## Annex 7 – Technical Specification

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| **Project Intervention:** | Forest restoration (1 111/ha planting density) |
| **Version:** | Version 3.0 |
| **Date Approved:** | 02 July 2025 (validation date) |
| **Methodology:** | PM001 “Agriculture and Forestry Carbon Benefit Assessment Methodology” – version 0.1 |
| **Modules/Tools:** | List of tools used in this technical specification:<br><br>AR-TOOL02 “Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities”<br><br>PU001 “ Estimation of baseline and project GHG removals by carbon pools in Plan Vivo projects”<br><br>AR-ACM0003 “A/R Large-scale Consolidates Methodology – Afforestation and reforestation of lands expect wetlands”<br><br>AR-TOOL14 version 04.2 “Methodological tool - Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”<br><br>AR-TOOL12 version 03.1 “A/R Methodological tool – Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities”<br><br>PU003 “Estimation of baseline and project GHG emissions from emission sources in Plan Vivo projects”<br><br>AR-TOOL07 “Estimation of direct nitrous oxide emission from nitrogen fertilization”<br><br>IPCC 2006 Chapter 11 “N2O emissions from managed soils, and CO2 emissions from lime and rea application”<br><br>AR-TOOL08 “Estimation of non-CO2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity”<br><br>AR-TOOL05 “Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities”<br><br>AR-TOOL16 “Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities”<br><br>PU004 “Estimation of GHG emissions from leakage in Plan Vivo projects” |

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| | AR-TOOL15 "Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity"<br><br>PU005 "Estimation of uncertainty of carbon benefit estimates in Plan Vivo projects"<br><br>Myrlin model "Methods of Yield Regulation with Limited Information" |
| **Certificate Type(s):** | Using this technical specification we will issue fPVCs and subsequently (after monitoring and verification rounds) rPVCs and vPVCs. |

**Applicability conditions**

This technical specification can be applied to the forest restoration component of the project, which is aimed at restoring (fallowed) agricultural land with planting a mix of native tree species. The technical specification can be applied to project zones and potential expansion zones under the following conditions:

- the project plot is located within the Nguru Mountains Landscape (for a detailed description of the project area see section 1.1 of the PDD).
- the project plot was historically covered by natural forest and has been used as agricultural land for a period of at least 10 years.
- the coverage of natural wooden vegetation within the plot does not exceed 10%. This is based on the fact that plots rarely have more than 20 trees per hectare left. Considering a canopy of 50 square metres per tree, the maximum tree cover would account for 1 000 square metres per hectare, thus 10% of a hectare.

**Additionality**

To describe the most likely land use scenario in absence of project activities and to do the additionality assessment of the project interventions, we followed the steps as indicated by AR-TOOL-02: "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities". The module dictates the following steps:

Step 0 – preliminary screening based on the starting date of the A/R project activity

The tree planting in the project area started in March 2023 with a pilot of 200 hectares. This means planting has started before the official registration under the Plan Vivo standard. From the very beginning stages of the project design the objective was to set-up a carbon project. In fact, the lease model is based on the long-term income derived from carbon sales. If needed, we can provide evidence that the incentive from the planned sale of CERs was seriously considered in the decision to proceed with the project activity.

Step 1 – identification of alternative scenarios

*Sub-step 1a – Identify credible alternative land use scenarios to the proposed project activities*

Based on presence in the field, land evaluation study and socio-economic data, we assume the following possible land-use scenarios that would occur on the land within the project boundary in absence of the project:

1) continuation of pre-project land use, that is subsistence agriculture using unsustainable agricultural practices;
2) Reforestation of the land within the project boundary performed without being registered as A/R CDM project activity;
3) Increase in agricultural production of cash crops such as cardamom due to increase in demand and investment from (inter)national actors. This would mean moving from predominantly subsistence agriculture to more commercial and intensive land use;

*Sub-step 1b - Consistency of credible alternative land use scenarios with enforced mandatory applicable laws and regulations.*

The continuation of pre-project land use is in compliance with local, regional and national regulations and laws that are in force in the project area. Just like the reforestation of land without being registered as A/R CDM project activity.

An increase in the cultivation of cash crops on existing agricultural land would not be opposing the applicable laws and regulations. However, the Tanzanian government doesn't actively promote the production of cash crops. Besides, if current agricultural lands would be expanded and cultivation would take place within the boundaries of Mkingu Forest Reserve, as it is already happening, this would be illegal. In the following steps we will therefore assess the barriers for farmers to move from subsistence farming towards cash crops on existing farmland.

Step 2 – Barrier analysis

*Sub-step 2a – identification of barriers that would prevent the implementation of at least one of the alternative land use scenarios.*

There are no barriers that would hamper the continuation of the pre-project land use. Due to unsustainable agricultural practices that are used in the business-as-usual scenario it can be expected that productivity and fertility of the land will decrease even further. Most likely this will lead to expansion of agricultural land at the expense of the existing forest, leading to further decreasing biomass and therefore a decreasing carbon stock under the baseline scenario.

For baseline scenario 2 and 3 there are several potential barriers. The following barriers are of influence on the other two baseline scenarios:

| **Barrier** | **Barrier to scenario:** |
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| Investment barriers:<br><br>A reforestation project such as the one we propose, requires significant investments to set up a nursery, pay for salaries, land rent and logistics. Additionally, the lease construction, where farmers will be paid for a period of 40 years, requires even larger investments. For this, income from carbon credits is believed to be essential. Looking at these high investments it is not possible for the community or local government themselves to set up a similar project. Besides this, the Nguru Mountains are an area that has received little attention from (inter)national NGOs. It is therefore unlikely that a reforestation project will be started by another organization. | Forestation without being registered as A/R CDM activity (2) |

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| There are small investment by the national NGO Sustainable Agriculture Tanzania (SAT) to support farmers in the Nguru area to implement agroforestry practices on (part of their) land. The available budget for this is limited and therefore it is not expected to have a high impact on current land use. Besides this, in the nearby future agroforestry will also be integral part of this project's approach. | Landscape dominated by cash crops (3) |
| Technological barriers:<br><br>There is a lack of technical expertise regarding forest restoration. This is mainly in terms of knowledge, for example the setting up of a nursery with indigenous tree species and an adequate planting strategy. | Forestation without being registered as A/R CDM activity (2) |
| Barriers related to local traditions:<br><br>From a cultural point of view in the project area, and this has been the case for centuries, the forest has been considered profitable as a place for hunting or when it is cut down, either for the use and sale of the timber obtained, or to make room for shade-growing crops such as cardamom, bananas or yams. There is a need for a sort of cultural leap to start thinking of the forest in different terms, and as an entity that can produce economic and other benefits while it grows and not when it is cut down. This leap and the transition to actively restore forests is not expected to be realized from within the local community without the initiation of a reforestation project. | Forestation without being registered as A/R CDM activity (2) |
| Farming in the project area consists mainly of subsistence farming, meaning nearly all of the crops are used to maintain the farmer and the farmer's family, leaving little, if any, surplus for sale or trade. It is unlikely that farmers will move away entirely from subsistence farming when incentives/investments are available to move towards cash crops. An increase in cash crops cultivated on existing farm land will therefore be limited. | Landscape dominated by cash crops (3) |
| Barriers due to prevailing practice:<br><br>Cardamon grows better under forest cover. Currently, cardamon production therefore takes place within the Mkingu Forest Reserve, leading to illegal clearing of the understory growth and degradation of the forest ecosystem. Increasing investments in cash crops such as cardamon are expected to lead to an increase of encroachment in the Mkingu Forest Reserve. Activities under scenario 3 are thus expected to lead to an increase in illegal activities, unless it is organized in such a way that cardamon will only be grown on existing agricultural plots. This is unlikely due to prevailing practice (see also barriers related to local tradition above). | Landscape dominated by cash crops (3) |
| Barriers due to social conditions: | |

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| Even in areas where cash crops are more commonly cultivated, and have been so for centuries (i.e. East and West Usambara mountains) farmers never move away completely from subsistence agricultural, both for a cultural stand but also for food security, in the event cash crops were to fail, even though these mountains are readily connected thru paved roads with the neighbouring lowlands were crops are chiefly cultivate. In our area, where the logistics of moving crops (both subsistence and cash) are difficult and expensive, it is very unlikely that farmers will shift to a landscape dominated by cash crops. | Landscape dominated by cash crops (3) |

*Sub-step 2b – Elimination of land use scenarios that are prevented by the identified barriers*

Based on the barrier analysis we conclude that the forestation without being registered as A/R CDM project activity can be excluded from the list of realistic baseline scenarios. The identified barriers to baseline scenario 3, a landscape dominated by cash crops, do not feel strong enough to eliminate this scenario altogether. Especially since there are currently already small-scale investments in agroforestry systems close to the project area. That leaves the following two baseline scenarios:

1) continuation of pre-project land use, that is subsistence agriculture using unsustainable agricultural practices.
2) Increase in agricultural production of cash crops such as cardamom due to increase in demand and investment from (inter)national actors. This would mean moving from predominantly subsistence agriculture to more commercial and intensive land use.

