure 25 and Figure 26 show clearly that growth rates of all species at Luhunga are faster, in terms of both height and basal diameter increment. The average height of seedlings in Luhunga (planted in 2000) is similar to the average height of seedlings in Lulanda plots planted in 1997 and 1998 (it is however recognised that the sample size at Luhunga is very small, making comparisons somewhat unreliable). There is an obvious difference in management between the two sites i.e. all regeneration is slashed in Luhunga and little clearing has been undertaken at Lulanda, however this is only one of many differences between the sites. Luhunga is at a higher altitude and has a very gentle slope, but perhaps most importantly the area was forested until very recently, and cultivation in the area took place for only three years. Assessing the direct and indirect impact of these factors on seedling survival and growth rates is beyond the possibilities of this survey. It is not possible to conclude that increased growth rates at Luhunga are due to the different approaches in management alone. Examination of different management techniques could be compared by establishing sample plots in Luhunga corridor that are planted with seedlings but not cleared of regenerating vegetation. The survival and growth rates between cleared and uncleared plots could then be monitored over time.

Observations from Lulanda corridor and other studies suggest that clearing of grasses around the base of planted seedlings may be beneficial. In the majority of Lulanda plots the grasses reach a height of 1 – 1.5 m, in many cases taller than the seedlings. Although there was no significant difference in seedling survival related to ground layer vegetation (section 4.2) this was largely because all plots in Lulanda were recorded as having >50% ground layer vegetation cover. Many (56%) of the seedlings in Lulanda were recorded as being totally covered by grass, a significant proportion of these (28%) were recorded as lying horizontally or leaning, these were often growing along the ground under the grass layer. Other researchers have shown that grasses can provide protection from harsh microclimatic conditions by reducing soil temperature and light intensity (Holl, 1999). Another study has shown that 'competition with pasture grasses is the primary factor impeding seedling survival and growth rates' (Holl *et al*, 2000). The extent to which competition with grasses in Lulanda is limiting seedling survival and growth rates is difficult to determine precisely, however the physical interference is enough of a reason to recommend clearing. Clearing grasses around the seedling should limit physical interference (allowing the plant to grow erect) and maintain the protective qualities of a ground vegetation layer. It will not however limit the competition for nutrients. It would be interesting to conduct a long-term study as described above, in Lulanda also. Enabling inter- and intra-site comparisons of the effects of management activities.

Lulanda corridor has the highest level of regeneration in terms of number of stems and average height, this is not surprising as it is also the 'oldest' site. Several of the planted species (e.g. *Albizia gummifera, Myrianthus holstii* and *Myrica salicifolia*) were recorded regenerating naturally in Lulanda, however stems of *Kotschya* spp. dominate the regeneration layer. Figure 18 shows that high densities of *Kotschya* spp. occur in plot 5 and to some extent in plot 4. The data suggest there is a positive relationship between number of stems per plot and seedling survival. This result concurs with the findings of Holl *et al*, who concluded that shrubs and remnant trees facilitate the establishment of woody species. The dominance of *Kotschya* spp. stems in some areas should not negatively affect seedling survival. A problem may arise however when the *Kotschya* spp. die (after about five to seven years, Kiando pers comm.) and collapse. In some areas in the corridor the collapse of *Kotschya* spp. created a layer of dead vegetation about 1-1.5m above the ground, any planted seedlings underneath had been smothered or squashed. The seedlings appeared to still be alive but were unable to break through the dense layer of suspended vegetation. *Kotschya* spp. although widespread did not seem to be regenerating aggressively, this is possibly because the very small seeds favour conditions present after burning (Mwangoka, pers comm.).

- It is recommended that the area around each sapling be cleared so that seedling growth is not limited during the time it takes for dead *Kotschya spp.* vegetation to decompose.

### 5.3 How representative of Lulanda forest is the species composition in the corridors?

As no comparative studies have been undertaken in the forests of the survey areas, it is not possible to quantitatively assess the representiveness of the corridor species composition. However, by comparing species occurring in the corridor to the draft summary of biodiversity for Lulanda Village Forest Reserve (TFCG internal document), and personal observations it is possible to draw some qualitative conclusions.

16 of the 56 species (29%) listed in the biodiversity summary were recorded by this survey. These 16 species account for only 13% of the total number of species recorded in this survey (as listed in Appendix ) and 31% of the species recorded in the systematic survey (as listed in Table 2). These relatively low percentages suggest that the corridor at present has a very different species composition to the forest. This is not surprising as the regenerating corridor is still very open and has many herbaceous and shrubby species that do not occur in the forest. Eventually, as the planted tree species mature and the canopy closes over, it is likely that the species typical of open habitats will decline, and the regeneration of forest species will be encouraged. The results of this survey are not able to predict when or indeed if this will definitely happen. The data do show that approximately 53% of planted seedlings in the Lulanda area have survived. It was also observed that tree and shrub species such as *Albizia gummifera* and *Myrica salicifolia* were regenerating well in certain areas. It is likely therefore that formation of secondary forest in the corridor will be patchy at first, centred around areas of high seedling success and remnant and regenerating tree and shrub species.

*Parinari* sp. dominates the canopy of the Lulanda forest patches (pers. obs.), this is possibly because of its unsuitability for pit sawing, being a very hard wood it is extremely difficult to cut by hand. It is noteworthy that no *Parinari* sp. was recorded surviving or regenerating in the corridor. However, other common forest canopy species such as *Bersama abyssinica, Rauvolfia caffra, Albizia gummifera* and *Millettia oblata* were numerous in the systematic survey although they were not the most abundant species. It seems that common forest species are present in the corridor but not at the same level of frequency as in the forest. Conversely, frequently recorded species in the corridor, such as *Aphloia theiformis, Macaranga kilimandscharia* and *Bridelia micrantha*, do not seem to be dominant species in the forest. Given the close proximity to the forest patches, it is probable that as regeneration takes place, 'common forest' species will increase in abundance in the corridor, as microclimatic conditions become more favourable. Monitoring the change in corridor species composition over time is the only way this can be assessed. Then, if necessary supplementary planting of common forest species can take place.

- The species composition of the corridor at present is very different to that of the forest patches (using limited data available). However, common forest species are growing and regenerating in the corridor area, with the notable exception of *Parinari* sp.. The more abundant species in the corridor are not common in the forest patches but should serve to create a semi-closed canopy that will encourage regeneration of common forest species.

- Continued monitoring of the corridor species composition is recommended. If it is observed that common forest species continue to occur at low densities, supplementary planting of common forest species could be considered.

### 5.4 How successful are the study corridors?

From a plant survival viewpoint, the corridors have been partially successful, 53 % of the planted seedlings in the Lulanda area have survived, and common forest species are surviving and regenerating in the corridors albeit at low densities. Given the high planting density of 2500 trees per ha, this survival rate equates to an average of approximately 1325 surviving tree seedlings per ha. This however disguises a large variation in seedling survival rates, over half of the plots in Lulanda corridor had survival rates greater than 60%. Regeneration of common forest species is occurring although at a relatively low frequency. The regeneration of forest species, seemed to be patchy, and often associated with remnant trees, this concurs with the findings of Holl *et al* (2000).

Comparison of seedling survival rates with other studies, has not been possible as no published data regarding these indigenous species was located in the literature search. However it is interesting to note that comparison with exotic species survival rates such as *Eucalyptus grandis*, where a minimum of 90% survival expected (Anderson pers. comm.), suggest that survival rates calculated in this study are poor. However it should also be noted that this is not a true comparison as seeds of commercial species have been selected over generations for vigour and other desirable qualities whereas the indigenous species planted represent wild stock. It is also interesting that in order to achieve 90% success for *Eucalyptus grandis,* seedlings have to be weeded at least four times in the first year, less thereafter (Anderson pers. comm.). Considering this fact, an area of concern is the high level of competition from grasses and other herbaceous vegetation. It is possible that this fierce competition will have permanently stunted the surviving tree seedlings, as happens in some commercial tree species such as *Eucalyptus grandis* (Anderson, pers. comm.). If in future monitoring in the corridors reveal that this is the case, intensive enrichment planting of well-maintained successful species would be required. Considering the differences in life histories of highly bred exotic species and naturally colonising forest pioneer species this costly scenario is unlikely.

As no systematic zoological data was collected during this survey, it is not possible to assess the success of the corridors in zoological terms. Primates were not observed using the corridor, which is not surprising given the early successional stage of its regeneration. Black and white colobus monkeys (*Colobus angolensis*) were seen crossing farmland and the road from Ihili forest patch into Fufu forest patch. This surprising observation suggests that there is a need for the colobus to move from one forest patch to another. At present Ihili and Lulanda corridors do not quite meet, although there was discussion by project staff that joining the corridors would be possible, but require the payment of compensation. Whilst this issue is being discussed, houses and shops are being built on the relevant section of roadside that are adding to the compensation costs. In the short term planting of broad reaching species along the edges of the road may aid dispersal. This strategy has been employed for the section of road that cuts through Magwilwa forest, where road and verges have separated the canopy.

A very important positive effect of the corridor will be amelioration of edge effects on the forest fragments by decreasing the relative edge length. As no study of the forest patches was undertaken during this survey, it is not possible to establish the progress of this beneficial factor. However it is likely that benefits will have already occurred and continue to do so as the corridor vegetation structure increases. The corridor offers excellent sites for natural regeneration given the close proximity to natural forest patches. Monitoring this change will yield unique and important information both for the project itself and other restoration attempts globally.

The ultimate success or otherwise of the corridors will only be evident in time and with further monitoring.

## 5.5 Suggestions from other studies.

Aide *et al* (2000) studied the natural regeneration of forests in Puerto Rico, and states that 'patterns of natural recovery suggest strategies for accelerating natural recovery by planting a suite of generalist species that are common'. This study also demonstrates 'that one restoration strategy for tropical forest in abandoned pasture is simply to protect the areas from fire, and allow natural regeneration to produce secondary forest. This highlights the importance of maintaining the fire line at Lulanda. Maintenance of the fire lines is the single most important management issue within TFCG's forest corridors. If nothing else can be done it is of the utmost importance that efforts continue to ensure the regular clearing of the fire lines. As demonstrated in 1995, a single fire sweeping through an area can destroy years of natural regeneration and kill planted individuals.

