The Reforestation of Madagascar

Indication of seedling development of endemic species in relation to associated influence variables in Ranomafana National Park in Madagascar

Marloes Fröling

The Reforestation of Madagascar

Indication of seedling development of endemic species in relation to associated influence variables in Ranomafana National Park in Madagascar

Marloes Fröling

900704001

4th year student tropical forestry

Hogeschool VHL, University of Applied Sciences

Internal coach: Erika van Duijl

05-06-2014

Abstract

Deforestation leaves tropical rain forests highly fragmented, which creates isolated areas too small to maintain populations. The biodiversity encounters increasing negative influences because even though the rainforests are highly important to many plant and animal species, it is difficult to halt the clearance of forests. The rapid forest decline leads to a change in the biotic composition of the ecosystems. This can finally cause extinction to many of the island's endemic species, because natural succession of trees usually proceeds not fast enough. Harsh environmental conditions and the seclusion from existing forest edges are the main courses of the failing natural reforestation visions.
Many projects/programs are working nonprofit and most often in cooperation with local communities to reforest areas and bridge fragmented areas by selecting the best suitable tree species for reforestation projects. This is crucial because many species have special environmental requirements. It is ideally to select species that combines a fast growth with a high survival. To avoid a negative outcome in the success rate, it is becoming a more accepted method to plant with a mixed species composition, which have the potential to increase the conservation of the biodiversity.

Centre ValBio's goal is to preserve the remaining forest of the Ranomafana National Park and expend it by putting effort in reforestation projects. But reforestation can encounter a lot of difficulties in the process, such as seed dispersal limitations, grass competition, fire, drought and low soil nutrients availability. The seedling mortality is much higher when the light, water and nutrients availability is low, mostly caused by the competition with exotic grasses growing on recovering areas.
This research includes a study of the growth, development and survival rate of recent planted seedlings on locations close to Ranomafana National Park. The study sites selected for this research are part of the reforestation project of Centre ValBio. The seedlings used for planting are pioneer species, because they form the first basis of new trees on a degraded area.
The data that was collected consisted of the seedling characteristics diameter, height and quality and the site characteristics which contain the specific variables that can influence the development of the seedlings. The relationship between these characteristics and the variables (environment type, steepness of the slope, elevation and weed coverage) has been displayed and analyzed in many ways.

The total of study sites consisted of 28 different tree species. The number of seedlings measured differed a lot per species. The highest total survival rate of all species per study site was *Kianja Maitso* with 89%. For the variable steepness of the slope the study site *Friends of Madagsacar* had the steepest slope with 53.13° and an associated survival rate of 46.67% and the study site *Ambatovaky* was located the highest (1263.5 m) of the study sites with a survival rate of 8.67%. The majority of the study sites (13 out of 18 sites) had a weed coverage of at least 50%.
The species *Cryptocarya (Tavolo spec.)* had the highest survival rate in Vohiparara (67%). In many cases the seedling characteristics corresponded with the influence variables occurring on the study sites. But in some cases the results were conflicting with the logical assumption.

A lot of information about the growth and development of the seedlings and how they are being influenced by different variables has been obtained. It is important to maintain planting sites and the seedlings because of the big competition with weeds for water and nutrients. This is why it is recommended to improve cooperation with villages and try to keep this up. Also it can be helpful to make some trials with planting seedlings with compost to see the effect on the development and growth of the seedlings.

Acknowledgements

This report was commissioned by Centre ValBio in Madagasccar and Hogeschool VHL University of Applied Sciences. I would like to thank Dr. Patricia Wright of Centre ValBio for giving me the opportunity to perform a research on the reforested areas and giving me an inside of the organization.

It has been a great couple of months living in the Centre, collecting data and experiencing Madagascar.

I'd like to thank Eileen Larney, Chief Technical Advisor (CVB Head of Operations) and Research Coordinator, for helping me with the setup of my proposal and guiding me with performing the fieldwork. My special thanks go to my guides Lucien, Velo and Tovo for helping me collecting the data and getting familiar with the plant species names.

I'd also like to thank the entire staff of Centre ValBio for their help (financial and organizational) and their hospitality.

Of Hogeschool VHL, I would like to thank Erika van Duijl for her guidance, advice and support during the whole thesis process and Jorn Dallinga for his help and advice in the writing part of this report.

At last I would like to dedicate this research report to my uncle Peter Fröling, with whom I shared a deep connection with the tropics. Unfortunately I never had the chance to show him this result.

Table of contents

Abbreviates

Cm	Centimeters
CVB	Centre ValBio
D	Diameter
H	Height
Km	Kilometer
LMA	Leaf Mass per unit Area
M	Meters
MATE	Man And The Environment
MBP	Madagascar Biodiversity Partnership
N	Nitrogen
NGO	Non-Governmental Organization
P	Phosphorus
Q	Quality
RNP	Ranomafana National Park

List of Figures

List of Tables

1. Introduction

1.1 *Motivation and subject*

1.1.1 Deforestation worldwide

Tropical rainforests are known as the lungs of the world. They play an important role in the world's share of biodiversity. Unfortunately the clearance of these forests and their valuable ecosystems is a fact. The phenomenon deforestation has been investigated, analyzed, explained and discussed in literature so frequently that it is sometimes difficult to focus on the important message; to reduce the clearance of forests.
Although tropical forests cover less than 10% of the earth's surface (Mayaux, et al., 2005; Harper, et al., 2007) they host at least 50% of its species and contain 45% of the above-ground carbon in vegetation (Watson et al., 2000). Deforestation plays a huge role in the extinction of plant and animal species by threatening the survival rate and destroying forest habitats. Deforestation leaves forests highly fragmented, which creates isolated areas too small to maintain populations and it increases edge effects too. This leads to affecting the micrometeorology over short distances and increasing exposure to damaging winds, fire frequency and give access to livestock or other non-forest animals and hunters (Harper et al., 2007).

Forests that have been turned into cattle pasture in the past can face big challenges in forest recovery. These challenges range from a lower ecosystem evapotranspiration to a net loss of carbon released into the atmosphere. Also the probability of fire is bigger which increases the possibility of losing species (Uhl et al., 1988; Uhl and kauffman, 1990; Wright et al., 1992; Nobre et al., 1991; Nepstad et al., 1994).
If fire is occurring more frequently, the soil can be depleted, which will reduce the seedling growth (Aide & Cavelier, 1994) and thereby impeding the forest to recover (Buschbacher, Uhl & Serrao, 1988).
Another natural difficulty is the occurrence of grasses. When a forest area is turned into a pasture many exotic grasses will occur even after these pastures are abandoned. These grasses limit the tree regeneration because they compete with tree seedlings for water and nutrients (Nepstad, 1989; Nepstad et al., 1996), increase the frequency of fire and thereby arrest the regeneration in abandoned deforested areas all over the world (Nepstad, Uhl & Serrao, 1990).

The biodiversity of tropical rain forests could encounter increasing negative influences because even though the rainforests are highly important for many plant and animal species, it is difficult to halt the clearance of forests. There are always people depending on them for survival, because forests have an industrial and ecological value for humans. This is a well-known problem worldwide but Madagascar probably suffers the most.

1.1.2 Madagascar

Madagascar owes its unique biodiversity to the island separation from Africa approximately 165 million years ago (Rakotosamimanana, 2003; Harper et al., 2007). It separated from India about 70 million years ago, leaving the island with an extremely high biological endemism. This process went on for millions of years until the interference of foreigners started the deforestation of Madagascar back in 1896, when it became a French colony. This had a dramatic impact on the biodiversity and caused rapid depletion of forests by fugitive locals who survived in the forests and turning it into shifting cultivation fields. With shifting cultivation is meant the process of clearing and planting temporary agricultural fields continuously (Peters and Neuenschwander, 1988). The remaining primary vegetation of the island is shown in figure 1.

More than 90% of its endemic animal species live exclusively in forest or woodlands (Harper et al., 2007). Madagascar suffered contractions up to 90% or more of their original area in the last 60-70 years (Sayer & Whitmore, 1992).

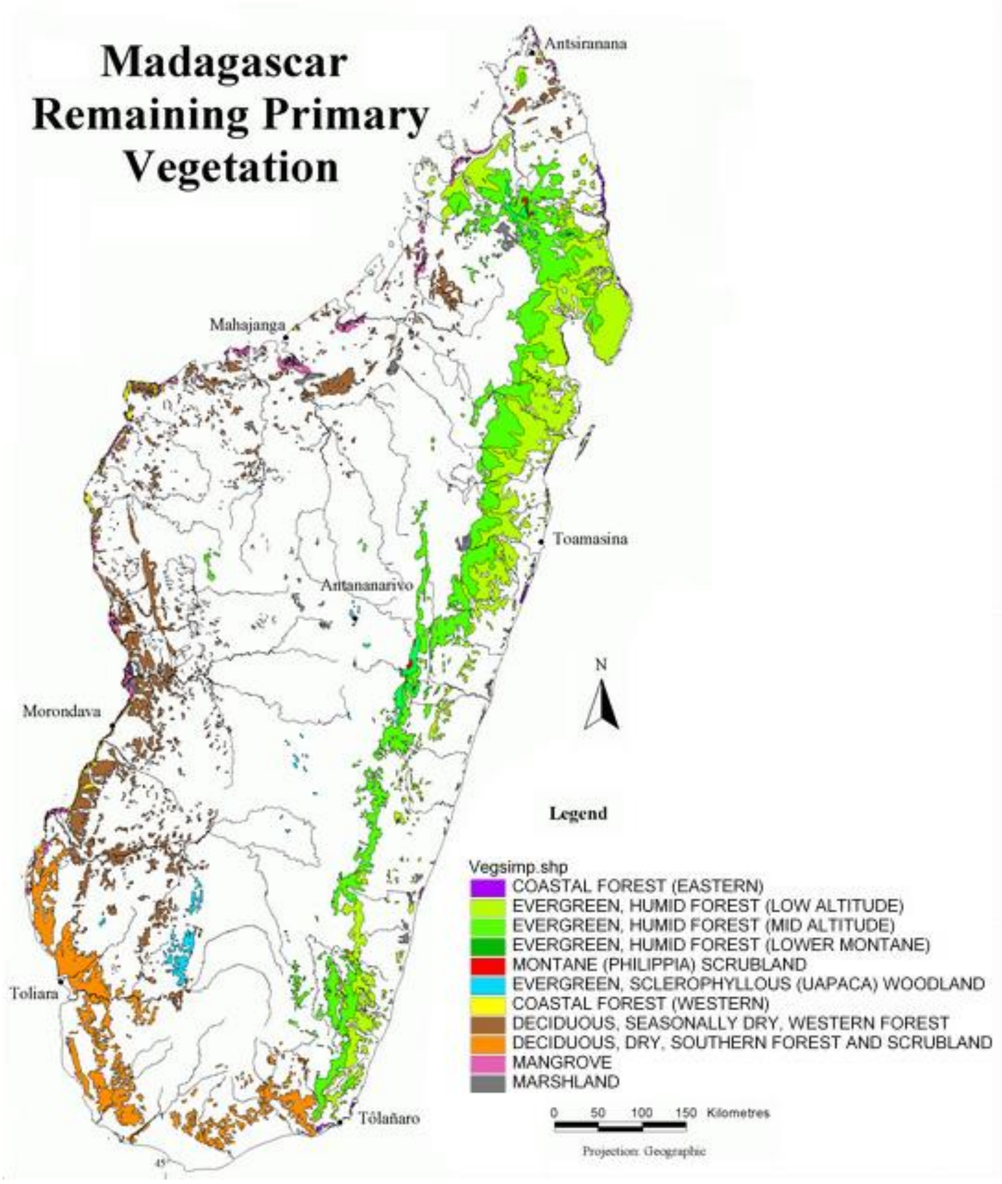


Figure 1. The remaining primary vegetation of Madagascar.
Source: www.kew.org & www.mobot.org

The exact causes of Madagascar's initial deforestation are quite uncertain. There are a lot of different factors that play a role in the clearance of forests, but old sediments with charcoal has been found in caves in NW Madagascar, suggesting burning by humans may have been a cause (Burney, et al., 1997).
In the time period 1900-1940 forests on Madagascar have been cut down to establish agricultural fields for crop fields. Also subsistence plots for wage workers and timber concessions were formed at the former forest sides. This had some impact on the island's landscape but not much to do with the population growth rates and shifting cultivation (Jarosz, 1993). The impact on the landscape came later when countries like China and the European Union were allowed to exploit timber species, especially rosewood (*Dalbergia* species), due to government instabilities (Innes, 2010).

The rapid forest decline over the past few decades results in smaller and isolated forests, which leads to a change in the biotic composition of the ecosystems. This can finally cause extinction to many of the island's endemic species (Goodman & Rakotondravony, 2000). Extinction mostly takes place where forest is already fragmented and of limited extent, it is likely to exceed that following the loss of an equivalent area in one of the major forest blocks. The reduction of forest area reduces numbers of individuals and leading to loss of ecosystems. Even if a species survives it has lost much of its genetic diversity. This is an deceitful but widespread consequence of current tropical deforestation (Sayer & Whitmore, 1992).

1.1.3 Natural regeneration

Many abandoned pastures are making an attempt to naturally regenerate to their original forests. But this natural succession of trees usually proceeds very slow, so it is mostly not considered as a successful option for reforestation. Harsh environmental conditions and the seclusion from existing forest edges (and thereby seed sources) are the main courses of the failing natural reforestation visions (Cubina and Aide, 2001; Gunter et al., 2007; Myster, 2004; Uhl et al., 1988), provoking increasing fragmentation.

But natural regeneration could be considered as a valuable option when the distance to forest edges is not too far and if the degraded sites did not lose too much topsoil, because that could lead to a reduction in soil fertility. Loosing soil fertility could complicate the re-colonization of the original tree species. This also counts for the presence of aggressive grasses (Folke et al., 2004; du Toit, Walker and Campbell, 2004). Also when light gaps close and pioneers are over grown by more shade-tolerant species (Brokaw, 1985) or die (King, 1994), it could mean the end of natural regeneration in that particular area.

1.1.4 Reforestation projects

According to Shono, Stuart, & Chua Yen (2006), a principal reforestation objective is "to accelerate succession and thereby restoring lands of degraded vegetation to mature secondary forest that contains significant primary forest components". Also in this case a part about promoting the restoration of animal communities could be added as an important aspect (Yu et al., 1994; Jansen, 1997; Parrotta et al., 1997a (Wheiher & Keddy, 1999); Sanchez-Deleon et al., 2003).

But it is a real challenge for forest managers and conservationists to restore the biodiversity on degraded lands (Lamb et al., 2005; Carnus et al., 2006), looking at all the obstacles they can face.

Fortunately a lot of reforestation practices, like the Non-governmental Organization (NGO) Vakan'Ala in Vakanala, Manambolo in North-East Madagascar, are being implemented in Madagascar to realize these principal objectives. Many projects/programs are working nonprofit and most often in cooperation with local communities to reforest areas and bridge fragmented areas.

An example of another NGO working on reforestation practices is Man And The Environment (MATE). This NGO tries to create harmony between preservation of habitats and the needs of local communities. They manage the Vohimana rainforest and the tree nurseries (www.news.mongabay.com).

Madagascar Biodiversity Partnership (MBP) is located in Kianjavato, east Madagascar. They are mainly focused on conservation research, community-based conservation, education & outreach (www.madagascarpartnership.org). It is located close to the organization Centre ValBio, located in Ranomafana were this research is performed.

1.1.5 Reforestation species

Selecting the best suitable tree species for a reforestation project is crucial, because many tree species do have special environmental requirements. When areas are heavily degraded, harsh environmental conditions may develop. It could be that pioneer species grow faster and also have a higher survival rate than non-pioneer species (Davidson et al., 1998; Dos Santos et al., 2006; Nepstad et al., 1990).

It is ideally to select species for reforesting that combine a fast growth with a high survival. This survival depends on a lot of the species functional traits. Weiher et al. (1999) and Voille et al. (2007) described how these species have specific plant strategies which are formed by multiple characteristics resulting in species growth and survival affection.

During the first years of the succession in degraded areas most individual species will underlie a similar experience with the occurring environmental conditions. These conditions mostly include high irradiance, high heat loads and low water availability, which are caused by the absence of adult trees. Later on fast growing species (pioneer) may continue to experience these high light conditions and start to overgrow the slow growing species (non-pioneer) which would become shaded. This indicates the importance of shaping good indicator environmental conditions for the longer term species performance (Martinez-Garza, 2013).

1.1.6 Mixed species and reforestation methods

To avoid a negative outcome in the success rate of planted species in abandoned areas it is becoming a more accepted method to plant with a mixed species composition. These mixtures have the potential to increase the conservation of the biodiversity. Also they improve soil fertility and nutrients cycling (Montagnini, 2000). Apart from these facts, mixed plantations also accelerate natural succession in deforested areas (Lamb et al., 2005; Hall et al., 2011) and herbivory is assumed to be lower here (Barbosa et al., 2009; Letourneau et al., 2011). A good statement for mixed plantations compared to monocultures is that it might lead to higher tree performance due to interactions among the different species that reduce competition or suppresses pests (Forrester et al., 2005; Plath et al., 2011b). Also the positive aspect that mixtures provide a variety of goods and services of traditional and/or marketable value is considered promising for tropical reforestation practices (Hall et al., 2011).

The establishment of reforestation plantations on degraded areas can improve the microclimate and soil conditions of the environment and can create a habitat for seed dispersing wildlife (Parotta et al., 1997a; Carnis et al., 2006). After the seedlings have been raised in nurseries they can be planted on the degraded areas usually in lines of 1 m width cut through vegetation (Hardwick, 1997).

1.1.8 Centre ValBio's mission

Centre ValBio (CVB), an organization started in 1991 by Dr. Patricia Wright, is located in the middle of the Ranomafana National Park, along the road from the highland plateau to the east coast. They try to reforest degraded areas around the park to form corridors between fragmented forest, to sustain a lot of plant and animal species. The organization is interested to know more about the success of these plantings. Important animal species that they try to retain are different kinds of lemur species that are endemic to Madagascar.

Centre ValBio's mission is to assist the indigenous people and the international community to better understand the value of conservation in Madagascar and around the world.
Their mission has three main objectives;

- To promote world-class research in one of the world's most biologically diverse and unique ecosystems;
- To encourage environmental conservation by developing ecologically sustainable economic development programs with local villages;
- To provide the local villagers with the knowledge and tools to improve their quality of life through projects focused on sanitation, diet, and education, and ultimately reduce poverty in the area.

