Agroforestry in Sierra Leone – examining economic potential with carbon sequestration

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Abstract

This thesis aimed to examine the possibilities and benefits of implementing agroforestry projects in Sierra Leone by comparing different agroforestry systems used in a Tanzanian project that consider carbon sequestration. Farmers involved in this type of projects get income from sold carbon credits as well as from other products that an agroforestry system could provide.

Sierra Leone is one of the most vulnerable countries to climate change, with most of the population living in rural conditions. It was investigated what the potential economic and environmental impact different agroforestry systems considering carbon storage could have in Sierra Leone. The study was based on empirical material from a case community Makari. The conclusions were that Sierra Leone could benefit greatly from agroforestry projects, especially at community level where it could provide additional sources of food and income. From a greater perspective it could give environmental benefits as well as securing wood commodities like fuelwood for the future. Starting up a project would however be a high risk investment with a troublesome implementation process and complications on a daily basis.

Keywords; Sierra Leone, carbon trade, carbon sequestration, agroforestry, Makari
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1. Introduction

The last years we have begun to see the negative effects of climate changes around the world with increasing temperatures in the atmosphere, mostly in the poorer countries (IPCC, 2013).

In the industrialized regions, climate compensating initiatives; i.e. carbon sequestration projects have rapidly been increasing the last decade and a growing number of companies/organizations are aiming at a net zero carbon footprint. To meet this demand, organizations are providing reforestation projects to decrease the carbon dioxide in the atmosphere – many of these projects are currently taking place in East African countries like Tanzania, where much research has been done in the fields of integrating trees in agricultural landscapes i.e. agroforestry (Faße & Grote, 2013) and carbon sequestration (Bozmoski & Hultman, 2010).

Sierra Leone is considered to be the third most vulnerable country in the world to climate change (Mears, 2013). As Sierra Leone has already gone through several years of civil war (1991-2002), a thesis on reforestation in Sierra Leone seems to be of importance for several purposes including sustainable livelihood. Around 75% (Sowa, 2013a) of the West African population work as farmers which is also the case in Sierra Leone. Poverty is wide spread and the few ways of securing an income are from working for the industrial companies (mining, road constructions etc.) or engage in farming activities.

Since securing food year around is a big challenge for most communities it is common that the whole village needs to engage in farming activities in order to provide enough food, which also impedes the farmers from taking other jobs (Sowa, 2013a). The farming activities are also the main causes of land degradation and deforestation since the methods used are basic and unsustainable. Examples are; lack of forest management models and upheld regulations. This leads to unsustainable harvesting of forest products like firewood. Lack of knowledge in soil conversion and overuse of fertilizers (Assah, 2013) make agriculture unsustainable.

Reforestation projects in Sierra Leone are not prioritized by the government due to other existing basic issues like healthcare and education that takes precedence. The efforts that have been made to reforest certain areas are seldom done with long term focus and the success rate has in general been low due to lack of long term commitment.

1.1 Objective and research questions

The studies previously conducted concerning impact of reforestation are mostly done from a macro perspective. I was interested to see if it was
possible to go deeper in detail and find out what the impact of reforestation would have on a farmer/village level. This study focused on the economic and environmental impact of an agroforestry reforestation project with carbon sequestration in mind on a farmer and a rural community like Makari in Sierra Leone. The research questions that this study tried to investigate and answer were:

- Could it be possible to start a reforestation project in Sierra Leone that considers carbon binding benefits?
- What are the economic impacts of a reforestation project that considers carbon binding benefits at a farmer and community level?
- How much carbon dioxide do a farmer, village, chiefdom and district level sequestrate using different agroforestry methods?

1.2 Limitations

Climate change and reforestation is a large and complex subject which subsequently means that this thesis needed to exclude a lot of information about efforts and programmes that aims to improve climate conditions in different ways. There are many NGOs (Non-Government Organization) and organizations active in Sierra Leone working with environmental issues including reforestation. Although they deserve to be mentioned, they have not been included in the thesis. Some of these organizations are; ENFORAC (Environmental Forum for Action), SLEPA (Sierra Leone Environmental Protection Agency) etc.

No available GIS data (e.g. land boundary information) with sufficient details could be found online for Sierra Leone. In the search for this data I also asked organizations like; UNDP (United Nations Development Programme), EPA (Environmental Protection Agency) and Ministry of lands and country planning, but the data could not be found.
2. Method

In order to answer the research questions a literature study as well as a case study were performed. The case study was made on the Makari village located in the Bombali district in Sierra Leone.

Since Eastern Africa and especially Tanzania has had a lot of successful reforestation projects the last years, a lot of useful information thought to be learned from their experiences and then be adopted to Sierra Leonean conditions. One of these successful projects is the Emiti Nibwo Bulora project. To find out ways and alternatives for Makari and Sierra Leone to aim its future reforestation efforts the Emiti Nibwo Bulora project was used as a model. This model project provided background data and parameters for calculations and estimations made for Makari.

To be able to adopt experiences of the Emiti Nibwo Bulora project it was important to understand the similarities and differences between the two countries Sierra Leone and Tanzania. The literature study was thus based on; project documents and scientific research papers on reforestation, carbon storage and agroforestry in Tanzania and in Sierra Leone. In addition, numerous research reports were included to cover aspects such as timber and fuelwood trading and agroforestry.

The literature study was complemented with information gathered in the field. Information was collected on field trips around Sierra Leone together with the NGO ENFORAC as well as with ICRAF (International Research Institute). Then it was possible to assess information on the conditions of the native communities. One field visit was made to Makari to help understand the conditions and prerequisites needed for starting a reforestation project. Also a high level seminar was attended together with national officials, representatives from the EU Delegation and national and international forest specialists. The focus of the seminar was to start a project to protect and reforest large parts of Sierra Leone in order to bind carbon and to counter degradation and negative aspects of deforestation - a so called REDD+ project.

The analysis of Makari, Sierra Leone, was based on an estimated potential size of a reforestation project. Parameters from the literature as well as from the model project in Tanzania were used to estimate income and cost for four different agroforestry systems in Sierra Leone: Woodlot, Boundary Planting, Dispersed Interplanting and Fruit Orchard. Potential income at different geographical levels was estimated as well as the carbon sequestration potential. The analysis also included identification of potential risks.

The structure of the thesis follows the principle of visualizing on a national level first then on a local level. The chapters in each level will follow the
structure of covering forest impacts with carbon sequestration and environment. Then cover economy in general and potential income. The analysis chapter will differ from this structure and start with using a local perspective as a baseline in order then to see impact on larger national level.
3. Background/literature study

3.1 Tanzania

Tanzania is located on the East Coast of Africa bordering the Indian Ocean, between Kenya and Mozambique (Figure 1). It covers an area of 947,300 km² which makes it the 31st largest country in the world. It lies between latitude 1° and 12°S of the Equator and longitudes 30° and 40°E (CIA, 2013a). The climate in Tanzania varies from tropical along the coast with temperatures between 20° and 30°C to the highlands where temperatures range between 10° and 20°C. The rainy season ranges from October to April. From Lake Victoria to the coast there is an extended rain period from October to December and from March to May.

An increasing population in Tanzania has led to increased pressure on the forests causing deforestation in searching for firewood, charcoal and building materials (UNDP, 2013a). The forests of Tanzania stand for over 92% of the energy resources (firewood and charcoal) (UNEP, 2013). Thus, forestry is very important for Tanzania and it plays an important role for the economy. However, in relative terms, forestry only contributes to 3.4% of the country’s GDP (gross domestic product). According to UNEP (2013) forests and woodlands cover 37.8% of the total land mass which is approximately 33.5 million hectares.

Figure 1. Map of Africa where Sierra Leone is marked as red to the left and Tanzania is marked as red to the right.

Tanzania ranks as having one of the most biologically diverse forests in the world (place 12 of most diverse countries in the world). These forests are important for the wild life and holds Africa’s largest number of mammals, second largest number of plants, third largest number of birds, fourth largest number of amphibians and fourth largest number of reptiles. The forests of
Tanzania stands for over 92% of the energy resources (firewood and charcoal) (UNEP, 2013)

In 1987 trade policies through policy incentives aimed to increase the export of forest products. The measurements taken were; removal of trade distortions in production and marketing of forest products to ensure effective market-determined prices, removal of fiscal and non-fiscal barriers in trade and promotion in the forestry sector. This resulted in a rapid growth in domestic and foreign trade. However, the largest use of timber products is still in firewood for local markets, around 60%. The downside of the trade policies is that Tanzania lost almost 20% of its forests during the period 1990 to 2010 (Mongabay, 2013), which has drastically affected the amount of carbon dioxide in the atmosphere (Fabiano et al., 2011). The trade liberalization in the forestry sector increased the extraction of forest products and therefore also increased deforestation, which have had a negative impact on the environment. The reforestation done by the government has been minimal and no other organization has been responsible to support the rehabilitation of the deforested areas (UNEP, 2013).

Tanzania is a poor country in terms of income per capita, but has a high overall growth rate because of gold extraction and tourism. The country has transitioned to an open market economy, with a few exceptions in telecommunications, banking, energy, and mining, where the government still has a strong presence (CIA, 2013a). The GDP was $609 per capita in 2012 (Worldbank, 2012) with an annual growth rate of 6% from 2009 to 2012 (IMF, 2013). The corruption ranking of Tanzania is number 102 of 174 countries. The poverty ranking was in 2002 52 out of 157 (CIA, 2013a). Since 1990 agroforestry programs have been introduced and established in order to halt deforestation and provide alternative livelihoods for people in Tanzania. These projects are managed by NGOs like Vi-Agroforestry.
3.2 Sierra Leone

Sierra Leone is a small country which covers an area of 72 300 km\(^2\) on the western coast of Africa between Guinea to the northeast and Liberia to the southeast (Figure 1). It is positioned between latitudes 7° and 10°N (a small area is south of 7°) and longitudes 10° and 14°W. The climate of Sierra Leone is tropical with a rainy season and a dry season. The rainy season ranges from March to October and the dry season from November to April. The annual average temperature is between 23° and 29°C (CIA, 2013b).

Sierra Leone was originally, before large scale deforestation began, covered with more than 60% dense evergreen, semi-deciduous forest types. Today almost 70% of the original forest has been cut down so that the ground could be used for slash-and-burn agriculture, large scale agricultural investments and timber production for construction wood and mining industry. Only 5% of the primary forest is still intact around the hills and mountain tops (Sowa, 2013). Pictures of primary forests and areas previous covered with forests can be seen in Appendix 5.

Since the end of the civil war in 2001 the wood trade industry has been growing and today it is an important source of income as well as it provides essential fuel in the form of firewood and charcoal, the largest energy source available for the people. Other large commodities on the market are fiber boards and poles for building.

The control of the timber trade is complicated and not well governed. The fee collection method is based on informal localized systems, which makes it ineffective and inconsistent. Some traders pay for example minimal fees whereas others have to operate illegally in order to make profit (Munro & van der Horst, 2012). The export of timber from Sierra Leone is small scale due to the government temporarily banning logging on and off due to uncontrolled and unsustainable logging. In 2008 and 2010 the trade was banned and in the end of 2012 the ban was lifted (Sierra Express Media, 2013).

The government of Sierra Leone has, in order to protect the quality of drinking water among other reasons, established various organizations in order to protect the remaining forests, mainly the national parks, forest reserves and forests around hills (ENFORAC, 2013). In these parks and reserves also most of the primary forests of the country still exist. One of the concerns for the future is the demand of charcoal, which is the preferred household fuelwood in the country. Many of the environmentally and economically valuable trees get targeted and harvested in young ages in order to keep up with this demand. Especially the tree species \textit{Gmelina arborea} since it can be used for several different wood commodities and also makes high quality boards (Munro & van der Horst, 2012).