*Sub-step 2c – determination of baseline scenario (if allowed by the barrier analysis)*

Reforestation without being registered as an A/R CDM activity is excluded from the list of land use scenarios. After elimination of this scenario there are two land use scenarios left. Based on the decision tree we assess the removals by sinks for each scenario and select the scenario with the highest GHG removals by sinks as the baseline scenario.

The continuation of pre-project activities means the landscape will be dominated by a mix of perennial and annual crops. Deforestation rates could increase when population pressure increases or if improved infrastructure increases the accessibility of the project area. These are speculative developments so to be conservative we will assume that deforestation rates in the Mkingu Forest Reserve remain similar to current rates or are expected to increase in parallel with deforestation rates in other forest ecosystems in Tanzania. Carbon removal is expected to be limited because of slash and burn practices, as well as escaped fires, and the limited amount of perennial (woody) crops.

The scenario under which a move from subsistence agriculture to cultivation of cash crops will take place is expected to have higher removals since this would mean a shift towards perennial crops instead of annual crops. This would mean more biomass over time. However, the most likely cash crops grow best under the shade of the existing forest. We expect an increase in cash crops will lead to encroachment and clearing of understory in the Mkingu Forest Reserve. This hypothesis is based on the observation that other initiatives tyring to promote the cultivation of cash crops have caused farmers to increase production inside natural forests. One example was brought to us by Natural Extracts Tanzania, in the direct vicinity of the project area. While they were promoting local communities to grow vanilla on their farms, they also collected information on farmers growing cardamom. What they reported is the use of forest material (poles, truncheon cuttings) for growing the vanilla outside the forest boundaries but also heavy destruction of forest habitat for the cultivation of cardamom inside the forest reserve. Overall it is therefore expected that the increase in carbon emissions due to forest clearing will outweigh the increase in carbon removal resulting from the perennial crops. This will lead to higher carbon emissions as compared to the continuation of pre-project activities.

We therefore select the continuation of the pre-project land use as the baseline scenario. Because forestation without being registered as A/R CDM project activity is excluded we will move on to step 4, the common practice test.

<u>Step 4 – common practice analysis</u>

No similar forestation activities to the one proposed in this Plan Vivo project, have taken place since 31 December 1989. In fact, the region has undergone substantial deforestation over the past decades. Between 2001 and 2021 Mkingu Forest Reserve has lost 1940 hectares of tree cover, equivalent to an 8.6% decrease, while in the same period, the extended project area (Mkingu and Kanga Reserves and the areas between them) lost 4.67 kha of tree cover, equivalent to a 9.7% decrease in tree cover since 2000 (information retrieved from Global Forest Watch on 06/02/24). We can therefore conclude that the proposed activity is not the baseline scenario and, hence, it is additional.

**<u>Project activities</u>**

See chapter 3.6 of the PDD for a complete list of the project activities.

**<u>Carbon benefits</u>**

The crediting period of this project is set at 30 years. For the pilot plots restored in 2023, this means that the crediting period will be until 2053.

**<u>Carbon Pools and Emission Sources</u>**

In the table below we provide a brief justification for the inclusion or exclusion of carbon pools and emission sources. A more elaborate explanation for the inclusion or exclusions of the carbon pools and emissions sources is provided in the sections below where we will quantify pools and emissions sources for both the baseline and the project scenario.

| **Carbon pools and emission sources that are included or excluded in the quantification** | | |
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| **Pools or emission sources** | **Type of pool or emission source** | **Included?** |
| **Carbon pools** | Aboveground woody biomass | YES: planting of trees is the main component of the forest restoration component of this project. |
| | Aboveground non-woody biomass | NO: conservatively excluded |
| | Belowground biomass | YES: a significant part of biomass of the planted trees consists of roots. This will be calculated from above ground biomass, using a root-to-shoot ratio. |

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| | Litter | NO: conservatively excluded |
| | Deadwood | NO: (part of) the deadwood is expected to remain in the field. Although this will slowly decay, contributing to the carbon storage realized during the project period, we conservatively exclude it. |
| | Soil organic carbon | YES: soils in the project area are degraded, in various degrees, after years of agricultural use. Forest soils contain a large amount of organic carbon. The reforestation sites are expected to accumulate SOC during the project period. |
| | Wood products | NO: conservatively excluded |
| **Emission sources** | Nitrogen fertilisers ($N_2O$) | YES: a small amount of fertilizer will be used during the planting. |
| | Nitrogen fixing species ($N_2O$) | NO: conservatively excluded |
| | Biomass burning ($CH_4$) | NO: conservatively excluded |
| | Fossil fuel use ($CO_2$) | YES: there will be an increase in fossil fuel consumption due to project logistics as compared to the baseline. Also some international flights from project staff or partners will lead to increased emissions. |
| | Enteric fermentation ($CH_4$) | NO: livestock in the project area is very limited. Project activities will not lead to an increase or decrease in methane emissions. |
| | Manure deposition ($CH_4$, $N_2O$) | NO: manure is neither used on a large scale under the baseline nor the project scenario. |
| | Soil methanogenesis ($CH_4$) | NO: project activities will not lead to an increase in soil methanogenesis as compared to the baseline. |

**Expected Baseline Emissions/Removals**

For the calculation of the baseline emissions and removals we follow the methodology PM001. The change in carbon stocks under the baseline scenario is calculated following the steps described in PU001 ("Estimation of baseline and project GHG removals by carbon pools in Plan Vivo projects"). Below we go through the argumentation and calculations step by step.

Step 0 – showing applicability of PU001

There are two conditions that have to be met, project activities should not lead to [1] excessive soil disturbance and [2] alteration of hydrology of project area or connected wetlands.

1) The project land is not a wetland and since the use of agricultural inputs such as manure and fertilizer is not common in the project area, PU001 can be applied to our project, based on Appendix 2 of module AR-ACM0003. The project land does however contain organic soils, meaning soil disturbance due to project activities should be under 10%. Soil disturbance due to project activities consists only of digging of planting holes. Based on the planting density (1 111/ha, 3 x 3 m spacing) and size of the planting holes (0.3 x 0.3 m) soil disturbance will equal a surface of 99.99 $m^2$. This equals a maximum soil disturbance of 0.99%, well under the 10% threshold. During the maintenance (weeding) of planting sites we will be careful to not cause an increase in soil erosion. Weeding is done manually by slashing grasses, brambles and bracken fern and subsequently leaving them on site to create a layer of mulch.
2) The project activities do not have negative impacts on the hydrology within the project area or any wetlands in the watershed. There will not be any excessive use of water for irrigation, as seedlings will be irrigated when in the nursery only, and not in the fields. In fact, the project is expected to deliver positive effects on water retention and infiltration as compared to the baseline. First-hand in situ experience and bibliography clearly shows how a plot of land with barren soil is unable to absorb the vast majority of the rainfall which runs off, often at great speed, washing off topsoil. On the contrary, forested plots and healthy soils are able to absorb great quantities of rainfall which renew the subterranean aquifers, whilst retaining carbon-rich topsoil.

Both applicability conditions apply to the project intervention, PU001 can thus be applied for calculations of baseline removals within this project.

Step 1 – Woody biomass

*Sub-step 1a – Stratification*

All land under the baseline scenario consists of agricultural land. There are however differences in biomass distribution according to the crops that are cultivated on the land. Roughly a distinction can be made between annual crops (maize, beans etc) and perennial crops (cardamon, banana etc). Land is left fallow for periods between 1-5 years. After the fallow period, these lands will be cleared, usually with the help of fire, again and used for either annual or perennial crops for a next cultivation cycle.

*Sub-step 1b – Baseline removals in woody biomass*

Based on section 5 of AR-TOOL14 "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities", carbon stock in trees in the baseline can be accounted as zero if all of the following conditions are met:

1) The pre-project trees are neither harvested, nor cleared, nor removed throughout the crediting period of the project activity. Pre-project woody vegetation consist of native species, which will be left in the field during the crediting period:
2) The pre-project trees do not suffer mortality because of competition from trees planted in the project, or damage because of implementation of the project activity, at any time during the crediting period of the project activity. In the baseline scenario pre-project trees are likely to be pruned or felled over time. Within the project scenario the trees will be allowed to grow. Especially in the first years after planting the trees will not suffer competition from the seedlings. In later stages, when the pre-project trees are part of the young forests' canopy, the trees might suffer from competition, like would be the case in any natural forest;
3) The pre-project trees are not inventoried along with the project trees in monitoring of carbon stocks but their continued existence, consistent with the baseline scenario, is monitored through the crediting period of the project activity.