Holl *et al* (2000), identified seed dispersal, seed predation, low germination rates, lack of nutrients, high light intensity, herbivory and competition with grasses as the principal barriers to tropical forest recovery in abandoned pasture land. The nature of the reforestation programme has overcome the difficulties of seed dispersal, seed predation and low germination rates by actively planting seedlings. Herbivory was recorded on only a few occasions in Lulanda corridor and not at all in Luhunga, however in Ihili corridor it proved to be a greater problem. Goats had entered the corridor and eaten a large number of recently planted seedlings. The village government dealt with the problem and hopefully more care of livestock will be taken in future. Suggested management solutions to this problem (Holl *et al*, 2000) such as fencing the regenerating areas are prohibitively expensive.

The use of exotic species to facilitate regeneration is an attractive idea as the income generated by timber production can offset management costs and provide an incentive for local communities. However evidence suggests that regeneration beneath exotic plantations is impoverished in terms of species diversity and stocking characteristics in comparison to natural logged and unlogged forest (Finbel & Finbel 1996). Whilst there is no direct comparison of regeneration success of land cleared for agriculture this study does suggest that use of exotic species is not an entirely successful strategy. In addition, the negative impacts of the use of exotic species in the rehabilitation of forests as demonstrated by Chapman & Chapman (1996) (damage during felling operations), and Struhsaker (1989) (death of nearby natural forest tree species) also need consideration. Where possible, opportunities to undertake reforestation without the financial incentive of exotic timber species should pursued.

The use of bird perches to facilitate regeneration of forest species has been investigated by Holl *et al*, (2000). They conclude that bird perches alone are not an effective strategy to facilitate forest recovery as they only overcome problems of seed dispersal, and do not contribute to overcoming barriers to regeneration. In the Lulanda context bird perches would probably not be that useful as remnant trees and larger planted individuals already provide perching opportunities.

It is positive and interesting to note that the TFCG reforestation programme employs methods recommended by Holl *et al* (2000) 'the most promising strategies (for facilitating forest recovery) appear to be establishing woody species, either through retaining some remnant pasture trees when possible or planting shrubs or native tree seedlings'.

## *5.6 Monitoring*

Recommended monitoring activities are outlined in Appendix 7. Using the data collected during this study as a baseline, enables TFCG to monitor the long-term changes in species composition and growth rates of indigenous planted species. This could be done by returning annually or biannually to each of the plots established and re-measuring each of the planted individuals. If resources allowed it would be interesting to re-assess the number and species of regenerating stems and vegetation cover within the plot. The information generated would be useful in terms of management, and interesting scientifically as little is known about the rates of growth of regenerating species. Continued 'casual' monitoring of planted seedlings, simply checking for disease, herbivory or later cutting is very desirable. Any problems encountered can then be dealt with promptly. TFCG project staff can do this type of monitoring as they go about their normal duties in the corridor, or during clearing activities.

If resources allow, a periodic repeat of the fixed point photography methods employed in this study would provide a good visual record of regeneration in the corridors. Every two years is suggested as an appropriate time scale.

Below are some suggestions of interesting and useful areas of study that go beyond monitoring but would aid the understanding of natural processes at work in the corridor areas. These are suitable projects for students or other researchers to undertake.

- Comparison of forest patch and corridor soil nutrients.
- Comparison of forest patch and corridor soil micro- and macro- fauna.
- Use of the corridor by all faunal groups (e.g. mammals, reptiles, amphibians and invertebrates), and how this changes over time and successional changes.
- Comparisons of faunal populations in the corridor with forest fauna.
- Identification of indicator species, to monitor regeneration.
- The implication of different management regimes on regeneration and planted species.

## 5.7 Conclusions

- Approximately 53% of planted seedlings in the Lulanda area have survived which equates to approximately 1325 trees per ha.
- Lulanda area has a wide range of survival rates varying from 16% to 81%, with an average survival rate of 55%.
- Ihili area had a generally lower seedling survival rate ranging from 24% to 54 % with an average of seedling survival 41%.
- Luhunga has the highest seedling survival rate (93%), but this is only recorded from a single plot.
- The best performing species were *Aphloia theiformis, Bridelia micrantha, Macaranga kilimandscharia* and *Syzygium cordatum*
- Growth rates are higher at Luhunga, but the exact reasons for this are unknown.
- Dense stands of *Kotschya* spp. do not affect seedling survival, but may crush planted seedlings when they die and collapse. It is recommended that in areas where stands of *Kotschya* spp. have collapsed, the immediate area around each sapling be cleared so that seedling growth is not inhibited during the time it takes for dead vegetation to rot.
- At present the species composition of the corridor is very different to that of the forest patches (using limited data available).
- Common forest species are growing and regenerating in the corridor area. The more abundant species in the corridor are not common in the forest patches but should with time, serve to create a semi-closed canopy that will encourage regeneration of common forest species.
- It is likely that formation of secondary forest in the corridor will be patchy at first, centred around areas of high seedling success and remnant and regenerating tree and shrub species.
- Continued monitoring of the corridor species composition is recommended. If it is observed that common forest species continue to occur at low densities, supplementary planting of common forest species could be considered.
- **Maintenance of fire lines is the single most important management issue in TFCG's reforestation programme.**

# 6 References


**Aide, T. & Cavelier, J. 1994** Barriers to Lowland Tropical Forest Restoration in the Sierra Nevada de Santa Marta, Colombia. *Restoration Ecology* Vol. 2 No. 4 pp. 219-229.

**Aide, T., Zimmerman, J., Pascarella, J., Rivera, L. & Marcano-Vega, H. 2000** Forest regeneration in a chronosequence of tropical abandoned pastures: implications for restoration ecology. *Restoration Ecology* Vol. 8 No. 4 pp. 328 – 338.

**Ashby, W. 1987** Forests. pp 89 – 108. In: Jordan, W., Gilpin, M. & Aber, J. 1987 *Restoration Ecology: A synthetic approach to ecological research.* Cambridge University Press, Cambridge, Great Britain.

**Beentje, N. 1994** *Kenya Trees, Shrubs and Lianas*. National Museums of Kenya, Nairobi, Kenya. 1 – 722 pp.

**Buckley, G. & Knight, D. 1995** The feasibility of woodland reconstruction. pp 171 – 188. In: Buckley, G. 1995 *Biological Habitat Reconstruction*. John Wiley & Sons, Chichester, Great Britain.

**Buckley, G. 1995** *Biological Habitat Reconstruction*. John Wiley & Sons, Chichester, Great Britain.

**Chapman, C. & Chapman L. 1996** Exotic Tree Plantations and the regeneration of natural forests in Kibale National Park, Uganda. Biological Conservation 76: 253-257

**Feras-Kaan, R. 1995** *The Ecology of Woodland Creation.* John Wiley & Sons, Chichester, Great Britain.

**Frelich, L. & Puettmann, K. 1999** Restoration Ecology. pp 498 – 524. In: Hunter, M. 1999. *Maintaining Biodiversity in Forest Ecosystems*. Cambridge University Press, Cambridge, Great Britain.

**Finbel, A. & Finbel, C. 1996** The role of exotic conifer plantations in rehabilitating degraded tropical forest lands: A case study from the Kibale Forest in Uganda. *Forest Ecology and Management* 81: 215-226.

**Frontier Tanzania, 2001a** Doody, K.Z., Howell, K.M. and Fanning, E. (Eds.) Amani Nature Reserve: A biodiversity Survey. East Usambara Conservation Area Management Programme Technical Paper No. 52. Frontier Tanzania; Forestry and Beekeeping Division and Metsahallitus Consulting, Dar es Salaam, Tanzania and Vantaa, Finland.

**Frontier Tanzania, 2001b** Doody, K.Z., Howell, K.M. and Fanning, E. (Eds.) Segoma Forest Reserve: A biodiversity Survey. East Usambara Conservation Area Management Programme Technical Paper No. 50. Frontier Tanzania; Forestry and Beekeeping Division and Metsahallitus Consulting, Dar es Salaam, Tanzania and Vantaa, Finland.

**Frontier Tanzania, 2001c** Doggart, N.H., Doody, K.Z., Howell, K.M. and Fanning, E. (Eds.) Semdoe Forest Reserve: A biodiversity Survey. East Usambara Conservation Area Management Programme Technical Paper No. 42. Frontier Tanzania; Forestry and Beekeeping Division and Metsahallitus Consulting, Dar es Salaam, Tanzania and Vantaa, Finland.

**Frontier Tanzania, 2001d.** New Dabaga/Ulangambi Forest Reserve – Botanical and Forest Use Report. Doody, K.Z., Howell, K.M. and Fanning, E. (Eds.). *Report for the Udzungwa Mountains Forest Management and Biodiversity Conservation Project, MEMA, Iringa, Tanzania.* 1 – 117 pp

**Holl, K. 1999** Factors limiting tropical moist forest regeneration in agricultural land: soil, microclimate, vegetation and seed rain. *Biotropica* 21:229-242

**Holl, K., Loik, M., Lin, E. & Samuels, I. 2000** Tropical montane forest restoration in Costa Rica: Overcoming barriers to dispersal and establishment. *Restoration Ecology* Vol. 8 No. 4 pp. 339 - 349.

**Haila, Y. 1999** Islands and fragments. In: **Hunter, M. 1999** *Maintaining Biodiversity in Forest Ecosystems*. Cambridge University Press, Cambridge, Great Britain. pp.234 – 264

**Hunter, M. 1999** *Maintaining Biodiversity in Forest Ecosystems*. Cambridge University Press, Cambridge, Great Britain. 698 pp.

**Jordan, W., Gilpin, M. & Aber, J. 1987** *Restoration Ecology: A synthetic approach to ecological research.* Cambridge University Press, Cambridge, Great Britain.

**Kent, M. & Coker, P. 1992** *Vegetation Description and Analysis: A practical approach*. John Wiley & Sons, Chichester, Great Britain.

**Loik, M. & Holl, K. 1999** Photosynthetic responses to light for rainforest seedlings planted in abandoned pasture, Costa Rica. *Restoration Ecology* Vol. 7 No. 4 pp. 382 -391.

**Matlack, G. and Litvaitis, J. 1999** Forest edges. In: **Hunter, M. 1999** *Maintaining Biodiversity in Forest Ecosystems*. Cambridge University Press, Cambridge, Great Britain. pp.210 – 233

**Moffat, A. & Buckley, G. 1995** Soils and Restoration Ecology. pp 75-90 In: Feras-Kaan, R. 1995 *The Ecology of Woodland Creation.* John Wiley & Sons, Chichester, Great Britain.