On a national level Sierra Leone is one of the poorest countries in the world ranking as 180 out of 187 countries in the Human Development Index.
(UNDP, 2013b) and ranking as number 5 out of 157 countries with highest percentage of the population living below poverty line (CIA, 2013b). The GDP per capita was 635 USD in 2012 (Worldbank, 2012). Around 75% of the West African population work as farmers which is also the case in Sierra Leone (Sowa, 2013a). The few ways of securing an income on an individual/community level are from farming activities, to work for the industrial companies (mining, road constructions etc.) or to sell firewood cut from the forests. Securing food year around is a challenge for most communities which might explain the low life expectancy of about 48 years (Sowa, 2013a).

3.3 Comparison of Tanzania and Sierra Leone

The climate is quite similar in both countries, due to being close to the Equator. Other similarities are that they are both very poor countries with low life expectancy 48 to 60 years, rank low on the Human Development Index, have low literacy rate and are both having problems with corruption. The two countries have both been colonies to the British; have gained their independence and thereafter had difficulties getting their economy and government into order. Both countries are rich in natural resources and both have had substantial problems with deforestation which they are trying to recover from. There are 92 tree species in Sierra Leone compared to 266 species found in Tanzania (World Agroforestry Center, 2013).

However, there are also differences between the two countries. Sierra Leone is only about one tenth the size of Tanzania and has furthermore only one tenth of the population. The fact that Sierra Leone is a much smaller country makes the negative impacts of deforestation more obvious since it is a problem spread across the whole nation whereas in Tanzania there are still large untouched forests.

Tanzania has a good infrastructure (compared to Sierra Leone), is closer to Kenya, where a lot of forestry institutions are active, has for a longer time been politically stable and is part of east Africa which might be more developed in general and has a lot of tourism. This could make it easier in this country for private owned companies to start reforestation projects that are economical viable. All these factors could affect the success of new reforestation projects.

3.4 Carbon Market and REDD

About 30% of the global carbon storage is in the vegetation. Deforestation and changes in how we use our lands contribute to 17% of the global greenhouse gas emissions, agriculture another 14%, industries 19%, transports 13%, residential and commercial buildings 8%, waste and waste
water 3% and energy usage 26% (IPCC, 2007). The amount of greenhouse gases in the atmosphere slowly increases due to the increasing emissions from the use of fossil fuels. The net flux of carbon from land use change, including deforestation, accounted for 12.5% of carbon emissions during the period 1990-2010 (Houghton et al., 2012). When forests are protected or trees are planted they act as a sink for carbon dioxide. Emissions done by fossil fuels could then be “compensated” for by planting and reforestation.

A way for industries, governments and organizations to reduce their impact of carbon emissions is to purchase carbon emission credits through organizations like Plan Vivo (Plan Vivo, 2013a). These organizations certify different projects that plant trees in rural countries in order to mitigate climate change or help communities with alternative livelihoods.

Carbon trading is a market-place where buyers and sellers meet to exchange money for carbon emission credits. Some governments and companies are obligated to buy by law or international agreements e.g. the Kyoto Protocol and the EU emissions trading scheme. These obligated schemes are called the regulated or compliance market. They aim to regulate the emissions by setting limits of allowed emitted carbon units making it necessary for parties to pay for every emission made above the regulated limit. In 2008 US$119 billion were traded on the regulated market. Only a few countries follow regulations that demand climate compensating by buying carbon emission credits on the obligated regulated market, and it is only a few sectors, e.g. heavy industries, which are obligated to buy credits (Peters-Stanley & Yin, 2013).

Another market is the voluntary carbon market that in 2008 stood for a trade of US$704 million. This represents less than 0.1% of the global carbon market. The voluntary market is used by buyers that want to minimize carbon footprints by compensating for emissions made e.g. by travels. It could also include communities or families that want to buy credits to compensate for their emissions for a period of time. Carbon credits can be purchased through a private exchange or through an over-the-counter (OTC) market, where buyers buy credits through an online broker. (Peters-Stanley & Yin, 2013). Table 1 shows the difference in prices (Value) and volumes (Transaction Volumes) of regulated and voluntary markets for the Global Carbon Market in 2010 and 2011.
Table 1. Difference in prices (Value) and volumes of regulated and voluntary markets in 2010 and 2011. MtCO₂e = Million tonnes Carbon Dioxide emissions, OTC = Over The Counter, CCX = Chicago Climate Exchange. Source: Peters-Stanley & Yin (2013).

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume (MtCO₂e)</th>
<th>Value (USD millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
<td>2011</td>
</tr>
<tr>
<td>Voluntary OTC-traded</td>
<td>128</td>
<td>93</td>
</tr>
<tr>
<td>CCX (exchange-traded and OTC-cleared)</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Other exchanges</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total Voluntary Markets</td>
<td>133</td>
<td>95</td>
</tr>
<tr>
<td>Total Regulated Markets</td>
<td>8 702</td>
<td>10 094</td>
</tr>
<tr>
<td>Total Global Markets</td>
<td>8 835</td>
<td>10 189</td>
</tr>
</tbody>
</table>

In 2006 the total amount of compensated carbon was 32 million MtCO₂e, and in 2012 the amount was 101 million MtCO₂e (Figure 2). The last five years the traded amount has not changed drastically.
Figure 2. The development of the total amount tCO₂e (tonnes of Carbon Dioxide equivalent) compensated. Chicago Climate Exchange operated in North America as the only voluntary exchange to trade carbon emissions according to New York Times (2011). Source: Peters-Stanley & Yin (2013).
In 2012 buyers committed more than $523 million to offset 101 million metric tonnes of greenhouse gas emissions (Table 2). The carbon offset demand increased 4% from 2011 to 2012 but the price decreased 11%. The volume-weighted average price was in 2012 $5.9/tCO2. This could be compared with The United Nations’ regulatory Clean Development Mechanism (CDM) carbon offset price which was less than a $1/tCO2 (Peters-Stanley & Yin, 2013). A low price per tonne emitted carbon dioxide enables companies to become “carbon neutral” even though the emissions bought are not enough to compensate the actual emitted amount.


<table>
<thead>
<tr>
<th></th>
<th>Volume (MtCO2e)</th>
<th>Value (USD Millions)</th>
<th>Average Price (Volume-Weighted $/tCO2e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voluntary Offsets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contracted Over-the-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counter</td>
<td>93</td>
<td>98.5</td>
<td>572</td>
</tr>
<tr>
<td>Voluntary Offsets Traded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>on an Exchange</td>
<td>2</td>
<td>2.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Historical Transactions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracked and Added in</td>
<td>1.8</td>
<td>-</td>
<td>10.9</td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voluntary Carbon Markets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>98</td>
<td>101</td>
<td>586.5</td>
</tr>
</tbody>
</table>

One of the efforts to create a financial value for carbon stored in forests is the programme REDD (Reducing Emissions from Deforestation and Degradation) that offers incentives for developing countries to reduce emissions from forest covered lands and invest in a sustainable development through a low-carbon path. The programme REDD+ covers, similar to REDD, deforestation and degradation but also includes aspects of conservation, sustainable management of forests and enhancement of carbon stocks. REDD and REDD+ programmes are often supervised by the EU who aims to make a variety of countries compliant with the REDD/REDD+ framework. REDD/REDD+ covers implementation from a community level to national and international level (UN-REDD Programme, 2014).
4. Model – the Emiti Nibwo Bulora project in Tanzania

4.1 Background

The Emiti Nibwo Bulora project is located in the Kagera region in the northwestern parts of Tanzania. The region is 40 838 km², of which lakes, e.g. Lake Victoria, covers 11 885 km². The project area is located in an agro-ecological zone that is suitable for growing banana and coffee due to the high elevation of 1300 to 1600 meters above sea level. The region has a mean annual temperature of 20°C and an annual rainfall of 1000-1250 mm. The main crops are banana and beans and coffee which make 89% of the cash crop. Declining soil fertility, soil erosion, leaching and lack of crop rotation are wide spread problems and affect most farmers (Plan Vivo, 2010).

The project started in 2009 and aimed to involve farmers in the Kagera region. The startup initiative was taken by Vi-Agroforestry and the primary objective of the project was to improve the living conditions for the farmers in the region. This was done by supporting small-scale farming communities learning about agroforestry, land-use and forest management. The farmers that are involved in the project plant trees that contribute to migration of greenhouse gas emissions and climate change in the area. This allows the farmers to access carbon finance through a process of aggregation of carbon assets. They receive additional carbon income through adoption of productivity enhancing practices and technologies. The income depends on what the buyers of the credits are willing to pay, the productivity of planted areas and also on additional payments for environmental services. Expect for the projects additional income, farmers enhance resilience to climate variability and change in the area, and carbon is stored in the soils and in the forest biomass.

In 2012 the project covered an area of 433.7 ha. In total around 800 farmers divided in approximately 30 communities have participated in the project, that has submitted issuance for 55 131 tCO₂ (Masologo, 2012). The project works together with Plan Vivo, which is an organization that provides a certification framework to access financial support to smallholder communities in exchange for environmental actions like reforesting lands.
When starting up projects at villages, Plan Vivo go through the following stages (Plan Vivo, 2008):

1. Project coordinators target people who want to get involved in the project.

2. Project attendants receive training in planning and different planting methods.

3. Farmers make plans for their land and these are then evaluated by the project coordinator according to Plan Vivo standards.

4. Long-term land management plans are made by the farmers. Carbon reduction activities are funded by selling VERs (voluntary emission reductions) in the form of Plan Vivo certificates.

5. When a project has been registered the potential carbon credits can be calculated using a specification that is Plan Vivo approved.

6. The carbon credits are sold by the project coordinator as Plan Vivo certificates after sales agreements have been made with the farmers.

7. Monitoring and payments are made at five occasions during a 25-year period. Performance targets need to be met in order for payment to take place.

8. Annual reports are sent to the Plan Vivo foundation in order to secure transparency.

The time-span of the project is 25 years (Plan Vivo, 2010), since the peak of carbon uptake is within this period. After this period the trees could be cut down for timber and the lands could be replanted. All farmers sign agreements that oblige them to keep the forests during this period. The startup cost for registration and validating a Plan Vivo project, which is needed in order to generate Plan Vivo certificates that can be traded to generate funding in exchange of planted carbon binding trees, is estimated to $7 550 – $12 550 (Plan Vivo, 2013b). Plan Vivo is just one way/organization that can be used in order to trade on the voluntary carbon market.

In the following chapters the four different agroforestry reforestation systems tested in Emiti Nibwo Bulora; Boundary planting, Dispersed Interplanting, Fruit Orchards and Woodlot are described.
4.2 Boundary Planting

One of the main objectives of this method is to define the area of landholding. This is fulfilled by planting of a variety of trees around the perimeters of the farmer’s property. The mixture of trees planted can both include native and exotic species. Either hardwood for timber, fruit trees, trees that provide shade or fuel or nitrogen fixing trees can be used. The trees could also provide as wind shelter for e.g. banana plantations, or used to minimize the amount of wind-spreading dust, to improve water flow and be used to prevent soil erosion. Boundary Planting is a good option for farmers who don’t want to jeopardize their lands planted with crops. The planting should be done along the sides of roads or by water courses.

In Emiti Nibwo Bulora 33 trees was planted along 100 meters of a boundary (3 meters between the trees). In 2012, in total 99 300 m have been planted with this method (Onyango et al., 2010a). The trees were planted on a distance of 3 meters to the boundary between neighboring lands. In some cases several rows of Boundary Planting was made. Before planting the soils had to be prepared; removal of shrubbery and competing vegetation that would disturb the establishment of the seedlings, collection of litter from the site, removal of tree stumps and creation of holes for the plants. Planting was then made when the weather was suitable (during onset of rain).