Besides these social-economic missions (see Appendices A.) there is one related goal; to preserve the National Park as it is and even expend it by putting effort in reforestation projects. These are set up with the parks surrounding villages and schools.

1.2 Problem analysis

1.2.1 Difficulties reforestation

Reforestation can play an important role in the recovery and the increase of remaining forests. Reforestation could also have a positive influence on the survival of many plant and animal species. Although currently the attention to reforestation projects might have been increased looking at the news worldwide, these projects are not always successful. They are facing problems with the reforestation of fragmented forest areas. This can be caused by the failing seedling establishment. But it may also fail because of the lack in cooperation between the local communities and the government. The social-economic value that is connected to the ecological part of forests is not always considered an important aspect by many people.

1.2.2 Difficulties natural regeneration

Reforestation can encounter a lot of difficulties in the process. Many of these difficulties set as natural processes such as seed dispersal limitations, grass competition, fire, drought and low soil nutrients availability. These factors often delay the forest regeneration on abandoned degraded areas (Uhl, Buschbacher & Serrao, 1988; Aide et al., 1995). Many descriptive and experimental studies on the problems of tree establishment have been carried out. These studies looked at the seed availability and seedling herbivory, and compared the survival rate and growth with various abiotic variables. Nepstad et al (1996) created a comparative method to identify the difference of tree establishment on abandoned pasture and natural tree establishment within intact forest ecosystem. If trees establish successfully, it could lead to partial recovery of forest structure and function.

1.3 Influences reforestation success

1.3.1 Variables

The survival, growth and development of planted tree seedlings are affected by many different influences from the environment. For this research these are named as the influence variables. The most known abiotic variables are soil moisture availability, light levels (Poorter, 1999) and temperature (Eagles, 1967).

Also drought, poor root establishment, herbivory, branch falls, erosion and mammal digging (Augspurger, 1984) are high influences on seedling development, but there are many more causes. For example, the slope can cause too much water run-off when it is too steep causing a lack of water infiltration into the soil. This results in desiccation of the seedlings. The direction of the slope influences the amount of sunlight a seedling is receiving so this variable can be important in reforestation practices. Also the presence of nearby vegetation influences the seedling development enormously both in a positive way (by providing shelter and nutrients exchange) or a negative way (by overshadowing and nutrient competition).

1.3.2 Light

The presence of light is very important for seedling development. A well-studied subject concerning light are the regeneration of seedlings in forest gaps. These are critical for the establishment of many seedlings and even conclude a higher survival rate than studies that include open regeneration sides (Richards, 1952; Whitmore, 1975; Denslow, 1980; Harshorn, 1980; Pickett, 1983). The level of irradiance on the forest floor limits the establishment of many seedlings, even the high shade-tolerant species (Whitmore, 1984; Chazdon, 1988). Also studies have been performed about tree-fall gaps and their relation to the promotion of species coexistence by Rincon and Huante (1992). In this study the relationship of species regeneration variation between the shade tolerant species and non-shade tolerant species has been investigated.

In case of abandoned pastures, a higher light level and low water availability is present than in forests understory and gaps (Chazdon and Fetcher, 1984; Williams-Linera et al., 1998). In large forest gaps, species with a high Leaf Mass per unit Area (LMA) may have, in contrast to pastures, a higher growth rate than species that do not develop light adapted leaves (Popma and bongers, 1988; Poorter, 1999). Because of this, species with a high LMA and those that are more drought resistant are likely to survive and grow well in pastures (LDMC, Markesteijn et al., 2011).

1.3.3 Water availability and soil moisture

Seedling mortality is much higher when the water availability is low (Burslem, Grubb and turner, 1996; Gerhard, 1993; Lloyd & Pigott, 1967; Nepstad et al., 1996). A cause for low water availability can be the competition with exotic grasses, which occur particularly when seedlings are planted in abandoned pastures instead of forest tree fall gaps (Nepstad, 1989; Nepstad et al., 1996).

Blain and Kellman (1991) stated that rainfall patterns are not the only cause of water availability for seedlings but it also depends on the soil characteristics. Droughts do not only affect the water limitation but also the nutrients supply. The soil moisture regime may influence the balance between growth limitations by Nitrogen (N) and Phosphorus (P) (Lloyd & Pigott, 1967). This is because the Nitrogen mineralization rate depends on the soil water status.

1.3.4 Soil structure and nutrients availability

Furthermore, soil type and soil structure also influences the survival and growth of tree seedlings (Grime, 2002; Pugnaire & VAlladares, 1999). Soil can be very vulnerable to fire and water availability as stated before. This will impoverish soils and reduces the chance of forest recovery.

There is a big competition for nutrients when exotic grasses are overgrowing the recovering areas (Nepstad, 1989; Nepstad et al., 1996). When there is a low availability of nutrients, it limits the establishment and development of the tree seedlings (Burslem, Grubb and Turner, 1996).

1.3.5 Predation and weed coverage

Predation can be a serious setback for the growth of tree seedlings. Especially combined with more factors like low seed availability, grass competition, soil degradation and other unfavorable microclimate aspects (Uhl and Jordan, 1984; Uhl, 1987, 1988; Uhl et al., 1988).

The competition with weeds is playing a big role in the development of established tree seedlings. Abandoned pastures are mostly overgrown with different weed species that arrest the succession of tree seedlings (Aide et al., 1995; Cohen et al., 1995; Kuusipalo et al., 1995) by competing for water and nutrients (Nepstad 1989; Nepstad et al., 1995).

Besides the competition for survival, grass invasion also increases the likelihood of fire (Nepstad, uhl & Serrao, 1990). This forms a bigger problem for pastures that have been subjected to overgrazing, repeated weeding or being burned over long periods, because these areas could become dominated by non-forage grasses and shrub vegetation (Uhl et al., 1988).

1.3.6 Other influences

Some last but quite important variables that influence the growth and development of seedlings are the conditions of the seedlings when they are planted. Whether they are nursed in plastic bags or big seed banks can be important for the adaption of the seedlings when planted on their final location. Also the method of planting and the period are important. It is not considered wisely to plant seedlings just at the beginning of the dry season because then they need too much water for their start. Usually the rainy season is the best period to plant seedlings. By the end of the rainy season the seedlings will be mostly adapted to their environment. At last is the management of the planted seedlings important. After planting the seedlings need maintenance to help them get adapted to the environment. This is why cooperation with the local villages to take care of the seedlings, is important.

Taken into account all these variables that are influencing the development of tree seedlings, this research includes a follow up study of the growth, development and survival rate of recent planted seedlings on locations close to Ranomafana National Park.

The results of the data collection will contribute to a recommendation for Centre ValBio and maybe find a neutral solution to determine deforestation rates in Madagascar by encountering both people and the forests in the process.

1.4 Research objective and questions

Looking at the current and previous deforestation rates of Madagascar it is important to support reforestation projects and facing their setbacks with planting successes. For this research an objective is formed that is consistent to the goal of improving these reforestation practices.

Objective;
"To clarify the current reforestation practices of Centre ValBio in the Ranomafana National Park and present the analyzed seedling development and survival rate of various common used species to their associated influence variables."

Research questions;

1) What kind of variables are playing an active role in the selected reforestation sites adjacent to Ranomafana National Park?
2) What is the survival rate of the total of seedlings per study area plot?
3) Is there a relationship between the separate variables; environment type, steepness of the slope, elevation and weed coverage and their associated survival rates?
4) Does the survival rate of planted seedlings depend on the species planted?
5) What is the relationship between the different seedling characteristics of the study sites per planting year and their influence variables?

Recommendation questions;

6) Which seedling species are recommended to use for future planting activities?
7) What kind of features are recommended for future planting sites to have higher successful rate?

1.5 Justification

For this research a couple of influence variables are selected based on the availability of collection methods on location. The environmental variables slope direction, slope steepness and elevation are measured. Also the variable surface water availability, which is indicated by the observation of the abundance of surface water nearby, and the vegetation type has been observed as well. A similar process is performed for the weed coverage of the measured seedlings. Later in the research period a new selection of variables has been made based on the selection of relevant research questions. This resulted in that the variable slope direction is mentioned in the results but no further details were analyzed because of the lack of depth in the literature research. The variable water availability is left out of the results because only the surface water availability was measured and the focus of the variables in this research was on the moisture of the soil, which was difficult to measure. The last change that made was the switch of the name vegetation types into environment types. The reason for this was that after the inventory of the nearby vegetation types, it was clear that the study sites were located in three environmental types. This contained information about the influences on the different study sites.

The climate influences are not included in the analyses of this research because the sub factors (temperature, light and rainfall) are assumed to be the same for all the study areas. However the micro climate does differ between the study sites. But for this research it was complicated to include this. The conditions of the seedlings were assumed to be similar too and thereby not included. Soil samples were taken on every study site to measure the pH and nutrients content but after collecting the samples it became clear that soil analyzes were too complicated to perform in the center.

1.6 Limitations

During this research several limitations have been noticed. The most important one is that there was a misunderstanding about the amount of data already present of the replanted sites. It appeared that this research was one of the firsts being performed after the planting, which meant that comparative data of earlier measurements did not exist. This led to some moments of indistinctness about the research proposal and goal. It made it more difficult to perform proper data analyses with the present data and thereby draw exact conclusions to shape good recommendations. But new ways have been developed to still obtain the required data and conclusions.

2. Study location

2.1 *Ranomafana National Park*

Ranomafana National Park (RNP) is located on the east of the country (see Figure 2.), on the edge of Madagascar's High Plateau. This is an extremely mountainous area, with elevations ranging from 500 meters to 1,500 meters (see Figure 3.). The steepness of the slopes had preserved the park from exploitation before 1986. The range of altitudes allows for many different forest types to grow, from lowland rainforest to cloud forest and high plateau forest. The park is divided into a protected zone centrum of 41,500 hectares surrounded by a zone in which some exploitation of the forest is permitted. In this zone there are more than 100 villages with over 25,000 residents. RNP became the fourth national park in Madagascar when it was inaugurated on May 31, 1991 (www.stonybrook.edu).

Figure 2. Location Ranomafana National Park
Source: www.madbookings.com

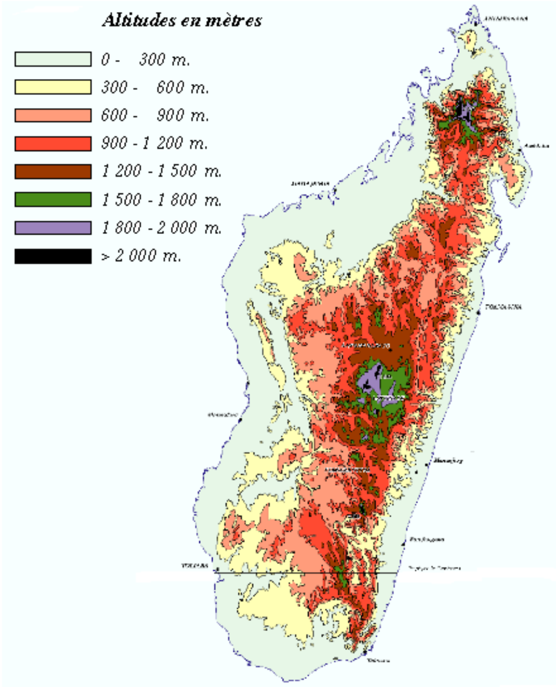
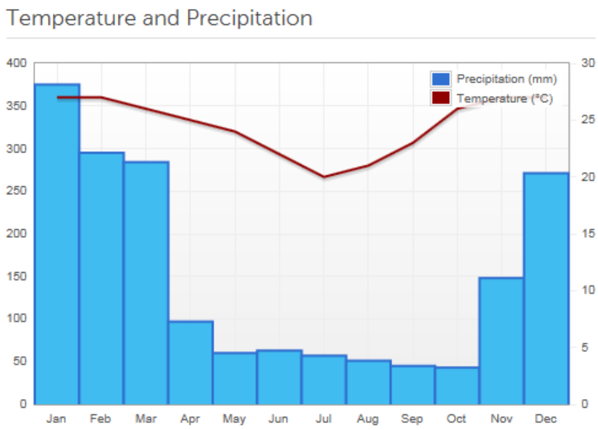


Figure 3. Altitude map of Madagascar.
Source: www.fao.org

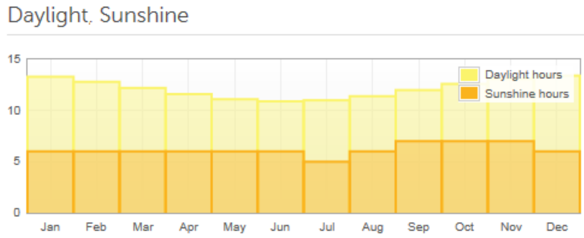
2.2 *Climate*

Madagascar knows two seasons. One is a hot, rainy season from November till April and the other is a cooler, dry season from May till October. There is a great variation in climate because of the differences in elevation and due to dominant winds.

These southeastern trade winds originate from the Indian Ocean. Because of these winds, the east coast has a subequatorial climate with the heaviest rainfall. This region has a hot and humid climate that can cause a lot of cyclones and thunderstorms during the rainy season. The central highlands are appreciably drier and also cooler because clouds discharge much of their moisture east of the highest elevations. Ranomafana National Park is located in these central highlands. From April till October it is for the most part drier but also cooler in the park than from November till March (see Figure 4.).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	375	295	284	97	60	63	57	51	45	43	148	271
Temperature (° C)	27	27	26	25	24	22	20	21	23	26	27	27



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sunshine hours	6	6	6	6	6	6	5	6	7	7	7	6
Daylight hours	13.3	12.8	12.2	11.6	11.1	10.9	11.0	11.4	12.0	12.6	13.1	13.4

Figure 4. Temperature and daylight of Ranomafana National Park.
Source: www.weather2Travel.com

The west coast of Madagascar is drier than the east because the trade winds lose their humidity by the time they reach the highlands and further west. The southwest and the south have a semi desert climate, surface water is scarce in the west and south of the islands (www. wildmadagascar.org).

2.3 Vegetation cover

Related to the climate properties, the vegetation cover of Madagascar differs a lot as well. The flora of Madagascar can be classified in Windward flora and Leeward flora. Windward flora grows in the east of Madagascar, including all areas that come under the direct influence of the moist southeast trade winds. These winds produce moderate to very high levels of orographic deposits when they encounter the highlands of the island (including RNP).

The Leeward flora includes the west of Madagascar plus the far north. These areas come under the influence of the drying effects of the trade winds. Resulting in undergoing warming after crossing over the central plateau (www.mobot.org).

The vegetation types of RNP are shown in figure 5. The park is mainly composed by mid-altitude rainforest. At the west side of the park there are several savanna areas with and without woodlands, on the east side of the park does low-altitude rainforest and agricultural fields occur. The red areas present mid-altitude rainforest that is degraded.
Most villages are located at the borders of the park or close by the main road that crosses the park in the middle.

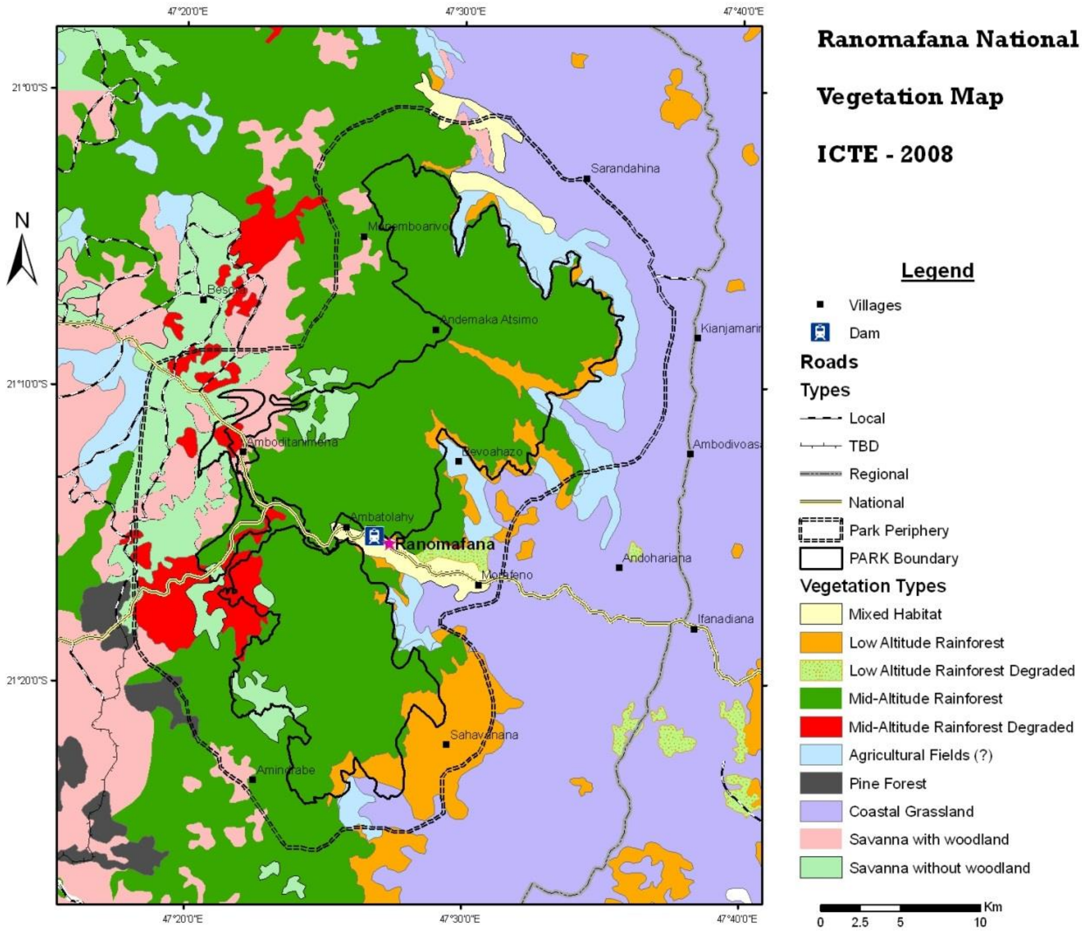


Figure 5. Vegetation map of Ranomafana National Park. Source: Centre ValBio

2.4 Geology and soil

The geology of Madagascar can be divided into two groups (Besairie, 1973). One group are the sedimentary rocks, that occur all along the coastal zones. This is about one third of the island. The other group is the basement complex which is located at the highlands (including RNP) and covers two third of the island (www.fao.org).