**Norton, D. 1999** Forest Reserves. In: **Hunter, M. 1999** *Maintaining Biodiversity in Forest Ecosystems*. Cambridge University Press, Cambridge, Great Britain. pp. 525 – 555

**Schulman, L., Junikka, L., Mndolwa, A. and Rajabu, I. 1998** *Trees of Amani Nature Reserve.* The Ministry of Natural Resources and Tourism, Tanzania. ISBN: 9987-646-01-8

**Spellerberg, I. (Ed.) 1996** *Conservation Biology.* Longman Group Limited. England. ISBN 0-582-22865-4 pp. 242

**Stewart, A. and Hutchings, M. 1996** Conservation of Populations. In: **Spellerberg, I. (Ed.) 1996** *Conservation Biology.* Longman Group Limited. England. ISBN 0-582-22865-4 pp. 122 – 140.

**Struhsaker, T., Kasenene, J., Gaither, J., Larsen, N., Musango, S. and Bancroft, R. 1989** Tree mortality in the Kibale Forest, Uganda: A case study of dieback in Tropical Rain Forest Adjacent to Exotic Conifer Plantations. *Forest Ecology and Management* 29 165-185.

**Urbanska, K., Webb, N. R. and Edwards, P. 1997** *Restoration Ecology and Sustainable Development.* Cambridge University Press, United Kingdom.

**Webb, N. R. 1997** The development of criteria for ecological restoration. In: **Urbanska, K., Webb, N. R. and Edwards, P. 1997** *Restoration Ecology and Sustainable Development.* Cambridge University Press, United Kingdom. 133 – 160 pp.

**Woodcock, K. 1998** Changing roles in natural forest management: A case study from the Udzungwa Mountains. *Journal of East African Natural History* Vol. 87 Parts 1 / 2 Special Issue. ISSN 0012-8317

**Zar, J. 1984** *Biostatistical Analysis* Second Edition. Prentice-Hall, Inc. New Jersey, USA.

# 7 Appendices

**Appendix 1 List of plant specimen 'MM' numbers and current species identifications.**

Habitat details for each species given in Appendix 7.

| Specimen Number | Family | Genus | Species | Subspecies / Variety |
|---|---|---|---|---|
| MM 2550 | *Rutaceae* | *Zanthoxylum* | *usambarense* | |
| MM 2551 | *Rubiaceae* | *Parvetta* | *lynessii* | |
| MM 2552 | *Asparagaceae* | *Asparagus* | *asparagoides* | |
| MM 2553 | *Rubiaceae* | *Rutidea* | *orientalis* | |
| MM 2554 | *Sapindaceae* | *Deinbolia* | *borbonica* | |
| MM 2555 | *Araceae* | *Culcasia* | *falicifolia* | |
| MM 2556 | *Flacourtiaceae* | *Aphloia* | *theiformis* | |
| MM 2557 | *Rubiaceae* | *Psychotria* | *megatopus* | |
| MM 2558 | *Apocynaceae* | *Rauvolfia* | *manii* | |
| MM 2559 | *Celastraceae* | *Maytenus* | *undata* | |
| MM 2560 | *Lobeliaceae* | *Lobelia* | *giberroa* | |
| MM 2561 | *Rosaceae* | *Rubus* | *rigidus* | |
| MM 2562 | *Malvaceae* | *Hibiscus* | *diversifolia* | |
| MM 2563 | *Loganiaceae* | *Baddleja* | *salviifolia* | |
| MM 2564 | *Papilionaceae* | *Kotschya* | *aeschynomerioides* | |
| MM 2565 & 2662 | *Graminae/Poaceae* | *Panicum* | *culvum* | |
| MM 2566 | *Graminae/Poaceae* | *Hyparrhenia* | *schimperi* | |
| MM 2567 | *Lamiaceae* | *Iboza* | *multiflora* | |
| MM 2568 | *Asteraceae* | *Vernonia* | *lasiopus* | |
| MM 2569 | *Asteraceae* | *Bidens* | *magnifolia* | |
| MM 2570 | *Ericaceae* | *Agauria* | *salicifolia* | |
| MM 2571 | *Papilionaceae* | *Dalbergia* | *lactea* | |
| MM 2572 | *Papilionaceae* | *Eriosema* | *montanum* | |
| MM 2573 | *Rubiaceae* | *Pentas* | *schimperana* | |
| MM 2574 | *Asteraceae* | *Helichrysium* | *schimperi* | |
| MM 2575 | *Vitaceae* | *Rhoicissus* | *tridentata* | |
| MM 2576 & 2608 | *Papilionaceae* | *Tephrosia* | *elata* | |
| MM 2577 | *Bignoniaceae* | *Tecoma* | *nyassae* | |
| MM 2578 | *Rubiaceae* | *Pentas* | *zanzibarica* | |
| MM 2579 | *Hypericaceae* | *Hypericum* | *roeperianum* | |
| MM 2580 | *Verbenaceae* | *Lippia* | *javanica* | |
| MM 2581 | *Rubiaceae* | *Pentanisia* | *ouranogyne* | |
| MM 2582 | *Rubiaceae* | *Anthospermum* | *usambarense* | |
| MM 2583 | *Scrophulariaceae* | *Halleria* | *lucida* | |
| MM 2584 | *Proteaceae* | *Faurea* | *wentzeliana* | |
| MM 2585 | *Papilionaceae* | *Kotschya* | *carsonii* | |
| MM 2586 | *Anacardiaceae* | *Rhus* | *longipes* | *var.schinoides* |
| MM 2587 | *Sapindaceae* | *Dodonea* | *viscosa* | |
| MM 2588 | *Papilionaceae* | *Rhynchosia* | *hirta* | |
| MM 2589 | *Myrsinaceae* | *Myrsine* | *africana* | |
| MM 2590 | *Papilionaceae* | *Dalbergia* | *fischeri* | |
| MM 2591 | *Myrtaceae* | *Syzygium* | *cordatum* | |
| MM 2592 | *Rubiaceae* | *Rubia* | *cordifolia* | |
| MM 2593 | *Verbenaceae* | *Lantana* | *trifolia* | |
| MM 2594 | *Asteraceae* | *Conyza* | *welwischii* | |

**Appendix 1 continued**

| **Specimen Number** | **Family** | **Genus** | **Species** | **Subspecies / Variety** |
|---|---|---|---|---|
| MM 2595 & 2640 | *Apocynaceae* | *Carvalhoa* | *campanulata* | |
| MM 2596 | *Tiliaceae* | *Triumfetta* | *brachyceras* | |
| MM 2597 | *Comvulvulaceae* | *Ipomoea* | *involucrata* | |
| MM 2598 | *Lamiaceae* | *Haumaniastrum* | *callianthum* | |
| MM 2599 | *Melastomataceae* | *Dissotis* | *senegambiensis* | |
| MM 2600 | *Mimosaceae* | *Albizia* | *gummifera* | *var. gummifera* |
| MM 2601 | *Myrsinaceae* | *Maesa* | *lanceolata* | |
| MM 2602 & 2607 | *Rubiaceae* | *Mussaenda* | *arcuata* | |
| MM 2603 | *Asteraceae* | *Sphaeranthus* | *suaveolens* | |
| MM 2604 | *Lamiaceae* | *Pecnostachyus* | *speciosa* | |
| MM 2605 | *Olaceae* | *Schrebera* | *alata* | |
| MM 2606 | *Cecropiaceae* | *Myrianthus* | *holstii* | |
| MM 2609 | *Rubiaceae* | *Psychotria* | *goetzei* | |
| MM 2610 | *Malvaceae* | *Hibiscus* | *fuscus* | |
| MM 2611 | *Loganiaceae* | *Nuxia* | *floribunda* | |
| MM 2612 | *Celastraceae* | *Maytenus* | *acuminata* | |
| MM 2613 | *Basalminaceae* | *Impatiens* | *eryaleia* | *sub sp. eryaleia* |
| MM 2614 | *Zingerberaceae* | *Afromomum* | *alpinium* | |
| MM 2615 | *Menispermaceae* | *Stephania* | *abyssinica* | *var. tormentosa* |
| MM 2616 | *Ranunculaceae* | *Clematis* | *hirtsuta* | |
| MM 2617 | *Solanaceae* | *Solanum* | *anguivi* | |
| MM 2618 | *Comvulvulaceae* | *Cascuta* | *sp.* | |
| MM 2619 | *Lamiaceae* | *Plectranthus* | *sp.* | |
| MM 2620 | *Asteraceae* | *Gutenbergia* | *cordifolia* | |
| MM 2621 | *Adiantaceae* | *Pteris* | *pteridiodes* | |
| MM 2622 | *Guttiferae/Clusiaceae* | *Psorospermum* | *febrifugum* | *var. ferrugineau* |
| MM 2623 | *Rubiaceae* | *Keetia/Cantheum* | *lulandensis* | |
| MM 2624 | *Papilionaceae* | *Milletia* | *oblata* | *var.intermedia* |
| MM 2625 | *Asteraceae* | *Bothriocline* | *longipes* | |
| MM 2626 | *Cyperaceae* | *Cyperus* | *platycaulis* | |
| MM 2627 | *Caesalpiniaceae* | *Chamaecrista* | *kirkii* | |
| MM 2628 | *Papilionaceae* | *Grysine* | *wightii* | |
| MM 2629 | *Euphorbiaceae* | *Bridelia* | *micrantha* | |
| MM 2630 | *Asteraceae* | *Solanecio* | *mannii* | |
| MM 2631 | *Cucurbitaceae* | *Raphidiocystis* | *crysocoma* | |
| MM 2632 | *Asteraceae* | *Vernonia* | *myriantha* | |
| MM 2633 | *Merianthaceae* | *Bersama* | *abyssinica* | *ssp. abyssinica var. abyssinica* |
| MM 2634 | *Lauraceae* | *Cryptocarya* | *liebertiana* | |
| MM 2635 | *Tiliaceae* | *Grewia* | *mildbraedii* | |
| MM 2636 | *Apocynaceae* | *Rauvolfia* | *caffra* | |
| MM 2637 | *Flacourtiaceae* | *Casearia* | *battiscombei* | |
| MM 2638 | *Rubiaceae* | *Keetia/Canthium* | *guanzii* | |
| MM 2639 | *Rubiaceae* | *Rytigynia* | *lichenoxenos* | |
| MM 2641 | *Papilionaceae* | *Kotschya* | *uguenensis* | |
| MM 2642 | *Ebenaceae* | *Euclea* | *sp.* | |
| MM 2643 | *Ulmaceae* | *Trema* | *orientalis* | |
| MM 2644 | *Polygonaceae* | *Rumex* | *abyssinicus* | |
| MM 2645 | *Papilionaceae* | *Desmodium* | *repandum* | |
| MM 2646 | *Rubiaceae* | *Hallea* | *rubrostipulata* | |
| MM 2647 | *Tiliaceae* | *Sparmannia* | *ricinocarpa* | |