Based on the fact that the three assumptions above are met, we can also assume that changes in carbon stocks in trees and shrubs in the baseline are zero. Additionally, we can demonstrate that the following indicators stated in AR-TOOL14 apply:

- Presence of plant species locally known to be indicators of infertile land, such as *Pteridium aquilinum* are present throughout the project area;
- Land is subjected to periodic cycles. After leaving the land fallow for a period of 1-5 years for the land is cleared to be taken into agricultural production. Perennial crops are also subject to periodic cycles, cardamom for example is removed from the fields after 6 to 7 years. Clearing land involves slash-and-burn practices. This way the biomass oscillates between a minimum and maximum value in the baseline.

Because the conditions above are met, we assume that the carbon stock and carbon stock changes in woody biomass in the baseline scenario are zero.

<u>Step 2 – Non-woody biomass</u>

In line with argumentation above, that land is subjected to periodic cycles, we argue that non-woody biomass stock and change under the baseline scenario are zero.

<u>Step 3 – Belowground biomass</u>

Since we assume aboveground biomass in the baseline scenario to be zero, there is no need to calculate below ground biomass using root to shoot ratios. The stock and changes in stock of belowground biomass under the baseline scenario therefore, is zero too.

<u>Step 4 – Baseline removals in dead wood and litter</u>

We assume dead wood under the baseline does not remain in situ and will be used by the community members for firewood or to make tools. The same applies to litter, which will be burned on site before the onset of new crop cycles. We therefore assume removals from dead wood and litter to be zero under the baseline scenario.

<u>Step 5 – baseline removals in Soil Organic Carbon (SOC)</u>

As shown under step 0, the applicability conditions of module AR-ACM003 "A/R Large-scale Consolidates Methodology – Afforestation and reforestation of lands expect wetlands" apply to the project, meaning we can assume that removals in soil organic carbon under the baseline are zero. Due to prevailing unsustainable agricultural practices, which are not expected to change under the baseline, it could even be argued that soil organic carbon would decrease under the baseline scenario. A possible decrease in SOC under the baseline will not be taken into account, meaning we apply a conservative estimate in this sense.

Step 6 – Wood products

Land use under the baseline is dominated by agricultural activities, wood production for construction or wood is not prevalent. If wood is used for these purposes, this wood is derived from remnant trees or illegally from the Mkingu Reserve. A recent example is the construction of two bridges by local communities using 30 meter tall native trees from within the forest boundaries.

Step 7 – Harvesting

As mentioned above production of wood is not actively practiced. Wood is used as firewood, charcoal production or small tools and construction. This wood is mainly derived from the remnant trees or illegally from the Mkingu Reserve. This would lead to a slight decrease in woody biomass under the baseline scenario, which is conservatively left out of the equation.

**Concluding this section, we state that the changes in carbon stocks in trees, shrubs and SOC under the baseline scenario within the project area may conservatively be estimated as zero.**

The module PU003 "Estimation of baseline and project GHG emissions from emission sources in Plan Vivo projects" can be used to estimate net GHG emissions by emission sources in the baseline scenario for reforestation and forest restoration projects. The module is therefore applicable to this project. The following emissions sources are assessed:

Step 8 - Nitrogen fertilisers

According to the project staff in the field only a very small percentage of farmers use fertilisers. Only two farmers acknowledged to use small quantities of fertilisers to grow tomatoes. To be conservative in the calculations of the baseline emissions we will leave this limited fertiliser use out of the equation.

Step 9 - Nitrogen fixing species

Under the baseline scenario, some nitrogen-fixing species are cultivated by farmers. The main nitrogen fixing species that are cultivated are beans, which are grown in one-year cycles. Nitrogen fixing species can either mitigate (in case $CO_2$ sequestration outweighs soil N2O emissions) or exacerbate (vice versa) climate change. During the year the beans sequester a small amount of $CO_2$ directly via their own growth. The decomposition of N-rich tissues leading to increased soil N is limited, especially when taking into account post-harvest residues are burnt in the field. It is therefore expected that emissions and sequestration are in balance or that emissions outweigh sequestration. To be conservative we leave emissions caused by nitrogen fixing species out of the equation.

Step 10 - Biomass burning

In the project area, under the baseline scenario, slash and burn practices are common. Fire is used for site preparation and to clear the land of harvest residues prior to replanting. Depending on the cultivated crops and the fallow period the incidence and extent of fires varies from year to year. Besides fire used for preparation, incidentally fire spreads to surrounding patches affecting a bigger area than intended. Under the baseline scenario this is not expected to change. These fires are expected to lead to increased $CO_2$ emissions, but are hard to quantify using existing data. To be conservative, we decided to leave emissions due to fire occurrence out of the equation.

Step 11 - Fossil fuel combustion

AR-TOOL05 “Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities” can be used to estimating increases in GHG emissions due to fossil fuel combustion. The sources of emissions that are included are vehicles and mechanical equipment (e.g. portable such as chainsaws and stationary such as generators or water pumps). Fossil fuel combustion under the baseline scenario is very limited, mainly consisting of fuel for motorbikes and small equipment such as chainsaws. Motorbikes and motor-tricycles are used to move agricultural products and people, whereas chainsaws have occasionally recorded in the area for the logging of both remnant and forest trees. It might be that over the project period fossil fuel combustion will increase due to for example an increase in use of motorbikes or mechanical equipment. Currently this trend is not visible in the field and therefore, to be conservative, we assume fossil fuel combustion to remain the same under the baseline scenario.

Step 12 - Enteric fermentation / step 13 – Manure decomposition

The numbers of livestock in the project area are very limited and are not expected to change under the baseline scenario, nor the project scenario. Emissions resulting from enteric fermentation and manure decomposition therefore are not taken into account in the calculations for the baseline and project scenario.

Step 14 - Soil methanogenesis

The project area is not subjected to conditions of flooding or saturation, due to elevation and height differences, and therefore emissions from soil methanogenesis are not taking into account in the calculations for the baseline and project scenario.

**Conclusion: based on the approved methods above we estimate the change in carbon stock under the baseline to be zero. In fact, we could argue that the carbon stock would most likely decrease over time due to [1] the unrealistic assumption that all pre-project trees would persist over time in the baseline scenario (whereas chances are high that they will be felled during the project period), [2] an expected decrease in SOC due to prevailing poor agricultural practices, [3] an expected increase in illegal extraction and encroachment within Mkingu Forest Reserve, [4] a possible increase in the use of fertilisers under the baseline scenario, [5] increased emissions caused by fires and fossil fuel combustion. However, to provide a conservative estimate we have decided to leave these possible decreases in carbon stocks or increases in emissions out of the equation.**

**Expected Project Emissions/Removals**

Step 0 – showing applicability of PU001

Project removals will be calculated by PU001, applicability has been demonstrated previously.

Step 1 – Woody biomass

*Sub-step 1a – Stratification*

Stratification will be based on planting year only. Although there are slight differences between current land use (fallow, perennial or annual crops) and elevation throughout the project area, these factors are expected to have a minimal impact on the growth rates of trees. The calculation of woody biomass does not have to be done for multiple strata, meaning the accumulation of woody biomass for the forest restoration activity is expected to be the same throughout the entire project area. Since there might be differences in forest development we will install Permanent Sample Plots (PSPs) in each years' plantings. This way we can keep track of growth for each planting year, which is important for possible adjustments to growth models during the crediting period. More information on this will be presented in the monitoring plan.

*Sub-step 1b – Project removals in woody biomass*

At the project start, expected project removals in woody biomass for the entire crediting period need to be estimated through the modelling of tree growth following procedures in AR-TOOL14 "Estimation of carbon stocks and change in carbon stocks in trees and shrubs in A/R CDM project activities". AR-TOOL14 makes two assumptions: [1] Linearity of biomass growth for trees and shrubs and [2] root-shoot ratios are an appropriate method to estimate below-ground biomass.