Before planting the seedlings were watered in a nursery to help later establishment in the soil. A lot of care was taken in order not to damage the plants when pruning the roots and preparing them for planting. The seedlings were planted in a proper depth and then top soil was placed around the seedling (Onyango et al., 2010a). The first years it was important to remove competing vegetation. Weeding should be done twice the first year and thereafter once a year until the seedlings had been properly established (Onyango et al., 2010a).

Potential income from timber in a Boundary Plantation is estimated to 579 USD per 100 meters. Then it is assumed that 1 hectare equals 300 m$^3$ (Onyango et al., 2010a), the recovery rate is 25% and that 1m$^3$ equals 260 USD. With these assumptions 100 meters of Boundary Planting would yield: $(300 \times 0.0297) \times 25 \times 260/100 = 579$ USD.

Potential income from fuelwood is 120 USD per 100 meters and this estimate is based on the assumptions that were made in the Emiti Nibwo Bulora project: 1 hectare equals 300 m$^3$, 1m$^3$ fuelwood equals 18 USD and that the proportion of fuelwood in a cutting is 75%. Then the income is $(300 \times 0.0297) \times 75 \times 18/100 = 120$ USD.

The associated costs are estimates and only meant to be an indicator for planting 33 seedlings per 100 meters. The activities during startup were: purchasing seeds, digging and mixing of soil, filling the pots, transfer and topping, seed sowing and seed bed management, selection of seeds, transfer,
watering and sanitation. The startup cost in the nursery was procurement of tree seeds. In total the startup costs were estimated to 9 USD per 100 meters of planting. The activities during the establishment phase were: demarcation and testing of soils, clearing of bushes and vegetation, marking of planting areas and planting. The estimated total cost for this phase was 20 USD per 100 meters of planting (33 seedlings) (Onyango et al., 2010a). The activities in the first year include: managing spot weeding, uprooting shrubs, creating firebreaks and grass cutting when needed. The total cost for the first year was estimated to 10 USD per 100 meters. The second year involved the same activities as the first year expect for more focus on activities for maintenance. The cost was estimated to 6 USD for 33 trees. In the following 3 to 5 years focus was on maintaining firebreaks and the cost was estimated to 12 USD per 100 meters of planting each year (Onyango et al., 2010a).

4.3 Dispersed Interplanting

The main objective of this method is to improve soil fertility so that the agricultural food production could be increased. Other benefits of this method are that it could improve water flow and quality, improve soil evaporation, prevent siltation of water, prevent erosion, enhance biodiversity (protection of animals and plants) and contribute to additional income through firewood, medicine, bees and other non-timber products. Trees for this method are chosen for their nitrogen fixing qualities and they are combined with other agroforestry tree species suitable for low stocking densities. Crops are established between the trees and in Emiti Nibwo Bulora 200 seedlings per hectare was planted using this method (Onyango et al., 2010b). The establishment of Dispersed Interplanting is made intertwined with the crops. First a row of trees is planted with 5 meters distance between the trees. The second row, with similar spacing between the trees, is planted 10 meters from the first row. This creates a 10 meter wide corridor between rows, where the crops are sown (Onyango et al., 2010b).

Before planting the soils had to be prepared. Shrubbery and competing vegetation was removed and all foliage and green waste should be spread out to enrich the soil. Furthermore, planting holes 5-10 cm deep were created. The trees were then planted in periods when rain was expected (the beginning of the wet season). Before planting the seedlings were watered in a nursery to promote later establishment in the soil. A lot of care was taken in order not to damage the plants when pruning the roots and preparing them for placement in ground. The plants were planted at proper depths and then top soil was placed around the seedlings (Onyango et al., 2010b). Weeding control is important the first year after planting. The second year some pruning can be done to control the lower branches of the trees. Within the first two years dead trees should be replaced as soon as possible. Foliage and
green waste should be left on the ground and not be burnt. Harvest of trees is done when they reach 30 years (Onyango et al., 2010b).

Income from this method is low since there is no revenue from timber during the 25-year period. Also the fuelwood is nonexistent since no wood should be obtained when pruning the trees (Onyango et al., 2010b).

The cost is an estimation and is only meant to be an indicator for planting 200 seedlings per hectare.

Activities during startup was: Purchasing seeds, digging and mixing of soil, filling the pots, transfer and topping, sowing and seed bed management, selection of seeds, transfer, watering and sanitation. The costs included in the startup of local nursery were; procurement of tree seeds, nursery equipment and operation cost. In total the cost is estimated to 73 USD for planting 200 seedlings per hectare. The activities in this phase were; demarcation and testing of soil, clearing the bush of vegetation, marking of planting areas. A spacing of 5 m between trees and 10 m between rows were used when planting. The estimated total cost for this phase was 50 USD per hectare.

Activities needed in the first year include; managing spot weeding, uprooting shrubs, creating firebreaks and do the grass cutting when needed. The total cost for the first year was estimated to 35 USD per hectare. The second year involved the same actions as the first year except for more focus on maintenance. The cost was estimated to 20 USD per hectare. The following 3 to 5 years the focus was on maintaining the firebreaks estimated to a cost of 45 USD per hectare a year. The equipment needed for maintenance included: one slasher, a hoe, a machete, a pair of boots and an overall coat for 52 USD in total. The overall cost for maintenance the first 5 years was estimated to 275 USD (Onyango et al., 2010b).

4.4 Fruit Orchards

This method focuses on fruit production. Fruit trees are planted to supply the community with an alternative food source and for commercial production. In this method around 150 fruit trees per hectare is planted. Additional benefits with this method are soil conservation, improved water quality and enhanced biodiversity. Fruit Orchards should be planted on neglected or degraded land and is a good alternative for individual farmers with small areas of landholding since it contribute to food production. It could also be adopted on community land, larger landholdings (>1 hectare) i.e. by farmers that have sufficient land not to jeopardize their crops. Roadsides and public places could be used for planting as well. Environmental impacts are; protection of wildlife, improving water flow and preventing soil erosion (Onyango et al., 2010c).
Avocado trees of Fruit Orchards should be planted at a spacing of 9×9 meters and mango trees at a spacing of 8×8 (Onyango et al., 2010c). Planting areas need preparation in form of: Removal of shrubbery and competing vegetation and removal of all litter and tree stumps. Further activities are marking of planting spots, digging holes for seedlings, 60 cm diameter. Seedlings are planted after 50 mm rain fall. Before seedlings were planted they were watered in nursery to help later establishment in the soil. A lot of care was taken in order not to damage the plants when pruning the roots and preparing them for placement in the ground. The seedlings were planted at proper depths and top soil was placed around the seedlings (Onyango et al., 2010c). Cutting of grass was done at two occasions the first year and at one occasion the following year when the seedlings were established. The following years additional grass removal was done when necessary (Onyango et al., 2010c).

The potential income of this method comes mainly from fruit production. If mango trees are planted maximum 70 kg of mango is produced annually for a single tree. Avocado trees can yield 250-300 kg each season. The market value in Tanzania was in 2013 2 USD per kg mango and 0.4 USD per kg avocado (Onyango et al., 2010c).

The cost is an estimate and is only meant to be an indicator when planting 150 seedlings per hectare. The activities during startup were: purchasing seeds, digging and mixing of soil, filling the pots, transfer and topping, sowing and seed bed management, selection of seeds, transfer, watering and sanitation, grafting and green house sheeting. The cost of the startup of local nursery was: procurement of tree seeds, nursery equipment and 3 hoes, 2 spades, 1 machete, shade netting, poles, water and fuel. In total the cost was estimated to 520 USD per hectare.

The activities in the preparation phase was: demarcation and testing of soil, clearing the bush of vegetation, marking of planting areas and planting. The estimated cost for this phase was 35 USD per hectare. The activities needed the first year includes; managing spot weeding, uprooting shrubs, create firebreaks and do the grass cutting when needed. The total cost for the first year was estimated to 25 USD per hectare. The second year involved the same activities as the first year expect for more focus on maintenance. The cost was estimated to 50 USD per hectare. Additional cost for equipment is estimated to 50 USD per hectare (Onyango et al., 2010c).

4.5 Woodlots

This method focuses on planting trees in order to reverse the effects of deforestation. It involves planting of a variety of indigenous timber producing tree species on fragmented land plots that is not used properly because of labor shortage, long distances, theft or other reasons. The planted areas diversify farm productivity with timber, firewood, building materials,
medicine, non-timber products and fodder. Environmental and social benefits are soil conservation through the reduction of soil evaporation and soil erosion, improved water quality and flow, prevented siltation of water, enhanced biodiversity through the protection of wildlife (birds and smaller animals) and keeps air pleasant. The land used is mainly marginalized farmland or other degraded lands (Onyango et al., 2010d).

In Emiti Nibwo Bulora eight different tree species were planted with spacings of either 3×3m or 4×4m depending on species (Onyango et al., 2010d). Management methods applied aimed to produce firewood and timber of high quality. Intercropping was used in the beginning of the growing season for maintenance benefits. Areas that were to be planted needed preparation in form of: Removal of shrubbery and competing vegetation, collection of litter and removal of tree stubs. Digging holes and planting was made when the weather was suitable (during onset of rain). Before the seedlings were planted they were watered in nursery to help later establishment in soil. A lot of care was taken in order not to damage the plants when pruning the roots and preparing them for placement in ground. The seedlings were planted at proper depths and top soil was placed around the seedling. In this method 698 seedlings per hectare was planted (Onyango et al., 2010d).

The first years it is important to remove competing vegetation and weeding should be done twice the first year after planting and then once a year until the seedlings have been properly established. Replanting of dead trees is also necessary. Thinnings were typically made in year 8 with a thinning strength of 50%, and then a second time between ages 12-15. Clear cutting of timber should be made after 20-40 years depending on species. Harvest of firewood is done around year 8 (Onyango et al., 2010d).

The two major incomes of this method are timber and fuelwood. The income is based on assumptions and is only thought to give an indication of the potential income.

Income from timber using the following assumptions: 1 hectare equals 300 m³, recovery rate is 25% and 1m³ equals 260 USD. Then one hectare would yield: 300×25×260/100=19 500 USD. Income for fuelwood with the following assumptions: 1m³ fuelwood equals 18 USD and proportion of fuelwood in cuts is 75%. 300×75×18/100= 4 050 USD. Fuelwood from the first and second thinning equals 60 m³. 60 m³×18= 1080 USD (Onyango et al., 2010d).

The cost is an estimate and is only meant to be an indicator when planting 698 seedlings per hectare. The activities during startup were: purchasing seeds, digging and mixing of soil, filling the pots, transfer and topping, sowing and seed bed management, selection of seeds, transfer, watering and sanitation. The costs included in the startup of local nursery were; procurement of tree seeds, nursery equipment and 3 hoes, 2 spades, 1
machete, shade netting, poles, water and fuel. In total the costs were estimated to 190 USD per hectare. The activities done before planting were; demarcation and testing of soil, clearing the bush of vegetation, marking of planting areas and planting. The estimated cost for this phase was 210 USD per hectare.

The activities needed the first year include; managing spot weeding, uprooting shrubs, creating firebreaks and do grass cutting when needed. The total cost for the first year was estimated to 165 USD per hectare. The second year involved the same activities as the first year except for more focus on maintenance. The cost was estimated to 170 USD per hectare. The following 3 to 5 years the focus was on maintaining the firebreaks and the cost for this was estimated to 180 USD per hectare a year. The equipment needed for maintenance included: a slasher, a hoe, a machete, a pair of boots and an overall coat for 40 USD in total. The overall cost for maintenance the first 5 years was estimated to 515 USD (Onyango et al., 2010d).

4.6 Carbon sequestration

Plan Vivo projects are examples of projects in the voluntary carbon market that sells carbon credits in advance before the offset has been generated. There are also projects that sell credits after they have been generated.