**Appendix 1 continued**

| **Specimen Number** | **Family** | **Genus** | **Species** | **Subspecies / Variety** |
|---|---|---|---|---|
| MM 2648 | *Cyatheaceae* | *Cyathea* | *manniana* | |
| MM 2649 | *Cucurbitaceae* | *Lagenaria* | *abyssinica* | |
| MM 2650 | *Asteraceae* | *Mikania* | *cordata* | |
| MM 2651 | *Celastraceae* | *Maytenus* | *buchananii* | |
| MM 2652 | *Polygonaceae* | *Polygonum* | *salicifolium* | |
| MM 2653 | *Hypericaceae* | *Hypericum* | *peplidifolium* | |
| MM 2654 | *Orchidaceae* | *Eulophia* | *sp.* | |
| MM 2655 | *Euphorbiaceae* | *Acalpha* | *volkensii* | |
| MM 2656 | *Myrsinaceae* | *Embelia* | *schimperi* | |
| MM 2657 | *Cucurbitaceae* | *Zehneria* | *scabra* | |
| MM 2658 | *Lamiaceae* | *Leucas* | *deflexa* | *var. kondowensis* |
| MM 2659 | *Asteraceae* | *Crassocephalum* | *vitellinum* | |
| MM 2660 | *Classulaceae* | *Kalanchoe* | *densiflora* | |
| MM 2661 | *Papilionaceae* | *Indigofera* | *sp.* | |
| MM 2663 | *Connaraceae* | *Agelaea* | *sp.* | |
| MM 2664 | *Papilionaceae* | *Dalbergia* | *sp.* | |
| MM 2665 | *Sapotaceae* | *Chrysophyllum* | *gorungosanum* | |
| MM 2666 | *Papilionaceae* | *Craibia* | *brevicaudata* | |

**Appendix 2: Frequency of regenerating tree and shrub species per plot.**

| | | | Plot | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Family** | **Genus** | **Species** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **Total** |
| Anacardiaceae | *Rhus* | *longipes* | | | | 10 | 4 | | | | | | | | | | | | 1 | | 4 | | | | 19 |
| Apocynaceae | *Rauvolfia* | *manii* | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Apocynaceae | *Rauvolfia* | *caffra* | | | | | 3 | | 1 | | | | | | | 2 | | | | 2 | | | | | 8 |
| Asteraceae | *Bidens* | *magnifolia* | | 3 | 27 | | 2 | 6 | 1 | 12 | | | 6 | 3 | | | | | | | 2 | | | | 62 |
| Asteraceae | *Chassocephalum* | *manii* | | | | | | | | | | 1 | | | | | | | | | | | | | 1 |
| Asteraceae | *Vernonia* | *myriantha* | | | | | | | | | | | 2 | 3 | | | | | | | | | | | 5 |
| Bignoniaceae | *Tecoma* | *nyassae* | | | 2 | | | | | | | | | | | | | | | | | | | | 2 |
| Cecropiaceae | *Myrianthus* | *holstii* | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| Ebenaceae | *Diospyros* | *squarosa* | | | | | | | | | | | | | | | | | | | | | | 2 | 2 |
| Erbenaceae | *Euclea* | *Sp.* | | | | | | | | | | | | | | | | 1 | | | | | | | 1 |
| Ericaceae | *Agauria* | *salicifolia* | | 1 | | 14 | | | | | | | | | | | | 1 | | | | | | | 16 |
| Euphorbiaceae | *Macaranga* | *kilimandscharia* | | | | | | | | | | | | | | | | | | | | | | 12 | 12 |
| Flacourticaeae | *Aphloia* | *theiformis* | | | | | | | | 1 | | | | | | | | | | | | | | 2 | 3 |
| Guttiferae/Clusiaceae | *Psorospermum* | *febrifugum* | | | | | | | | | | | | | 2 | | | | | | | | | | 2 |
| Labiatae | *Iboza* | *multiflora* | | 1 | | | | | | | | | | | | | | | | | | | | | 1 |
| Lamiaceae | *Plectranthus* | *Sp.* | | | | | | | | | | | | 1 | | | | | | | | | | | 1 |
| Loganaceae | *Buddleja* | *salviifolia* | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | | | 4 |
| Malvaceae | *Hibiscus* | *fuscus* | | | | | | | | | | 2 | 1 | 3 | | | | | 1 | | | | | | 7 |
| Malvaceae | *Hibiscus* | *diversifolius* | 1 | | | | | | | | | | | | | | | | | | | | | | 1 |
| Melastomataceae | *Dissotis* | *speciosa* | | | | 5 | | | | | | | | | | | 2 | | | | | | | | 7 |
| Melianthaceae | *Bersama* | *abyssinica* | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Mimosoideae | *Albizia* | *gummifera* | 1 | | 1 | | | | 11 | 12 | | | | | | | | | 7 | | | | | | 32 |
| Myricaceae | *Myrica* | *salicifolia* | 3 | 3 | | 7 | 1 | | | | | 1 | | | 1 | | | 1 | | | | | | | 17 |
| Myrsinaceae | *Embelia* | *schimperi* | | | | | | | | | | | | | | | | | | 2 | | | | | 2 |

Continued below.

## Appendix 2 continued:

**Regenerating Tree Species** **Plot**

| Family | Genus | Species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Myrsinaceae | *Maesa* | *lanceolata* | | | | | | | 1 | 1 | 1 | | | | | | | 2 | | | | | | | 5 |
| Myrtaceae | *Syzigium* | *cordatum* | | | | | | | | | | | | 1 | | | | | | | | | | | 1 |
| Oleaceae | *Schrebera* | *alata* | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| Papillionanceae | *Dalbergia* | *lactea* | | 2 | | | | | 2 | | | | | | | | | | | | | | | 3 | 7 |
| Papillionanceae | *Kotschya* | *aeschynomerioides* | 1 | 57 | 54 | 12 | 165 | 16 | 1 | 1 | 43 | 6 | 6 | | 30 | 50 | 2 | | | | 8 | | | | 452 |
| Papillionanceae | *Kotschya* | *carsonii* | | | | 70 | | | | | | | | | | | | | | | | | | | 70 |
| Papillionanceae | *Milletia* | *oblata* | | | | | | | | | | | | | | | | | | 2 | | | | 2 | 4 |
| Papillionanceae | *Tephrosia* | *elata* | | | 1 | | | | | | 6 | | | | 2 | | 5 | | | | | | | | 14 |
| Coniferae | *Pinus* | *petula* | | | | | | | | | | | | | | | | 6 | | | | | | | 6 |
| Proteaceae | *Faurea* | *wentzeliana* | | | | 1 | | | | | 1 | | | | | | | | | | | | | | 2 |
| Rubiaceae | *Hallea* | *rubrostipulata* | | | | | | | | | | | | | | | | | 1 | | | | | | 1 |
| Rubiaceae | *Keetia/Cantheum* | *lulandensis* | | | | | | | | | | | | | | | | | | | | | | 2 | 2 |
| Rubiaceae | *Pentas* | *schimperana* | | | 3 | 1 | | 1 | | | | | | | | | | | | | | | | | 5 |
| Rubiaceae | *Teclea* | *nobilis* | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Rutaceae | *Clausena* | *anisata* | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Sapindaceae | *Dodoneia* | *viscosa* | | | | 8 | | | | | | | | | | | | | | | | | | 2 | 10 |
| Scrophulariaceae | *Hallea* | *rubrostipulata* | 3 | | | 1 | | | | | | | | | | | | | | | | | | | 4 |
| Solanaceae | *Solanum* | *anguivi* | | | | | | | | | | | | 1 | | | | | 1 | | | | | | 2 |
| Tiliaceae | *Sparmannia* | *ricinocarpa* | | | | | | | | | | | | | | | | | 3 | | | | | | 3 |
| Tiliaceae | *Triumfetta* | *brachyceras* | | | | | | | | | | | 1 | | | | | | | | | | | | 1 |
| Verbenaceae | *Lippia* | *javanica* | | | | | | | 2 | | | | | | | | 3 | 1 | | | | | | | 6 |
| Verbenaceae | *Vernonia* | *lasiopus* | | 1 | | | | | | | | | | | | | | | 3 | | | | | | 4 |
| | **Regenerating subtotal** | | **10** | **69** | **88** | **129** | **175** | **23** | **20** | **29** | **51** | **10** | **16** | **13** | **35** | **52** | **12** | **12** | **17** | **6** | **14** | **0** | **0** | **29** | **810** |

## Appendix 3: Frequency of planted tree species per plot

**Planted Tree Species**

| **Family** | **Genus** | **Species** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Euphorbiaceae | *Bridelia* | *micrantha* | | | | 10 | 5 | | | | | 2 | 11 | | | | 1 | 1 | | 1 | | 6 | | | 37 |
| Euphorbiaceae | *Macaranga* | *kilimandscharia* | | | | 3 | 2 | | | | 1 | 3 | | | | | | | | | 19 | | | | 28 |
| Flacourticaeae | *Aphloia* | *theiformis* | | 21 | 15 | 1 | 3 | | 3 | 17 | 10 | 9 | 16 | 6 | 10 | 2 | 6 | | | 1 | | 20 | | | 140 |
| Lauraceae | *Cryptocarya* | *liebertiana* | | | | | | 2 | | | | 1 | 6 | | | | | 1 | | | | | | | 10 |
| Loganiaceae | *Nuxia* | *floribunda* | | | | | | | | | | | 1 | | 4 | | | | | | | | | | 5 |
| Melianthaceae | *Bersama* | *abyssinica* | | | | | | | | 1 | | | | | | 3 | 2 | | | | | | | | 6 |
| Mimosoideae | *Albizia* | *gummifera* | | | | | | | 3 | | | | | | | | | | | | | | | | 3 |
| Myrtaceae | *Syzigium* | *cordatum* | | | | 1 | | | 1 | | 5 | | 2 | | | | | | | | | 9 | | | 18 |
| Papilionaceae | *Craibia* | *brevicaudata* | | | | | | | | | | | | | 1 | | | | | | 14 | | | | 15 |
| Papillionanceae | *Milletia* | *oblata* | | | | | | | | | | 1 | | | | | | | | | | | | | 1 |
| Rubiaceae | *Keetia* | *gueanzii* | | | | | | | | | | | 3 | | | | | | | | 1 | | | | 4 |
| Rubiaceae | *Keetia/Cantheum* | *lulandensis* | | | | | | | | | | | | | 1 | | | | | | | | | | 1 |
| Rubiaceae | *Psychotria* | *goetzei* | | | | | | | | | | 3 | | | | | | | | | | | | | 3 |
| Rubiaceae | *Teclea* | *nobilis* | | | | | | | | | | | | 1 | | | | | | | | | | | 1 |
| | **Planted subtotal** | | **0** | **21** | **15** | **15** | **10** | **2** | **7** | **18** | **16** | **19** | **39** | **7** | **16** | **5** | **9** | **2** | **0** | **2** | **34** | **35** | **0** | **0** | **272** |