Madagascar is known as the Red Island because of its red lateritic soils. These soils mostly occur in the central highlands of the country and are exposed by the large amounts of deforestation (www.iias.nl). There are much richer soils in Madagascar but these occur in areas with former volcanic activity, more north. On the east coast a narrow band of alluvial soils is found and at the west coast, at the mouths of the rivers, clay, sand and limestone mixtures (www.wildmadagascar.org). The south has more shallow or skeletal laterite and limestone present.

To give a more clear distribution of the soils, Roederer (1971) separated the soils of Madagascar into four different types. The first ones are the ferralitic soils, with several variants due to their parent rock. These soils are located in the highlands and the east coast and occupy about 40 percent of the island. The second soil type is the ferruginous tropical soils. These cover large areas of the west and south (about 28 percent of the island).

The deforestation practices have large impacts on these two soil types. They continuously undergo an erosive process. This is partly because of their topographic position but also because of bush fires and clearing of forests, or other human activities. Hydromorphic soils are the third type. They occur in lower lands and are important for the rice cultivation. They cover about 6.5 percent of the island. The last type is the alluvial soils. These are juvenile soils but very fertile. They mainly occur close to big rivers in the west of the country and cover about 26 percent of Madagascar (www.fao.org). Ranomafana National Park is located on the basement complex. The soil type that is occurring here is the ferralitic soil, but it is also located close to the narrow band of alluvial soils. This makes the soil of the park very fertile.

2.5 Reforestation project Centre ValBio

The reforestation projects of Centre ValBio contain many planting sites (see Figure 6.). Although the organization exists since 2003, the replanting of degraded areas started in 2006. The planting sites are mostly located near the borders of the national park on degraded parts, which could lead to the expansion of the forest surface. But some sites are located on (abandoned) agricultural lands nearby villages.

In many cases the reforestation projects are performed in cooperation with schools or villages to cover degraded areas or to create corridors to other forest patches. Some planting sites are located further away from the borders in remote villages. When replanting is in cooperation with schools it is usually because of the project child trees fund that teaches children and parents to reforest their areas round the schools and villages. Generally CVB tries to replant many small degraded areas to help the environment turn back into forest, not always with success. The cooperation of the community is very enthusiastic in the beginning, many people help with the planting. But later on this attitude changes when maintenance needs to be performed on the seedlings. This leads to CVB doing lots of follow up work itself.

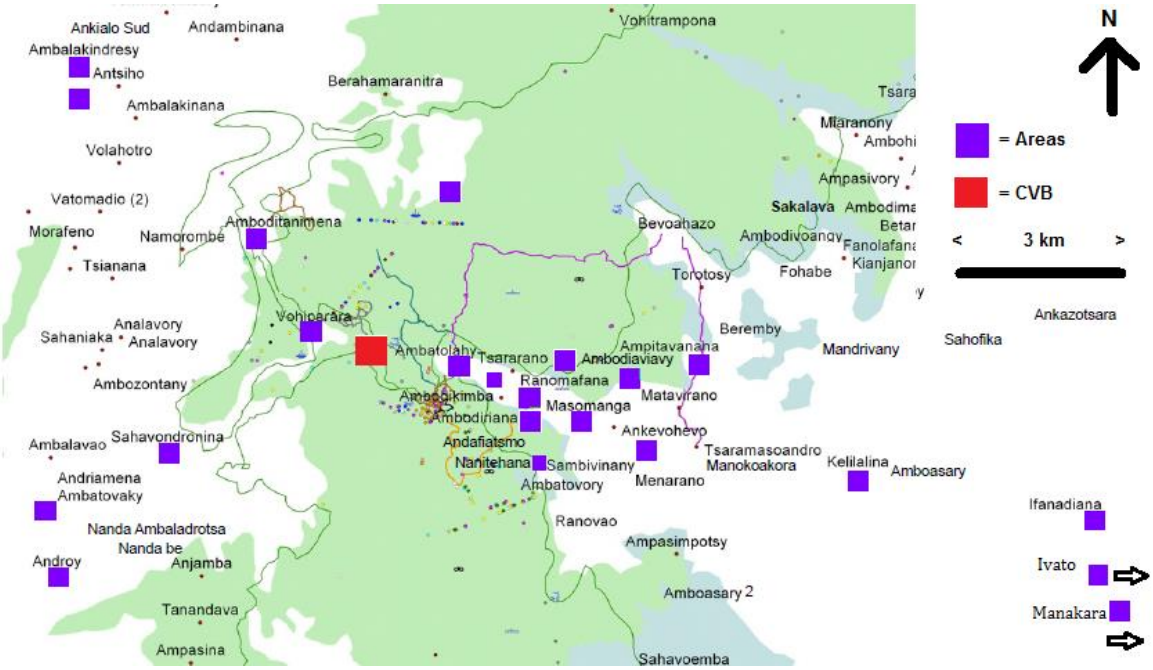


Figure 6. All reforestation project areas of Centre ValBio

2.6 Seedling species and the nursery

The species that are used for the reforestation projects are endemic species to Madagascar. The seeds are collected in the forest nearby the Centre and then nursed in a nursery named Kianjo Maitso, which is located in the village Ranomafana.

The species used for the reforestation projects from Centre ValBio were chosen because they grow easily in the vicinity of Ranomafana National Park and they correspond to the needs of the people living nearby. No previous trials have been carried out to test the species development, but CVB has experience with these species for a long time due to the presence of local employees who know their environment very well.

In the nursery the seeds are divided per species to germinate. Seedling do not need to be at a certain height before they can be replanted. So they stay in the nursery until they are needed for planting which could lead up to be at least one year. An example of how the nursery processes their seedling availability is the planting project of 2012.

The seeds used for this were planted in the nursery in 2011. A total of 11,713 seeds from 13 species (Faritraty, Tavolomanitra, Sandramimena, Sandramimaitso, Voabe, Rotrafotsy Rahiaka, Harina, Natojabo, Natovoraka, Ramiavontoloho, Rotramena, Tavolomolaliambo) have been collected and sown. For every species the germination date is tracked. On January the 25th 2012, a total of 3,492 seeds has germinated.

The conditions of the seedlings before planting are similar; like the properties regarding the way they have been sown in plastic bags, the water they have been received and the way in which they are planted on the study sites (approximately 1,5 – 2 meters apart).

The variables of distribution of rainfall, light, temperate and soil nutrients (Khurana & Singh, 2001) are similar in the nursery too.

3. Methods

3.1 Selection of study sites

For this research 22 potential locations and their associated properties were discussed in a conversation with the technical supervisor of Centre ValBio. All these study sites (see Appendices B.) are part of the reforestation project of Centre ValBio and planted by volunteers, employees, local schoolchildren and in cooperation with the local villagers.

Many sites of this list were not easily accessible or feasible to measure. Some were too far located from the park so these would not add any valuable information about the reforestation practices of the park itself. Based on these points, a selection of 18 sites was made (see Table 1.). Some were located around the borders of the park, some more into degraded areas around local villages.

Table 1. Locations study sites

Nr.	Location
1	Ambodiaviavry
2	Vohiparara
3	Morafeno
4	Kelilalina
5	Ampitavanana
6	Ambatolahy
7	School ambatolahy
8	Ambalakindresy 80
9	Ambalakindresy 205
10	School ranomafana
11	Kianja Maitso
12	Sahavondronana
13	Ambatovaky
14	Voloero
15	Androy
16	Ifanadiana
17	Friends of Madagascar
18	Soafianara

The study site Ambalakindresy was divided in two separated sites, because the influence factors differed too much to count as one. Appendices B gives an overview of the different study sites that were available for this research, in what year the seedlings are planted and how many seedlings were planted.

An overview of the selected study sites is given in figure 7. The sites are located along the borders of the National Park. The selected sites are well spread, which increases the probability distribution, which makes the results more representative.
The size of the study sites differs between approximately 20x20 m and 70x70 m. All the sites were located within an hour drive from Centre ValBio.

The seedling species used for the reforestation of all the study sites are listed in table 2. Most of these are pioneer species, because they form the first basis of new trees on a degraded area. Climax species will follow after some years to start a new generation.

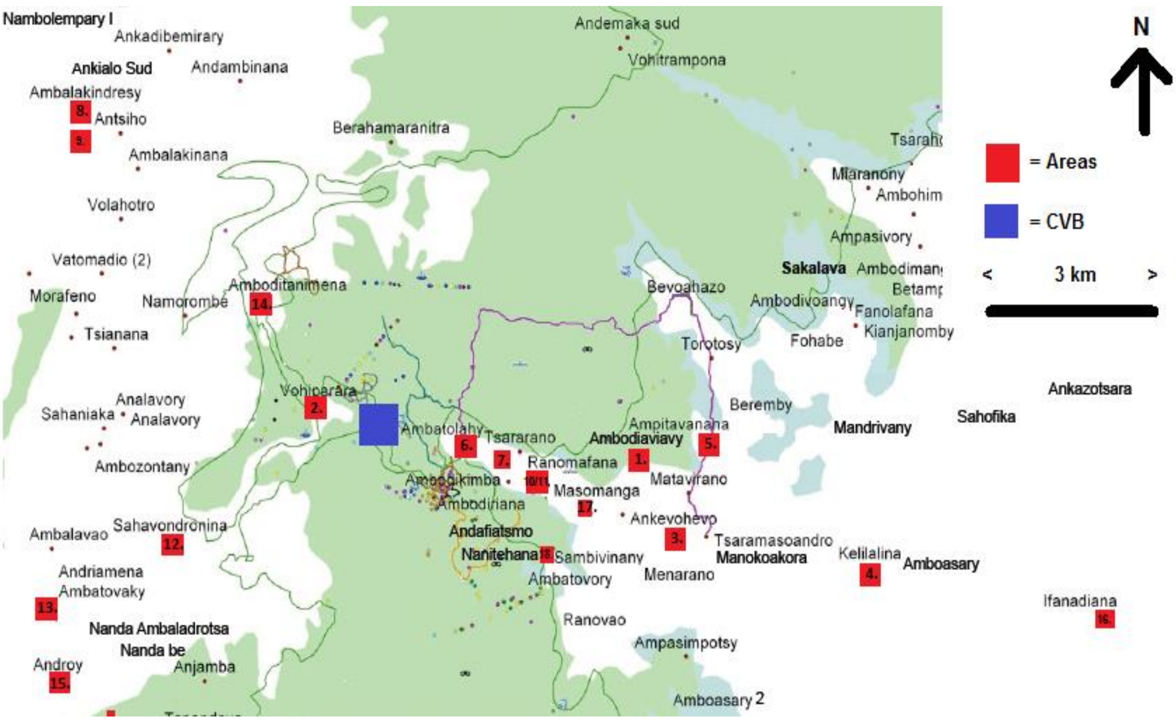


Figure 7. Selected study sites around Ranomafana National Park. Source: Centre ValBio

Table 2. Planted species

Scientific name	Family	Species name
Cryptocarya	Lauraceae	Tavolo spec.
Protorhus abrahamia	Anacardiaceae	Sandramy
Bridelia tulasneana	Euphorbiaceae	Harina
Ocotea	Lauraceae	Varongy
Mammea vatoensis	Clusiaceae	Nato voraka
Schizolaena turkii	Sarcolaenaceae	Schizoleana
Beguea	Sapindaceae	Lanary spec.
Dalbergia baroni	Fabaceae	Voamboana
Canarium madagascariensis	Burseraceae	Ramy
Brachylaena ramiflora	Asteraceae	Mananitra
Syzygium	Myrtaceae	Rotra
Streblus dimepate	Moraceae	Mahanoro
Pavonia	Malvaceae	Hafotra
Chrysophyllum boivinianum	Sapotaceae	Rahiaka
Calophyllum paniculatum	Clusiaceae	Vitanina
Antidesma petiolare	Euphorbiaceae	Voatsirivodrivotra
Dypsis fibrosa	Arecaceae	Vonitra
Garcinia ou mammea	Clusiaceae	Kimbaletaka
Tambourissa thoverotii	Momomiaceae	Ambora
Aspidostemon hummbertianum	Lauraceae	Longotra
Sloanea rhodantha	Elaeocarpaceae	Vanana
Pittosporum verticillatum	Pittosporaceae	Ambovitsika
Weinmannia bojeriana	Cunoniaceae	Maka
Dilobeia thouarsii	Proteaceae	Ramandriona
Dombeya	Malvaceae	Hafitrataivalales
Dracaena xiphophylla	Convallariaceae	Taviavola
Grewia	Malvaceae	Hafotaikalalao
Maesa lanceolata	Maesaceae	Voarafy

3.2 Data collecting

The data that was collected at the study sites during the field work consisted of the seedling characteristics like diameter, height and quality and the site characteristics which contain the specific variables that can influence the development of the seedlings. All this data were written down on field forms that were created for this research (see Appendices C).

The diameter was measured with a diameter measurement tape, or when the seedling was too small, with a small caliper. The diameter was given in centimeters (cm). The height was measured, also in cm, with a measurement tape and when the trees were too tall, an estimation has been made. A quality class was given to every seedling ranging from 1 till 3 (1=good, 2 = sufficient and 3 = bad). Good means that the seedling had developed leaves without brown spots or other disorders. Sufficient means that the seedlings had some leaves, but brown spots and other disorders could occur and the stem could be a bit curved. Bad means that the seedling had no leaves (anymore), or totally brown leaves and the stems had dead ends. Remarks and picture numbers were also mentioned as background information on the field form.

During the data collecting, it became more clear what kind of variables influenced the growth and development of the seedlings. In the beginning, many variables were measured and written down on the field forms. Every piece of information was marked to be relevant. These also included the availability of surface water, the direction of the slope and soil sample collection. Later in the process was decided to use 5 important variables for this research. All measured variables are described below;

- Year of planting; It is important to know the planting year when the study sites were replanted to give an indication of the age of the seedlings and how well they developed. These data were provide by CVB.
- Environment type; This has been displayed in a brief description on the field forms. For this variable the environment where the study sites were located was observed. Afterwards these descriptions has been pooled and divided in three main types; secondary forest, degraded land and degraded hill. The reason for the subdivision of the last two classes was that there was a clear difference between sites that were degraded on a flat plateau or that were located on steeper slopes.
- Slope steepness; To obtain the slope variable information, the elevation at the bottom of a slope and on the top were measured with a GPS. The steepness of the slope has been calculated by taking the sinus of the height difference/ slope length difference. For the general data analyses in the chapter results the slope steepness was divided into classes to give a clear picture about the deviation of the steepness per site. Class 1=0-10°, 2=11-20°, 3=21-30°, 4=31-40°, 5=41-50° and 6=>50°.
- Elevation; For the variable elevation the average elevation per study site plot has been measured with a GPS to get a clear picture of the elevation of each site. The classes of the elevation were; class 1= 400-599 m, 2= 600-799 m, 3= 800-999 m, 4= 1000-1199 m and 5= >1200 m.
- Weed coverage; This variable is quit important to get a clear picture of the maintenance of the study sites by measuring the weed coverage in percentage. This was performed by taking a square meter in every study site and indicate the percentage of occurring weeds. Then there was a quick look at the whole study site to see if this square meter represented the whole surface. The deviation of the weed coverage classes were; class 1=0-20%, 2=21-40% 3=41-60%, 4=61-80% and 5=>80%.

- Slope direction; This variable is measured with a compass during the data collecting and mentioned in the beginning of the results but after consideration not further taken into account in the results part because it was unclear what the exact relationship with the seedling development was.
- Surface water availability; This variable was taken into account during the data collecting, but was considered not useful for further data analyzes because no clear relationship with the seedling development could be found.
- Soil pH; The soil samples that were taken of all the study sites could not be investigated properly in the research center and were thereby excluded from this research.
- Animal species; Here for traces of animal appearance were observed, like insect damage or bigger herbivores. It was difficult to prove the infestation of the seedlings by any animals so this variable was left out of this research.
- Use of compost; This variable was skipped after the fieldwork, because for 17 of the 18 areas there was no use of compost. This seemed to be a mismatch for further data analysis.

3.3 Data analysis

With all the field forms with collected data, an analysis was performed by using Microsoft Excel and Microsoft Access. First all data were transferred to Microsoft Excel. Tables were created to display the seedling species and study sites properties. With the list of numbers of seedlings planted per site that was provided by CVB (see Appendices B.) and the numbers of measured seedlings provided by this research, a general survival rate per site could be calculated with the formula = (nr. seedlings measured * 100)/ nr. seedlings planted. Then for the selected four variables (environment type, steepness of the slope, elevation and weed coverage) different tables and graphs were created to display their relationship with the survival rate per study area.

After this a specialization with the species of 3 selected areas was performed by linking the survival rate per species to the associated seedling properties. For the comparison of different aspects of the data base Microsoft Access was used. Then, the seedlings properties and development per planting year were viewed and compared with the influence variables.
By looking close at all of this, the research questions could be answered, discussed, and an improvement for more suitable management practices could be applied. Also a recommendation could be provided to help CVB by choosing new planting locations in the future.

4. Results

4.1 Planted tree species

The total of study sites consisted of 28 different tree species. The number of seedlings measured differed a lot per species. Seven species were measured more than 100 times. The species measured the most was Cryptocarya (Tavolo spec.), with 451 individual seedlings (see Table 3.). Then followed, in descending order, by Protorbus (Sandramy), Bridelia tulaspeana (Harina), Ocotea (Varongy), Mammea vatoensis (Nato voraka), Schizolaena turkii (Schizoleana) and Beguea (Lanary spec.). The last 15 species were not even occurring more than a maximum of 9 times. An overview of all different species per site is given in Appendices D. This list presents the current situation of the different study sites with the total number of the occurring species (with scientific name) per site, their associated average diameter, average height and average quality.