To calculate the above ground biomass we use an adapted and simplified version of the Myrlin model, to make sure the calculations are in line with the methods proposed in AR-TOOL14. In fact we will only use parameter data of the Myrlin model, not the model and underlying assumptions itself. Meaning the calculations below are done in manually in Excel format. The main reason for using the Myrlin parameters instead of the species-specific growth data as suggested in PM001 is the limited availability of data for the planted species. For most species there is only scientific data from plantations or standing forests in regions with different environmental conditions. Inventory data consists mainly of annual diameter of height increases from the first few years of growth only. This might lead to an overestimation of tree growth since a large part of the species are fast growing in the first 10 years, after which growth is expected to slow down. The Myrlin model allows species to be added using species characteristics such as plant form, mature diameter, ecological guild and wood density. Based on these characteristics each species will be attributed to a Myrlin species group. Each species group has a different mature diameter, annual diameter increment, and value for wood density. The attribution to species groups will be explained into depth later on. Using species groups proofs very useful for reforestation projects with rare species for which little data is available, such as is the case in this project. The steps to calculate AGC and BGC stock with Myrlin are in line with the principles presented in paragraph 8.2 of AR-TOOL14. The main components of Myrlin to model tree growth and stand development are:

- Modelling tree growth based on annual diameter increment (per Myrlin group), allometric equation and maximum mature diameter. The allometric equation chosen by us is the one published in Masota et al. (2014), a locally determined Tier 3 equation according to IPCC terminology. The equation was reviewed and also compared with the biomass equations in Malimbwi et al. (2016), based on the same data set for the moist tropical forest trees. The approach seems to be sound and of high quality. The Chave equation, often used for Tier 1 (generic) estimates in carbon accounting, is influenced by large data sets from Amazonia and SE Asia where trees tend to be taller and of higher volume for a given diameter. It has also been recently noted elsewhere that the Chave equation tends to give excessive values for some locales (Mundhenk et al, 2019). In contrast to the Chave allometric equation, which is based on both diameter and height increments ($AGB = 0.0559 * (p * D^2 * H)$), the Masota allometric equation calculates volume from diameter increment only: $V_{total} = exp(-7.41201 + 2.1901527 * ln(DBH))$ *(see Table 4, model 3 in Masota et al, 2014)*. To calculate AGB, volume is multiplied by the wood density: $AGB = V_{total} * p$.

- BGB is calculated using a root-to-shoot ratio of 0.25, published by Cairns et al (1997).
- $CO_2$ is calculated directly from AGB/BGB using the following equation: $CO_2 = 1.833 * AGB$ which is equal to the multiplication of carbon content in biomass (0.5) with the conversion from C to $CO_2$ (44/12).
- We calculated the yearly amount of $CO_2$ stored per hectare taking into account annual growth diameter increment (based on Myrlin) and a 1% annual mortality rate from year 4 to year 30.

The main difference between the carbon curves that we present below and the carbon curves presented in other Plan Vivo projects is that the curves are not species specific but based on the Myrlin species groups. This means each species is attributed to a Myrlin group, which contain data on diameter increment and wood density. The main reason to do this is that for many species that are planted within the project there is no scientific data available on annual diameter or height increments, as a matter of fact, as stated elsewhere, a large proportion of the species planted are narrow endemic that have never been propagated before. The attribution is based on both ecological characteristics, wood properties and mature diameter. Each Myrlin group consists of a prefix letter and a suffix number that are attributed according to the tables below. The main objective of the prefix letter is to calibrate growth in absence of local Permanent Sample Plot (PSP) data. General inventory data or field observations of mature tree size, wood density and typical ecology from other localities are used to attribute the prefix letter, based on the table below:

| **Model letter** | **Guild/ecology** | **Ecology description** | **Probable wood properties** |
|---|---|---|---|
| **P** | Pioneer | Occurs mainly on heavily disturbed sites, rare in undisturbed forest. | Low density (300-400), very soft, whit, not durable. |
| **L** | Light-demanding | Infrequent in understory, gap opportunist or disturbed forest. Often emergent, large spreading canopy. | Light colour, lower density (450-550), less durable. |
| **M** | Intermediate | Typical canopy trees, also moderately common in understory, main component in less disturbed forest. | Medium density (550-750), often coloured red or brown, not too dark, moderately to very durable. Typical category for high value timbers. |
| **S** | Shade-bearer | Common in understory and lower canopy, but may be long-lived emergent. | Higher density (700+), often dark, usually very durable. Often used where high durability advantageous. |

The suffix number reflects mature size, as estimated from D95 statistics or field observations from other localities. The mature size ranges somewhat relative to the prefix letter. Attribution is according to table below:

| Model number | Occurrence at maturity | Typical range DBH |
|---|---|---|
| **1** | Understory or, for L-P, disturbed sites, gaps. | Up to 25 cm |
| **2** | Intermediate to lower canopy | 25-40 cm |
| **3** | Main canopy | 40-65 cm |
| **4** | Upper canopy and emergent | 65 cm and above |

After attribution of the prefix and suffix a tree species is attributed to a Myrlin category. Each category contains standard parameters that are used to model tree growth. The complete overview of Myrlin groups and the standard parameters can be seen in the table below.

| Mature diameter | Ecology | Wood properties | Growth model | D95 | Dinc | Wd |
|---|---|---|---|---|---|---|
| Less than 30 cm | Pioneers, found on recently very disturbed sites, roadsides, log landings, skid trails. Not found in closed forest. Rarely live more than 20 years. | Very light, low density, white wood, decays rapidly. SG < 0.45 | **P1** | 27.5 | 0.82 | 0.437 |
| 30-40 cm | | | **P2** | 33.9 | 1.45 | 0.371 |
| Less than 30 cm. | Persistent small understorey trees and many palms. | Moderately dense, SG around 0.6 | **S1** | 20.1 | 0.10 | 0.604 |
| 30-40 cm | Persistent understorey or lower canopy trees, some larger palms. | Moderately dense, SG around 0.6. | **M1** | 30.4 | 0.17 | 0.603 |
| 30-40 cm. | Light demanding, more persistent small pioneer trees, found in old gaps, roadsides and clearings persisting 30-40 years after disturbance. Rare in understorey of closed forest. | Less dense timber, typically light coloured, non-durable, SG around 0.5-0.55 | **L1** | 25.8 | 0.32 | 0.534 |
| 40-50 cm | Trees occurring in lower canopy and sub-canopy, typical of undisturbed forest or after long period of recovery. | Heavier, often strongly coloured timbers, SG around 0.7. | **S2** | 44.6 | 0.17 | 0.707 |
| 40-50 cm | Lower and mid canopy trees, most common component of mature forest, suggested default group if on other indications. | Medium density wood, around SG 0.55. | **M2** | 44.6 | 0.38 | 0.553 |
| 40-60 cm | Larger, light-demanding semi-pioneer trees common in disturbed forest after 30-40 years or in old gaps and trails, not found or rare in the understorey or lower canopy. | Lighter density and colour wood, around SG 0.5. | **L2** | 51.1 | 0.61 | 0.507 |
| 55-75 cm | Larger upper canopy trees, but of shade tolerant species, therefore also found in lower canopy and understorey as immature trees. | Dense, often dark or coloured wood, SG >0.7. | **S3** | 62.7 | 0.22 | 0.729 |
| 55-75 cm | Larger upper canopy trees, not common in understorey or lower canopy, but typical of recovered (40 years + post disturbance) or undisturbed forest. | Denser timber, often medium coloured, durable, SG around 0.6. | **M3** | 65.1 | 0.51 | 0.606 |
| 60-80 cm | Large light demanding trees typically regenerating in tree-fall gaps, occurring as upper canopy trees, not found in understory or under closed canopy. | Light coloured, low density timber, SG around 0.45. | **L3** | 72.7 | 0.79 | 0.455 |
| 80 cm + | Large emergent and upper canopy trees, but also shade tolerant and found in the understorey or sub-canopy as immature individuals, not typical of disturbed forest unless specially protected. Very long lived, often valuable timbers. | Heavy darker timber, SG > 0.7. | **S4** | 91.7 | 0.27 | 0.718 |
| 80 cm + | Larger emergent and upper canopy, some shade tolerance, may occur in lower canopy as regenerating individuals, default group for larger trees. | Moderate density, SG around 0.55 | **M4** | 90.6 | 0.59 | 0.555 |
| 80 cm+ | Larger emergent and upper canopy trees, light demanding, gap opportunist, usually with wide spreading crown. | Light colour, low density wood, non-durable as timber, SG around 0.4. | **L4** | 89.4 | 1.08 | 0.390 |

Before presenting the carbon curves per Myrlin group, we provide a general description of the tree species used in the pilot phase and the argumentation for the attribution of each species to a Myrlin group. Attribution is based on databases, literature, field studies and the knowledge of the projects' tropical botanist Andrea Bianchi on species characteristics in the project area.

***Khaya anthoteca* (Welw) C.DC.**

*Khaya anthoteca*, white mahogany, is a tall, canopy dominant or emergent tree found throughout tropical Africa. It is usually semi-deciduous and can exceed 60 meters in height (B.T. Styles & F. White, 1991). In our project area, due to higher rainfall, it behaves as an evergreen species. It is usually found in rainforests and riparian forests, from sea-level to an altitude of roughly 1 600 meters above sea level (Burrows et al., 2019).