**Total (regenerating + planted stems)** **1082**

**Appendix 4: Summary of information for each plot in survey.**

| Plot No. | Corridor | Slope (deg.) | Aspect | Altitude (m asl) | Topog. | Veg. type | Canopy layer cover | Shrub layer cover | Ground layer cover | Canopy ht (m) | Water assoc. | Distance to water (m) | Total no. of stems (15x15) | No. of planted trees (15x15) | Saplings (30x30) | Holes (30x30) | Total saplings + holes (30x30) | % Survival | No. of planted species | GPS Eastings UTM ARC 60 | GPS Northings UTM ARC 60 | Year Planted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lulanda | 0 | - | 1560 | VF | H/M/S | <10% | 10-50% | >50% | <10 | Pond | 0 | 10 | 0 | - | - | - | - | 0 | 36 7 88 900 | 90 47 900 | - |
| 2 | Lulanda | 26 | SW | 1619 | GUS | CF | 10-50% | >50% | >50% | 10-20m | None | - | 90 | 21 | 58 | 38 | 96 | 60 | 1 | 36 7 89 100 | 90 47 900 | 1997 |
| 3 | Lulanda | 30 | NE | 1655 | SMS | CF | <10% | >50% | >50% | <10 | None | - | 103 | 15 | 53 | 26 | 79 | 67 | 1 | 36 7 89 300 | 90 47 900 | 1999 |
| 4 | Lulanda | 19 | NW | 1593 | GUS | CF | 10-50% | >50% | >50% | <10 | Stream | 30 | 144 | 16 | 74 | 25 | 99 | 75 | 4 | 36 7 88 900 | 90 47 700 | 1996 |
| 5 | Lulanda | 15 | NW | 1606 | GMS | CF | <10% | >50% | >50% | <10 | None | - | 185 | 13 | 48 | 22 | 70 | 69 | 4 | 36 7 89 100 | 90 47 700 | 1996 |
| 6 | Lulanda | 25 | E | 1620 | GUS | CF | <10% | 10-50% | >50% | <10 | None | - | 25 | 2 | 8 | 43 | 51 | 16 | 1 | 36 7 89 300 | 90 47 700 | 1998 |
| 7 | Lulanda | 25 | SW | 1595 | GMS | CF | 10-50% | 10-50% | >50% | <10 | Stream | 50 | 27 | 8 | 22 | 52 | 74 | 30 | 4 | 36 7 89 500 | 90 47 700 | 1999 |
| 8 | Lulanda | 20 | S | 1610 | GMS | CF | 10-50% | >50% | >50% | <10 | None | - | 47 | 19 | 82 | 32 | 114 | 72 | 2 | 36 7 89 700 | 90 47 700 | 1999 |
| 9 | Lulanda | 15 | N | 1620 | GUS | CF | <10% | >50% | >50% | <10 | None | - | 67 | 16 | 83 | 20 | 103 | 81 | 3 | 36 7 89 500 | 90 47 500 | 1998 |
| 10 | Lulanda | 15 | W | 1620 | GUS | CF | 10-50% | >50% | >50% | <10 | None | - | 29 | 19 | 81 | 41 | 122 | 66 | 6 | 36 7 89 300 | 90 47 500 | 1997 |
| 11 | Lulanda | 12 | S | 1580 | GMS | CF | 10-50% | >50% | >50% | <10 | Spring | 25 | 55 | 39 | 109 | 37 | 146 | 75 | 6 | 36 7 89 100 | 90 47 500 | 1997 |
| 12 | Lulanda | 20 | N | 1580 | GMS | CF | <10% | 10-50% | >50% | <10 | Spring | 30 | 20 | 7 | 26 | 44 | 70 | 37 | 2 | 36 7 89 100 | 90 47 300 | 1997 |
| 13 | Lulanda | 10 | W | 1620 | GUS | CF | <10% | 10-50% | >50% | <10 | None | - | 51 | 16 | 55 | 49 | 104 | 53 | 4 | 36 7 89 300 | 90 47 300 | 1997 |
| 14 | Lulanda | 15 | W | 1610 | GUS | CF | 10-50% | 10-50% | >50% | <10 | None | - | 57 | 7 | 30 | 60 | 90 | 33 | 3 | 36 7 89 100 | 90 47 300 | 1997 |
| 15 | Lulanda | 20 | W | 1550 | GMS | CF | <10% | >50% | >50% | <10 | Stream | 50 | 21 | 9 | 9 | 11 | 20 | 45 | 3 | 36 7 88 900 | 90 46 900 | 1997 |
| 16 | Ihili | 19 | N | 1560 | GMS | CF | >50% | 10-50% | 10-50% | 20-30m | Stream | 70 | 14 | 2 | 12 | 15 | 27 | 44 | 2 | 36 7 88 000 | 90 47 900 | 2001 |
| 17 | Ihili | 17 | SW | 1500 | VF | CF / | <10% | 10- | 10- | 10- | Stream | 0 | 17 | 0 | 0 | 0 | 0 | - | 0 | 36 7 87 800 | 90 48 100 | 2001 |

| Plot No. | Corridor | Slope (deg.) | Aspect | Altitude (m asl) | Topog. | Veg. type | Canopy layer cover | Shrub layer cover | Ground layer cover | Canopy ht (m) | Water assoc. | Distance to water (m) | Total no. of stems (15x15) | No. of planted trees (15x15) | Saplings (30x30) | Holes (30x30) | Total saplings + holes (30x30) | % Survival | No. of planted species | GPS Eastings UTM ARC 60 | GPS Northings UTM ARC 60 | Year Planted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | H/M/S | | 50% | 50% | 50% | | | | | | | | | | | | |
| 18 | Ihili | 25 | W | 1570 | GLS | CF / H/M/S | <10% | <10% | >50% | <10 | Stream | 10 | 8 | 4 | 6 | 19 | 25 | 24 | 3 | 36 7 88 200 | 90 47 900 | 2001 |
| 19 | Ihili | 13 | S | 1580 | GMS | CF | 10-50% | >50% | >50% | <10 | None | - | 29 | 15 | 45 | 39 | 84 | 54 | 2 | 36 7 88 000 | 90 47 300 | 2001 |
| 20 | Luhunga | 4 | SE | 1848 | R/HT | CF | <10% | <10% | <10% | <10 | None | - | 54 | 54 | 221 | 16 | 237 | 93 | 4 | 36 7 70 700 | 90 52 650 | 2000 |
| 21 | Luhunga | 7 | E | 1823 | GUS | F/PD | <10% | <10% | >50% | <10 | None | - | 0 | 0 | - | - | - | - | 0 | 36 7 70 900 | 90 52 650 | 2000 |
| 22 | Luhunga | 7 | NE | 1824 | GUS | CF | <10% | >50% | <10% | <10 | None | - | 29 | 0 | - | - | - | - | 0 | 36 7 70 900 | 90 52 850 | 2000 |

Key: Topography: G=gentle, S=steep, LS=lower slope, MS=mid slope, US=upper slope, VF=valley floor, R/HT= ridge/hill top.
Vegetation type: CF=colonising forest, H/M/S= herb/marsh/swamp, F/PD= fallow previously disturbed.

## **Appendix 5:** Equations used to calculate statistical tests.

### Spearman's Rank Correlation ($r_s$)

Spearman's Rank Correlation ($r_s$) was used in this study to assess the relationship between percentage seedling survival and various other factors.

$$r_s = 1.0 - \frac{6\,\Sigma d^2}{n^3 - n}$$

Where d = difference between paired ranks
n = number of pairs of observations

(Kent & Coker, 1994).

### Significance t-test

The significance of the Spearman's Correlation Coefficient was then tested using the students t-test and comparing to critical t-test values printed in Zar, 1984.

$$t = r_s \sqrt{\frac{n - 2}{1.0 - r_s^2}}$$

Where $r_s$ = Spearman's Rank Correlation Coefficient

(Zar, 1984)

# **Appendix 6:** Results from selected statistical analyses.

1. Relationship between % seedling survival and the number of regenerating stems per plot.

**Spearman's rank correlation $r_s$ value = 0.48**

**Students t test value = 2.11**

**Critical t test value (0.05 <$\alpha$ 1) = 1.753**

Significant at 95 % confidence limits.

$H_O$ (null hypothesis - there is no relationship between % seedling survival and the number of regenerating stems) rejected.

$H_A$ (alternative hypothesis - % survival correlated with number of regenerating stems) accepted.

2. Relationship between % seedling survival and shrub layer vegetation cover per plot.

**Spearman's rank correlation $r_s$ value = 0.85**

**Students t test value = 6.23**

**Critical t test value (0.0005 $\alpha$ 1 and 0.001 $\alpha$ 2 ) = 4.073**

Significant at 99.9995 % confidence limits.

$H_O$ (null hypothesis - there is no relationship between % seedling survival and shrub layer vegetation cover) rejected.

$H_A$ (alternative hypothesis - % survival correlated with shrub layer vegetation cover) accepted.