Table 3. Number of measured seedlings per occurring species

Scientific name	Family name	Species name	Number of measured seedlings
Cryptocarya	Lauraceae	Tavolo spec.	451
Protorhus abrahamia	Anacardiaceae	Sandramy	334
Bridelia tulasneana	Euphorbiaceae	Harina	232
Ocotea	Lauraceae	Varongy	211
Mammea vatoensis	Clusiaceae	Nato voraka	140
Schizolaena turkii	Sarcolaenaceae	Schizoleana	125
Beguea	Sapindaceae	Lanary spec.	118
Dalbergia baroni	Fabaceae	Voamboana	55
Canarium madagascariensis	Burseraceae	Ramy	28
Brachylaena ramiflora	Asteraceae	Mananitra	18
Syzygium	Myrtaceae	Rotra	17
Streblus dimepate	Moraceae	Mahanoro	13
Pavonia	Malvaceae	Hafotra	11
Chrysophyllum boivinianum	Sapotaceae	Rahiaka	9
Calophyllum paniculatum	Clusiaceae	Vitanina	8
Antidesma petiolare	Euphorbiaceae	Voatsirivodrivotra	6
Dypsis fibrosa	Arecaceae	Vonitra	6
Garcinia ou mammea	Clusiaceae	Kimbaletaka	6
Tambourissa thoverotii	Momomiaceae	Ambora	6
Aspidostemon hummbertianum	Lauraceae	Longotra	4
Sloanea rhodantha	Elaeocarpaceae	Vanana	4
Pittosporum verticillatum	Pittosporaceae	Ambovitsika	3
Weinmannia bojeriana	Cunoniaceae	Maka	2
Dilobeia thouarsii	Proteaceae	Ramandriona	1
Dombeya	Malvaceae	Hafitrataivalales	1
Dracaena xiphophylla	Convallariaceae	Taviavola	1
Grewia	Malvaceae	Hafotaikalalao	1
Maesa lanceolata	Maesaceae	Voarafy	1

4.2 Species and study site characteristics

Regarding the number of species planted per site, only one site had most of the tree species growing. This was on the study site *School ranomafana* were 24 of the 28 occurring species were growing. Four (4) other study sites had 10 species or more growing. The other sites had 9 species or less growing. It appeared even that the study site *Ambalakindresy 205* had no species growing anymore (see Table 4.).

There were 2 sites planted in 2006 and 5 sites in 2007. Of those 5 sites, 3 were planted again in 2009. Six plantings sites were planted in 2010 of which 3 sites were planted again in 2011 or 2012. There is only one new site that was planted in 2011 and two new sites that were planted in 2012.

Table 4. Overview study sites, number of occurring species and associated planting year

Study site	# measured species	Planting year
School ranomafana	24	2007
Kelilalina	13	2006
Kiaja Maitso	10	2011
Morafeno	10	2006
Vohiparara	10	2010/2011
School ambatolahy	9	2010/2012
Voloero	9	2012
Ambtolahy	7	2007/2009
Ampitavanana	7	2010/2011
Ambodiaviavy	6	2012
Sahavondronana	6	2011/2012
Friends of Madagascar	5	2010
Ambatovaky	4	2007
Anroy	4	2007/2009
Soafianara	4	2010
Ambalakindresy 80	3	2010
Ifanadiana	3	2010
Ambalakindresy 205	0	2007/2009

The study sites all contained environmental variables that influence the growth and development of the occurring tree seedlings. Seven (7) study sites were located within the defined environment type Degraded land. This was 8 sites for the type Degraded hill and 3 sites for Secondary forest. When looking at the steepness of the slope, the study site *Kianja Maitso* had the flattest slope of 0°. More than half of the study sites (11 out of 18) had a slope less than 30°. Five (5) of the 18 study sites had a steeper slope between 30° and 50° and only one site (*Friends of Madagascar)* had a slope steeper than 50°.

The slope direction of the study sites was mainly located south west or south (9 of 18 sites). Six (6) sites were located north or east or east. The study site without a slope direction was logically *Kianja Maitso*, the one without any slope.

For the variable elevation half of the study sites were located at an elevation of 600-800 m high. Seven (7) of the sites were located at a higher elevation between 1100 and 1300 m. Only the study site *Ifanadiana* was located at an elevation of 433,5 m and the remaining site laid between the two main groups, on 908 m high.

Only 5 of the 18 study site had a weed coverage of less than 50%. The other 13 sites had a quite high occurrence of weeds between 50 and 90%. The site *Kianja Maitso* had a really low occurrence of weeds, 0% around the seedlings (see Table 5.).

Table 5. Study sites with associated influence variables

Study site	Environment type	Slope steepness (°)	Slope direction	Elevation (m)	Weed coverage (%)
Ambalakindresy 205	Degraded land	7.18	S + SW	1223	40
Ambalakindresy 80	Degraded land	17.46	SSW	1242	50
Ambatolahy	Degraded hill	44.43	SW	763	70
Ambatovaky	Secondary forest	8.05	NE	1263.5	30
Ambodiaviavy	Degraded hill	33.37	SSW	635.5	50
Ampitavanana	Degraded hill	36.87	NNE	633	85
Anroy	Degraded hill	42.07	SW	1142	65
Friends of Madagascar	Degraded hill	53.13	SE	634	35
Ifanadiana	Degraded land	2.87	SW	433.5	75
Kelilalina	Degraded hill	30	E	624.5	85
Kianja Maitso	Degraded land	0	-	625	0
Morafeno	Degraded land	16.26	NNE	627	90
Sahavondronana	Degraded hill	9.21	SSN	1249	30
School ambatolahy	Degraded hill	11.54	SSW	737	50
School ranomafana	Secondary forest	26.74	S	620	70
Soafianara	Degraded land	36.87	SW	908	85
Vohiparara	Secondary forest	18.66	NW + NE	1148	60
Voloero	Degraded land	10.37	E	1184.5	75

4.3 Survival rate to selected variables

The highest total survival rate of all species per study site was *Kianja Maitso* with 89%. The site *Ambalakindresy 205* had the lowest total survival rate of 0% (see Table 6.). The study site *Kianja Maitso* distinguished itself in survival rate from the other sites. The main reason for this is that *Kianja Maitso* was located around a nursery and therefor has favorable site characteristics. This site was located on a degraded land without a slope and had probably more benefits of the weed maintenance.

Table 6. Study sites with amount of planted and measured seedlings with associated survival rate

Study site	#Seedlings planted	#Seedlings survived	Survival rate (%)
Ambalakindresy 205	205	0	0
Ambalakindrsey 80	80	3	4
Anroy	200	11	6
Ifanadiana	50	3	6
Ambatovaky	600	52	7
Soafianara	180	24	13
Kelilalina	400	58	15
Ambodiaviavy	160	35	22
Vohiparara	800	183	23
School ranomafana	556	152	27
School ambatolahy	146	44	30
Morafeno	300	93	31
Ambatolahy	88	28	32
Sahavondronana	1000	349	35
Voloero	1000	455	46
Friends of Madagascar	30	14	47
Ampitavanana	500	293	58
Kianja Maitso	18	16	89

To get a closer look at the influence variables, table 5 needed to be disassembled and each variable had to be examined individually. To see what the effects of the variable were on the seedlings development, the variable values were connected to the survival rate per study site.

4.3.1 Environment type

The environment type *Degraded hill* had the highest average survival rate, followed by *Degraded land* and then *Secondary forest* (see Appendices E.). But there was a difference in accuracy of the amount of examined study sites per environment type and the range of the survival rate per environment type. The type *Degraded land* includes 7 study sites and has a survival rate range of 0-89 and an average of 26.9% but also has a high standard deviation, which meant that the amount of variation from the average was big. The type *Degraded hill* included 8 sites and had a smaller survival rate range. The average survival rate was bigger than the one for *Degraded land*, but the standard deviation was also smaller, which made the relationship between environment type and survival rate more accurate. Also more accurate was the standard deviation of the type *Secondary forest* (9.8), with a survival rate range from 9-27 and an average of 19.6%. But this type consisted only of 3 sites, which made that outcome not representative.

Table 7. Overview environment types and associated survival rate values

Environment type	Nr of sites	Survival Range (%)	Mean (%)	STDEVA
Degraded land	7	0-89	26.9	31.8
Degraded hill	8	6-59	30.5	17.0
Secondary forest	3	9-27	19.6	9.8
Degraded land without *Kianja Maitso*	6	0-46	16.6	17.9

When separated the range, mean and standard deviation values of the study site *Kianja Maitso* from the other sites of the environment type Degraded land, it appeared that the values were all lower than when the study site was included. Therefore the outcome was much more equal when compared to the environment types Degraded hill and Secondary forest (see Table 7.).

4.3.2 Steepness of the slope

It appeared that for the influence variable steepness of the slope the study site *Friends of Madagsacar* had the steepest slope with 53.13° and an associated survival rate of 46.67% (see Table 8.). The site with the least slope, but highest survival rate, was *Kianja Maitso*. This result was probably due to the fact that *Kianja Maitso* was located around a nursery as described in the previous paragraph. When looking at the ascending values of the slope steepness of the study sites, there was no clear relationship with a similar ascending survival rate. A steeper slope did not indicate a clear pattern in survival rate, but a linear line showed a slight decrease in the sites pattern (see Figure 8.) which could conclude a small decrease in survival rate when the slope steepness got higher. The average survival rate per slope class was lowest in class 5 which indicated slopes between 40 and 50° (see Figure 9.). The highest average survival rate was displayed in class 6 (>50°) but this class only contained 1 location which represented the average survival rate.

Table 8. Overview study sites survival rate with associated slope steepness

Study site	Slope steepness (°)	Slope steepness class	Survival rate (%)
Kianja Maitso	0	1	88.89
Ifanadiana	2.87	1	6.00
Ambalakindresy 80	7.18	1	3.75
Ambatovaky	8.05	1	8.67
Sahavondronana	9.21	1	34.90
Voloero	10.37	2	45.50
School ambatolahy	11.54	2	30.14
Morafeno	16.26	2	31.00
Ambalakindresy 205	17.46	2	0.00
Vohiparara	18.66	2	22.88
School ranomafana	26.74	3	27.34
Kelilalina	30	3	14.50
Ambodiaviavy	33.37	4	21.88
Soafianara	36.87	4	13.33
Ampitavanana	36.87	4	58.60
Anroy	42.07	5	5.50
Ambatolahy	44.43	5	31.82
Friends of Madagascar	53.13	6	46.67

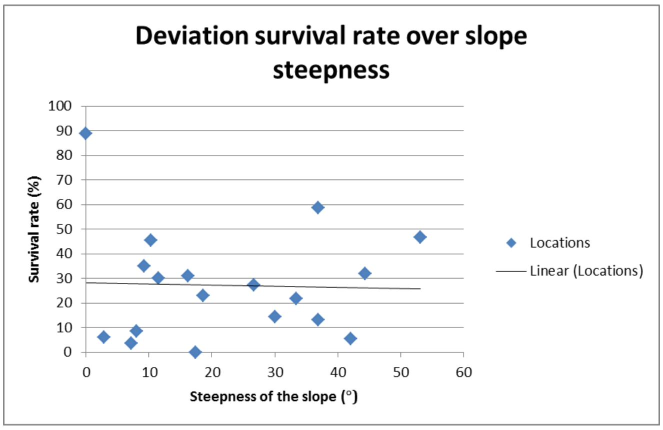


Figure 8. Deviation survival rate over slope steepness

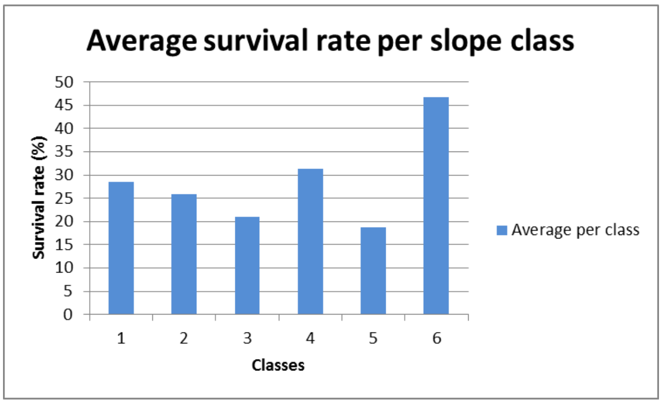


Figure 9. Average survival rate per slope class

4.3.3 Elevation

The study site *Ambatovaky* was located the highest (1263.5 m) of the study sites. It had a survival rate of 8.67%. The study site located lowest was *Ifanadiana* with 433.5 m had a survival rate of 6% which was almost as low as *Ambatovaky* (see Table 9.). When looking at the distribution of the locations it was clear that some elevation levels similar to each other had different survival rates (see Figure 10.). It is also clear that there were mainly two elevation clusters. The one contained 600-700 m and one contained 1100-1300 m. When looking at the deviation in classes (see Figure 11.) it was more distributed in class 2 (600-800m) , class 4 (1100-1200 m) and class 5 (>1200m). The average survival rate of the first cluster in figure 10 (class 2) is clearly higher than the average survival rate of the second cluster in class 4 (see Figure 11.).

Table 9. Overview study sites survival rate with associated elevation

Study site	Elevation (m)	Elevation class	Survival rate (%)
Ifanadiana	433.5	1	6.00
School ranomafana	620	2	27.34
Kianja Maitso	625	2	88.89
Morafeno	627	2	31.00
Kelilalina	624.5	2	14.50
Ampitavanana	633	2	58.60
Friends of Madagascar	634	2	46.67
Ambodiaviavy	635.5	2	21.88
School ambatolahy	737	2	30.14
Ambatolahy	763	2	31.82
Soafianara	908	3	13.33
Anroy	1142	4	5.50
Vohiparara	1148	4	22.88
Voloero	1184.5	4	45.50
Ambalakindresy 80	1223	5	3.75
Ambalakindresy 205	1242	5	0.00
Sahavondronana	1249	5	34.90
Ambatovaky	1263.5	5	8.67

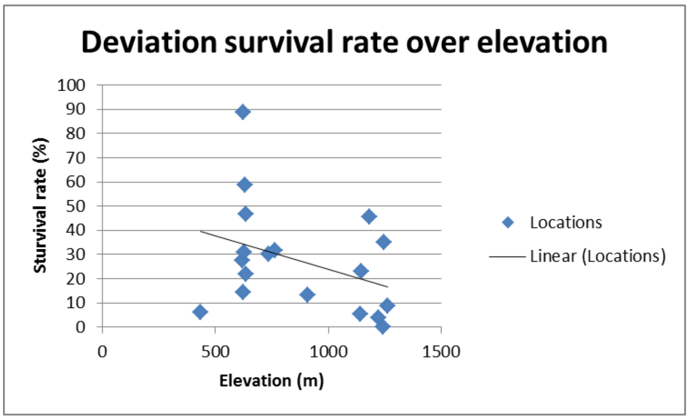


Figure 10. Deviation survival rate over elevation

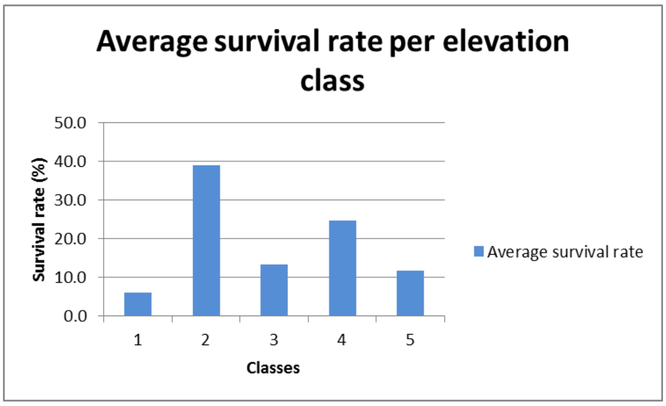


Figure 11. Average survival rate per elevation class

4.3.4 Weed coverage

The study site *Morafeno* had the highest weed coverage (90%) with an associated survival rate of 31% (see Table 10.). Only study site *Kianja Maitso* had a weed coverage of 0% and the highest survival rate because of the fact that it was located around a nursery as described in the previous paragraphs. This study site was followed by 4 sites that had a weed coverage of less than 50%. The majority of the study sites (13 out of 18 sites) had a weed coverage of at least 50% (see Figure12.). Of this majority only 4 study sites had a survival rate of less than 20%. As pointed out by the linear line, a decrease in survival rate was occurring when the weed coverage increased. The distribution of the average survival rate per class gave an indication of a high average survival rate of class 1 (0-20%) and circa equal average survival rate of class 2 (21-40%), 3 (41-60%), 4 (61-80%) and 5 (>80%) (see Figure 13.).

Table 10. Overview study sites survival rate with associated weed coverage

Study site	Weed coverage (%)	Weed coverage class	Survival rate (%)
Kianja Maitso	0	1	88.89
Ambatovaky	30	2	8.67
Sahavondronana	30	2	34.90
Friends of Madagascar	35	2	46.67
Ambalakindresy 80	40	2	3.75
Ambalakindresy 205	50	3	0.00
Ambodiaviavy	50	3	21.88
School ambatolahy	50	3	30.14
Vohiparara	60	3	22.88
Anroy	65	4	5.50
School ranomafana	70	4	27.34
Ambatolahy	70	4	31.82
Ifanadiana	75	4	6.00
Voloero	75	4	45.50
Soafianara	85	5	13.33
Kelilalina	85	5	14.50
Ampitavanana	85	5	58.60
Morafeno	90	5	31.00

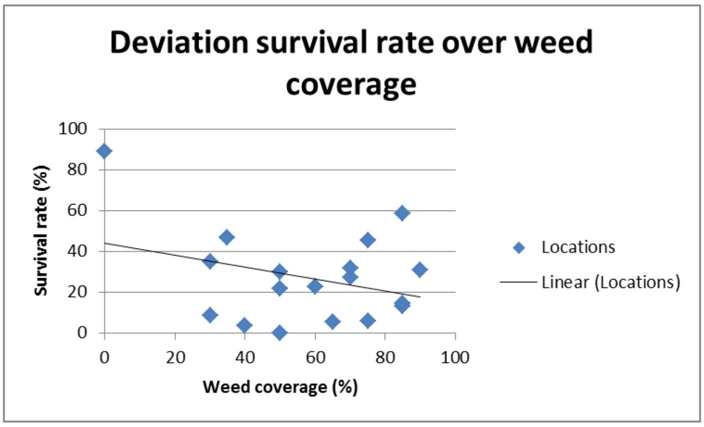


Figure 12. Deviation survival rate over weed coverage

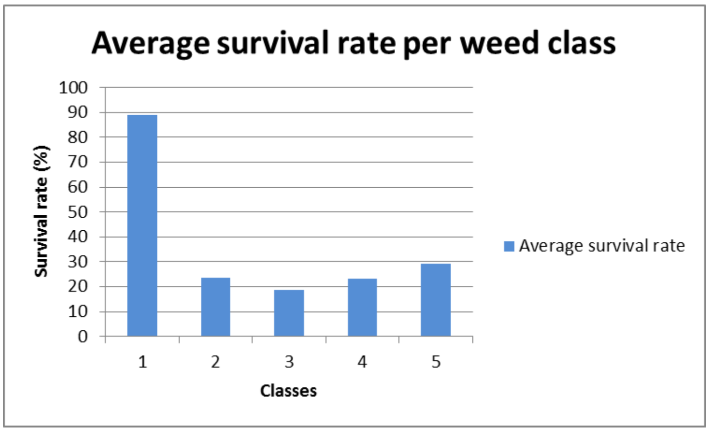


Figure 13. Average survival rate per weed cover class

4.4 Survival rate per species

A specification of the survival rate per species was performed on three of the total study sites. These were selected because only of these sites the exact number of seedlings planted per species was known. The study site *Sahavondronana* had 7 occurring species, *Voloero* had 9 and *Vohiparara* had 11.