Its pole-like bole can be free of branches for over 20 meters and usually up to 1.2 meters in diameter, with the largest specimens measured at over 5 meters in diameter (B.T. Styles & F. White, 1991).. The bole is not buttressed in younger individuals, but the trunk of large specimens is markedly buttressed to a height of 6 m (Lovett et al. 1992)

It is a fairly quick growing tree with rates of 1.5 meters per annuum not being uncommon, although when young it can be heavily attacked by *Hypsipyla robusta* shoot borers. The only known remedy to avoid infestation of the borer is not to plant pure stands of this species, and we will not be using it at a density of over 25% to cautious (PROTA, Denis Alder pers. comm.). Also, scientific literature shows that white mahogany saplings are attacked less often or not at all when planted in a healthy agro-ecosystem; being very close to Mkingu Forest NR we are in the ideal situation where beneficial animals (birds and predatory/parasitoid insects) will keep the numbers of the borer under control (Opuni-Frimpong, 2020). As of January 2024, only one single affected sapling has been noted.

White mahogany has been and is severely extracted, and natural regeneration is scarce, it is listed as 'Vulnerable' in the IUCN Red List of Threatened species (Burrows et al., 2019).

Seeds of Khaya are collected locally (mostly in plantations, as the species has been extracted almost completely from the neighboring forests) and germination rates up to 70% (but more commonly 50%) are expected in 2-6 weeks. Seeds are sown directly in polytubes, and are stored for periods of less than one year at PAMS seedbank in Arusha.

The wood density varies (being higher for trees found in more open, drier areas) and the following values can be obtained from scientific literature and from wood databases:

| Wood density ($kg/m^3$) | Reference |
|---|---|
| 545 | The Wood Database |
| 490-660 | PROTA Database |
| 610 | Tropical Timber Database |
| 390* | MYRLIN |

*values in the MYRLIN tables are given in $g/cm^3$. For the sake of comparison values are presented here in $kg/m^3$.

*Khaya anthoteca* falls, without any doubt, into Myrlin group L4: it is indeed a large emergent or upper canopy tree, gap opportunist, light demanding, usually with a big spreading crown, and its capacity of attaining very large diameters easily places it in suffix 4, trees with a mature diameter of 65cm or above.

**Myrlin group: L4**

**Planting density: 25%**

***Markhamia lutea*** **(Benth.) K.Schum**

Markhamia lutea, the Nile Tulip, is an attractive small to medium size tree, usually growing up to 15 meters tall but with impressive trees reaching heights of 40 meters (Lovett et al, 2006). In a plantation in DRC, 60-year-old trees were 30 meters tall (PROTA). The short bole is usually 30 cm in diameter at breast height, but again larger specimens in Tanzania have been measured at 60 cm in diameter (Moses Mwangoka, TROPICOS). It is a pioneer or a semi-pioneer tree, meaning that it will indeed act as a pioneer (growing well and fast in full sun) but is also capable of persisting in disturbed forests (Useful Tropical Plants). It is naturally found in forested savannah and submontane forests, throughout most of tropical Africa, although absent from the lowlands: it is commonly found at medium-high altitudes, and in the Eastern Arc it can be found between 700 and 2 000 meters above sea level. Records of this species in the lowlands of Tanzania (as in Magombera forest, Morogoro Region) are most likely due to identification mistakes.

Due to the ample quantity of mulch that the Nile Tulip provides while growing it is a commonly used and encountered species in agroforestry settings and in coffee plantations. It is one of the fastest growing native species and if provided good soil and plenty of water it is capable of annual height increments of over 2 meters, although in plantations in previously cultivated soils these increments are reduced considerably. Seeds of this species are collected by PAMS staff in coffee plantations in and around Arusha, processed and cleaned there and then brought to the nursery, where they germinate quickly (2-3 weeks) but with a germination rate of less than 50%. The flat, light seed are usually sown in large seed beds, covered with a very thin layer of soil and transplanted to polytubes at the cotyledon stage. Seeds are orthodox and can be stored indefinitely at PAMS seed bank in Arusha.

As in *Khaya, Markhamia* seedlings are attacked by shoot borers but the same precautions are taken, and these silvicultural measures will greatly reduce or eliminate the damage done by shoot borers.

The wood density varies due to the ecology but also due to the provenance of the mother tree:

| **Wood density ($kg/m^3$)** | **Reference** |
|---|---|
| 410 | Muga et al (2014) |
| 560-575 | Pl@ntNet Database |
| 507* | MYRLIN |

*values in the MYRLIN tables are given in $g/cm^3$. For the sake of comparison values are presented here in $kg/m^3$.

Due to its ecology, being intermediate between pioneer and a light demanding, Nile Tulip is conservatively included in group L, and although DBH of 60cm may suggest a suffix class 3, it is again conservatively placed in class 2 as most of diameters recorded fall between 25cm and 40cm, and it is not usually found as an element of the canopy of mature forests.

**Myrlin group: L2**

**Planting density: 20%**

***Antiaris toxicaria* Lesch. subsp. *welwitschii* (Engl.) C.C.Berg var. *usambarensis* (Engl)**

False Mvule is a large deciduous (even in rainforest habitats such in our case) tree up to 50 meters tall, with a clear, almost white, straight bole up to 20 meters tall before the first branch (Lovett et al, 2006). The bole is well buttressed but only in old specimens, the diameter of the bole above the buttresses can be up to 1.8 meters. The large crown can be flat-topped but is more usually rounded and sometimes conical in larger specimens. As the common name suggests *Antiaris* can be confused with Mvule, *Milicia excelsa.* The latter has a much darker, almost black bark and more rounded leaves (Lovett et al, 2006). False Mvule has a very wide natural distribution occurring in tropical Africa as well as tropical Asia and northern Australia. Due to its large distribution and variability, a multitude of subspecies and varieties have been described, and the one found in Mkingu Forest NR and planted in the project is *Antiaris toxicaria* Lesch. subsp. *welwitschii* (Engl.) C.C.Berg var. *usambarensis* (Engl) (J. & S. Burrows. 2003). False mvule can be found in various forest types, in lowland semi-deciduous, evergreen riparian, swamp and rain- forests. In drier rocky areas it is seldom a tree higher than 20 meters, while in forest habitats it attains a large size and is indeed a component of the canopy layer or an emergent (J. & S. Burrows. 2003). It is usually found between sea level and 1 500 meters above sea level, rarely up to 1 800 m (TROPICOS). *Antiaris* has been planted both as an ornamental and shade tree as well as a plantation tree in various parts of Africa (PROTA). It is very fast growing, attaining full height in 20-30 years under good growing conditions. The egg-shaped seeds, between 1 and 1.5 cm in diameter, are recalcitrant (Useful Tropical Plants) and needs to be sown as soon as possible, and we try not to store them more for more than 2 weeks, to maximize germination percentages, usually around 60% in 4-8 weeks. Seeds are collected from local communities in and around Mkingu Forest NR, and sown in individual polytubes.

Wood density values vary dramatically, even though no clear reason is reported in literature, it may again depend on its wide variability:

| **Wood density ($kg/m^3$)** | **Reference** |
|---|---|
| 250-450 | Agroforestree Database |
| 470 | Tropical Timber Database |
| 370-660 | PROTA Database |
| 390* | MYRLIN |

*values in the MYRLIN tables are given in $g/cm^3$. For the sake of comparison values are presented here in $kg/m^3$.

The ecology of *Antiaris* and its dimensions a clearly places it in the light demanding/canopy-emergent trees, and thus included in group L. The DBH in older specimens is well above the one required to fit in group class 4.

**Myrlin group: L4**

**Planting density: 15%**

***Afzelia quanzensis* Welw.**

Pod Mahogany is a medium to large tree, with a big, open canopy. Although it typically grows to 12-15 meters only, under ideal conditions it can reach 35 meters in height (Coates Palgrave, 1977).

It is a tree more often encountered in dry forests and woodland (SANBI), but ‘enters’ wet forests in the eastern arc where it is almost unrecognizable, resembling a true forest tree (Lovett et al., 2006). The bole, free of buttresses, can be up to 1 meter in diameter (2 meters in exceptional specimens) and it is beautifully patterned with raised rings that flake off irregularly, leaving circular parches on the bark surface (Coates Palgrave, 1977).

In Tanzania it grows from sea level to 1 400 meters above sea level (TROPICOS), but in the eastern arc it is usually found either at lower altitude or in drier habitats. The hard, durable wood of Pod Mahogany has caused its over-extraction across most of its range, spanning from across southern and eastern Africa. Most of the largest specimens have been logged and cut for railway sleepers (Coates Palgrave, 1977).