**Appendix 7:** Species list

This is a total species list, giving details of species recorded casually (Cas) in and around the forest areas, and in the vegetation plots (VP).
Lul = recorded in Lulanda corridor. Ihi = recorded in Ihili corridor. Luh = recorded in Luhunga corridor.
* indicates details taken from Beentje, 1994, all other information is taken from the List of East African Plants, (LEAP).
Life forms: T = Tree. S = Shrub. C = Climber. TF = Treefern.
Regions in Tz, refer to those regions used in the Flora of tropical East Africa, Region 7 = Southern highlands of Tanzania including the Udzungwa Mountains.

| Family, Genus and Species | Author | Life form | Region in Tz | Endemic | Lower Altitude m a.s.l. | Upper Altitude m a.s.l. | Habitat | Location | | VP or Cas |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Regenerating | Planted | |
| **Anacardiaceae** | | | | | | | | | | |
| *Rhus longipes* var. *schinoides* | R. Fern. | T | 24578 | No | 1200 | 2200 | Riverine forest, forest margins, wooded grasslands.* | Lu Ih Luh | | VP |
| **Apocynaceae** | | | | | | | | | | |
| *Carvalhoa campanulata* | K.Schum. | S | | No | 350 | 350 | Forest* | Lul | | Cas |
| *Rauvolfia caffra* | Sond. | | 12345678 | No | 10 | 2290 | Riverine forest/thicket less often in forest away from water* | Luh | Lul Ihi | VP |
| *Rauvolfia mannii* | Stapf | T | 23678 | No | 300 | 2440 | Moist forest, especially at margins and in disturbed areas.* | Luh | | VP |
| **Araceae** | | | | | | | | | | |
| *Culcasia falcifolia* | Engl. | H | 13467 | No | 500 | 2100 | | Lul | | Cas |
| **Asparagaceae** | | | | | | | | | | |
| *Asparagus asparagoides* | (L.) Druce | | 7 | No | | | | Lul | | Cas |
| **Balsaminaceae** | | | | | | | | | | |
| *Impatiens eryaleia subsp. eryaleia* | [Launert] | H | 678 | No | 1750 | 2100 | | Lul | | Cas |
| **Bignoniaceae** | | | | | | | | | | |
| *Tecoma nyassae* | Oliv. ex Hook. | | | | | | | Lul | | VP |
| **Cecropiaceae** | | | | | | | | | | |
| *Myrianthus holstii* | Engl. | T | 3678 | No | 900 | 2100 | | Lul | | VP |

| Celastraceae | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Maytenus acuminata* | (L.f.) Loes. | T* | 123467 | No | 1050 | 3300 | Moist forest.* | Lul | | Cas |
| *Maytenus buchananii* | (Loes.) R.Wilczek | T* | 123457 | No | 60 | 2640 | Riverine or swampy sites less often in forest margins or bushed grasslands.* | Ihi | | Cas |
| *Maytenus undata* | (Thunb.) Blakelock | S | 123467 | No | 0 | 3150 | Moist upland and lowland forest, forest remnants, evergreen bushland near sea.* | Lul | | Cas |

| Family, Genus and Species | Author | Life form | Region in Tz | Endemic | Lower Altitude m a.s.l. | Upper Altitiude m a.s.l. | Habitat | Location | | VP or Cas |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Regenerating | Planted | |
| **Compositae** | | | | | | | | | | |
| *Bidens magnifolia* | Sherff | | 3567 | No | | | | Lul Ihi | | VP |
| *Bothriocline longipes* | (Oliv. & Hiern) N. E. Br. | | | | | | | Lul | | Cas |
| *Conyza welwitschii* | (S.Moore) Wild | | 7 | No | 2700 | 2700 | | Lul | | Cas |
| *Solanecio mannii* | (Hook. f.) C. Jeffrey* | T* | | No | 700 | 2650 | Dry evergreen forest edges, degraded secondary forest, riverine rocky slopes in bushland.* | Lul | | VP |
| *Crassocephalum vitellinum* | (Benth.) S.Moore | | 147 | No | | | | Ihi | | Cas |
| *Gutenbergia cordifolia* | Benth. ex Oliv. | | | No | 122 | 122 | | Lul | | Cas |
| *Helichrysum schimperi* | (Sch. Bip. ex A.Rich.) Moeser | H | 23678 | No | 1350 | 3300 | | Lul | | Cas |
| *Mikania chenopodifolia* | Willd. | | | No | | | | Ihi | | Cas |
| *Sphaeranthus suaveolens* | (Forssk.) DC. | | 23578 | No | 1100 | 2700 | | Lul | | Cas |
| **Connaraceae** | | | | | | | | | | |
| *Agelaea pentagyna* | (Lam.) Baill. | | | | | | | Luh | | Cas |
| **Convolvulaceae** | | | | | | | | | | |
| *Cuscuta sp.* | | | | | | | | Lul | | Cas |
| *Ipomoea involucrata var. involucrata* | [P.Beauv.] | H | 12345678 | No | 100 | 2700 | | Lul | | Cas |
| **Crassulaceae** | | | | | | | | | | |
| *Kalanchoe densiflora* | Rolfe | H | 2367 | No | 1000 | 3000 | | Ihi | | Cas |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cucurbitaceae** | | | | | | | | | | |
| *Lagenaria abyssinica* | (Hook.f.) C.Jeffrey | C | 267 | No | 1350 | 2750 | | Ihi | | Cas |
| *Raphidiocystis chrysocoma* | (Schumach.) C.Jeffrey | C | 36 | No | 300 | 1370 | | Lul | | Cas |
| *Zehneria scabra* | (L.f.) Sond. | C | 12345678 | No | 80 | 3350 | | Ihi | | Cas |
| **Cyatheaceae** | | | | | | | | | | |
| *Cyathea manniana* | Hook. | TF* | 1234678 | No | 1350 | 2500 | Moist evergreen forest along streams and in valleys, less often in more open forest remnants*. | Ihi | | Cas |
| **Cyperaceae** | | | | | | | | | | |
| *Cyperus platycaulis* | Baker | | | | | | | Lul | | Cas |
| **Family, Genus and Species** | **Author** | **Life form** | **Region in Tz** | **Endemic** | **Lower Altitude m a.s.l.** | **Upper Altitiude m a.s.l.** | **Habitat** | **Location** | | **VP or Cas** |
| | | | | | | | | **Regenerating** | **Planted** | |
| **Ebenaceae** | | | | | | | | | | |
| *Diospyros squarrosa* | Klotzsch | T* | 3568 | No | 10 | 1350 | Woodland/bishland or thicket, occaisionally forest margins.* | Luh | | VP |
| *Euclea sp.* | | | | | | | | Ihi | | VP |
| **Ericaceae** | | | | | | | | | | |
| *Agarista salicifolia* | (Comm. ex Lam.) G. Don | T | | No | 1250 | 3300 | Forest edge, secondary forest, high altitude bushland.* | Lul Ihi | | VP |
| **Euphorbiaceae** | | | | | | | | | | |
| *Acalypha volkensii* | Pax | H | 123 | No | 765 | 3000 | | Ihi | | Cas |
| *Bridelia micrantha* | (Hochst.) Baill. | S | 12345678 | No | 50 | 2300 | Riverine forest margins, less often in bushland/wooded grassland.* | | Lul Ihi Luh | VP |
| *Macaranga kilimandscharia* | Pax | T | 23467 | No | 1310 | 3000 | Moist upland forest, abundant at forest edges.* | Luh | Lul | VP |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Luh | |
| **Flacourtiaceae** | | | | | | | | | | |
| *Aphloia theiformis* | (Vahl) Benn. | S | 23678 | No | 1300 | 2900 | Upland moist forest.* | Lul Luh | Lul Ihi Luh | VP |
| *Casearia battiscombei* | R.E. Fr. | T | 2367 | No | 1125 | 2440 | | Lul | | Cas |
| **Gramineae** | | | | | | | | | | |
| *Hyparrhenia schimperi* | (Hochst. ex A. Rich.) Anderrson ex Stapf | H | 234567 | No | 700 | 1700 | | Lul | | Cas |
| *Panicum calvum* | Stapf | H | 2347 | No | 1000 | 2900 | | Lul | | Cas |
| **Guttiferae** | | | | | | | | | | |
| *Hypericum peplidifolium* | A.Rich. | H | 234678 | No | 1170 | 3600 | | Ihi | | Cas |
| *Hypericum roeperianum* | Schimp. ex A.Rich. | T | 23 | No | 1500 | 2900 | Riverine thicket, less often foresst margins away from water* | Lul | | Cas |
| *Psorospermum febrifugum var. ferrugineum* | (Hook. f.) Keay & Milne-Redh. | S | 14567 | No | 50 | 1950 | Wooded grassland.* | Lul | | VP |
| **Labiatae** | | | | | | | | | | |
| *Haumaniastrum callianthum* | (Briq.) Harley | | | | | | | Lul | | Cas |
| *Iboza multiflora* | (Benth.) E.A. Bruce | S* | 12 | No | 1200 | 1200 | Bushland on rocky slopes.* | Lul | | VP |
| *Leucas deflexa var. kondowensis* | (Baker) Sebald | | | No | 1524 | 2400 | | Ihi | | Cas |
| *Plectranthus sp.* | | | | | | | | Lul | | VP |
| *Pycnostachys speciosa* | Gürke | | 1 | No | 1000 | 1500 | | Lul | | Cas |
| **Lauraceae** | | | | | | | | | | |
| *Cryptocarya liebertiana* | Engl. | S | 3678 | No | 1080 | 1800 | Moist forest.* | | Lul Ihi | VP |