Figure 3 shows that carbon from the atmosphere gets absorbed by trees and then transferred to the soil through biomass and wood products. Later carbon gets released into the atmosphere again. The carbon is bound in biomass and organic soil matter for a long period, which makes it effective in removing high amounts of carbon from the atmosphere.
Two models for measuring carbon offset are CO2FIX (Masera et al., 2003) and SCUAF (Young et al., 1998).

- CO2FIX requires information regarding growth and yield of the tree species that are being modelled. Much of this information is available in different databases and literature.
- SCUAF requires a lot of site specific information about the environmental conditions and only a little information about tree growth.

The availability of data determines which model that should be used (Berry, 2008a). A summary and comparison of the two models is found in Appendix 2.

The carbon baseline is the starting amount of carbon sequestered and stored in vegetation without crops or trees and vegetation. When finding the amount of carbon and carbon dioxide a land area can sequestrate, the baseline must be subtracted. There is no difference between the baselines for cultivated or neglected land. The amount is 2 tonnes carbon per hectare (Berry, 2008a).

In order to calculate the potential long term carbon storage in biomass and forest products in Plan vivo the net increase of carbon storage was used for a 25-year period relative to the baseline. This approach was used to calculate
the growth rates of trees from gathered measurements data. The potential uptake of carbon was calculated for each species using the CO2FIX-V3 model (Masera et al. 2003).

Using the results of carbon uptake per tree species a technical specification was put together for each species with specific lengths of rotations. This resulted in that e.g. the Woodlot planting system could bind 50 tonnes of carbon per hectare over a period of 25 years (Table 3). Species used in these calculations are presented in Appendix 3.

In order to use Plan vivo for selling carbon credits a certificate is needed. Plan Vivo demands that 20% of all carbon credits (emissions) remains as a risk buffer and is not tradable. The farmers received an average of 6.3 USD/tCO2 (Masologo, 2012). The final amount of tradable tCO2/ha depends then on how much a system binds and on Plan Vivos required buffer.
Table 3 shows that the Woodlot system binds 50 tC/ha (sink) and that the ground without trees (baseline) binds 2 tC/ha. The sink minus the baseline equals the net carbon benefit. Including Plan Vivos required buffer stock the tradable tC/ha is 38. The amount of tradable tCO2/ha is then calculated with the CO2FIX-V3 model.

Table 3. Net carbon benefit, tradable carbon offset and buffer stock for the Woodlot system. Source: Onyango et al. (2010d).

<table>
<thead>
<tr>
<th>Technical specification</th>
<th>Sink (tC/ha)</th>
<th>Baseline (tC/ha)</th>
<th>Net carbon benefit (tC/ha)</th>
<th>Buffer stock (%)</th>
<th>Tradable carbon offset (tC/ha)</th>
<th>Tradable carbon offset (tCO2/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodlot</td>
<td>50</td>
<td>2</td>
<td>48</td>
<td>20</td>
<td>38</td>
<td>140</td>
</tr>
</tbody>
</table>

To be able to receive funding for sold carbon credits there are some criteria’s that needs to be fulfilled. The whole planting must be established, i.e. for the Woodlot system 90% of the seedlings must be alive the third year and for Dispersed Interplanting, Fruit Orchard and Boundary Planting 90% must be alive the fourth year. From the fourth year the monitoring is based on the average breast height of trees and carbon sequestration estimates is based on the predicted mean annual diameter increment (Onyango et al., 2010d).

4.7 Risks

In Emiti Nibwo Bulora several risks related to the reforestation projects were identified:

- Farmers lacked some technical skills and there was no support from the government or the NGOs
- Limited availability of seedlings
- Animals, diseases or pests caused a threat to planted areas
- Planted areas changed the microclimate that might affect agricultural crops
- Investment cost caused some problems
- Farmers thought that planting involved to much work that would result in less time to work with crops
- Theft and illegal cutting
- Lack of agricultural knowledge and capacity and how to combine this with tree planting may cause negative perception of agroforestry
- Land relocation according to existing legislation might change and affect the carbon sink benefits
- If timber prices goes up it might tempt farmers to cut down trees earlier than the optimal carbon binding rotation age (Onyango et al., 2010d).
5. Empirical data – Makari in Sierra Leone

5.1 National approaches to climate change in Sierra Leone

In 2006, Sierra Leone ratified the Kyoto Protocol and steps were taken to develop a national approach to climate change. In 2007 the national programme for action climate change (NAPA) was created. In 2012 a national secretariat for climate change (NSCC) was established with the task of developing a climate change policy and establishing effective regulatory frameworks and procedures to support future implementation of the Clean Development Mechanism (CDM) and REDD+ projects. The promotion of REDD+ and CDM was included in the Poverty Reduction Strategy paper 2009 to 2012 also called “the agenda for change”. In this agenda the carbon markets are identified as sustainable financing mechanism to support the conservation and development of the forestry sector. In 2012 the first step of REDD+ was completed and Sierra Leone achieved REDD+ readiness which includes having a; reporting and verification system, cost assessment for conversion of forest areas and the start of defining a national REDD+ policy (The REDD desk, 2013).

The UN is one of the major active organizations that implements REDD+ in Sierra Leone. The UN funded REDD+ programme started in 2011 together with the forestry division of the Ministry of Agriculture, Forestry and Food security (MAFFS). The REDD+ project was promised 488 000 hectares to be dedicated to the REDD+ project by the government, but it was a failure since the government had not grounded the plans with the land owners of these lands and because the domestic land owning structure is unclear and complicated. Often the communities think they own land since they have been using the land for generations but sometimes it belongs to the government in reality. Many conflicts occur when these lands gets sold or promised to foreign investors who plan to cultivate, deforest, establish plantations and use it to extract minerals or similar (The REDD desk, 2013).

In 2013 there was a launch of a REDD+ project funded by EU with a budget of 5 000 000 EUR (EU delegation, 2013). The project was to be implemented by the year 2016 with the long term goal of establishing low-carbon and pro-poor development through protection of forests and using revenue from sold carbon emissions to aid with poverty levels (MAFFS, 2013). The owner of the implementation process is the Government of Sierra Leone through the Ministry of Agriculture, Forestry and Food security (MAFFS).
5.2 Wood industry and trade

The timber export industry from Sierra Leone is not significantly active (Muir, 2013) and only a few of the tree species found in Sierra Leone are in the price list for active timber export industry of West Africa. More species like *Gmelina arborea* needs to be planted to be able to secure future boards and demand of charcoal. The forestry policy needs to be revised and restructured in order to secure this demand.

The different fees being charged and the collecting system for traders need to be improved in order for the forest division to regenerate income and to avoid traders cutting timber illegally. If the fees and system get revised the forest division could gain a lot of money that could for example be used to encourage reforestation.

A report by Energy For Opportunity (EFO), include the following recommended actions in regulations to improve timber trade (Munro & van der Horst, 2012):

1. Remove the fee collection system from checkpoints
2. Establish collection point at vendors
3. Renew chainsaw licensing and registration in order to make it cheaper and easier to accommodate
4. Improve verification of the chain of custody
5. Minimize all fees for trading with firewood
6. Remake the forestry act since it is outdated
7. Re-demarcate boundaries of forest reserves
8. Draft a national strategy for implementing REDD+

Following actions is recommended in research:

1. Make an updated inventory and a fact book of national tree species, the existing data is outdated
2. In-depth research and mapping of timber, firewood usage in the southern and eastern provinces
3. Research all areas of charcoal
4. Make an analyze of the national land coverage
5. Research more efficient plantation strategies


Following projects is recommended:

1. Make it easier to support and help cooperatives
2. Make chainsaw milling more efficient
3. Establish good relations with local authorities in order to make changes
4. Revise tree planting methods
5. Improve efficiency of wood-based commodities
6. Create a forestry information center online
7. Establish communication with forestry communities and forestry experts.
5.3 The Makari village

Makari Gbanti is 563 km\(^2\) large and is one of the 26 chiefdoms in the Bombali district that covers 7 985 km\(^2\) and is the second largest district in the country. There are 28 villages in the district where Makari is one covering approximately 10.7 km\(^2\) (Wikipedia, 2014). The district of Bombali is one of the poorest areas in the country (Figure 4). The population of Makari Gbanti chiefdom is approximately 40 000 and only a few hundred people live in the Makari village.

Figure 4, Map of Sierra Leone illustrating the levels of extreme poverty in different districts in 2003/2004. Source: Woldt et al., (2009).

Farming activities in Makari Gbanti chiefdom is essential for survival and the most staple crops are rice and groundnuts. The farmers use shifting cultivation and the slash-and-burn method. The decrease of land fertility is a concern as the farmers need to use more and more fertilizers, but the knowledge of how to use it is often low leading to overuse (Assah, 2013). Combined with the vulnerability to climate change the crops sometimes fail which lead to serious food shortages, the last one in 2012. The area around the chiefdom is heavily exploited for charcoal and fuelwood and together with annual outbreaks of wildfires the tree coverage of the region is small.
The northern part of the country, including the Bombali district is a combination of savannah and secondary brush. In general the population is concentrated and the lands are overgrazed by cattle.

A map over the vegetation cover can be seen in Appendix 4. In Sierra Leone 92 tree species can be found (native and exotic). Of these tree species 67 are present in both Sierra Leone and in Tanzania due to the similarities in climate and altitude. Of the tree species used in the Emiti Nibwo Bulora project 3 recommended species for the Woodlot system exists in Sierra Leone, 2 for Dispersed Interplanting, 2 for Boundary Planting and 3 for Fruit Orchard.

5.4 Experience from agroforestry training in Makari

In July 2013 I accompanied the UNDP and ICRAF staff to visit the Makari village. The purpose for the UNDP and ICRAF was to introduce the concepts of agroforestry and how a community driven nursery could function.

After arrival we were introduced to the village representatives and guided through the village. Everybody gathered in town hall, the spokesman/translator held a prayer and then introduced all village representatives and visiting parties. The town hall was filled up with local chiefs, men, women and children alike.

A presentation was made by Dr Ebenezar Assah from ICRAF covering agroforestry methodology and nursery practices as well as alternative food sources and the business potential in owning a community driven nursery. The villagers had a vote about which tree species they valued the most based on the criteria:s; food, medicine, fruit and other uses. Moringa, mango and avocado got the highest scores. Moringa was chosen mostly for being a good nutritional food source and for its medicinal qualities against malaria. The mango and avocado fruits are the easiest/most profitable fruits to sell on the market.

Only men participated in the questioning and answering session although women were attending. As a note I found out that women cannot own land in Sierra Leone. In general there was a lack of interest from the community in the workshop as can be seen in Appendix 5.

Some of the questions that were discussed included: How seeds were to be obtained, how work rotation could be done for nursery staff and the location of a potential community nursery. The guests and chiefs were seated by the wall behind the spokesman (Figure 5).
Figure 5. Dr Ebenezar Assah standing in white in the middle of the picture discussing benefits of different tree species in the Makari village.
5.5 Potential areas for reforestation in Makari

The lack of available GIS-data and the lack of structure and systems like web-pages/online databases with basic demographic and land ownership information as well as lack of infrastructure, electricity and internet in the country, forces a lot of work in Makari to start from a very basic level. These hinders seems not as big in Tanzania which makes project management there easier.

Subsequently, an estimation of the land area of Makari village is 10.8 km² (1 080 hectares) (Figure 6 and Table 4). This estimation is based on visual landmarks in the field, oral information from village inhabitants which were later interpreted through Google Earth for further measurements.

It is not possible to confirm that boundaries in the mapping are correct and recognized by all. The land ownership is complicated since some land belongs to the village, but some land belongs to families. There is no structure of land ownership, but based on historical usage.