The species *Protorhus abrahamia (Sandramy)* had the highest survival rate of the occurring species on the study site Sahaondronana. Besides this species only one other species (*Schizolaena turkii (Schizoleana))* had a survival rate of more than 50%. The species *Syzygium (Rotra)*, had the lowest survival rate of 0%. Another species that was not very successful on this study site was *Aspidostemon hummbertianum (Longotra)*, which had a survival rate of 6% (see Table 11.).

Table 11. Amount of planted and measured seedlings per species of Sahavondronana

Species planted		2012	2011	Measured	Survival rate (%)
Total		800	200	349	35
Protorhus abrahamia	**(Sandramy)**	150		97	65
Schizolaena turkii	**(Schizoleana)**	50		26	52
Cryptocarya	**(Tavolo spec.)**	300	150	150	33
Bridelia tulasneana	**(Harina)**	234		68	29
Mammea vatoensis	**(Nato voraka)**	30		6	20
Aspidostemon hummbertianum	**(Longotra)**	34		2	6
Syzygium	**(Rotra)**	2	50	0	0

For the study site Voloero, the species *Cryptocarya (Tavolo spec.)* had the highest survival rate, closely followed by the species *Beguea (Lanary spec.)* and *Protorhus abrahamia (Sandramy).* The species with the lowest survival rate was *Aspidostemon hummbertianum (Longotra)* with 9% (see Table 12.).

Table 12. Amount of planted and measured seedling species of Voloero

Species planted		2012	Measured	Survival rate (%)
Total		1001	455	45
Cryptocarya	**(Tavolo spec.)**	246	139	57
Beguea	**(Lanary spec.)**	115	64	56
Protorhus abrahamia	**(Sandramy)**	125	65	52
Mammea vatoensis	**(Nato voraka)**	157	51	32
Aspidostemon hummbertianum	**(Longotra)**	11	1	9
Bridelia tulasneana	**(Harina)**		49	
Syzygium	**(Rotra)**		1	
Dalbergia baroni	**(Voamboana)**		41	

Cryptocarya (Tavolo spec.) was the species with the highest survival rate of the study site Vohiparara. Only for two other species the survival rate could be calculated. *Syzygium (Rotra)* had the lowest survival rate of 0% and with 32% the species *Schizolaena turkii (Schizoleana)* was the middle one. For the rest of the species it was unknown how many per species were planted exactly in 2007, 2010 or 2011 (see Table 13.).

Table 13. Amount of planted and measured seedlings per species of Vohiparara

Species planted		2007	2010	2011	Measured	Survival rate (%)
Total		600	140	60	183	48
Cryptocarya	**(Tavolo spec.)**		40	15	37	67
Schizolaena turkii	**(Schizoleana)**	100		25	40	32
Syzygium	**(Rotra)**		11		0	0
Bridelia tulasneana	**(Harina)**	?	19	?	28	
Beguea	**(Lanary spec.)**	?		10	10	
Mammea vatoensis	**(Nato voraka)**	?	20		15	
Canarium madagascariensis	**(Ramy)**	?	10		4	
Protorhus abrahamia	**(Sandramy)**	?	20	10	32	
Ocotea	**(Varongy)**	?	20		15	
Calophyllum paniculatum	**(Vitanina)**	?				
Dalbergia baroni	**(Voamboana)**	?				

Only the species *Cryptocarya (Tavolo spec.)* occurred on all three study sites but had the highest survival rate in Vohiparara (67%) in contrast to the species *Syzygium (Rotra)* which did not do well on any of the sites. The species *Aspidostemon hummbertianum (Longotra)* had a very low survival rate on the study sites Sahavondronana (6%) and Voloero (9%) and the survival rate of *Schizolaena turkii (Schizoleana)* varied between 52% in Sahavondronana and 32% in Vohiparara. *Protorhus abrahamia (Sandramy)* did well in Sahavondronana and Voloero with a survival rate higher than 50%.

4.5 Species properties per planted year per area

To display the correlation between the development of the seedlings and the year they were planted, first a selection has been made to form the top 7 of most occurring measured species (see Table 14.). This decision was based on the species that occurred more than 100 times in de study site data. With this list further analyzes of the data per planting year has been performed.

Table 14. Top 7 most measured species

Species name	Amount
Cryptocarya (Tavolo spec.)	451
Protorhus abrahamia (Sandramy)	334
Bridelia tulasneana (Harina)	232
Ocotea (Varongy)	211
Mammea vatoensis (Nato voraka)	140
Schizolaena turkii (Schizoleana)	125
Beguea (Lanary spec.)	118

4.5.1 Planting year 2006

The planting year 2006 included 2 study sites, *Morafeno* and *Kelilalina*. On the site Morafeno, 4 of the top 7 species occurred and on the site Kelilalina 6 of 7 species occurred (see Table 15.). The average diameter and height was given in cm. The average quality was given in classes of 1,2 or 3.

The study sites Morafeno and Kelilalina differed in measured seedling properties per species. Of the species Cryptocarya (Tavolo spec.), Bridelia tulasneana (Harina) and Mammea vatoensis (Nato voraka) which occurred on both sites it was clear that the seedlings on the site Morafeno had a higher average diameter than the ones in Kelilalina. This also counted for the average height of the species occurring on both sites. The average quality of the seedlings was quite similar on both sites, but for the species Mammea vatoensis (Nato voraka) clearly higher in Kelilalina (see Figures 14 and 15.).

Table 15. Overview properties top 7 species planted in 2006

Morafeno	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	2.51	209.10	1.00
Protorhus abrahamia (Sandramy)	2.47	274.30	1.28
Bridelia tulasneana (Harina)	2.40	252.00	1.50
Mammea vatoensis (Nato voraka)	1.73	167.50	1.00
Kelilalina	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	1.05	149.67	1.00
Bridelia tulasneana (Harina)	1.61	207.00	1.40
Ocotea (Varongy)	1.40	209.67	1.00
Mammea vatoensis (Nato voraka)	0.50	31.00	2.00
Schizolaena turkii (Schizoleana)	1.73	207.50	1.25
Beguea (Lanary spec.)	0.60	40.00	1.00

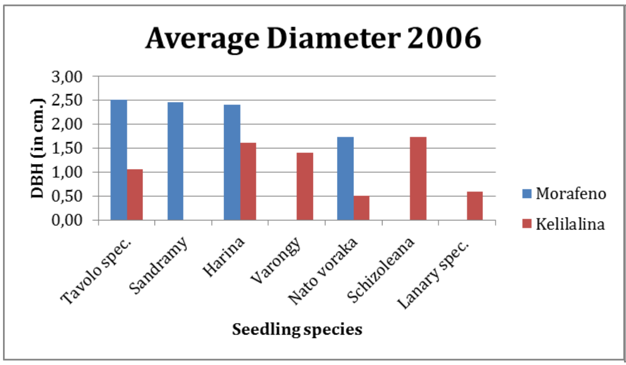


Figure 14. Average diameter per species of study sites of 2006

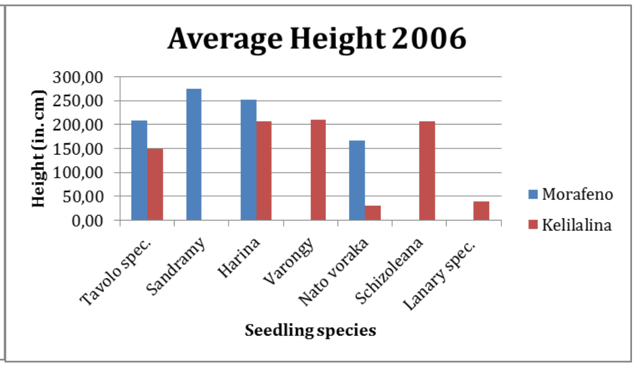


Figure 15. Average height per species of study sites of 2006

Looking at the influence variables (see Table 16.) there was a difference in the variables environment type and slope steepness. The study site Kelilalina had a steeper slope and was located on a Degraded hill. This corresponded with a slightly smaller tree development of Kelilalina.

Table 16. Overview of the influence variables of the planting year 2006

	Morafeno	**Kelilalina**
Environment type	Degraded land	Degraded hill
Slope steepness (°)	16.26	30
Elevation (m)	627	624.5
Weed coverage (%)	90	85

4.5.2 Planting year 2007

The planting year 2007 included 4 study sites, *Ambatolahy, School ranomafana, Ambatovaky* and *Anroy*. Ambatolahy had 5 of the top 7 occurring species, School ranomafana had all 7, Ambatovaky had 3 and Anroy had 1 (see Table 17.). The average diameter and height were both the highest for all the occurring species on the study site School Ranomafana (see Figures 16 and 17.). The average quality was almost equal for all species except for the site Ambatolahy, which had an outlier with the average quality of the species Schizolaena turkii (Schizoleana).

Table 17. Overview properties top 7 species planted in 2007

Ambatolahy	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Protorhus abrahamia (Sandramy)	0.97	126.33	1.00
Bridelia tulasneana (Harina)	1.20	160.00	1.00
Ocotea (Varongy)	0.60	56.33	1.00
Mammea vatoensis (Nato voraka)	1.15	72.50	1.00
Schizolaena turkii (Schizoleana)	0.73	105.25	1.50
School ranomafana	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	6.88	524.55	1.09
Protorhus abrahamia (Sandramy)	2.70	328.75	1.17
Bridelia tulasneana (Harina)	8.33	543.75	1.13
Ocotea (Varongy)	3.73	355.17	1.13
Mammea vatoensis (Nato voraka)	2.28	159.67	1.17
Schizolaena turkii (Schizoleana)	3.50	175.00	1.00
Beguea (Lanary spec.)	1.82	207.00	1.17

Amabatovaky	Average diameter (in cm)	Average height (in cm)	Average quality
Protorhus abrahamia (Sandramy)	0.84	97.82	1.18
Ocotea (Varongy)	0.64	52.43	1.11
Schizolaena turkii (Schizoleana)	0.52	31.42	1.25

Anroy	Average diameter (in cm)	Average height (in cm)	Average quality
Beguea (Lanary spec.)	1.15	54.13	1.00

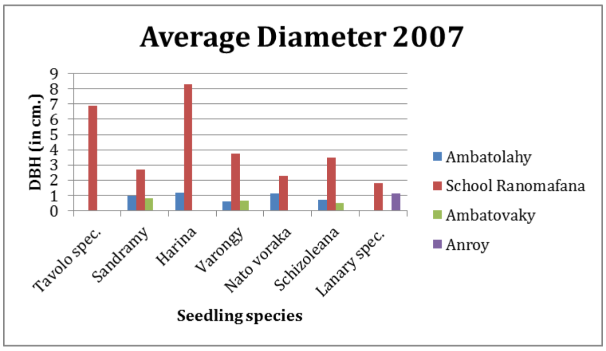


Figure 16. Average diameter per species of study sites of 2007

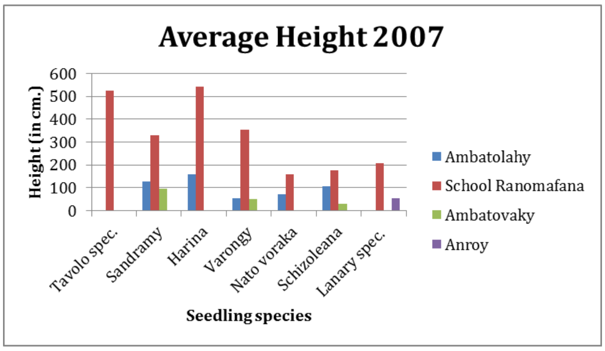


Figure 17. Average height per species of study sites of 2007

The influence variables Environment type Degraded hill occurred in 2 of the 4 study sites as well as the type Secondary forest, which occurred in the other 2 study sites (see Table 18.). The variable of the Steepness of the slope had divergent results, displaying a very low slope steepness for the study site Ambatovaky, a higher steepness for the site School Ranomafana and more or less equal steepness for the other two sites. The elevation variable showed two lower numbers in the study sites Ambatolay and School ranomafana and two higher ones for the sites Ambatovaky and Anroy. Of the variable weed coverage only study site Ambotovaky showed a quite low weed coverage percentage. The variables Environment type and Slope steepness of study site School Ranomafana corresponded with the tree development of this site. The variable weed coverage did not correspond, because this was higher than the weed coverage on study sites Ambatovaky and Anroy and still had a better tree development .

Table 18. Overview of the influence variables of the planting year 2007

	Ambatolahy	School ranomafana	Ambatovaky	Anroy
Environment type	Degraded hill	Secondary forest	Secondary forest	Degraded hill
Slope steepness (°)	44.43	26.74	8.05	42.07
Elevation (m)	763	620	1263.5	1142
Weed coverage (%)	70	70	30	65

4.5.3 Planting year 2009

The planting year 2009 included 2 study sites, *Ambatolahy* and *Anroy*. Ambatolahy had 5 of the top 7 occurring species and Anroy had only 1 (see Table 19.). Most species of the planting year 2009 only occurred on the study site Ambatolahy and the others occurred only on the site Anroy (see Figures 18 and 19.). This made analyzing the data and comparing the diameter, height and quality per species impossible.

Table 19. Overview properties top 7 species planted in 2009

Ambatolahy	Average diameter (in cm)	Average height (in cm)	Average quality
Protorhus abrahamia (Sandramy)	0.97	126.33	1.00
Bridelia tulasneana (Harina)	1.20	160.00	1.00
Ocotea (Varongy)	0.60	56.33	1.00
Mammea vatoensis (Nato voraka)	1.15	72.50	1.00
Schizolaena turkii (Schizoleana)	0.73	105.25	1.50
Anroy	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Beguea (Lanary spec.)	1.15	54.13	1.00

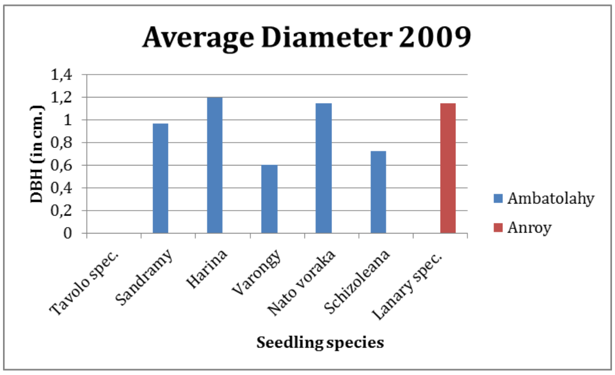


Figure 18. Average diameter per species of study sites of 2009

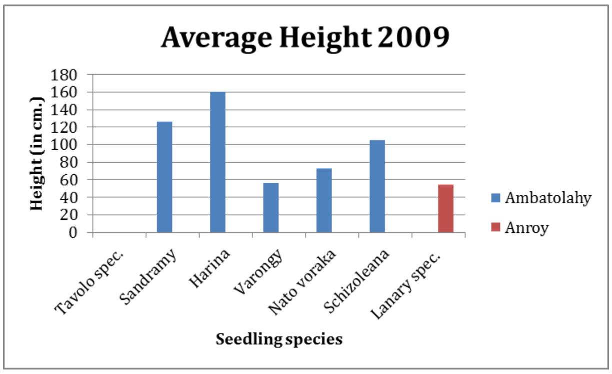


Figure 19. Average height per species of study sites of 2009

The influence variables were all similar to each other. Only the elevation was much higher on the study site Anroy than on the site Ambatolahy (see Table 20.) but this did not indicate a clear relationship with the tree development of the 2 sites.

Table 20. Overview of the influence variables of the planting year 2009

	Ambatolahy	Anroy
Environment type	Degraded hill	Degraded hill
Slope steepness (°)	44.43	42.07
Elevation (m)	763	1142
Weed coverage (%)	70	65

4.5.4 Planting year 2010

The results for the planting year 2010 included the study sites *Vohiparara, Ampitavnana*, *School Ambatolahy*, *Ambalakindresy 80*, *Friends of Madagascar* and *Soafianara*. Voloero and Ampitavanana both had 7 of the top 7, School ambatolahy and Friends of Madagascar both had 5 species, Ambakalkindresy 80 had 1 and Soafianara had 3 (see Table 21.). The average diameter and height were for almost all the occurring species the highest on study site School Ambatolahy (see Figures 20 and 21.). Only the average quality of the species was similar for all sites. Only the study site School Ambatolahy had a clear stand out with the species Bridelia tulasneana (Harina).