Although *Afzelia quanzensis* is usually reported to be a very slow growing tree, it can grow quite fast in good sites, with annual increments of up to 60 cm (PROTA). The large, beautiful red and black seeds are collected in and around the project area by local communities, and either sent directly to the nursery or stored indefinitely, until needed, at PAMS seedbank. The hard seedcoat requires scarification before sowing (done manually with secateurs) and the removal of the orange/red aril (Useful Tropical Plants). Once these horticultural practices have been followed, the seeds are individually placed in polytubes and attain a germination percentage of 95-100% in 2-3 weeks.

As previously stated, the wood of Pod Mahogany is hard, heavy and durable, and the following values can be found from scientific papers and online wood density databases:

| **Wood density (kg/m$^3$)** | **Reference** |
|---|---|
| 800-920 | Pl@ntNet Database |
| 820 | Betterwood Database |
| 835 | The Wood Database |
| 606* | MYRLIN |

*values in the MYRLIN tables are given in g/cm$^3$. For the sake of comparison values are presented here in kg/m$^3$.

Pod Mahogany is an intermediate tree, being commonly present in the canopy and in less disturbed forests, so included in group M. It may fall into suffix group 4, but it is conservatively included in group 3 as the vast majority of individuals do not grow up to the sizes of class 4.

**Myrlin group: M3**

**Planting density: 10%**

***Bombax rhodognaphalon K. Schum. Ex Engl. (= Rhodognaphalon schumannianum A. Robyns)***

Bombax rhodognaphalon, the Wild Kapok Tree, is a large, tall tree growing up to 40 (45) meters in height. It behaves as a deciduous tree even in rainforests, dropping leaves in the drier cooler season. The straight bole can be free of branches for up to 21 meters, buttressed up to 3 meters in older individuals, and is capable of attaining diameters at breast heigh of 150 cm, even though the vast majority of mature trees are below 100 cm in diameter (Lovett et al., 2006. Burrows et al., 2019). It is an east African endemic tree (POWO), occurring in the lowland and submontane forests of Kenya, Tanzania, Malawi and Mozambique at elevations from sea level up to 1100 meters (Lovett et al., 2019, TROPICOS). It is more commonly found in regenerating forests, along water courses and in forest gaps (Useful Tropical Plants), yet persisting in the upper layers of the canopy, growing together with taller and dominant tree species such as *Khaya anthoteca, Cephalosphaera usambarensis* and *Milicia excelsa* (pers. obs.)

The medium sized, round seeds are covered in very light, brown to orange hairs similar to the ones of Kapok or cotton, giving it its local name. The seeds are dispersed by the wind and thus difficult to collect, and local communities do so in the project area as well as in the Udzungwa and Usambara mountains. Seeds do not respond well to storing and are usually sown within one month of collection in individual plots.

The high germination rate (80%), the high survival rate and the quick or very fast growth rate (1-2 meters per annuum) would make us want to plant this species in higher densities, but we are unfortunately prevented in doing so by the small quantity of seeds that local communities are able to collect each year. It is indeed a perfect candidate to grow in-vitro to be able to meet the demand in the following years. In the 2023 fruiting season El Niño rains have cause the vast majority of seeds to rot before being dispersed.

Wood densities obtained online and from scientific papers are quite consistent:

| **Wood density (kg/m$^3$)** | **Reference** |
|---|---|
| 465 | Makonda et al (2008) |
| 430 | African Wood Density Database |
| 360 | Can be found FAO Forestry Paper (1997),<br>but it is not measured directly and derived from a regression equation.<br>Therefore it is excluded. |
| 455* | MYRLIN |

*values in the MYRLIN tables are given in g/cm$^3$. For the sake of comparison values are presented here in kg/m$^3$.

Being a component of the main canopy of the eastern arc rainforests, but never emerging above it (in mature forests), and having a DBH usually less than one meter in diameter the Wild Kapok tree falls in Myrlin group L3.

**Myrlin group: L3**

**Planting density: 10%**

***Bridelia micrantha*** **(Hochst.) Baill.**

Coast Goldleaf is small to medium size tree, sometimes deciduous, up to 20 meters tall (K. Coates Palgrave, 1977). It is characterized by a dense, round crown. The tree is often branching from the ground level (especially in sites where it is disturbed by fire, overgrazing and firewood collection) but can also form a tall bare stem which is rarely more than 35 cm in diameter, but can exceptionally grow up to 100 cm (K. Coates Palgrave. 1977). It is a pioneer of a very wide range of habitats throughout tropical Africa, from Senegal eastwards to Ethiopia and south to Angola and South Africa; it has been recorded from sea level to 2000 m in elevation (TROPICOS), in grasslands, miombo, riverine and evergreen forests (Useful Tropical plants). It is a multipurpose tree widely used for fuel (both wood and charcoal) as well as medicine and food (the smelly fleshy fruit are sometimes eaten) (Lovett et al., 2006). It is one of Africa's native fastest growing trees, with annual increments up to 2 meters not being uncommon, and it is planted for soil erosion control and in agroforestry settings as the leaves provide a good mulch (SANBI). The small, black fruits are most often eaten and the seeds dispersed by a wide range of birds, and in our project we prefer to collect small seedlings (=wildlings) at the cotyledon stage in neighboring fallow fields. This allows us to avoid a lengthy and cumbersome seed collection and to 'save' seedlings in fields that would be lost as soon as cultivation commenced. It is generally a very hardy species, but in the recent El Nino rainy season it suffered the adverse effects of a fungal infestation, which was fortunately taken care of with two rounds of systemic fungicide. Being a pioneer species, it is surprisingly characterized by a relative hardwood, with the following values of wood density:

| **Wood density ($kg/m^3$)** | **Reference** |
|---|---|
| 500-705 | PROTA Database |
| 470 | FAO Forestry Paper (1997) |
| 670 | Agroforestree Database |
| 507* | MYRLIN |

*values in the MYRLIN tables are given in $g/cm^3$. For the sake of comparison values are presented here in $kg/m^3$.

*Bridelia micrantha* can be classified as a semi-pioneer tree as, although it will behave as a pioneer species in many conditions, it has the ability to persist for a longer time in the canopy before being outcompeted by other species. It is thus included in class L, and in suffix 2 as the mature diameter is usually less than 40 cm.

**Myrlin group: L2**

**Planting density: 10%**

***Ricinodendron heudelotii* (Baill.) Heckel**

Manketti Nut is an impressive, beautiful, large tree capable of growing to 50 meters in height. It has a wide, open and round canopy, and is deciduous. The large bole is usually straight and up to 120-150 (rarely up to 270) cm in diameter at breast height, often but not always characterized by large buttresses extending into big superficial roots (Lovett et al., 2006, Burrows et al., 2019). It is found as pioneer-intermediate tree species in a very wide variety of habitats, from sand forests, to woodland, deciduous forests and abandoned farmland, but it is indeed in rainforests habitats that is capable of reaching the most impressive sizes (Useful Tropical Plants). It occurs throughout tropical Africa, chiefly in the lowlands, occurring at altitudes between sea level and 1400 m (TROPICOS). Manketti Nut's deep roots reach deep in the soil and then cause little competition for water and nutrients in the upper soil layers, it is indeed frequently planted or left standing in cocoa plantations, and in West Africa it is often referred to as 'the cocoa friend' (PROTA). To extract the hard, roundish seeds, fallen fruits are collected by local communities (in the Nguru and Usambara Mountains of Northern Tanzania) and left to rot in big piles; once the flesh is rotten, the seeds can be washed off and left to dry in partial shade. Seeds are orthodox and are stored in PAMS seedbank, but they require a scarification treatment to increase germination percentages, without this horticultural operation germination rates would fall below 10%. Seeds are individually planted in polytubes. It is a very fast-growing species, and trees are reportedly able to reach full maturity size (40+ m) in 30 years. The wood of Ricinodendron is very light and could be used as a substitute of Balsa wood, reported densities are as follows:

| Wood density (kg/m$^3$) | Reference |
|---|---|
| 130-300 | PROTA Database |
| 260 | Tropical Timber Database |
| 220-400 | DELTA Database |
| 390* | MYRLIN |

*values in the MYRLIN tables are given in g/cm$^3$. For the sake of comparison values are presented here in kg/m$^3$.

The ecology of *Ricinodendron* and its dimensions clearly places it in the light demanding/canopy-emergent trees category, and is included in group L. The DBH in older specimens is well above the one required to fit in group class 4. *Ricinodendron* is one of those interesting species, such as *Antiaris* that occupies a very wide range of habitats and could then be included in two different myrlin groups; they are both to be considered in L4 if grown in wet forests, but L3 in drier habitats.