| Family, Genus and Species | Author | Life form | Region in Tz | Endemic | Lower Altitude m a.s.l. | Upper Altitiude m a.s.l. | Habitat | Location | | VP or Cas |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Regenerating | Planted | |
| **Leguminosae - Caesalpinioideae** | | | | | | | | | | |
| *Chamaecrista kirkii* | (Oliv.) Standl. | | | | | | | Lul | | Cas |
| **Leguminosae - Mimosoideae** | | | | | | | | | | |
| *Albizia gummifera* var. *gummifera* | [(J.F.Gmel.) C.A. Sm.] | T | 2345678 | No | 0 | 2440 | Dry or wet, upland or lowland forest edges, riverine forest.* | Lul Ihi | Lul | VP |
| **Leguminosae - Papilionoideae** | | | | | | | | | | |
| *Craibia brevicaudata subsp. schliebenii* | (Harms) J. B. Gillett | T | 367 | No | 1100 | 1800 | | | Lul Ihi | VP |
| *Dalbergia fischeri* | Taub. | T | 45678 | No | 200 | 1350 | | Lul | | Cas |
| *Dalbergia lactea* | Vatke | S | 1234678 | No | 540 | 2400 | Riverine.* | Lul Luh | | VP |
| *Dalbergia sp.* | | | | | | | | Luh | | Cas |
| *Desmodium repandum* | (Vahl) DC. | H | 12345678 | No | 1000 | 3000 | | Ihi | | Cas |
| *Eriosema montanum* var. *montanum* | [Baker f.] | H | 1234678 | No | 900 | 2520 | | Lul | | Cas |
| *Neonotonia wightii* | (Graham ex Wight & Arn.) J. A. Lackey | | | | | | | Lul | | Cas |
| *Indigofera sp.* | | | | | | | | Luh | | Cas |
| *Kotschya aeschynomerioides* | (Welw. ex Baker) Dewit & | S | 1234578 | No | 1350 | 2550 | Upland grassland and evergreen bushland, often in shallow soil pockets in rocks then in dense stands.* | Lul Ihi | | VP |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P. A. Duvign. | | | | | | | | | |
| *Kotschya carsonii* | (Baker) Dewit & P. A. Duvign. | S | 478 | No | 1500 | 2250 | | Lul | | VP |
| *Kotschya uguenenesis* | (Taub.) F.White | S | 347 | No | 1000 | 2010 | | Ihi | | Cas |
| *Millettia oblata* subsp. *intermedia* | J. B. Gillett | T | 367 | Yes | 1000 | 1700 | | Ihi Luh | Lul | VP |
| *Rhynchosia hirta* | (Andrews) Meikle & Verdc. | C | 12345678 | No | 0 | 1800 | Bushed or wooded grassland, forest margins.* | Lul | | Cas |
| *Tephrosia elata* | Deflers | H | 23 | No | 300 | 2000 | | Lul | | VP |
| **Lobeliaceae** | | | | | | | | | | |
| *Lobelia giberroa* | Hemsl. | S | 234678 | No | 1200 | 3000 | Forest margins, secondary forest, swamp or riverine foresst, bamboo edges.* | Lul | | Cas |
| **Loganiaceae** | | | | | | | | | | |
| *Buddleja salviifolia* | (L.) Lam. | S | 7 | No | 1450 | 2400 | | Lul | | VP |
| *Nuxia floribunda* | Benth. | T | 23467 | No | 1200 | 2000 | Forest (remnants).* | | Lul | VP |

| Family, Genus and Species | Author | Life form | Region in Tz | Endemic | Lower Altitude m a.s.l. | Upper Altitiude m a.s.l. | Habitat | Location | | VP or Cas |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Regenerating | Planted | |
| **Malvaceae** | | | | | | | | | | |
| *Hibiscus fuscus* | Garcke | S | 1234567 | No | | | | Lul Ihi | | VP |
| *Hibiscus diversifolius* | Jacq. | S | 12478 | No | 470 | 2500 | | Lul | | VP |
| **Melastomataceae** | | | | | | | | | | |
| *Dissotis senegambiensis* | (Guill. & Perr.) Triana | | | | | | | Lul | | Cas |
| *Dissotis speciosa* | Taub. | H | 147 | No | 900 | 2250 | | Lul | | VP |
| **Melianthaceae** | | | | | | | | | | |
| *Bersama abyssinica subsp. abyssinica* | [Fresen.] | T | 124578 | No | 1140 | 2250 | Upland grassland, dry and wet montane and riparian forest glades and edges.* | Luh | Lul | VP |
| **Menispermaceae** | | | | | | | | | | |
| *Stephania abyssinica var. tomentella* | (Oliv.) Diels | C | 236 | No | 1450 | 3500 | | Lul | | Cas |
| **Myricaceae** | | | | | | | | | | |
| *Morella salicifolia* | (Hochst. ex A.Rich.) Verdc. & Polhill | | 2345678 | No | 1810 | 2360 | Dry rocky bushland and eroded slopes.* | Lul Ihi | | VP |
| **Myrsinaceae** | | | | | | | | | | |
| *Embelia schimperi* | Vatke | S | 123567 | No | 1000 | 3200 | Upland evergreen forest.* | Ihi | | VP |
| *Maesa lanceolata* | Forssk. | S | 12345678 | No | 360 | 2550 | Secondary forest pioneer, in forest margins.* | Lul Ihi | | VP |
| *Myrsine africana* | L. | S | 23457 | No | 1200 | 3600 | Upland dry forest and rocky hillsides.* | Lul | | Cas |
| **Myrtaceae** | | | | | | | | | | |
| *Syzygium cordatum* | Hochst. | | 34678 | No | 305 | 2400 | Riverine.* | Lul | Lul Luh | VP |
| **Oleaceae** | | | | | | | | | | |
| *Schrebera alata* | (Hochst. | T* | 237 | No | 1950 | 2250 | Dry forest (edges and remnants), evergreen | Lul | | VP |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ) Welw. | | | | | | (secondary) bush and less often in scattered tree grassland.* | | | |
| **Orchidaceae** | | | | | | | | | | |
| *Eulophia sp.* | | | | | | | | Ihi | | Cas |
| **Pinus** | | | | | | | | | | |
| *Pinus patula* | Schiede, Schltdl. & Cham. | | | | | | | Ihi | | VP |
| **Polygonaceae** | | | | | | | | | | |
| *Polygonum salicifolium* | Brouss. Ex Willd. | H | 12345678 | No | 2400 | 2400 | | Ihi | | Cas |
| *Rumex abyssinicus* | Jacq. | H | 1234678 | No | 750 | 3300 | | Ihi | | Cas |
| **Family, Genus and Species** | **Author** | **Life form** | **Region in Tz** | **Endemic** | **Lower Altitude m a.s.l.** | **Upper Altitiude m a.s.l.** | **Habitat** | **Location** | | **VP or Cas** |
| | | | | | | | | **Regenerating** | **Planted** | |
| **Proteaceae** | | | | | | | | | | |
| *Faurea wentzeliana* | Engl. | T | 234678 | No | 1400 | 3000 | | Lul | | VP |
| **Pteridaceae** | | | | | | | | | | |
| *Pteris pteridioides* | (Hook.) Ballard | | 6 | No | 1200 | 1650 | | Lul | | Cas |
| **Ranunculaceae** | | | | | | | | | | |
| *Clematis hirsuta* Guill. & Perr. [not synonym of *C. brachiata* Thunb. Which is correct?] | Thunb. | C | 24578 | No | 700 | 3000 | Forest margins, secondary bushland, woodedd grasslands.* | Lul | | Cas |
| **Rosaceae** | | | | | | | | | | |
| *Rubus keniensis*** | Standl. | S | | Yes | 1950 | 2670 | Forest margins, also riverine or secondary forest.* Endemic to Mt Kenya and Nyandarua.* | Lul | | Cas |
| **Rubiaceae** | | | | | | | | | | |
| *Anthospermum usambarense* | K. Schum. | S | 2378 | No | 1300 | 4050 | Heathzone or moorland or mountains, also on rocky hills in grassland or bushland, rarely in forest margins.* | Lul | | Cas |
| *Mitragyna rubrostipulata* | (K. | T | 123467 | No | 900 | 2190 | | Lul Ihi | | VP |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Schum.) Havil. | | | | | | | | | |
| *Keetia gueinzii* | (Sond.) Bridson | S | 12345678 | No | 90 | 2450 | Moist forest (margins), secondary bushland, riverine forest. | | Lul Ihi | VP |
| *Keetia lulandensis* | Bridson | C | 7 | Yes | 1450 | 1520 | | Luh | | VP |
| *Mussaenda arcuata* | Lam. ex Poir. | S | 134678 | No | 700 | 1830 | Bushed or wooded grassland, secondary bushland, forest margins.* | Lul | | Cas |
| *Pavetta lynesii* | Bridson | T | 67 | Yes | 1200 | 2300 | | Lul | | Cas |
| *Pentanisia ouranogyne* | S. Moore | H | 123567 | No | 550 | 2415 | | Lul | | Cas |
| *Pentas schimperana subsp. schimperana* | [(A.Rich.) Vatke] | S | 47 | No | 1450 | 3000 | Forest clearings.* | Lul | | VP |
| *Pentas zanzibarica* var. *zanzibarica* | [(Klotzsch) Vatke] | H | 1235678 | No | 0 | 2600 | | Lul | | Cas |
| *Psychotria goetzei* | (K. Schum.) E. M. A. Petit | | | | | | | | Lul | VP |
| *Psychotria megalopus* | Verdc. | S | 67 | Yes | 1140 | 1850 | | Lul | | Cas |
| *Rubia cordifolia* subsp. *conotricha* | (Gand.) Verdc. | C | 12345678 | No | 1140 | 2640 | | Lul | | Cas |
| *Rutidea orientalis* | Bridson | S | 13467 | No | 800 | 2250 | Moist forest.* | Lul | | Cas |
| *Rytigynia lichenoxenos* | (K. Schum.) Robyns | | | | | | | Lul | | Cas |
| **Rutaceae** | | | | | | | | | | |
| *Vepris nobilis* | (Delile) Mziray | S | 1234578 | No | 900 | 2600 | Moist forest.* | Luh | Lul | VP |
| *Clausena anisata* | (Willd.) Hook. f. ex Benth. | S | | No | 1 | 2450 | Moist or dry forest margins, secondary bushland, riverine sometimes wollded grassland.* | Luh | | VP |
| **Family, Genus and Species** | **Author** | **Life form** | **Region in Tz** | **Endemic** | **Lower Altitude m a.s.l.** | **Upper Altitiude m a.s.l.** | **Habitat** | **Location** | | **VP or Cas** |
| | | | | | | | | **Regener** | **Plant** | |