Table 21. Overview properties top 7 species planted in 2010

Vohipara	Average diameter (in cm)	Average height (in cm)	Average quality
Cryptocarya (Tavolo spec.)	0.47	39.97	1.30
Protorhus abrahamia (Sandramy)	0.69	99.59	1.25
Bridelia tulasneana (Harina)	0.46	71.85	1.29
Ocotea (Varongy)	0.43	51.87	1.20
Mammea vatoensis (Nato voraka)	0.48	39.67	1.07
Schizolaena turkii (Schizoleana)	0.55	86.13	1.25
Beguea (Lanary spec.)	0.41	49.22	1.50
Ampitavanana	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	0.76	63.96	1.11
Protorhus abrahamia (Sandramy)	1.03	151.11	1.05
Bridelia tulasneana (Harina)	0.72	89.61	1.34
Ocotea (Varongy)	0.71	77.39	1.05
Mammea vatoensis (Nato voraka)	0.84	61.65	1.02
Schizolaena turkii (Schizoleana)	1.00	107.53	1.03
Beguea (Lanary spec.)	0.60	55.87	1.10
School ambatolahy	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	3.60	213.04	1.12
Bridelia tulasneana (Harina)	2.90	220.00	2.00
Ocotea (Varongy)	3.30	297.33	1.00
Mammea vatoensis (Nato voraka)	2.88	139.60	1.40
Beguea (Lanary spec.)	1.53	94.00	1.00
Ambalakindresy 80	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Protorhus abrahamia (Sandramy)	0.70	35.00	1.00
Friends of Madagascar	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	1.39	91.50	1.00
Protorhus abrahamia (Sandramy)	2.48	199.25	1.00
Bridelia tulasneana (Harina)	3.85	250.00	1.25
Ocotea (Varongy)	1.70	111.00	1.00
Mammea vatoensis (Nato voraka)	1.52	98.50	1.00
Soafianara	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Protorhus abrahamia (Sandramy)	0.70	141.00	1.00
Bridelia tulasneana (Harina)	1.87	250.00	1.05
Schizolaena turkii (Schizoleana)	0.60	75.00	1.00

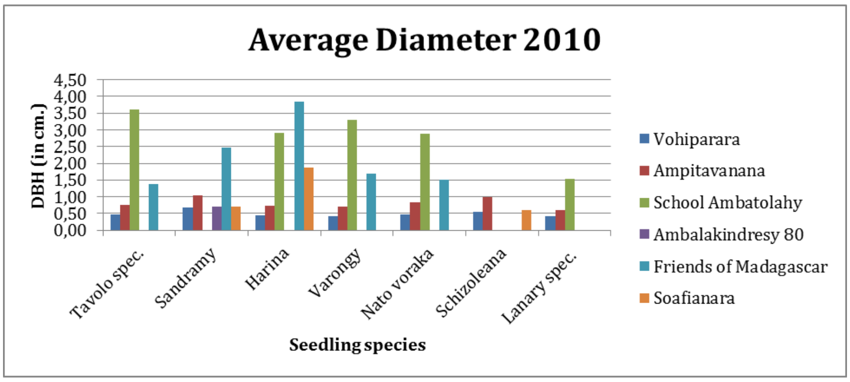


Figure 20. Average diameter per species of study sites of 2010

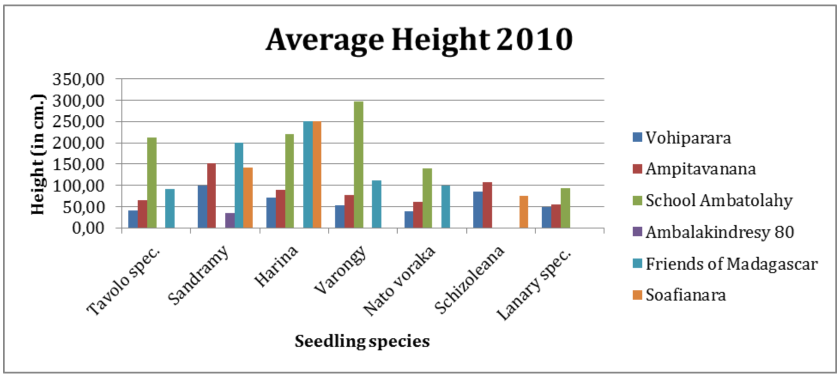


Figure 21. Average height per species of study sites of 2010

The influence variables differed a lot between the study sites (see Table 22.). All three types of environment were present on the study sites. The steepness of the slopes differed between 7.18° to 53.13°. Also the elevation varied widely and the weed coverage differed between 35 and 85%. The influence variables did correspond with the tree development on study site School Ambatolahy, but this did not count for all the study sites. The other study sites had conflicting results between the influence variables and their tree development.

Table 22. Overview of the influence variables of the planting year 2010

	Vohiparara	**Ampitavanana**	**School ambatolahy**	**Ambalakindresy 80**	**Friends of Madagascar**	**Soafianara**
Environment type	Secondary forest	Degraded hill	Degraded hill	Degraded land	Degraded hill	Degraded land
Slop steepness (°)	18.66	36.87	11.54	7.18	53.13	36.87
Elevation (m)	1148	633	737	1223	634	908
Weed coverage (%)	60	85	50	40	35	85

4.5.5 Planting year 2011

The planting year 2011 included 4 study sites, *Vohiparara, Ampitavanana, Kianja Maitso* and *Sahavondronana*. Vohiparara and Ampitavanana both had all 7 occurring species. Kianja Maitso had 4 and Sahavondronana had 5 of the top 7 most measured species (see Table 23.). The study site Ampitavanana had for almost all species the highest results at the average diameter and average height (see Figures 22 and 23.). Only for the average quality the site Sahavondronana was slightly higher for most of the species, together with the site Kianja maitso for the species Schizolaena turkii (Schizoleana) and Beguea (Lanary spec.).

Table 23. Overview properties top 7 species planted in 2011

Vohiparara	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	0.47	39.97	1.30
Protorhus abrahamia (Sandramy)	0.69	99.59	1.25
Bridelia tulasneana (Harina)	0.46	71.85	1.29
Ocotea (Varongy)	0.43	51.87	1.20
Mammea vatoensis (Nato voraka)	0.48	39.67	1.07
Schizolaena turkii (Schizoleana)	0.55	86.13	1.25
Beguea (Lanary spec.)	0.41	49.22	1.50

Ampitavanana	Average diameter (in cm)	Average height (in cm)	Average quality
Cryptocarya (Tavolo spec.)	0.76	63.96	1.11
Protorhus abrahamia (Sandramy)	1.03	151.11	1.05
Bridelia tulasneana (Harina)	0.72	89.61	1.34
Ocotea (Varongy)	0.71	77.39	1.05
Mammea vatoensis (Nato voraka)	0.84	61.65	1.02
Schizolaena turkii (Schizoleana)	1.00	107.53	1.03
Beguea (Lanary spec.)	0.60	55.87	1.10
Kianja Maitso	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	0.80	85.50	1.00
Mammea vatoensis (Nato voraka)	0.70	79.00	1.00
Schizolaena turkii (Schizoleana)	0.50	72.00	2.00
Beguea (Lanary spec.)	0.60	69.00	2.00
Sahavondronana	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	0.46	34.75	1.75
Protorhus abrahamia (Sandramy)	0.48	46.85	1.55
Bridelia tulasneana (Harina)	0.39	24.59	1.62
Mammea vatoensis (Nato voraka)	0.62	29.83	1.33
Schizolaena turkii (Schizoleana)	0.46	33.96	1,23

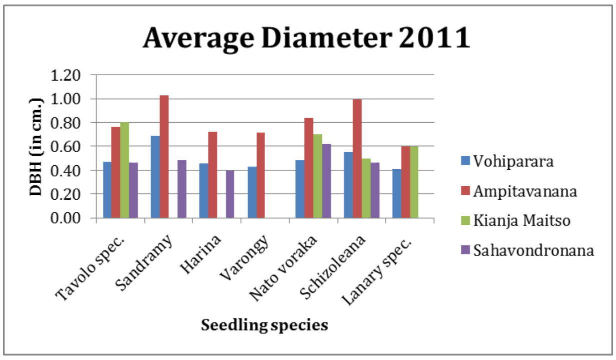


Figure 22. Average diameter per species of study sites of 2011

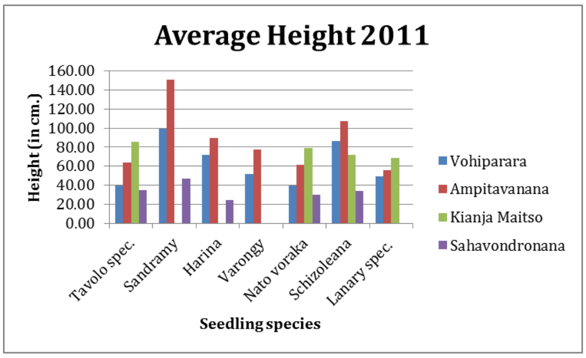


Figure 23. Average height per species of study sites of 2011

The variable slope steepness differed a lot between study sites, ranging from 0 till 36.87°. Kianja Maitso was not located on a slope and had also no occurring weeds. Two of the study sites were located on a lower elevation and the other two had a higher elevation (see Table 24.). The occurring variables slope steepness and weed coverage of study site Ampitavanana did not correspond with its high tree development.

Table 24. Overview of the influence variables of the planting year 2011

	Vohiparara	Ampitavanana	Kianja Maitso	Sahavondronana
Environment type	Secondary forest	Degraded hill	Degraded land	Degraded hill
Slope steepness (°)	18.66	36.87	0	9.21
Elevation (m)	1148	633	625	1249
Weed coverage (%)	60	85	0	30

4.5.6 Planting year 2012

There were 4 study sites planted in the year 2012. These were *Ambodiaviavy, School ambatolahy*, *Sahavondronana* and *Voloero.* Ambodiaviavy had 3 of the top 7 species, School ambatolahy and Sahavondronana both had 5 of the 7 species and Voloero had 6 species occurring (see Table 25.). For the year 2012 the site School Ambatolahy had a high standout in results of the average diameter and height in the species Cryptocarya (Tavolo spec.), Bridelia tulasneana (Harina), Ocotea (Varongy), Mammea vatoensis (Nato voraka) and Beguea (Lanary spec.) (see Figures 24 and 25.). For the quality it varied a lot between the species.

Table 25. Overview properties top 7 species planted in 2012

Ambodiaviavy	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	0.45	44.99	1.00
Protorhus abrahamia (Sandramy)	0.39	65.78	1.00
Schizolaena turkii (Schizoleana)	0.33	22.50	1.75
School ambatolahy	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	3.60	213.04	1.12
Bridelia tulasneana (Harina)	2.90	220.00	2.00
Ocotea (Varongy)	3.30	297.33	1.00
Mammea vatoensis (Nato voraka)	2.88	139.60	1.40
Beguea (Lanary spec.)	1.53	94.00	1.00
Sahavondronana	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	0.46	34.75	1.75
Protorhus abrahamia (Sandramy)	0.48	46.85	1.55
Bridelia tulasneana (Harina)	0.39	24.59	1.62
Mammea vatoensis (Nato voraka)	0.62	29.83	1.33
Schizolaena turkii (Schizoleana)	0.46	33.96	1.23
Voloero	**Average diameter (in cm)**	**Average height (in cm)**	**Average quality**
Cryptocarya (Tavolo spec.)	0.63	37.13	1.32
Protorhus abrahamia (Sandramy)	0.43	31.66	1.58
Bridelia tulasneana (Harina)	0.45	25.21	1.15
Ocotea (Varongy)	0.44	25.96	1.56
Mammea vatoensis (Nato voraka)	0.56	28.32	1.18
Beguea (Lanary spec.)	0.48	27.89	1.38

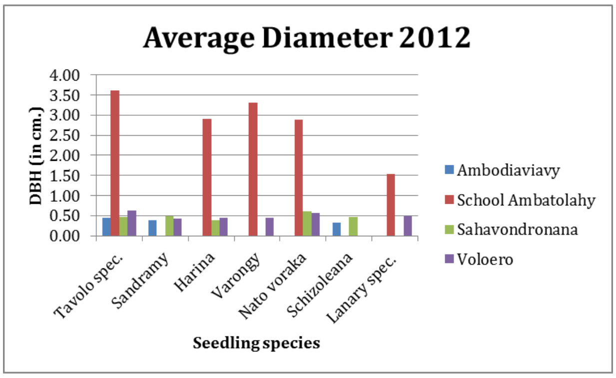


Figure 24. Average diameter per species of study sites of 2012

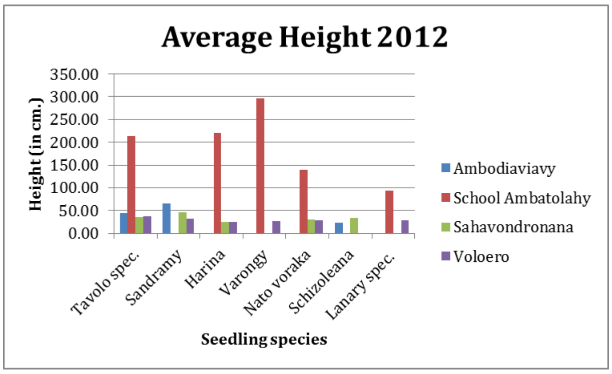


Figure. 25. Average height per species of study sites of 2012

The influence variable envrionment type was similar for all 4 study sites (see Table 26.). The other variables had much variation. The steepness varied from 9.21° to 33.37°. The elevation of the first two sites were comparable and for the last two sites too. The variables of study site School ambatolahy did correspond with the tree development of that site. When looking at the variables of study site Sahavondronana, this should correlate too with its tree development but these values were clearly less high.

Table 26. Overview of the influence variables of the planting year 2012

	Ambodiaviavy	**School ambatolahy**	**Sahavondronana**	**Voloero**
Environment type	Degraded hill	Degraded hill	Degraded hill	Degraded land
Slope steepness (°)	33.37	11.54	9.21	10.37
Elevation (m)	635.5	737	1249	1184.5
Weed coverage (%)	50	50	30	75

5. Discussion and Conclusion

5.1 Objective

This research has successfully given new insights and opportunities in seedling growth and development of planted species and thereby reached its objective to clarify the current situation of Centre ValBio. With the search for targeted information about the topic, explicate the methods, collecting and analyzing the data and describing and discussing the results this research has almost become to an end. A lot of information about the growth and development of the seedlings has been obtained and how they are being influenced by different variables. Below the research questions are being answered as specific as possible.

5.2 Questions

What kind of variables are playing an active role in the selected reforestation sites adjacent to Ranomafana National Park?

The variables that are playing an active role on the reforestation areas in RNP are; the environment type, steepness of the slope, elevation, weed coverage and age.

The results of this research are based on these variables. Other variables where included too in the literature part and data collection. These others include management, conditions of the seedlings before planting and slope direction. Also the availability of water and nutrients plays a huge role in influencing the seedlings and the soil contents.

There are a lot of literature references that describe the abiotic influence variables on seedling development like soil moisture availability, light and temperature (Poorter, 1999; Eagles, 1967) Also more specific variables are described in research reports like drought, root establishment, herbivory, erosion, branch falls and mammal digging (Augspurger, 1984). On the variables light (Richards, 1952; Whitmore, 1975; Denslow, 1980; Harshorn, 1980 and Pickett, 1983), water availability (Burslem, Grubb and turner, 1996; Gerhard, 1993; Lloyd & Pigott, 1967; Nepstad et al., 1996), soil structure (Grime, 2002; Pugnaire & VAlladares, 1999), nutrients availability (Burslem, Grubb and Turner, 1996), predation (Uhl and Jordan, 1984; Uhl, 1987, 1988; Uhl et al., 1988). and weed coverage (Aide et al., 1995; Cohen et al., 1995; Kuusipalo et al., 1995; Otsam et al., 1995) there is a lot of literature references present.

There is a difference between the variables investigated in the literature part and the ones actually measured in practice. Before the start of this research expectations to investigate more variables were made than it turned out at the end. It was meant to include the variables light in relation to the slope direction, soil pH and nutrients availability and predation occurrence too. The variables that were investigated and analyzed were not referred as much, because of a lack of materials and methods a different selection of variables was made for this research.

What is the survival rate of the total of seedlings per study area plot?

The survival rate per site varied between 0 to 88,89%.

The difference between the sites with the highest two survival rates (Ampitavanana and Kianja Maitso) is 30%. All the other sites did not differ more than maximum 13%. The standard deviation in the results shows that when the site Kianja Maitso is excluded from the calculation, the results are much more credible.

Is there a relationship between the separate variables; environment type, steepness of the slope, elevation and weed coverage and their associated survival rates?
The relationship between the influence variable environment type and the survival rates shows that the type Degraded hill has the best survival rates, followed by Secondary forest and Degraded land.
Literature references stated they importance of present forest edges to the regeneration of species of degraded areas (Cubina and Aide, 2001; Gunter et al., 2007; Myster, 2004; Uhl et al. 1988). Degraded sites can lose too much topsoil when not located close to existing forest. With this topsoil loss a lot of nutrients are disappearing too. Folke et al (2004) and du Toit, Walker and Campbell (2004) also stated that this counts for the presence of aggressive grasses too.
As explained in the chapter methods and results, the variable environment type contains three different types; Degraded land, degraded hill and secondary forest. To indicate any differences in survival rate, these types are grouped per type. By laying side by side these results it can be stated looking at the average survival rate the type degraded hill has the highest percentage, giving the degraded land type a non-adding benefit in this. Looking at the median the degraded hill also has the highest percentage. It is quite unlikely that a degraded hill can have the highest survival rate of seedlings over degraded land and secondary forest. This conclusion is not really reliable because the type secondary forest only consist of three areas. For a reliable test more areas with this type should be investigated.

According to the results there is a relationship between the influence variable slope steepness and the survival rates on the study sites. If the steepness increases a little bit, the survival rate increases too.
This conclusion is very unlikely because it is a logical assumption that when a slope gets steeper, water run-off will take place more easily and this will influence the development of the seedlings in a negative way. An explanation for this contradictory result might be a shortage in study sites and thereby data, which can lead to a not representative outcome.

There is a relationship between the influence variable elevation and the survival rates on the study sites. The results state that if the elevation decreases, the survival rate of the seedlings increases. This can be explained by the fact that Ranomafana National Park is located in a mid-altitude rainforest area on the central highlands. These are appreciably drier and cooler because of the cloud discharge of the moisture east. This could relate to the statement that some species are more used to a cooler and drier climate than others. This could explain the fact that in this research the survival rates decreases when the study areas are located higher. The exact cause of this is unclear. It could also have something to do with the higher located sites more remote and could not be prepared or maintained very well.

The results of the weed coverage data shows that when the weed coverage decreases, the survival rate per study site increases.
Like stated by Aide et al (1995), Cohen et al (1995) and Kuusipalo et al (1995) overgrowing weeds are arresting the succession of seedling development. The competition for water and nutrients is getting bigger when more weeds are occurring (Nepstad, 1989; Nepstad et al., 1995). This is why the results are of increasing survival rates when the present amount of weeds is decreasing is relating to the expectation of this process and associated literature references.

Does the survival rate of planted seedlings depend on the species planted?
The species Protorhus abrahamia (Sandramy), Schizolaena turkii (Schizoleana) and Cryptocarya (Tavolo spec.) distinguish themselves when looking at species with the most complete records. All three species grow on at least 2 or 3 of the measured study sites and have a survival rate of at least 30%.

Other species also had high survival rates but their planting records were incomplete which would lead to abnormally high survival rates and therefor are marked with an question mark.
The survival rates per species of the three selected sites differed between 1,59% to 63,61%. Most of the current species measured on these sites had a survival rate between 20 and 60%.
It was expected that these three species would be present in the total species occurrence. It was known that these were part of the endemic species that were used for the reforestation areas of RNP. During the measurements these species occurred in the top most frequent species, what could mean that these species have a higher tolerance to influence variables than others. The relation to literature references was difficult because there was not much research performed on similar topics with these endemic species in Madagascar.