**Myrlin group: L4**

**Planting density: 5%**

***Milicia excelsa*** **(Welw.) C.C.Berg**

African Teak, or Iroko, is a large evergreen tree or deciduous tree, usually growing to 40 meters tall but cable of reaching 50 meters in height (Burrows et al., 2019). It has a wide, flat crown originating from an impressive bole that can be branchless for 20 meters or more and up to 3.5 meters in diameter. The tree is usually buttressed but these are short and small (Lovett et al., 2006). *Milicia excelsa* can be found in deciduous, semi-deciduous and in evergreen forests, where it behaves as a pioneer/intermediate tree: it indeed needs exposure to sunlight to germinate and grow, and cannot tolerate dense shade. It persists in the canopy where it can, or could, be found both as dominant or emergent (Useful Tropical Plants). In Tanzania it can be found from sea level to 1400 meter, but is more chiefly distributed between 300 and 1 200 meters above sea level (TROPICOS). Milicia is dioecious, meaning that male and female flowers occur on different plants, so individuals of both sexes are needed to produce seeds (World Agroforestry). If fertilized, female flowers mature into long and thin fruits, fleshy, that are dispersed by birds and bats. Embedded in the flesh are small, round and hard seeds, whose extraction from the fruit is cumbersome and time consuming: it is the most expensive seeds bought by PAMS for the restoration project, with an average price of 100-150$ per kilogram. Seeds are somehow intermediate between orthodox and recalcitrant and are kept for a few years at PAMS seedbank. When needed, they are soaked in water for one night and then sown in a large seedbed. When they show the first true pair of leaves, they are individually transplanted in polytubes, and fertilized. As *Khaya,* Iroko is also susceptible by the attack of shoot borers (*Hypsila sp.)* and should not planted at high densities; our planting percentage of 5% is well below the minimum percentages suggested in literature (25%)(Bosu et al., 2006).  African Teak is one of the most desirable and valuable of all African timber species, over-exploited in the past, and now in danger of disappearing. Although it has been assessed as 'Near Threatened' by the IUCN, this species needs to be re-assessed urgently (Burrows et al., 2019). It is one of the fastest growing hardwoods, and trees are ready to be harvested at 50 years (Useful Tropical Plants). The brown, durable wood has medium density:

| **Wood density (kg/m$^3$)** | **Reference** |
|---|---|
| 590-650 | Tropical Timber Database |
| 550-750 | Rozendale Agroforestry Database |
| 560-660 | The Wood Database |
| 660 | The Wood Component Company |
| 390* | MYRLIN |

*values in the MYRLIN tables are given in g/cm$^3$. For the sake of comparison values are presented here in kg/m$^3$.

The ecology of *Milicia excelsa,* behaving as a pioneer but also being a typical element of the upper layer of the canopy, unmistakably places it in category L. The impressive diameters reached by the bole clearly place it in suffix 4.

**Myrlin group: L4**

**Planting density: 5%**

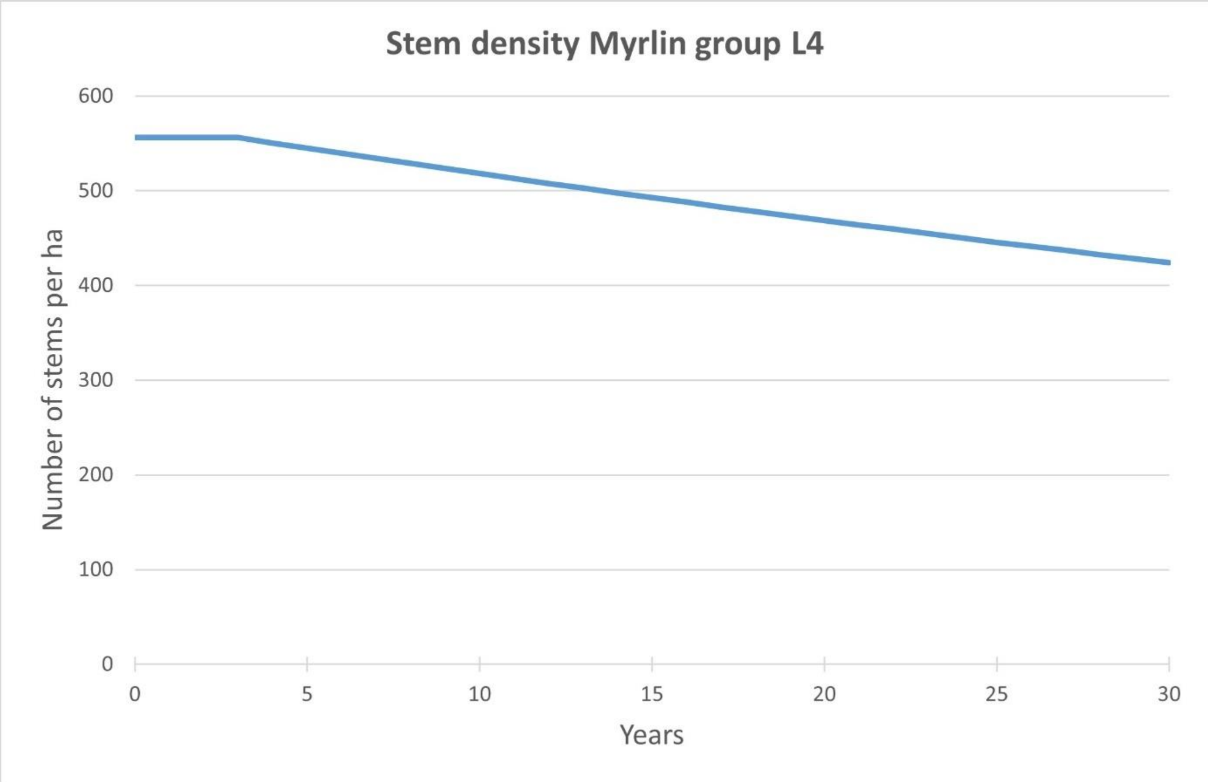
The species presented above are attributed to four different Myrlin groups. Based on this attribution and planting densities of each species provide four carbon curves, based on the following overview.

| Myrlin group | Species (planting density) | Combined planting density |
|---|---|---|
| **L4** | *Khaya anthotheca* (25%), *Antiaris toxicaria* (15%), *Ricinodendron heudelotii* (5%), *Milicia excelsa* (5%) | 50% |
| **L2** | *Markhamia lutea* (20%), *Bridelia micrantha* (10%) | 30% |
| **M3** | *Afzelia quanzensis* (10%) | 10% |
| **L3** | *Bombax rhodognaphalon* (10%) | 10% |

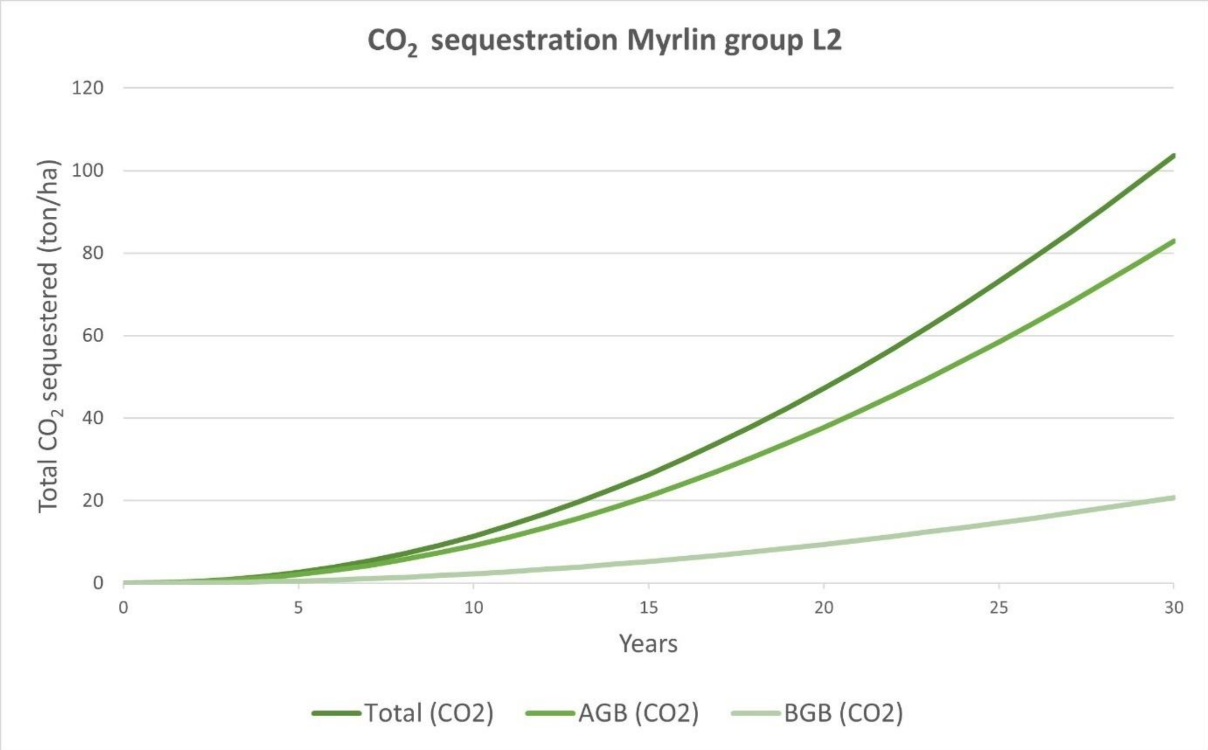
Although the percentages of each planted species may vary in the future years (and more species will be added) the planting density of each of the above Myrlin groups is representative of the future plantings too. Indeed, such a high percentage of pioneer species (group L) is favored in any reforestation/restoration project, where canopy closure is needed as soon as possible in order to minimize competition with grasses, brambles, ferns and shrubs. A large proportion of L4 species mean that the very same species acting as pioneers (favoring high light intensity and fast-growing) will in turn become the canopy elements of the future forest, outcompeting a smaller percentage (30%) of short-lived pioneers (L2) which will not persist for decades in the upper layer of the canopy. M3 species will survive in the shade of L4 contributing to carbon stocks.