![Figure 6. Map showing the Makari village. White line surrounding the Makari village, red lines surrounding vegetation/forest cover, yellow lines surrounding housing areas, blue lines surrounding area dedicated to crops.](image)

From the rough mapping in Figure 6, it could be concluded that there are a lot of available marginalized farmland and other degraded lands suitable for planting trees. When land not suitable for planting like bad soil conditions,
roads and other factors (not visible on the mapping) is excluded there should be at least 300 hectares out of the 663 hectares of marginalized farmland, other degraded or unknown lands available land for planting in one village alone. Then it is presumed that at least half of the non-marked land on the rough mapping is land good enough for planting trees.

Table 4. Estimated area of Makari village made from field observations and maps.

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total village area</td>
<td>1 080</td>
</tr>
<tr>
<td>2nd forest/vegetation</td>
<td>236</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>166</td>
</tr>
<tr>
<td>Houses</td>
<td>15</td>
</tr>
<tr>
<td>Marginalized farmland, other degraded or unknown lands</td>
<td>663</td>
</tr>
</tbody>
</table>
6. Analysis and discussion

6.1 General assumptions

The average farmer in the Vi-Agroforestry model project in Tanzania dedicated lands around 0.5 ha available for each farmer for planting trees in 2012 (433.7 ha/800 farmers = 0.5 ha per farmer). This assumption is also made in the analysis of the Makari region. Since only the men in a household are allowed to own land in Sierra Leone, the concept of farmer will be used to include the farmer’s family. Calculated income and cost of implementing a reforestation project is based on that 1 hectare is managed by 2 farmers. The startup cost for a Plan Vivo certification is 7 550-12 550 USD and in the calculations 10 000 USD was used as an average.

In order to make recommendations of which tree species to use in Makari, information from the project in Sierra Leone was used, but extensive research needs to be done to find out which trees species are the most suitable for the different planting methods. Data on agroforestry planting methods (Appendix 9) is used as proxy data.

Income estimates were based on the products timber and fuelwood. The reason is that these two bring relatively high income and the four different agroforestry systems could easily be compared. All income estimates may include sources of errors. Supply and demand of forest products will affect the prices and there are many aspects to consider that may not be covered in the following tables and calculations.

6.2 Potential income

The survival rate of the tree species used in the reforestations projects aimed at 90% for the first four years in the Plan Vivo monitoring process. This was to be ensured by replanting damaged seedling the first years. Expected timber yield is based on the estimation by Vi-Agroforestry that 25% of the planted seedlings become quality timber at the age of 25 years which also is the age of harvest. The timber can also be processed into boards (see Appendix 5) and in Appendix 7 there is an alternative way of calculating income of boards instead of timber.

The same assumption on the amount of collected fuelwood made by Vi-Agroforestry was made in this analysis. Fuelwood can be gathered at age 8 in the form of fallen branches, branches cut through thinnings and timber not suitable for export or boards. This assumption leads to a recovery rate of 75% fuelwood during a 25-year period. The income for poles is not included in the analysis since the trees planted are planned to stand 25 years. In Appendix 6 there is an alternative way of calculating income from charcoal instead of fuelwood.
6.2.1 Income Boundary Planting and Woodlot

The same division between timber and fuelwood and the same assumption that one hectare yields 300 m³ is used for the Emiti Nibwo Bulora project since other supporting data for the relevant species (except the one supplied by Vi-Agroforestry/Plan Vivo) could not be found. Furthermore the recovery rate of timber in the calculations is 25% fuelwood 75%. The collection of fuelwood is assumed mostly being done by thinning of non-timber trees or collecting fallen branches.

The income for timber is calculated below. The same calculation method used for the Emiti Nibwo Bulora Project was used. The timber price 260 USD/m³ used in Emiti Nibwo Bulora was however a little too high compared to current timber prices for Liberia and Sierra Leonean trees. Sierra Leonean timber only represented some trees in an extensive price list of West African timber and they had an average price of 175 USD/m³ (SGS, 2011) (Appendix 1).

The calculations include potential income of timber and fuelwood from thinnings.

Boundary Planting-timber

Income for timber with the following assumptions: 1 hectare yields 300m³ of timber, the recovery rate is 25% and 1m³ of timber is worth 175 USD. Then one hectare would give the income of: \(300 \times 0.0297 \times 25 \times 175 / 100 = 390\) USD.

Boundary Planting-fuelwood

Assumptions: 1m³ firewood gives 18 USD (the same price as for Tanzania, due to lack of data for Sierra Leone). Fuelwood from timber off cuts is 75%. Then one hectare would be equal to: \(300 \times 0.0297 \times 75 \times 18 / 100 = 120\) USD.

When timber and fuelwood from boundary planting (from above text) is added then the total income of timber and fuelwood is: **390 + 120 = 510 USD per 100m**

Woodlot- timber

Income for timber with the following assumptions: 1 hectare equals 300m³, the recovery rate is 25% and 1m³ is 175 USD. Then one hectare would be worth: \(300 \times 25 \times 175 / 100 = 13 125\) USD.

Woodlot-fuelwood

Assumptions: 1m³ fuelwood is 18 USD (the same price as for Tanzania, due to lack of data for Sierra Leone) and fuelwood from timber off cuts was 75%. Then one hectare would be worth \(300 \times 75 \times 18 / 100 = 4 050\) USD.
Fuelwood from the first and second thinning yield 60 m$^3$. $60 \text{ m}^3 \times 18 = 1080$ USD.

Total income of timer and fuelwood (from above text): $13,125 + 4,050 + 1,080 = 18,255$ USD (Table 5).

Table 5. Total income of timber and fuelwood for Woodlot and Boundary Planting. Woodlot = USD/ha, Boundary Planting = USD/100 m.

<table>
<thead>
<tr>
<th></th>
<th>Timber income</th>
<th>Fuelwood income</th>
<th>Thinning income</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodlot</td>
<td>13,125</td>
<td>4,050</td>
<td>1,080</td>
<td>18,255</td>
</tr>
<tr>
<td>Boundary Planting</td>
<td>390</td>
<td>120</td>
<td>0</td>
<td>510</td>
</tr>
</tbody>
</table>

6.2.2 Income for Fruit Orchard

When calculating the income of the Fruit Orchard method only two of the most popular fruit species were included; mango and avocado. These fruits were amongst the top selections for farmers at Makari village when voting for the most favored trees to have in a community nursery. In the Tanzania project 250 kg of fruit per tree was assumed for avocado which seems a bit high and which is supported by Factfish (2014), Avocadosource (2014) and Mickelbart et al. (2012). The amount should more likely be around 45 kg per tree in average for a spacing of 123 trees per ha. That mango yields 70 kg per tree is supported by Srinidhifarm (2014) and ESD (2009).

The following assumptions were made in the calculations: A mix of mango and avocado is used. 1 fruit = 1 kg, the price of 5 fruits = 1 USD = 0.2 USD/fruit and kg, income per tree = number of fruits per tree and year $\times$ price per kg. Income per year = income per tree $\times$ number of trees planted. Total income = fruit bearing years $\times$ income per year.
Table 6. Assumptions and income of mango and avocado.

<table>
<thead>
<tr>
<th></th>
<th>Fruit price at farmer (Freetown market 2013) (5000le=1USD)</th>
<th>number of trees planted per ha (Onyango et al., 2010c)</th>
<th>number of fruit in a kg</th>
<th>USD price per kg</th>
<th>Income per tree USD</th>
<th>Fruits in kg per tree and year</th>
<th>Income per year and hectare USD</th>
<th>Fruit bearing years</th>
<th>Total income for 25 years per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>5 for 5000le</td>
<td>156</td>
<td>1</td>
<td>0.2</td>
<td>14</td>
<td>70</td>
<td>2184</td>
<td>20</td>
<td>43680</td>
</tr>
<tr>
<td>Avocado</td>
<td>3 for 5000le</td>
<td>123</td>
<td>1</td>
<td>0.33</td>
<td>15</td>
<td>45</td>
<td>1845</td>
<td>20</td>
<td>36900</td>
</tr>
</tbody>
</table>

6.2.3 Income for Dispersed Interplanting

In Dispersed Interplanting no income for timber or fuelwood is assumed due to trees are not harvested within a 25-year period.

6.2.4 Income from sold carbon

The price per sold tCO2 was 6.3 USD/tCO2 in the Emiti Nibwo Bulora project. To best analyze the potential carbon income for Sierra Leone the global volume-weighted average price per tCO2 for 2012 was used, since it was the latest price that could be found. According to Table 2 the price was 5.9 USD/tCO2 in 2012.

6.2.5 Costs

For one hectare of planted Woodlot (300m$^3$), the income would be 18 255 USD if startup cost is not included. With the startup cost the income will be 8 255 USD. The break-even for when the startup cost becomes insignificant compared to the income from sold carbon credits is; 303 ha for Boundary Planting, 28 ha for Dispersed Interplanting, 100 ha for Fruit Orchard and 12 ha for Woodlot. See Appendix 8 for details. Costs for maintenance is described in chapter 4 for each agroforestry method.

6.2.6 Concluding comments concerning potential income

According to Table 7 Dispersed Interplanting and Boundary Planting are not cost-effective methods when used separately in dedicated land, but could be used to fill out areas not suitable for planting Fruit Orchards or Woodlots. Depending on the needs of the landowner and the areas that are to be planted a mixture of the different methods could probably be an optimal solution.
Dispersed Interplanting could be used where the soil conditions are bad and the planting of trees might improve the soil enough to continue with agriculture. Boundary Planting is a good alternative to fill out unused areas where Fruit Orchard or Woodlot is not possible due to lack of space i.e. close to roads, rivers, houses and to mark boundaries. Fruit Orchard could be a first method implemented in poor communities since the benefits of the fruits can really make a big difference to provide an alternative food source as well as income. A risk of planting fruits is however that sales channels, roads, markets etc. have to be in order to be able to be sold. This is not always the case and planting of fruit trees could also lead destroyed fruits in the heat.

For the analyzed period of 25 years both Woodlots and Fruit Orchards are even if the planting areas are small. One hectare Woodlot yields 8 126 USD over 25 years which is an annual income of 325 USD. Payments in a Plan Vivo project come in five different installments, fuelwood and poles can be sold only after a few years and timber can be sold after 25 years. For the Fruit Orchard method fruits can be sold continuously, approximately after 3 to 5 years after planting. A landowner of 1 hectare Fruit Orchard with avocado and mango trees would profit 29 710 USD in a 25-year period (1188 USD per year). This is considerably more than the expected income for the Woodlot.

The value change over time has not been considered in the analysis. However, it seems that the income that one farmer can get for planting trees is substantial considering most of the people in the province villages are living below the poverty line. As the demand of timber and timber products may increase in the future it could be a good idea to start thinking of how reforestation projects could be established.

When comparing prices land owners gets for timber in Liberia, which are applicable for Sierra Leone, they are 170 USD/m³ for the most common tree species and 280 USD/m³ for the most exotic species. The tree species of Sierra Leone had an average timber price of 175 USD/m³ in the SGS price list (Appendix 1). All tree species used in the Emiti Nibwo Bulora were however not included. In total nine tree species were similar to trees in Sierra Leone according to the World Agroforestry Center database providing the SGS price list. Many trees species were from the same family and tribe.
### Table 7. Total income for the different agroforestry methods.

<table>
<thead>
<tr>
<th></th>
<th>Boundary Planting (USD/100m)</th>
<th>Dispersed Interplanting (USD/ha)</th>
<th>Fruit Orchard (USD/ha)</th>
<th>Woodlot (USD/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Startup cost</td>
<td>-10 000</td>
<td>-10 000</td>
<td>-10 000</td>
<td>-10 000</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>-57</td>
<td>-275</td>
<td>-680</td>
<td>-955</td>
</tr>
<tr>
<td>Timber income</td>
<td>390</td>
<td>0</td>
<td>0</td>
<td>13 125</td>
</tr>
<tr>
<td>Fuel income (including thinnings)</td>
<td>120</td>
<td>0</td>
<td></td>
<td>5130</td>
</tr>
<tr>
<td>Fruit income (a mix of mango and avocado)</td>
<td>0</td>
<td>0</td>
<td>(43680+ 36900)/2 = 40290</td>
<td>0</td>
</tr>
<tr>
<td>Income from sold carbon Credits</td>
<td>33</td>
<td>359</td>
<td>100</td>
<td>826</td>
</tr>
<tr>
<td>Sum</td>
<td>-9 514</td>
<td>-9 915</td>
<td>29 710</td>
<td>8 126</td>
</tr>
</tbody>
</table>

#### 6.2.7 Income at different geographical levels

In order to get an understanding of the potential of reforestation levels of village, chiefdom, district and country, respectively, the following analysis was made.