What is the relationship between the seedling characteristics of the study sites per planting year and their influence variables?
When looking at the results of the year 2006, the areas Morafeno and Kelilalina differ in measured properties per species as described in the results. The average diameter and height per species were higher in the area Morafeno. This matches the survival rate of that area which is 31%. This is higher than the 14.5% of Kelilalina.
For the year 2007, the areas Ambatolahy, School Ranomafana, Ambatovaky and Anory were measured. The average diameter and height were both the highest in area School Ranomafana. This explains the high survival rate of 27.34%. Area Ambatolahy has a slightly higher survival rate of 31.82%. This could be because it matches a higher average quality of the seedlings in this area.
Year 2009 was hard to conclude because of the seven species, 5 occurred only in one area and the other species in the other one. This made it impossible to compare the areas on level of diameter, height and quality level.
For the year 2010 all the properties of the species were almost all higher in the area School Ambatolahy, followed by Friends of Madagascar. School Ambatolahy does not have the highest survival rate. Ampitavanana has the highest survival rate (58,60%), followed by Friends of Madagascar (46,67%).
All 4 areas of 2011 have quite high survival rates. This matches the data of the properties measurements. Kianja Maitso has only a couple of species and these have a slight advantage because they are growing on a nursery. This is why the survival rate is highest here. The second highest survival rate is 58,60% in Ampitavanana. This area has also the highest average diameter and height of the seedlings. Followed by Sahavondronana with 34,90% and the highest average quality and a 22,80% of Vohoparara.
For 2012, School Ambatolahy has again the highest average diameter and height but not the highest survival rate. This is the area Voloero with 45,50%, followed by Sahavondronana with 34,90% and then School of Ambatolahy with 30,14%. Last is Ambodiaviavy with 21,88%.
It is important to take into account that in the first fifty years of the succession in degraded areas most individual species will underlie a similar experience with the occurring environmental conditions (Martinez-garza, 2013). This could mean that the differences in development of the species measured and catheterized per year of this research are not really representative. The time period of measured different years is only 7 years (from 2006 till 2013) and this might be not enough to make clear statements about the development of the species.
All the researched questions were tried to be answered with supporting results. A lot of clearance is brought into the case of looking at the current situation of CVB. Like Lamb et al (2005) described, it is a real challenge to restore degraded lands because of all the obstacles they could face. The results of this research were analyzed in many ways to give an inside into the seedling growth and development of the

planted species. There were a couple of limitations to the measured results, that have something to do with incomplete and missing information in the beginning period of the research. Some changes had to be made to obtain enough relevant data for answering the questions. Despite these weaknesses, a lot of information was obtained and it connected in many ways to the existing knowledge about reforestation practices which could be important for the future of CVB's reforestation projects. This is because it can already give an inside look into how to keep record of research data relating to replanting areas and understanding a lot of the problems organizations are facing with the overall problem of the reforestation of Madagascar.

5.3 Recommendation

With the collected data of this research CVB has an indication of the success of their reforestation projects. Two questions were set up to illustrate a recommendation for future projects;

Which seedling species are recommended to use for future planting activities?
This research focused on the species used mostly for planting projects, the top 7. It would be recommended to keep using these species because CVB already has experience with planting them. Species Sandramy, Schizoleana and Tavolo came out of the survival rate per species test as the ones with highest survival rates. These species also have high records in the part of the properties measurements. Also it is recommended to keep using a mixture of species over monoculture of one species. Mixtures have the potential to increase the conservation of the biodiversity (Hastley, 2002). According to Montagnini (2000) they also improve the soil fertility and nutrients cycle. Also Lamb et al (2005) and Hall et al (2011) describe how mixed plantations also accelerate natural succession in deforested areas.

What kind of features are recommended for future planting sites to have a more successful outcome?
This question has a complicated answer because many variables were measured in the areas. Looking at the ones used for the analysis and with the associated literature check, the following structure has been created.
It would be recommended to focus reforestation project mostly in areas where already some vegetation is present. This could be near the forest borders what would help to expand the forest or close to scarce occurring trees in degraded areas. Literature shows the importance of influence of other vegetation on seedlings, like soil improvement and water retention. According to this and other research, planting seedlings far away from other vegetation, water or people to take care of them have less chance to survive.
For the variable steepness of the slope it is hard to tell where to plant, because answers of this research differ from what would be a logical, that increasing slope steepness decreases survival rate. This is substantiated with the literature about water runoff on steeper slopes which lead to a negative influence on seedling development. It would be recommended to use the slighter less steeper ones for better maintenance practices.
The elevation would not be considered a big problem when study sites are located higher, but for the same maintenance reason, areas less remote would be recommended. The last variable has nothing to do with existing possible areas but only with maintenance. The data show that it is important to keep seedlings free of weeds for as long as possible because of the big competition between them for water and nutrients. This is why it is recommended to improve cooperation with villages and try to keep this up. Also it can be helpful to make some trials with planting seedlings with compost to see the effect on the development and growth of the seedlings.

References

Adjers, G., Hadengganan, S., Kuusipalo, J., Nuryanto, K., & Vesa, L. (1995). Enrichment planting of dipterocarps in logged-over secondary forests: effect of width, direction and maintenance method of planting lnie on selected Shorea species. *Forest Ecology and Management 73*, 259-270.

Aide, M., Zimmerman, J., Rosario, M., & Herrara, L. (1995). Forest recovery in abandoned tropical pastures in Puerto Rico. *Forest Ecology and Management 77*, 77-86.

Aide, T., & Cavelier, J. (1994). Barriers to lowland tropical forest restoration in the Sierra Nevada de Santa Marta, Columbia. *Restoration Ecology 2*, 219-229.

Augsperger, C. (1984). Light requirements of neotropical tree seedlings: a comparative study of growth and survival. *J. Ecol. 72*, 777-795.

Barbosa, P., Hines, J., Kaplan, I., Martinson, H., Szczepaniec, A., & Szendrei, Z. (2009). Associational resistance and associational susceptibility: having right or wrong neighbors. *Annu. Rev. Ecol. Evol. Syst. 40*, 1-20.

Blain, D., & Kellman, M. (1991). The Effect of Water Supply on Tree Seed Germination and Seedling Survival in a Tropical Seasonal Forest in Veracruz, Mexico. *Journal of Tropical Ecology Vol. 7*, 69-83.

Brokaw, N. (1985). Gap-Phase Regeneration in a Tropical Forest. *Ecology 66*, 682-687.

Burney, D., James, H., Grady, F., Rafamantanantsoa, J., Ramilisonina, Wright, H., & Cowart, J. (1997). Environmental change, extinction and human activity: evidence from caves in NW Madagascar. *Journal of Biogeography 24*, 755-767.

Burslem, D., Grubb, P., & Turner, I. (1996). Responses to Simulated Drought and Elevated Nutrient Supply among Shade-Tolerant Tree Seedlings of Lowland Tropical Forest in Singapore. *Biotropica Vol. 28 No. 4*, 636-648.

Buschbacher, R., Uhl, C., & Serrao, E. (1988). Abandoned pastures in Eastern Amazonia 2. Nutrient stocks in the soil and vegetation. *Journal of Ecology 76*, 682-699.

Carnus, J., Parrotta, J., Brockerhoff, E., Arbez, M., Jactel, H., Kremer, A., . . . Bradley, W. (2006). Planted forests and Biodiversity. *Journal of Forestry Vol. 104*, 65-77.

Chazdon, R. (1988). Sunflecks and their imporatance to forest understory plants. *Adv. Ecol. Res. 18*, 1-63.

Chazdon, R., & Fetcher, N. (1984). Photosynthetic light envrionments in a lowland tropical rain forest in Costa Rica. *J. Ecol. 72*, 553-564.

Cohen, A., Singhakumara, B., & Ashton, P. (1995). Releasing rain forest succession: a case study in the Dicranopteris linearis fernlands of Sri Lank. *Rest. Ecol. 3*, 261-270.

Cubina, L., & Aide, M. (2001). The Effect of Distance from Forest Edge on Seed Rain and Soil Seed Bank in a Tropical Pasture. *Biotropica 33*, 260-267.

Cullen, L., Bodmer, R., & Padua, C. (2000). Effects of hunting in habitat fragments of the Atlantic forests, Brazil. *Biological Conservation 95 (1)*, 49-56.

Davidson, R., Gagnon, D., Mauffette, Y., & Hernandez, H. (1998). Early survival, growth and foliar nutrients in native Ecuadorian trees planted on degraded volcanic soil. *Forest Ecology and Management 105*, 1-19.

Denslow, J. (1980). Gap partitioning among tropical rainforest trees. *Biotropica 12*, 47-55.

dos Santos, U., Goncalves, J., & Feldpausch, T. (2006). Growth, leaf nutrient concentration and photosynthetic nutrient use efficiency in tropical tree species planted in egraded areas in central Amazonia. *Forest Ecology and Management 226*, 299-309.

du Toit, J., Walker, B., & Campbell, B. (2004). Conserving tropical nature: current challenges for ecologists. *Trends in Ecology and Evolution Vol. 19*, 12-17.

Eagles, C. (1967). The effect of temperature on vegetative growth in climatic races of Dactylis glomerata in controlled environments. *Annals of Botany 31*, 31-39.

Enserink, M. (1999). Biological invaders sweep in. *Science 285 (5435)*, 1834-1836.

Ferreira, L., & Laurance, W. (1997). Effects of forest fragmentation on martality and damage of selected trees in Central Amazonia. *Conservation Biology 11 (3)*, 797-801.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., & Holling, C. (2004). Regime Shifts, Resilience, and Biodiversity in Ecosystem Management. *Annu. Rev. Ecol. Evol. Syst. 35*, 557-581.

Forrester, D., Bauhus, H., & Cowie, A. (2005). on the success and failure of mixed-species tree plantations: lessons learned from a model system of Eucalyptus globulus and Acacia meamsii. *Forest Ecology and Management 209*, 147-155.

Gerhardt, K. (1993). Tree seedlign development int ropical dry abandoned pasture and secondary forest in Costa Rica. *J. Veg. Sci. 4*, 95-102.

Goodman, S., & Rakotondravony, D. (2000). The effects of forest fragmentation and isolation on insectivorous small mammals (Lipotyphla) on the Central High Plateau of Madgascar. *Journal of Zoology*, 193-200.

Grime, J. (2002). *Plant Strategies, Vegetation Processes, and Ecosystem Properties* (2e ed.). West Sussex, England: John Wiley & Sons Ltd.

Gunter, S., Weber, M., & Erreis, R. (2007). Influence of distance to forest edges on natural regeneration of abandoned pastures: a case study in the tropical mountain rain forest of Southern Ecuador. *Eur J Forest Res 126*, 67-75.

Hall, J., Ashton, S., Garen, E., & Jose, S. (2011). The ecology and ecosystem services of native trees: implications for reforestation and land restoration in Measoamerica. *Forest Ecology and Management*, 1553-1557.

Hardwick, K., Healey, J., Elliott, S., Garwood, N., & Anusarnsunthorn, V. (1997). Understanding and assisting natural regeneration processes in degraded seasonal evergreen forests in northern Thailand. *Forest Ecology and Management 99*, 203-214.

Harper, G., Steininger, C., Tucker, D., Juhn, D., & Hawkins, F. (2007). Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation 34 (4)*, 325-333.

Harris, L. (1984). *The Fragmented Forest: Island biogeographic Theory and the Preservation of biological Diversity.* Chicago, IL, USA: The University of Chicago Press.

Ingram, J., & Dawson, T. (2005). Climate change impacts and vegetation response on the island of Madagascar. *Phil. Trans. R. Soc. A 363*, 55 - 59.

Innes, J. (2010). Madagascar rosewood, illegal logging and the tropical timber trade. *Madagsacar conservation & development Vol.5*.

Jansen, A. (1997). Terrestrial invertebrate community structure as an indicator of the success of a tropical rainforest restoration project. *Rest. Ecol. 5*, 115-124.

Jarosz, L. (1993). Defining and Explaining Tropical Deforestation: Shifting Cultivation and Population Growth in Colonial Madagascar (1896-1940). *Economic Geography Vol. 69 No. 4 Environment and Development, Part 2*, 366-379.

Kapos, V. (1989). Effects of isolation on the water status of reforested patches in the Brazilian Amazon. *Journal of Tropical Ecology 5 (2)*, 173-185.

Khurana, E., & Singh, J. (2001). Ecology of tree seeds and seedlings: Implications for tropical forest conservation and restoration. *Current science Vol. 80 No 6.*, 748-757.

King, D. (1994). Influence of Light Level on the Growth and Morphology of Saplings in a Panamanian Forest . *American Journal of Botany Vol. 81*, 948-957.

Lamb, D., Erskine, P., & Parrotta, J. (2005). Restoration of degraded tropical forest landscapes. *Science 310*, 1628-1632.

Letourneau, D., Armbrecht, I., Rivera, B., Lerma, J., Carmona, E., Daza, M., . . . Gutierrez, C. (2011). Does plant diversity benefit agroecosystems? a synthetic review. *Ecological society of amerika Vol. 21*, 9-21.

Lieberman, M., Lieberman, D., Hartshorn, G., & Peralta, R. (1985). Small-scale altitudinal variationi n lowland wet tropical forest vegetation. *Journal of Ecology 73*, 505-516.

Lloyd, P., & Pigott, C. (1967). The influence of soil conditions on the course of succession on the chalk of souther england. *Journal of Ecology*, 137-146.

Markesteijn, L., Poorter, L., Paz, H., Sack, L., & Bongers, F. (2011). Ecological differentiation in xylem cavitation resistance is associated with stem and leaf structural traits. *Plant cell Environ. 34*, 137-148.

Martinez-Garza, C., Bongers, F., & Poorter, L. (2013). Are functional traits good predictors of species performance in restoration plantings in tropical abandoned pastures? *Forest Ecology and Management 303*, 35-45.

Mayaux, P., Holmgren, P., Achard, F., Eva, H., Stibig, H., & Branthomme, A. (2005). Tropical forest cover change in the 1990s and options for future monitoring. *Philisophical Transactions of the Royal Society of London Series B-Biological Sciences 360 (1454)*, 373-384.

Meziane, D., & Shipley, B. (1999). Interacting components of interspecific relative growth rate: constancy and change under differing conditions of light and nutrient supply. *Functional Ecology 13*, 611-622.

Montagnini, F. (2000). Accumulation in above-ground biomass and soil storage of mineral nutrients in pure and mixed plantations in a humid tropical lowland. *Forest Ecology and Management 134*, 257-270.

Myster, W. (2004). Regeneration filters in post-agricultural fields in Puerto Rico and Ecuador. *Vegetation 172*, 199-209.

Nepstad, D. (1989). *Forest regrowht in abandoned pastures of eastern Amazonia: limitations to tree seedling survival and growth.* New Have, CT: Yale University.

Nepstad, D., Carvalho, C., Davidson, E., Jipp, P., Lefebvre, P., Negreiros, G., Vieira, S. (1994). The rol of deep roots in the hydrologica and carbon cycles of Amazonian forests and pastures. *Nature 372*, 666-669.

Nepstad, D., Uhl, C., & Serrao, E. (1990). Surmounting barriers to forest regeneration in abandoned, highly degraded pastures: a case study from Paragomina, Para, Brazil. In A. Anderson, *Alternatives to Deforestation: Steps Toward Sustainable Use of the Amazon Rain Forest* (pp. 215-229). New York: Columbia University Press.

Nepstad, D., Uhl, C., Pereira, C., & Cardosa da Silva, J. (1996). A comparative study of tree establishment in abandoned pasture and mature forest of eastern Amazonia. *Oikos 76*, 25-39.

Nobre, C., Sellers, P., & Shukla, J. (1991). Amazonian deforestation and regional climate change. *J. Climate 4*, 957-988.

Pareliussen, I., Gunilla, E., Olsson, A., & Scott Armbruster, W. (2006). Factors Limiting the Survival of Native Tree Seedlings Used in Conservation Efforest at the Edges of Forest Fragments in Upland Madagascar. *Restoration Ecology*, 196-203.

Parrotta, J., Tunrbull, J., & Jones, N. (1997a). Catalyzing native forest regeneration on degraded tropical lands. *Forest Ecology and Management 99*, 1-7.

Peters, W., & Neuenschwader, L. (1988). *Slash and burn, Farming in the Third World forest.* Moscow, Idaho, USA: University of Idaho Press.

Pickett, S. (1985). *The Ecology of Natural Distrubance and Patch Dynamics.* London: Academic Press.

Plath, M., Mody, K., Potvin, C., & Dorn, S. (2011b). Establishment of native tropical timber trees in monoculture and mixed-species plantations: small-scale effects on tree performance and insect herbivory. *Forest Ecology and Management 261*, 741-750.

Poorter, L. (1999). Growth responses of 15 rain-forest tree species to a light gradient: the relative importance of morphological and physiological traits. *Functional Ecology 13*, 396-410.

Popma, J., & Bongers, F. (1988). The effect of canopy gaps on growth and morphology of seedlings of rain-forest species. *Oecologia 75*, 625-632.

Pugnaire, F., & Valladares, F. (1999). *Handbook of Functional Plant Ecology.* USA: Marcel Dekker, Inc.

Rakotosamimanana, B. (2003). Foreword in: The Natural history of Madagsacar. In S. G. Benstead, *The Natural history of Madagascar.* Chicago, IL, USA: University of Chicago Press.

Richards, P. (1952). *The tropical rain forest: an ecological study.* Cambridge: Cambridge University Press.

Rincon, E., & Huante, P. (1993). Trees. 202-207.

Sanchez-De Leon, Y., Zou, X., borges, S., & Ruan, H. (2003). Recovery of Native Earthworms in Abandoned Tropical Pastures. *Conservatio Biology Vol. 17*, 999-1006.

Sayer, J., & Whitmore, T. (1992). *Tropical Deforestation and Species Extinction.* London: Chapman & Hall.

Shono, K., Stuart, J., & Chua Yen, K. (2006). Regeneration of native plant species in restored forests on degraded lands in Singapore. *Forest Ecology and Management 237*, 574-582.

Uhl, C. (1987). Factors controlling succession following slash-and-burn agriculture in Amazonia. *J. Ecol. 75 (2)*, 377-407.