| | | | | | | | | ating | ed | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Zanthoxylum usambarense* | (Engl.) Kokwaro | T | 123 | No | 1600 | 2600 | Dry forests or its remnants such as clump thickets or secondary bushland.* | Lul | | Cas |
| **Sapindaceae** | | | | | | | | | | |
| *Deinbollia kilimandscharica* var. *adusta* | (Radlk.) Verdc. | T* | 3678 | No | 15 | 500 | Forest, secondary bushland, evergreen cosatal thicket, riverine bush.* | Lul | | Cas |
| *Dodonaea viscosa* var. *angustifolia* | (L.f.) Benth. | S* | 2347 | No | | | Sand near high water mark, dunes.* | Lul Luh | | VP |
| **Sapotaceae** | | | | | | | | | | |
| *Chrysophyllum gorungosanum* | Engl. | T | 3678 | No | 1300 | 2250 | Moist forest.* | Luh | | Cas |
| **Scrophulariaceae** | | | | | | | | | | |
| *Halleria lucida* | L. | S/T/C* | 1256 | No | 1000 | 2500 | Drier forest, associated with Podo, Cedar and bamboo.* | Lul | | Cas |
| **Solanaceae** | | | | | | | | | | |
| *Solanum anguivi* | Lam. | | | | | | | Lul Ihi | | VP |
| **Tiliaceae** | | | | | | | | | | |
| *Grewia mildbradii* | Burret | T | 2 | No | | | | Lul | | Cas |
| *Sparrmannia ricinocarpa* | (Eckl. & Zeyh.) Kuntze | | 235678 | No | 100 | 2500 | Forest margins or clearings, riverine secondary bushland where forest has disapeared, extends into Hagenia and Bamboo zones.* | Ihi | | VP |
| *Triumfetta brachyceras* | K. Schum. | | | | | | | Lul | | VP |
| **Ulmaceae** | | | | | | | | | | |
| *Trema orientalis* | (L.) Blume | S | 12345678 | No | 0 | 2100 | Forest margins, riverine, secondary bushland, woodland, wooded grassland, pioneer where forest is disturbed.* | Ihi | | Cas |
| **Verbenaceae** | | | | | | | | | | |
| *Lantana trifolia* | L. | S | 1234678 | No | 0 | 2400 | Dry forest margins, wooded grasslnds, bushland, secondary bushland, bushed grassland, ruderal.* | Lul | | Cas |
| *Lippia javanica* | (Burm. f.) Spreng. | S | 12345678 | No | 450 | 2350 | Secondary bushland or grassland, less often in wooded grassland.* | Lul Ihi | | VP |
| *Vernonia lasiopus* | O. Hoffm.* | S* | | No | 1050* | 2550* | Common in disturbed vegetation, (bushed) grassland and riverine woodland or forest.* | Lul | | VP |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Vernonia myriantha* | Hook. .f. | S* | 2345678 | No | 1600* | 1950* | Forest edges and ruderal places.* | Lul Ihi | | VP |
| **Vitaceae** | | | | | | | | | | |
| *Rhoicissus tridentata* | (L.f.) Wild & R. B. Drumm. | | 12345678 | No | 900 | 2280 | Wooded grassland, or bushland, rocky hillsides, drier forest margins.* | Lul | | Cas |
| **Zingiberaceae** | | | | | | | | | | |
| *Aframomum alpinum* | (Gagnep.) K.Schum. | H | 3 | Yes | 1200 | 1700 | | Lul | | Cas |

**Appendix 7: Recommended Management Activities**

This management plan deals with management activities arising from aspects of this study and does not make recommendations on current project activities such as running of the nursery and other project activities.

| Management Activity | Justification | Action Required | Undertaken by: | Time Period | Priority |
|---|---|---|---|---|---|
| 1. Fire Prevention<br><br>Aim: Prevention of fire entering the corridor areas. | A single fire sweeping through the corridors would destroy all progress to date: five years of regeneration and plant succession and the majority of planted seedlings would be lost. | 1.1 Maintain 15m wide strip free of all vegetation by physical cutting and clearing, and when necessary burning.<br><br>1.2 Routine patrolling of fireline during high risk period, checking for fires getting close to the corridor edges. | 1.1 Local community and TFCG project assistants.<br><br>1.2 TFCG project assistants and local community | 1.1 Prior to burning seasons – Aug/Sept<br><br>1.2 During periods of high fire risk – Sept /Oct | Highest |

| Management Activity | Justification | Action Required | Undertaken by: | Time Period | Priority |
|---|---|---|---|---|---|
| 2. Weeding of saplings<br><br>Aim : To clear vegetation from around each planted sapling. | Competition with grasses has been shown to limit seedling growth and survival (Aide & Cavelier, 1994). Clearing of all vegetation around seedlings (spot weeding) should be undertaken to promote growth of planted seedlings | 2.1 Ihili and Lulanda - Twice yearly spot weeding of all currently established seedlings.<br><br>2.2 Ihili and Lulanda - Twice yearly spot weeding of newly planted seedlings at least for the first two years.<br><br>2.3 Lulanda - Clearing of dead vegetation from around planted seedlings in areas where dense stands of vegetation e.g. *Kotshcya.* sp. have collapsed.<br><br>2.4 Luhunga – Clearing of all regenerating vegetation in planted areas | 2.1 TFCG project assistants and local employees.<br><br>2.2 TFCG project assistants and local employees.<br><br>2.3 TFCG project assistants.<br><br>2.4 TFCG project assistants and local employees. | 2.1 i Prior to long rains Jan/Feb<br>2.1 ii After long rains May/June<br><br>2.2 i At planting – Jan/Feb<br>2.2 ii After the long rains May –June<br>Estimated total time of 2.1 and 2.2 = 20 people for 1 month x 2 (twice a year)<br><br>2.3 As and when dense stands of *Kotshcya* spp. collapse.<br><br>2.4 After the rainy season – May-June | High<br><br>Highest<br><br>Moderate<br><br>High |

| Management Activity | Justification | Action Required | Undertaken by: | Time Period | Priority |
|---|---|---|---|---|---|
| 3. Fulfilment of planting activities<br><br>Aim: entire corridor areas to be planted with indigenous seedlings. | Extensive areas of Luhunga corridor are currently unplanted and limited areas of Lulanda and Ihili remain unplanted. Continuation of the planting programme should facilitate faster recovery throughout the entire corridor areas. | 3.1 Continued planting at Luhunga corridor.<br>2002: plant approx. 5 ha with approx. 10,000 seedlings (a mixture of *Aphloia, Bridelia, Macaranga* and *Syzygium*).<br>2003: plant remaining area (approx. 1 ha) with approx. 4,400 seedlings (a mixture of *Aphloia, Bridelia, Macaranga* and *Syzygium*). | 3.1 TFCG project assistants and local community. | Clearing of area and digging holes –prior to long rains Oct – Dec.<br>Planting of seedlings – beginning of long rains Feb/Mar | High |
| | | 3.2 Continued planting in Ihili corridor.<br>Plant up the north-eastern side of the corridor with a mixture of indigenous seedlings, focusing on those species identified as performing well in this report. | 3.2 TFCG project assistants and local community. | Clearing of area and digging holes – prior to long rains Dec 2002.<br>Planting of seedlings – beginning of long rains Feb/Mar 2003. | Low |
| | | 3.3 Continued planting in Lulanda corridor.<br>Plant up the strip of land around the western and northern edges of Fufu forest patch with a mixture of indigenous seedlings, focusing on those species identified as performing well in this report.<br><br>In all areas, the number of seedlings of each species planted type should be recorded to enable accurate counts of seedling survival.<br>. | 3.3 TFCG project assistants and local community. | Clearing of area and digging holes – prior to long rains Dec 2002.<br>Planting of seedlings – beginning of long rains Feb/Mar 2003. | Low |

| Management Activity | Justification | Action Required | Undertaken by: | Time Period | Priority |
|---|---|---|---|---|---|
| 4. Enrichment planting.<br><br>Aim: to supplement species diversity and stocking rates in areas where survival rates have been low. | Particular areas of Lulanda and Ihili corridor were observed to have very low seedling survival rates, e.g. Plot 6, 7 and 18. Poor survival rates were thought to be due to the planting of an inappropriate species. | 4.1 In conjunction with other planting activities (section 3) plant species that have been shown to perform well in areas that have been shown to have low survival rates i.e areas around plot 6, 7 and 18.<br><br>4.2 Using information gathered from monitoring activities (see below); continue to enrich areas that are shown to suffer from poor survival. | 4.1 TFCG project assistants and local community.<br><br>4.2 TFCG project assistants | 4.1 Clearing of area and digging holes – prior to long rains Dec. 2002. Planting of seedlings – beginning of long rains Feb/Mar 2003.<br><br>4.2 Ongoing - dependent on monitoring activities. | Moderate<br><br>Moderate |
| 5 Removal of exotic species<br><br>Aim: to remove all exotic timber species from within the corridor areas. | Exotic timber species such as *Pinus* sp. have been shown to limit regeneration of indigenous species and potentially kill indigenous trees nearby. | 5.1 Ensure that *Pinus* sp. are removed from the western edge of Ihili corridor as soon as they reach a harvestable size.<br><br>*It is noted that there is an agreement with the owners of the trees that they will harvest and not replant as soon as trees are large enough – this recommendation is simply to follow-up on this agreement. | 5.1 TFCG project manager. | When trees reach a harvestable size. | Low |

| Management Activity | Justification | Action Required | Undertaken by: | Time Period | Priority |
|---|---|---|---|---|---|
| 6 Monitoring<br><br>Aim: to monitor health of surviving saplings, resource use, growth rates of planted species, relative changes in species composition over time. | Continued monitoring will inform future management activities and provide a unique study of indigenous species survival and growth rates, results will also contribute to the knowledge about tropical restoration ecology.<br><br>The TFCG afforestation programme seems to be the first of its kind, as such, any information collected is valuable to other groups trying to regenerate areas of forest. | 6.1 **General monitoring of health and success of planted seedlings by regular patrols.**<br><br>During normal project activities in the corridors, staff should take note of any signs of disease or areas of high mortality. Project staff should also look out for signs of cutting and resource harvesting contrary to rules established by the village. This will become more important as the corridors mature. Effort should be made to visit more remote areas (away from the edge of footpaths) on a regular basis. | 6.1 TFCG project assistants. | 6.1 Monthly | High |
| | | 6.2 **Percentage seedling survival and growth rates.**<br>Twice a year (before and after the rainy season) each of the established plots should be re-assessed by:<br>a. relocating each planted seedling in each plot.<br>b. using the methods described in this report re-measure each seedling and assess its status.<br>c. re-tag the planted individuals to facilitate re-location.<br>d. calculate dbh, basal diameter and height increment, and any changes in seedling survival since previous surveys. | 6.2 TFCG project manager and assistants. | 6.2 Every six months One week in November/December and May/June.<br><br>* If it is not possible to conduct biannual surveys it would be best to survey once a year in November/December. | High |
| | | 6.3 **Changes in corridor species composition.**<br>Annually re-establish each sample plot. Using the methods described in this report re-assess the regenerating vegetation by:<br>a. identifying and measuring each regenerating stem >1cm dbh, in the sample plot.<br>b.<br>c. Calculate the difference in number of regenerating stems per plot.<br>d. Calculate the difference in number of species per plot. | 6.3 TFCG project manager and assistants. | 6.3 Annually in November – in conjunction with activity 6.2 | Moderate |