In Sierra Leone there are 12 districts where the Bombali district is one. Bombali is divided into 26 chiefdoms where Makari Gbanti is one. The population of Makari Gbanti is approximately 41 000 (Wikipedia, 2014). Makari Gbanti consists of 28 villages where Makari village is one. The population of Makari Gbanti divided by 28 villages gives 1464 inhabitants per village.

If the estimated 300 hectares of Makari, can be planted in each village then there would be 28×300 = 8 400 hectares of potential land for planting in Makari Gbanti chiefdom. In the Bombali district there would be 26×8400 = 218 400 hectares. Using these assumptions Table 8 indicates the potential income agroforestry could have at different geographical levels. There are however factors that affect the estimations made at the larger levels. One is the question of access to the land, another is that if larger areas are to be planted all chiefs of all levels (village, chiefdom and district) needs to agree. Furthermore, the access to a suitable marketplace is necessary and this does not exist in many areas in Sierra Leone.
Table 8. Income at different geographical levels in Sierra Leone. One hectare is used by two farmers.

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Boundary Planting USD</th>
<th>Dispersed Interplanting USD</th>
<th>Fruit Orchard USD</th>
<th>Woodlot USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (2 farmers)</td>
<td>-9 513</td>
<td>-9 915</td>
<td>29 710</td>
<td>8 126</td>
</tr>
<tr>
<td>2</td>
<td>-9 027</td>
<td>-9 830</td>
<td>69 420</td>
<td>26 252</td>
</tr>
<tr>
<td>25</td>
<td>2 151</td>
<td>-7 878</td>
<td>982 757</td>
<td>443 150</td>
</tr>
<tr>
<td>50</td>
<td>14 302</td>
<td>-5 755</td>
<td>1 975 515</td>
<td>896 300</td>
</tr>
<tr>
<td>300 (village)</td>
<td>135 812</td>
<td>15 470</td>
<td>11 903 090</td>
<td>5 427 800</td>
</tr>
<tr>
<td>8400 (chiefdom)</td>
<td>4 072 736</td>
<td>703 160</td>
<td>333 556 520</td>
<td>152 248 400</td>
</tr>
<tr>
<td>21 400 (district)</td>
<td>10 391 256</td>
<td>1 806 860</td>
<td>849 790 420</td>
<td>387 886 400</td>
</tr>
</tbody>
</table>

For 1 hectare (first row in table 8) the sum from Table 7 was used. The sum was then multiplied with the amount of hectares (start up cost was only counted once). Example of how calculations were made for Woodlot, 2 hectares: -955 + 13125 + 5130 + 826 = 18126 USD. 18 126 was then multiplied with the amount of hectares and then the start cost was subtracted: (18 126×2)-10 000 = 26 252 USD (marked in bold in Table 8).

6.3 Estimating carbon sequestration potential

A local farmer can benefit from a reforestation project if the land could be spared and there is time to manage the trees. It is also paramount that the project instigator can dedicate specialist knowledge to train and support the planting project in all the stages. Commitment from the project owner is important in all projects and especially in rural environments.

The potential of reforestations projects with carbon benefits is that payments can start already at an early age and, if using Plan Vivo, payment to the farmer will be done in five different installments. The alternative is that the communities get access to training, equipment and money so that they can start agroforestry projects without including the carbon binding aspect. This is probably the most realistic alternative for Sierra Leone as a whole in an initial stage, since it can be done with the demands of the supporting organization or companies only, and is not bound to demands of a certifying framework like Plan Vivo. The benefit of considering a project with carbon binding is that it can attract foreign investors that wants to climate compensate in a third world country.

Since the land owners are farmers they are usually working on the fields, managing crops or working for construction and mining companies around the province, in order to earn a living. The startup of a reforestation project
would demand a lot of time from the family or from a group of people in the villages in order to be successful. The income from sold carbon credits is not substantial enough to alone motivate the startup of a project by itself. The main income is from selling timber products and non-timber products such as fruit.

A local nursery is necessary on a smaller scale since it is not possible to buy seedlings in a convenient way from established nurseries or seed banks, also they have to be cultivated locally from harvested seeds. If the project meant to run on a larger scale to cover the needs of several villages then a modern nursery facility should be established within the country.

In order to get an idea of the potential carbon sequestration at a larger scale, rough estimates of available data were made.

The amount of the carbon binding capacity for each agroforestry system was gathered from the documentation used for the Project in Tanzania (5.6 tCO2 for boundary planting etc.) (Appendix 9). The amount of bound carbon dioxide for one hectare was multiplied with the amount of estimated hectare for a village, chiefdom and a district to get an idea of how much planted areas of different sizes could bind. Estimations are presented in Table 9.

Table 9. Amount of carbon dioxide bound (tCO2/ha) for different agroforestry methods, for a 25-year period and at different geographical levels.

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Boundary Planting (per 100m)</th>
<th>Dispersed Interplanting</th>
<th>Fruit Orchard</th>
<th>Woodlot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (2 farmers)</td>
<td>5.6</td>
<td>61</td>
<td>17</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>122</td>
<td>34</td>
<td>280</td>
</tr>
<tr>
<td>25</td>
<td>140</td>
<td>1525</td>
<td>425</td>
<td>3 500</td>
</tr>
<tr>
<td>50</td>
<td>280</td>
<td>3 050</td>
<td>850</td>
<td>7 000</td>
</tr>
<tr>
<td>300 (village)</td>
<td>1 680</td>
<td>18 300</td>
<td>5 100</td>
<td>42 000</td>
</tr>
<tr>
<td>8400 (chiefdom)</td>
<td>47 040</td>
<td>512 400</td>
<td>142 800</td>
<td>1 176 000</td>
</tr>
<tr>
<td>21 400 (district)</td>
<td>1 223 040</td>
<td>13 322 400</td>
<td>3 712 800</td>
<td>30 576 000</td>
</tr>
</tbody>
</table>

To put the estimations in Table 9 into perspective the amount of carbon dioxide that one hectare of Boundary Planting can store over a 25-year period is equivalent to the total carbon dioxide that one Swedish person emit yearly (World Bank, 2010). The amount of carbon dioxide that one hectare of Woodlot planting can store over a 25-year period is equivalent to the total carbon dioxide that 25 Swedish people emit yearly (World Bank, 2010) 300 ha of Fruit Orchard planting can store the same amount of carbon dioxide over 25 years that 911 Swedish persons emit over one year.
From an environmental point of view the Woodlot system is the most suitable method since it has the most environmental benefits and binds the most carbon, eight times more than the Fruit Orchard method. From an economic perspective it is however hard to argue not to use the Fruit Orchard system since the potential sales from fruit is such large and also provides an alternative food source in poor communities like Makari. However if larger land are to planted with Fruit Orchards i.e. infrastructure (transports, roads, markets etc) need to be improved to be able transport and sell the fruit.

Since charcoal and firewood is used for all cooking and forest areas are currently diminishing, there is a need to find ways to supply the population with these two commodities also in the future. Furthermore, soil fertility could be improved by using Dispersed Interplanting. All methods are important and should be used to reach specific goals. On a smaller scale one method may be suitable but on larges scales reforestation projects could be managed considering several goals i.e. income, additional food source, environmental impact through carbon sequestration, soil enhancement/improvement, timber and non-timber products, fuelwood and biodiversity.

Maybe the REDD+ initiative that started in 2013 can contribute to reforestation on a larger scale. Much focus will be on the existing forest reserves and national parks (MAFFS, 2013). Official details on effort distribution and number of hectares that will be reforested in the future has not yet released in February 2014. In my opinion, before the process of implementing REDD+, high priority should be to evaluate the corruption risk of the country since studies have shown that corruption has effected implementation of REDD+ in other countries such as Kenya. Sierra Leone and Kenya are both ranked as very corrupt countries (Transparency International, 2014). Since the implementation of REDD+ in Sierra Leone is at an early stage the outcome is still uncertain. However, both EU and the government of Sierra Leone are putting effort and money to reforest degraded lands in the country. One possibility could be that the government fund the Woodlot system or similar in order to benefit from the positive environmental effects, moreover to support communities establishing/managing Fruit Orchards to get additional food and income.
6.4 Potential impediments

There are many risks related to reforestation projects in a rural country like Sierra Leone. The education level and technical knowledge of farming practices are low and there are no supporting institutions for the communities to contact with questions or to get help with starting projects of their own. All efforts are pushed onto them by NGOs or similar. This could lead to low enthusiasm since they have not been involved in the process from the start in many cases. If a reforestation project is to be successful it is important that the villagers are involved in an early stage and offered sufficient training and long term management support.

The availability of seeds and seedlings can be a big issue for a project in Sierra Leone. Compared to Tanzania there are two actors in the country that sells different seeds (Table 10).

Table 10. Two nurseries in Tanzania.

<table>
<thead>
<tr>
<th>National Tree Seed Agency</th>
<th>Tanzania Forestry Research Institute (TAFORI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO Box 373</td>
<td>PO Box 95</td>
</tr>
<tr>
<td>Area: Morogoro</td>
<td>Area: Lushoto</td>
</tr>
<tr>
<td>Country: Tanzania</td>
<td>Country: Tanzania</td>
</tr>
<tr>
<td>Tel: (255-56) 3192, 3903</td>
<td>Phone: +255 023-2614498</td>
</tr>
<tr>
<td>Fax: (255-56) 3275</td>
<td>Website: <a href="http://www.tafori.org/">http://www.tafori.org/</a></td>
</tr>
<tr>
<td>Email: <a href="mailto:ttsa@ttsa.co.tz">ttsa@ttsa.co.tz</a></td>
<td></td>
</tr>
<tr>
<td>Website: <a href="http://www.ttsa.co.tz/">http://www.ttsa.co.tz/</a></td>
<td></td>
</tr>
</tbody>
</table>

There are no professional nurseries in Sierra Leone or possibly none in West Africa that could supply required seedlings of all tree species used in the different reforestation systems. All seedlings must be imported from other countries e.g. South Africa and Ghana, or gathered from existing trees manually and then cultivated in a local made nursery at village level which is not very effective with uncertain outcome. No information could be found about seedling import regulations or costs.

The risk of animals, pests and diseases is an important issue since farmers in general do not have the knowledge manage it. Overuse of chemicals like fertilizers in agriculture is common and the same problem might occur managing pesticides if not sufficient training is provided. Microclimate changes might negatively affect agricultural crops. This might discourage some farmers if encountered.

A threshold for starting up a reforestation project would be the starting costs since the capital of local organizations is in general very low or non-existent. Most likely it has to be supplied by foreign investors like private companies and foundations etc.
The farmers in Makari expressed a concern about time management since they need to spend all time in the rice fields or to manage crops in order to get food. If they work in the field they won’t have energy enough also to manage other activities. They would probably need help in understanding the work involved in tree planting and structuring their work with crops in order to become committed. The risks of theft, fire and illegal cutting is also an issue and has to be taken into consideration before starting a project.

The difference in income of the Woodlot system compared to Fruit Orchard may cause negative perception of Woodlot system, although the positive environmental benefits of planting Woodlots might help to promote the method.