Uhl, C. (1988). Restoration of degraded lands in the Amazon basin. In E. (. Wilson, *Biodiversity* (pp. 326-332). Washington: National Academy Press.

Uhl, C., & Jordan, C. (1984). Succession and Nutrient Dynamics Following Forest Cutting and Burning in Amazonia. *Ecological Society of America Vol. 65*, 1476-1490.

Uhl, C., Buschbacher, R., & Serrao, E. (1988). Abandoned pastures in eastern Amazonia. I. Patterns of plant succession. *J. Ecol. 76*, 663-681.

Uhl, C., Nepstad, D., Buschbacher, R., Clark, K., Kauffman, B., & Subler, S. (1990). Studies of ecosystem response to natural and anthropogenic disturbance provide guidelines for designing sustainable land-use systems in Amazonia. In e. A. Anderson, *Alternatives to Deforestation: Steps Toward Sustainable Use of the Amazon Rain Forest* (pp. 24-42). New York: Columbia University Press.

Violle, C., Navas, M., Vile, D., Kazakou, E., fortunel, C., Hummel, L., & Garnier, E. (2007). Let the concept of trait be functional. *Oikos 116*, 882-892.

Watson, R., Noble, I., Ravindranath, N., Verardo, D., & Dokken, D. (2000). *Land Use, land Use Change and Forestry: summary for Policy Makers.* Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Wheiher, E., & Keddy, P. (1999). Assembly rules as general constraints on community composition. In E. Wheiher, & Keddy P., *Ecological assembly rules: perspectives, advances, retreats* (pp. 251-271). Cambridge: Cambridge University Press.

Whitmore, T. (1984[2]). *Tropical rain forests of the Far East .* Oxford, England: Clarendon Press.

Whitmore, T., & Burnham, c. (1975). *Tropical rain forests of the Far East.* Oxford: Clarendon Press.

Williams, M., Malhi, Y., Nobre, A., Rastetter, E., Grace, J., & Pereira, M. (1998). Seasonal variation in net carbon exchange and evapotranspiration in a Braziliian rain forest: a modelling analysis. *Plant, Cell and Environment 21*, 953-968.

Wright, R., Wein, R., & Dancik, B. (1992). Population differentiation in seedling root size between adjacent stands of Jack Pine. *For. Sc. 38*, 777-785.

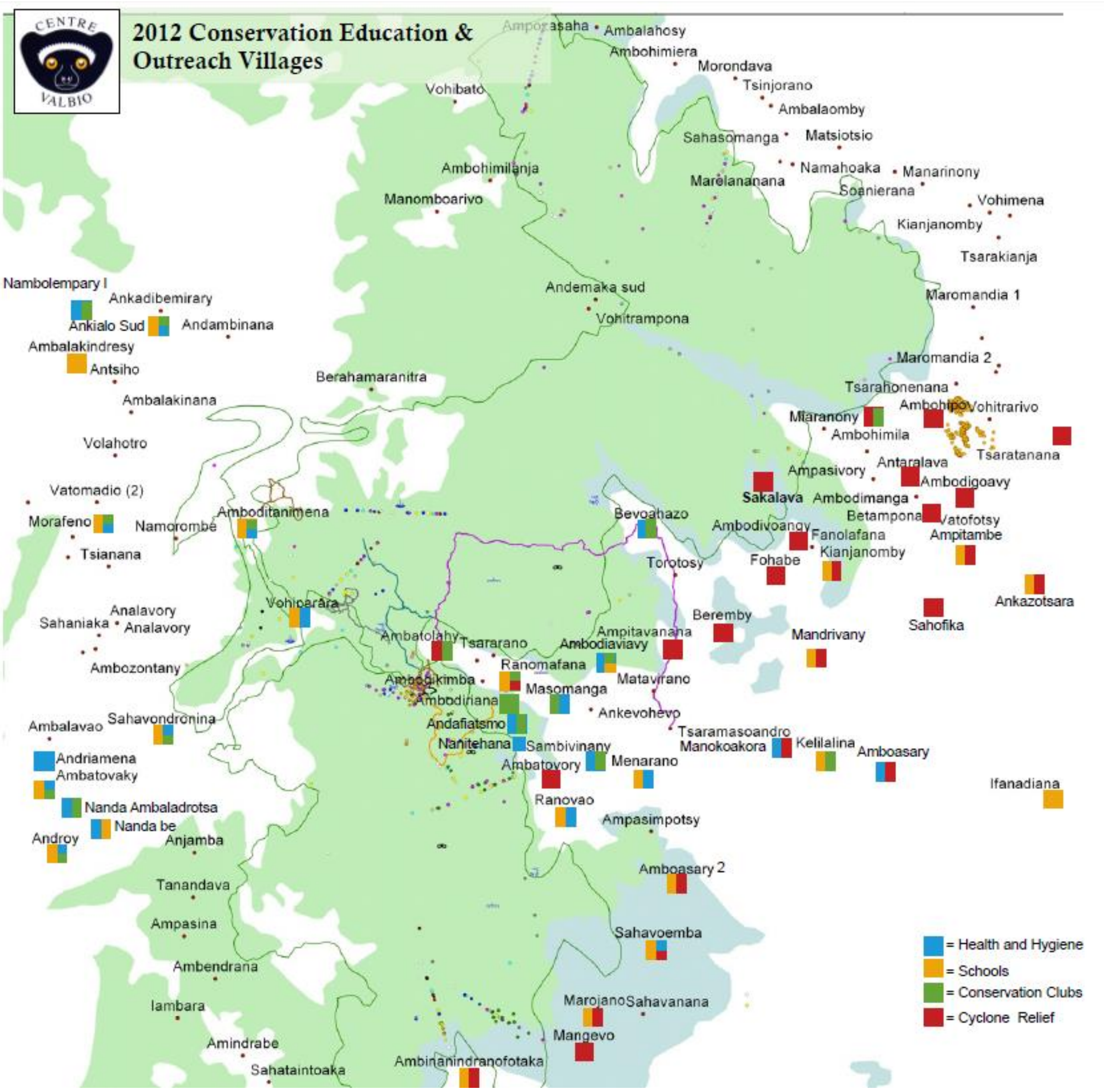
Yu, Z., Wang, Z., & He, S. (1994). Rehabilitation of eroded tropical costal land in Guangdong, China. *J. Trop. For. Sci. 7*, 28-38.

Visited websites:

www.fao.org (10-09-13)
www.iias.nl (14-11-2013)
www.kew.org (14-11-2013)
www.mobot.org (14-11-2013)
www.madagascarpartnership.org (18-12-13)
www.news.mongabay.com (18-12-13)
www.stonybrook.edu (10-09-2013)
www.weather2Travel.com (20-05-2014)
www.wildmadagascar.org (14-11-2013)

Appendices

A. *Map of Conservation, Education & Outreach Villages locations*



B. Overview available areas with number of planted seedlings

Year	**Location**	**Number**
2007-2009	EPP Ambatovaky	600
	EPP Androy	200
	EPP Vohiparara	600
	Ambalakindresy	205
	EPP Kelilalina (2006)	400
	EPP Morafeno (2006)	600
	EPP Ranomafana	556
	EPP Ambatolahy	88
2010	Lycée Ifanadiana	50
	Kianjavato	500
	Ampitavanana	200
	EPP Ambodiaviavy	110
	Centrest	100
	Madame Alice Masomanga	0
	Soafianara	180
	Fokontany Ambatolahy	126
	Lycée Ambalakindresy	80
	Ivato-Vondrozo	750
	Vohiparara	140
	Friends of Madagascar	30
2011	Manakara (Region V7V)	250
	Association de guide Ranomafana	20
	Sahavondronana	200
	Ampitavanana	300
	Vohiparara	60
	Kianja Maitso	18
2012	MNP Voloero	1000
	VOI Sahavondrona	800
	Village Ambodiaviavy	50
	EPP Ambatolahy	20

C. *Field form*

Location:		Plotnr:	Fieldform nr:		Start time:	:
Identificator:			Date:	/ /	End time:	:
Wheather condition:			Size:		Slope:	
Vegetation type:					Elevation:	
Soil information:					Age:	

Nr	Species name	DBH	H	Q	Pic.N	Remarks
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						

Waypoints:

Fieldform

Water availability:	
Management proceedings/weed control:	
Nearby Vegetation:	
Animal species:	
Use of compost:	

D. Overview all species per study site with associated average properties

Study sites	Local name	Number	Average diameter	Average height	Average quality
Ambalakindresy 80	Mahanoro	1	0.50	32.00	3.00
Ambalakindresy 80	Rotra	1	0.60	10.00	2.00
Ambalakindresy 80	Sandramy	1	0.70	35.00	1.00
Ambatolahy	Harina	1	1.20	160.00	1.00
Ambatolahy	Mahanoro	1	0.70	85.00	3.00
Ambatolahy	Nato voraka	2	1.15	72.50	1.00
Ambatolahy	Ramy	8	1.39	72.25	1.25
Ambatolahy	Sandramy	6	0.97	126.33	1.00
Ambatolahy	Schizoleana	4	0.73	105.25	1.50
Ambatolahy	Varongy	6	0.60	56.33	1.00
Ambatovaky	Sandramy	11	0.84	97.82	1.18
Ambatovaky	Schizoleana	12	0.52	31.42	1.25
Ambatovaky	Varongy	28	0.64	52.43	1.11
Ambatovaky	Voamboana	1	0.90	52.00	2.00
Ambodiaviavy	Hafitrataivalales	1	0.30	36.50	2.00
Ambodiaviavy	Rotra	5	0.42	54.70	1.00
Ambodiaviavy	Sandramy	9	0.39	65.78	1.00
Ambodiaviavy	Schizoleana	4	0.33	22.50	1.75
Ambodiaviavy	Tavolo spec.	9	0.46	44.49	1.00
Ambodiaviavy	Voatsirivodrivotra	7	0.39	53.76	1.00
Ampitavanana	Harina	38	0.72	89.61	1.34
Ampitavanana	Lanary spec.	30	0.60	55.87	1.10
Ampitavanana	Nato voraka	47	0.84	61.65	1.02
Ampitavanana	Sandramy	37	1.03	151.11	1.05
Ampitavanana	Schizoleana	32	1.00	107.53	1.03
Ampitavanana	Tavolo spec.	53	0.76	63.96	1.11
Ampitavanana	Varongy	56	0.71	77.39	1.05
Anroy	Ambora	2	0.80	42.50	2.00
Anroy	Lanary spec.	3	1.15	54.13	1.00
Anroy	Mahanoro	2	1.71	78.55	1.00
Anroy	Ramy	4	0.85	37.80	1.50
Friends of Madagascar	Harina	4	3.85	250.00	1.25
Friends of Madagascar	Nato voraka	2	1.52	98.50	1.00
Friends of Madagascar	Sandramy	4	2.48	199.25	1.00
Friends of Madagascar	Tavolo spec.	2	1.39	91.50	1.00
Friends of Madagascar	Varongy	2	1.70	111.00	1.00
Ifanadiana	Ramy	1	3.00	141.00	1.00
Ifanadiana	Rotra	1	1.20	122.00	1.00
Ifanadiana	Voamboana	1	1.00	45.00	1.00
Kelilalina	Hafotra	4	19.75	612.50	1.00
Kelilalina	Harina	15	1.61	207.00	1.40
Kelilalina	Lanary spec.	1	0.60	40.00	1.00
Kelilalina	Mahanoro	2	2.25	229.50	1.50
Kelilalina	Nato voraka	4	1.73	167.50	1.00
Kelilalina	Ramy	6	2.48	289.00	1.17

Kelilalina	Rotra	1	2.00	320.00	1.00
Kelilalina	Schizoleana	4	1.73	207.50	1.25
Kelilalina	Tavolo spec.	12	1.05	149.67	1.00
Kelilalina	Vanana	2	3.55	375.00	1.00
Kelilalina	Varongy	3	1.40	209.67	1.00
Kelilalina	Vitanina	2	4.00	288.50	1.00
Kelilalina	Voamboana	2	1.40	122.00	1.00
Kianja Maitso	Hafotaikalalao	1	3.10	190.00	1.00
Kianja Maitso	Lanary spec.	1	0.60	69.00	2.00
Kianja Maitso	Longtra	1	0.60	55.00	2.00
Kianja Maitso	Mahanoro	1	2.00	185.00	1.00
Kianja Maitso	Nato voraka	1	0.70	79.00	1.00
Kianja Maitso	Rotra	1	0.40	60.00	1.00
Kianja Maitso	Schizoleana	1	0.50	72.00	2.00
Kianja Maitso	Taviavola	1	0.60	15.00	1.00
Kianja Maitso	Tavolo spec.	2	0.80	85.50	1.00
Kianja Maitso	Vonitra	6	0.42	77.83	1.17
Morafeno	Hafotra	4	2.60	206.25	2.25
Morafeno	Harina	2	2.40	252.00	1.50
Morafeno	Kimbaletaka	5	2.26	206.60	1.00
Morafeno	Mahanoro	3	2.93	275.00	1.00
Morafeno	Mananitra	14	2.16	190.57	1.14
Morafeno	Nato voraka	1	0.50	31.00	2.00
Morafeno	Ramy	2	6.80	425.00	1.00
Morafeno	Sandramy	47	2.47	274.30	1.28
Morafeno	Tavolo spec.	10	2.51	209.10	1.00
Morafeno	Voamboana	5	2.02	146.80	1.20
Sahavondronana	Harina	68	0.39	24.59	1.62
Sahavondronana	Longtra	2	0.65	37.50	1.50
Sahavondronana	Nato voraka	6	0.62	29.83	1.33
Sahavondronana	Sandramy	97	0.48	46.85	1.55
Sahavondronana	Schizoleana	26	0.46	33.96	1.23
Sahavondronana	Tavolo spec.	150	0.46	34.75	1.75
School ambatolahy	Hafotra	3	6.17	266.67	1.33
School ambatolahy	Harina	1	2.90	220.00	2.00
School ambatolahy	Lanary spec.	3	1.53	133.00	1.00
School ambatolahy	Mahanoro	1	3.00	37.00	1.00
School ambatolahy	Nato voraka	5	2.88	139.60	1.40
School ambatolahy	Ramy	2	5.95	335.00	1.00
School ambatolahy	Tavolo spec.	25	3.60	213.04	1.12
School ambatolahy	Vanana	1	4.10	170.00	1.00
School ambatolahy	Varongy	3	3.30	297.33	1.00
School ranomafana	Ambaletaka	1	1.60	46.00	2.00
School ranomafana	Ambora	4	3.75	337.50	1.50
School ranomafana	Ambovitsika	2	5.45	425.00	1.00
School ranomafana	Hamfiska	1	3.50	430.00	1.00
School ranomafana	Harina	8	8.33	543.75	1.13
School ranomafana	Lanary spec.	6	1.82	207.00	1.17

School ranomafana	Mahanoro	2	3.25	305.00	2.00
School ranomafana	Maka	2	6.75	475.00	1.00
School ranomafana	Mananitra	4	2.90	350.00	1.75
School ranomafana	Nato voraka	6	2.28	159.67	1.17
School ranomafana	Rahiaka	9	5.08	470.78	1.11
School ranomafana	Ramandriona	1	4.20	550.00	1.00
School ranomafana	Ramy	1	4.10	430.00	1.00
School ranomafana	Rotra	4	3.75	363.50	1.00
School ranomafana	Sandramy	24	2.70	328.75	1.17
School ranomafana	Schizoleana	1	3.50	175.00	1.00
School ranomafana	Sitanona	1	3.90	300.00	1.00
School ranomafana	Tano	1	2.60	250.00	1.00
School ranomafana	Tavolo spec.	11	6.88	524.55	1.09
School ranomafana	Vanana	1	4.50	400.00	1.00
School ranomafana	Varongy	53	3.73	355.17	1.13
School ranomafana	Vitanina	4	5.05	355.00	1.00
School ranomafana	Voamboana	4	2.45	143.00	1.25
School ranomafana	Voarafy	1	5.30	300.00	1.00
Soafianara	Harina	19	1.87	194.79	1.05
Soafianara	Rotra	3	0.89	112.00	1.00
Soafianara	Sandramy	1	0.70	141.00	1.00
Soafianara	Schizoleana	1	0.60	75.00	1.00
Vohiparara	Harina	28	0.46	71.85	1.29
Vohiparara	Lanary spec.	10	0.41	49.22	1.50
Vohiparara	Nato voraka	15	0.48	39.67	1.07
Vohiparara	Ramy	4	0.60	60.75	1.25
Vohiparara	Sandramy	32	0.69	99.59	1.25
Vohiparara	Schizoleana	40	0.55	86.13	1.25
Vohiparara	Tavolo spec.	37	0.47	39.97	1.30
Vohiparara	Varongy	15	0.43	51.87	1.20
Vohiparara	Vitanina	1	0.40	44.00	1.00
Vohiparara	Voamboana	1	0.30	26.00	1.00
Voloero	Harina	48	0.45	25.21	1.15
Voloero	Lanary spec.	64	0.48	27.89	1.38
Voloero	Longtra	1	0.60	36.00	2.00
Voloero	Nato voraka	51	0.56	28.32	1.18
Voloero	Rotra	1	0.30	48.00	1.00
Voloero	Sandramy	65	0.43	31.66	1.58
Voloero	Tavolo spec.	139	0.63	37.13	1.32
Voloero	Varongy	45	0.44	25.96	1.56
Voloero	Voamboana	41	1.12	49.80	1.34

E. Overview environment types with survival rates of all areas

Overview degraded land with survival rate of 7 sites

Study site	#Seedlings planted	#Seedlings measured	Survival rate (%)
Ambalakindresy 205	205	0	0,00
Ambalakindresy 80	80	3	3,75
Ifanadiana	50	3	6,00
Soafianara	180	24	13,33
Morafeno	300	93	31,00
Voloero	1000	455	45,50
Kianja Maitso	18	16	88,89

Overview degraded hill with survival rate of 8 sites

Study site	#Seedling planted	#Seedlings measured	Survival rate (%)
Anroy	200	11	5,50
Kelilalina	400	58	14,50
Ambodiaviavy	160	35	21,88
School ambatolahy	146	44	30,14
Ambatolahy	88	28	31,82
Sahavondronana	1000	349	34,90
Friends of Madagascar	30	14	46,67
Ampitavanana	500	293	58,60

Overview secondary forest with survival rate of 3 sites

Study site	#Seedlings planted	#Seedlings measured	Survival rate (%)
Ambatovaky	600	52	8,67
Vohiparara	800	183	22,88
School ranomafana	556	152	27,34