In the Emiti Nibwo Bulora Project in Tanzania the majority of the farmers used the Woodlot system only (62.8%). Only one farmer dedicated his land to Fruit Orchards only. A summary of how the farmers chose to plant can be seen in Table 11.

Table 11. The distribution of used planting systems in Tanzania.
Source: Masologo (2012).

<table>
<thead>
<tr>
<th>Technical specification</th>
<th>No. of producers</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodlot (WL)</td>
<td>483</td>
<td>62.8</td>
</tr>
<tr>
<td>Boundary Planting (BP)</td>
<td>111</td>
<td>14.4</td>
</tr>
<tr>
<td>dispersed inter-planting (DI)</td>
<td>73</td>
<td>9.5</td>
</tr>
<tr>
<td>Fruit Orchard (FO)</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>WL + BP</td>
<td>54</td>
<td>7.0</td>
</tr>
<tr>
<td>WL + DI</td>
<td>14</td>
<td>1.8</td>
</tr>
<tr>
<td>DI + BP</td>
<td>26</td>
<td>3.4</td>
</tr>
<tr>
<td>WL + FO</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>WL + DI + BP</td>
<td>5</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>769</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

One explanation of the distribution in Table 11 could be that the farmers in Tanzania were unaware of the economic benefits of Fruit Orchards, perhaps due to lack of information and education.

The elusive land owning structure and corruption might lead to land relocation. If existing legislation is changed this would lead to a decrease of carbon binding.

If the timber market becomes a lucrative business and the prices goes up it might tempt farmers to cut down trees earlier than the optimal carbon binding rotation age of 25 years.
Since poverty is wide spread and food sources are a priority the carbon binding aspect cannot take precedence over food production, this makes alternative food sources like fruit trees a very good option which can be driven on large scale throughout the country and at the same time give some environmental benefits. Overall it can be said that it might be possible to start a reforestation project with maximal carbon binding in focus but the risks and challenges will definitely be many.

There is an uncertain future for trading with carbon emissions. Although the market is consistently expanding it is important that the prices per emission are not decreasing since that might lead to inflation like situation in the carbon market where companies can become “carbon neutral” much cheaper than they should be at the expense of the environment.

Based on the historical average value of 5.9 USD/tCO2, the estimated market value of the carbon market will be 2.3 billion USD in 2020, or if based on an average growth demand of 13% the market value will be 1.6 billion USD in 2020 (Peters-Stanley & Yin, 2013).
7. Summary and Conclusions

- Could it be possible to start a reforestation project with carbon binding benefits, in Sierra Leone?

Sierra Leone has many similarities in climate, local tree species, social starting conditions which speaks for that an agroforestry project like the one in Tanzania could work. There are several impediments when starting a project that is likely to be faced when starting a project in Sierra Leone. These impediments are: That the local people don’t have the technical skill to be involved without a lot of outside management. There is no way to get support for starting projects themselves from any institution. The lack of supporting facilities like established professional nurseries is a fact which leads to all seedlings must be cultivated small scale at village level or be imported. Animals, diseases or pests would be a threat to planted areas. The change in microclimate that planted areas bring, might affect agricultural crops. The investment cost involved for starting up a project would not be possible for communities to pay without support. The time lost when working with reforestation project would hinder the involved from managing crops and work with farming activities. The risk of theft, fire and illegal cutting is always present in poorer areas. Lack of agricultural knowledge and how to combine with tree planting may cause negative perception of reforestation. Land relocation according to existing legislation might change and therefore affecting the carbon sink benefits. If timber prices goes up it might tempt farmers to cut down trees earlier than optimal carbon binding rotation age. The political obstacles are unknown and hard to foresee but there might be many due to the high corruption ranking. Since poverty is wide spread and food sources are a priority the carbon binding aspect cannot take precedence over food production, this makes alternative food sources like fruit trees a very good option which can be driven on large scale throughout the country and at the same time give some environmental benefits. Initially Fruit Orchards should probably be established without considering certifying selling carbon credits due to the high startup cost and break-even at 100 ha before it is profitable selling the carbon credits.

Overall it can be said that it might be possible to start a reforestation project with maximal carbon binding in focus but the risks and challenges will definitely be many. The government should have a long term plan to work against deforestation and the negative effects that follows on a national level. Sold carbon emissions from protected areas that the REDD+ project aims to, might be a good idea to get additional funding that could be used for planting trees in other areas. To plant using the Woodlot system around the country at village level is an effective way to combat local negative environmental effects. If NGOs, UN or the government can establish some successful agroforestry projects in the country, then the chances that other reforestation projects with carbon sequestration as focus might find it easier and reassuring to try and start up a project as well. Starting a reforestation project
project with carbon sequestration in focus is probably not the first step to take. In my opinion starting agroforestry projects with fruit orchard at community level should be first priority, when a few communities have been provided with additional food source and the total areas planted exceeds a 100 hectares then the carbon aspect might be considered. The woodlot reforestation nationwide can consider the carbon aspect from the start and is needs long term commitment from the government since it is a long term strategy to secure future forest and forest products.

- What are the economic impacts of a reforestation project that considers carbon binding benefits at a farmer, village, chiefdom, and district level?

The calculations show that the potential income for a farmer or a village could be substantial. The project is however dependent on foreign aid in managing the project, funding it, and provide education/training. If these criteria’s are fulfilled, then a farmer could benefit greatly from the income gained from planting trees with carbon binding in focus. The income from sold carbon credits is not substantial enough to alone motivate the start-up of a project by itself. The main income are from selling of timber, timber products, non-timber products and fruit. The most efficient carbon binding planting method, the Woodlot method, cannot compete with the Fruit Orchard for profit. However the demand will only increase for timber and timber products and the fruits need to have sales channels, structural improvements (roads, markets etc.) in order to be able to profitable since fruit does go bad rapidly in the heat. Table 8 is an indicative estimation of the potential income of agroforestry project considering carbon could have. There are factors that will make it impossible to plant trees on larger scales that has not been included in the table such as; access to the land that, if bigger areas are to be planted on village level then all the chiefs of all levels(village, chiefdom, district) needs to agree. The access of a marketplace is necessary which does not exist for many areas in Sierra Leone. Supply and demand of forest products will affect the prices and there are many aspects to consider that is not covered in the table.

- How much carbon does a farmer, village, chiefdom, district sequestrate using different agroforestry methods?

Since the limited data available, the answer to this question is visualized with rough estimations in Table 9 and in a summary in Table 12. The amount of carbon per hectare of the different agroforestry methods was given from the Emiti Nibwo Bulora project in Tanzania and was applied on Sierra Leone. The estimation of the size of arable land was made on different scales and multiplied with the amount of possible bound carbon. A summary showing the amount of carbon sequestrated for the levels; farmer, village, chiefdom and district is visualized below in Table 12.
Table 12. Amount of carbon dioxide bound (tCO2/ha) for different agroforestry methods, for a 25-year period and at different geographical levels.

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Boundary Planting (per 100m)</th>
<th>Dispersed Interplanting</th>
<th>Fruit Orchard</th>
<th>Woodlot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (2 farmers)</td>
<td>5.6</td>
<td>61</td>
<td>17</td>
<td>140</td>
</tr>
<tr>
<td>300 (village)</td>
<td>1,680</td>
<td>18,300</td>
<td>5,100</td>
<td>42,000</td>
</tr>
<tr>
<td>8400 (chiefdom)</td>
<td>47,040</td>
<td>512,400</td>
<td>142,800</td>
<td>1,176,000</td>
</tr>
<tr>
<td>21,400 (district)</td>
<td>1,223,040</td>
<td>13,322,400</td>
<td>3,712,800</td>
<td>30,576,000</td>
</tr>
</tbody>
</table>

To put the numbers in perspective; The amount of carbon dioxide that one hectare of Boundary Planting can store over a 25 year period is equivalent to the total carbon dioxide that one Swedish person emit yearly (World Bank, 2010).

7.1 Future studies

Future studies are many since I only scratch the surface on many subjects in this thesis. It would be interesting to follow the future of agroforestry projects in Sierra Leone since it is currently in an early stage and has a lot of potential. Some examples of what I find interesting are to;

- Investigate a variety of tree species like oranges, cashew nut and cacao to see what their economic and carbon benefits are and if there is a potential market in Sierra Leone. For example cashew nuts are today imported from Ghana and are expensive in Sierra Leone.

- Go deeper in what tree species that should be the focused on when planting on a country level to be able to keep up with future demand of charcoal, poles and boards for the domestic market.

- Investigate the potential of timber trade and charcoal sustainability.

- Follow the REDD+ project and track the reforestation efforts to see how the money are distributed and which areas are being reforested since research points at many perils with carbon contracts in Africa (Tienhaara, 2012). It is important that the government of Sierra Leone has a long term plan to work with REDD+ and where the gained incomes from sold carbon credits gets reinvested into reforestation of new areas where trees and its products are most needed to keep up with future demand.

- Also the carbon sequestration aspect of the REDD+ project could be interesting to investigate.
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Appendix 1

6 out of the species in the list had exact names of species that exists in Sierra Leone. These are:

- Cola nitida
- Lovoa trichilioides
- Pterocarpus erinaceus
- Terminalia ivorensis
- Gmelina arborea
- Mangifera indica

SGS Pricelist
# Appendix 2

Comparison of the two different Carbon models mentioned in the report.

<table>
<thead>
<tr>
<th>Carbon stocks included</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Additional features</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COSTUV3.1</strong></td>
<td></td>
<td></td>
<td></td>
<td>Free download</td>
</tr>
<tr>
<td>- Woody biomass</td>
<td>Stem volume increment</td>
<td>N/A</td>
<td>Can simulate interaction between cohorts of different age and species</td>
<td>Free download</td>
</tr>
<tr>
<td>- Dead wood and litter</td>
<td></td>
<td></td>
<td>Allocation of net primary productivity to leaves, branches, stems, and dead wood</td>
<td>Free download</td>
</tr>
<tr>
<td>- Soil organic matter</td>
<td></td>
<td></td>
<td>Cost accounting model</td>
<td>Free download</td>
</tr>
<tr>
<td>- Wood products</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SCHAF v.0.0</strong></td>
<td></td>
<td></td>
<td></td>
<td>Free download</td>
</tr>
<tr>
<td>- Woody biomass</td>
<td>Initial net primary productivity in kg ha⁻¹ (excluding roots)</td>
<td>C, N, and P cycles</td>
<td>Can include tree and crop species</td>
<td>Free download</td>
</tr>
<tr>
<td>- Non-wood biomass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Dead wood and litter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Soil organic matter</td>
<td>Initial soil conditions</td>
<td>Soil plant feedback</td>
<td>Can include additions of organic and inorganic fertilizers, and transfer of pruning</td>
<td>Free download</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biological variables</th>
<th>Management information</th>
<th>Processes</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood density</td>
<td>Degradation rate</td>
<td>Initial biomass of leaves, branches, stems, and dead wood</td>
<td>Free download</td>
</tr>
<tr>
<td>Carbon content</td>
<td></td>
<td>Rotation length</td>
<td></td>
</tr>
<tr>
<td>Resilience time of</td>
<td></td>
<td>Recycling option</td>
<td></td>
</tr>
<tr>
<td>Carbon in products</td>
<td></td>
<td>Tree thinning</td>
<td></td>
</tr>
<tr>
<td>Cyanuric period of</td>
<td></td>
<td>Fraction of stand removed</td>
<td></td>
</tr>
<tr>
<td>leaves, branches, and roots</td>
<td></td>
<td>Allocation of dry wood to products</td>
<td></td>
</tr>
<tr>
<td>Decomposition and humification coefficients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human impact of soil</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Appendix 3
Species used for the different agroforestry methods in Tanzania

<table>
<thead>
<tr>
<th>METHOD</th>
<th>SPECIES</th>
<th>CARBON BASELINE PER HECTARE TCO2</th>
<th>METHOD</th>
<th>SPECIES</th>
<th>CARBON BASELINE PER HECTARE TCO2</th>
<th>METHOD</th>
<th>SPECIES</th>
<th>CARBON BASELINE PER HECTARE TCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary Planting</td>
<td>Markhamia lutea</td>
<td>5.6 per 100 m</td>
<td>Woodlot</td>
<td>Maesopsis eminii</td>
<td>140 Fruit Orchard</td>
<td>Mangifera indica</td>
<td>17</td>
<td>Dispersed Interplanting</td>
</tr>
<tr>
<td></td>
<td>Maesopsis eminii</td>
<td></td>
<td></td>
<td>Acrocarpus fraxinifolius</td>
<td></td>
<td>Persea americana</td>
<td></td>
<td>Maesopsis eminii</td>
</tr>
<tr>
<td></td>
<td>Albizia lebbeck</td>
<td></td>
<td></td>
<td>Casuarina equisetifolia</td>
<td></td>
<td>Artocarpus heterophyllus</td>
<td></td>
<td>Alibizia lebbeck</td>
</tr>
<tr>
<td></td>
<td>Grevillea robusta</td>
<td></td>
<td></td>
<td>Podocarpus spp</td>
<td></td>
<td></td>
<td></td>
<td>Alibizia coriaria</td>
</tr>
<tr>
<td></td>
<td>Acacia polyacantha ssp. polyacantha</td>
<td></td>
<td></td>
<td>Markhamia lutea</td>
<td></td>
<td>Acacia nilotica subsp nilotica</td>
<td></td>
<td>Acacia polyacantha ssp. polyacantha</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acacia nilotica subsp nilotica</td>
<td></td>
<td></td>
<td></td>
<td>Acacia polyacantha ssp. polyacantha</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Alibizia lebbeck</td>
<td></td>
<td>Acrocarpus fraxinifolius</td>
<td></td>
<td>Cedrela odorata</td>
</tr>
<tr>
<td></td>
<td>Acacia polyacantha ssp. polyacantha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4
Vegetation of Sierra Leone. Source: The University of Texas at Austin (1969)
Appendix 5
Pictures
Primary forest, Picket Hill, Sierra Leone
Areas that used to be covered with forest, outside Freetown, Sierra Leone
Beginning of agroforestry training

At the end of agroforestry training
Stack of timber

Stacks of firewood bundles

Weather changes fast and rain floods the streets
Fruit market near Makari

Housing in the villages where fuelwood is the most common energy source
Appendix 6

– Income of fuelwood in the form of charcoal

There are no standardized ways of measuring fuelwood and no standard volume of coal for charcoal bags. Charcoal bags are bought for 6000 le at village level and sold for 20000Le in town often in a 50 kg cement bag (Freetown market, 2013).

The pricing for charcoal in Sierra Leone is demonstrated in the table below. A land owner earns 6000Le (approx. 1.5 USD) per bag. And it is later sold at market for 22000 Le (approx. 4 USD)

Source: Munro & Van Der Horst. (2012)
**Boundary Planting - charcoal**

75% of timber offcuts

3 bags per tree (Practical Action Consulting East Africa, 2012)

33 trees per 100m

Bag price 6000le or 1.25 USD at village level

=3*1.25*33*0.75=93 USD per 100m

Total= 93 USD per 100 m

**Woodlot - charcoal**

Fuelwood (charcoal) 75% of timber offcuts

3 bags of charcoal per tree

698 trees per hectare

Bag price 6000le or 1.25 USD at village level

=0.75*3*698*1.25=1963 USD

**Woodlot - charcoal from additional thinnings**

If 300m³ is for 698 trees then, 60m³ is equal to

60m³ from thinnings = equals to 139 trees equals to 417 bags of charcoal per hectare

698/300*60=139.6

139.6*3=419 USD

417 bags*1, 25 USD=521 USD per hectare

Total 1963+521=2484 USD per hectare
Appendix 7
– Income from boards sold on local market instead export of timber

To get an indication of how much the timber would profit the farmer it could be interesting to calculate the income for a hypothetic case of income for boards. See Appendix 5 for picture of boards.

The recovery rate of timber in calculations is the same as for Emiti Nibwo Bulora project with 25% offset of trees for timber or boards and 75% becoming fuelwood.

The pricing for boards bought in the villages in Sierra Leone is demonstrated in table 4 below. The land owner earns 15000Le (approx. 3 USD) per board of a species like Gmelina arborea, that is cut from his land (Munro & Van Der Horst., 2012).

Pricing and fees related to boards in Sierra Leone. Source: Munro & van der Horst (2012).

<table>
<thead>
<tr>
<th>Item</th>
<th>Official Price (Le)</th>
<th>Unofficial Price (Le)</th>
<th>Type</th>
<th>#</th>
<th>Official Annual Total (Le)</th>
<th>Unofficial Annual Total (Le)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of boards at source village</td>
<td>15,000</td>
<td>15,000</td>
<td>per boards</td>
<td>8,400</td>
<td>126,000,000</td>
<td>126,000,000</td>
</tr>
<tr>
<td>Chainaw license</td>
<td>6,000,000</td>
<td>200,000</td>
<td>annual fee</td>
<td>1</td>
<td>6,000,000</td>
<td>200,000</td>
</tr>
<tr>
<td>FCC registration</td>
<td>250,000</td>
<td>150,000</td>
<td>annual fee</td>
<td>1</td>
<td>250,000</td>
<td>150,000</td>
</tr>
<tr>
<td>NRA tax</td>
<td>250,000</td>
<td>250,000</td>
<td>annual fee</td>
<td>1</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Forestry Retail Fee</td>
<td>500,000</td>
<td>0</td>
<td>annual fee</td>
<td>1</td>
<td>500,000</td>
<td>0</td>
</tr>
<tr>
<td>ACOTIDA membership</td>
<td>150,000</td>
<td>150,000</td>
<td>annual fee</td>
<td>1</td>
<td>150,000</td>
<td>150,000</td>
</tr>
<tr>
<td>ACOTIDA reforestation fee</td>
<td>50,000</td>
<td>25,000</td>
<td>per trip</td>
<td>12</td>
<td>600,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Forestry</td>
<td>1,500</td>
<td>200</td>
<td>per board</td>
<td>8,400</td>
<td>12,600,000</td>
<td>1,600,000</td>
</tr>
<tr>
<td>Chilدور fee</td>
<td>1,000</td>
<td>1,000</td>
<td>per board</td>
<td>8,400</td>
<td>8,400,000</td>
<td>8,400,000</td>
</tr>
<tr>
<td>Transport</td>
<td>7,500</td>
<td>7,500</td>
<td>per board</td>
<td>8,400</td>
<td>63,000,000</td>
<td>63,000,000</td>
</tr>
<tr>
<td>Unloading</td>
<td>1,000</td>
<td>1,000</td>
<td>per board</td>
<td>8,400</td>
<td>8,400,000</td>
<td>8,400,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>236,150,000</strong></td>
<td><strong>208,630,000</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| REVENUE | Boards | 35,000 | per board | 8,400 | 294,000,000 |

| ANNUAL PROFIT | | 67,850,000 | 55,370,000 |
Boundary Planting- boards

Boards 25% recovery rate

10 boards per tree and tree is 25cm dbh (diameter at breast height) at 25 years (Berry, 2008b)

33 trees per 100m

Board price 15000le or 3 USD at village level

=10*3*33*0, 25=248 USD per 100m

Woodlot- boards

Compared to income for local board production (instead of timber)

Assumptions:

Boards 25% recovery rate

10 boards per tree and tree is 25cm dbh (diameter at breast height) at 25 years (Berry, 2008b)

698 trees per hectare

Board price 15000le or 3 USD at village level

=10*3*698*0, 25=5235 USD per hectare
Appendix 8
Break-even when income from carbon sequestration equals registration cost for registration.

<table>
<thead>
<tr>
<th></th>
<th>Boundary Planting</th>
<th>Dispersed Interplanting</th>
<th>Fruit Orchard</th>
<th>Woodlot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Startup cost/carbon income per ha</td>
<td>10000/33</td>
<td>10000/359</td>
<td>10000/100</td>
<td>10000/826</td>
</tr>
<tr>
<td>hectares</td>
<td>303</td>
<td>28</td>
<td>100</td>
<td>12</td>
</tr>
</tbody>
</table>
## Appendix 9
Summary of agroforestry planting methods for Sierra Leone. Recommendation

<table>
<thead>
<tr>
<th>Method</th>
<th>Objective</th>
<th>Species recommended</th>
<th>Description</th>
<th>Maintenance</th>
<th>Carbon baseline per hectare tCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary Planting</td>
<td>Land demarcation, windbreaks, soil erosion control, shade/shelter, building poles, fuelwood</td>
<td>Markhamia lutea, Maesopsis eminii, Albizia lebbeck, Grevillea robusta, Acacia polyacantha</td>
<td>Trees are planted 3 meters apart in one or several rows. Distance between rows should be 2m, with space to neighboring land. 33 trees in a 100m stretch.</td>
<td>Weeding competing vegetation, thinning between years 4-15, harvest trees in year 20-25 and replanting</td>
<td>5.6 per 100 m</td>
</tr>
<tr>
<td>Dispersed Interplanting</td>
<td>Make soils more fertile and increase yield of crops and agriculture. Soil conservational and water improving benefits. Additional income through fuelwood and non-timber products</td>
<td>Markhamia lutea, Maesopsis eminii, Albizia lebbeck, Albizia coriaria, Acacia nilotica subsp nilotica, Acacia polyacantha sap. polyacantha, Acrocarpus fraxinifolius, Cedrela odorata</td>
<td>200 trees per hectare are planted on cultivated land and cut after 30 years when fully grown and maximum carbon uptake has been achieved. Weeding and pruning is required.</td>
<td>Weeding competing vegetation. Pruning in the 2nd year to about half the tree height may be needed to control low branching. Dead trees should be replaced at the beginning of the following wet season the first 2 years. Crops will continue to be grown throughout the area planted with trees. Any foliage and green waste should be left on site and worked into the ground. Woody material from pruning can either be used as fuelwood or for poles etc. Trees should not be harvested until 30 years old.</td>
<td>61</td>
</tr>
<tr>
<td>Fruit Orchard</td>
<td>Makes a great income source through production of fruits to be sold on local market. Also an additional food source. Soil and water improving benefits and can be planted on marginalized farmland or degraded land</td>
<td>Mangifera indica, Persea americana, Artocarpus heterophyllus</td>
<td>Mangoes 123 trees per hectare and avocado 156 trees per hectare. Pruning and weeding required. Trees should not be cut down until they are 50 years</td>
<td>Mangoes 123 trees per hectare and avocado 156 trees per hectare. Pruning and weeding required. Trees should not be cut down until they are 50 years</td>
<td>17</td>
</tr>
<tr>
<td>Woodlot</td>
<td>Diversifies the farmer’s production so they get timber, fuelwood, medicine, fodder and non-timber products. Large environmental benefits such as water and soil improvement and conservation. Enhanced biodiversity and income source</td>
<td>Maesopsis eminii, Acrocarpus fraxinifolius, Casuarina equisetifolia, Podocarpus spp, Markhamia lutea, Acacia nilotica subsp nilotica, Albizia lebbeck, Acacia polyacantha sap. polyacantha</td>
<td>Trees are planted either 3x3 or 4x4 meters apart depending on species. Weeding might be necessary and thinning should be done between 6-10 years. Harvest of timber can be done between 12-18 years. After which replanting must be done. Planting can be done on marginalized farmland or other degraded lands.</td>
<td>Weeding competing vegetation, thinning between years 4-15, harvest trees in year 20-25 and replanting</td>
<td>140</td>
</tr>
</tbody>
</table>