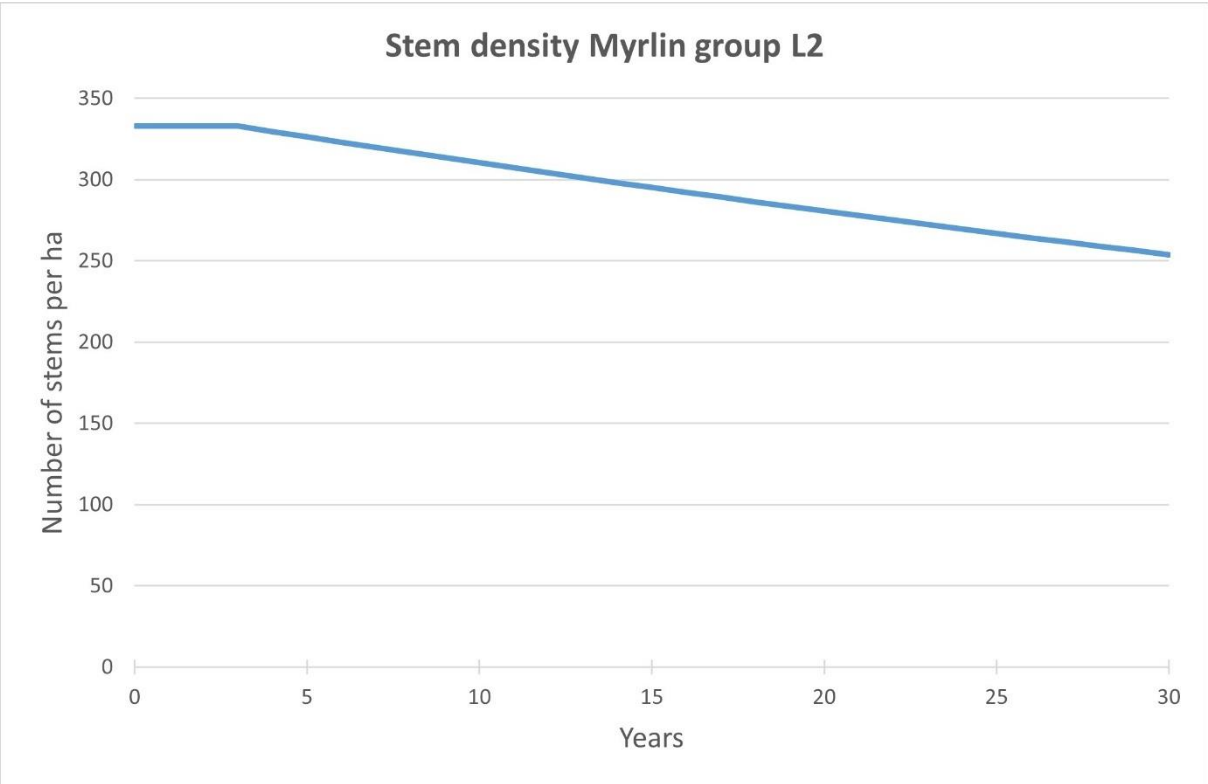
The carbon curves below are based on the attribution to Myrlin groups as described above and the combined planting density for each Myrlin group. During the first three years of the project the seedlings are extra vulnerable and mortality rates are expected to be higher than the annual mortality rate of 1% applied from year 4 to year 30. In our calculation we have kept stem density at 100% for the first 3 years, because of mortality replanting. From year 4 onwards the stem density decreases annually by 1%.

For each of the four Myrlin groups we present two graphs, one showing the $CO_2$ sequestration during the 30-year crediting period and one showing the decrease in stem density of the planted trees. Natural regeneration is not accounted for in both graphs, meaning the expected $CO_2$ sequestration and stem density is conservatively solely attributable to the trees planted in the first years. To conclude we present two graphs representing the total stem density and carbon sequestration. The total is calculated by adding up the outcomes for each of the four Myrlin groups. For transparency purposes we have added the datasheets of the performed calculations in Annex 6.

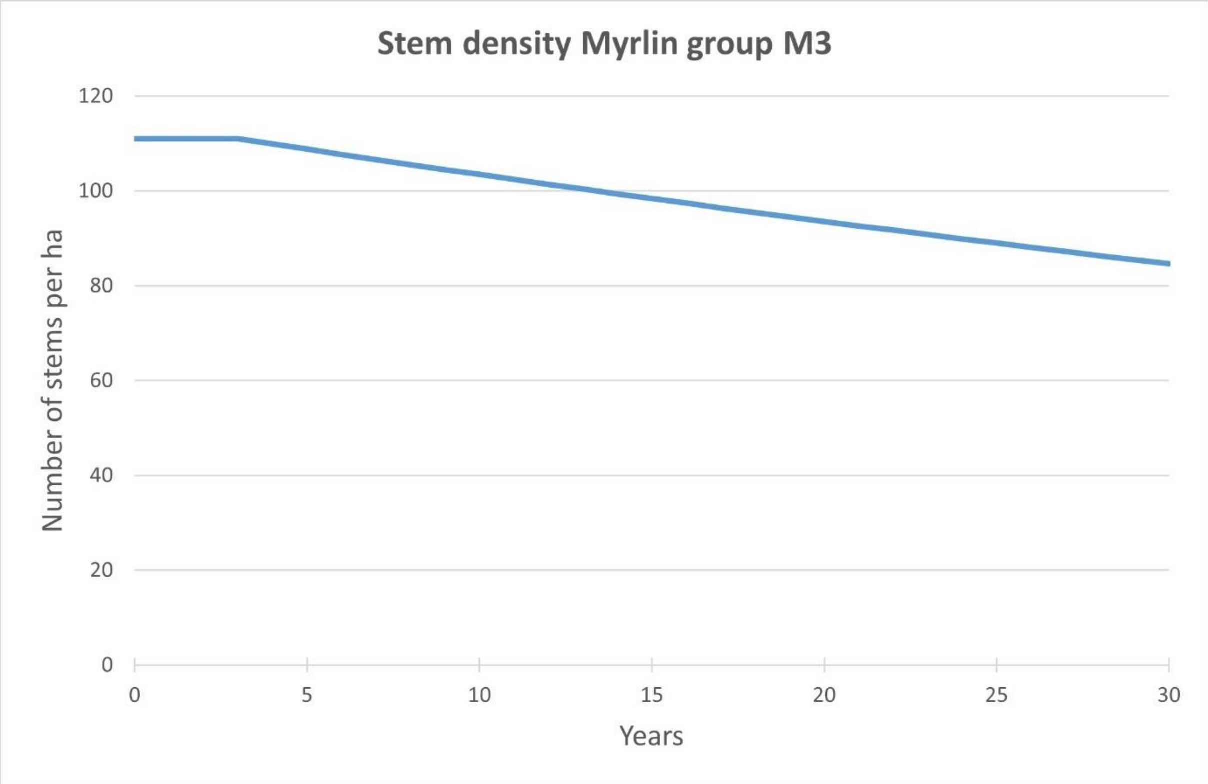




| L4 outcome | Value at year 0 | Value at year 30 |
|---|---|---|
| Stem density | 556 | 424 |
| $CO_2$ in AGB | 0 | 372 |
| $CO_2$ in BGB | 0 | 93 |
| Total $CO_2$ | 0 | 465 |

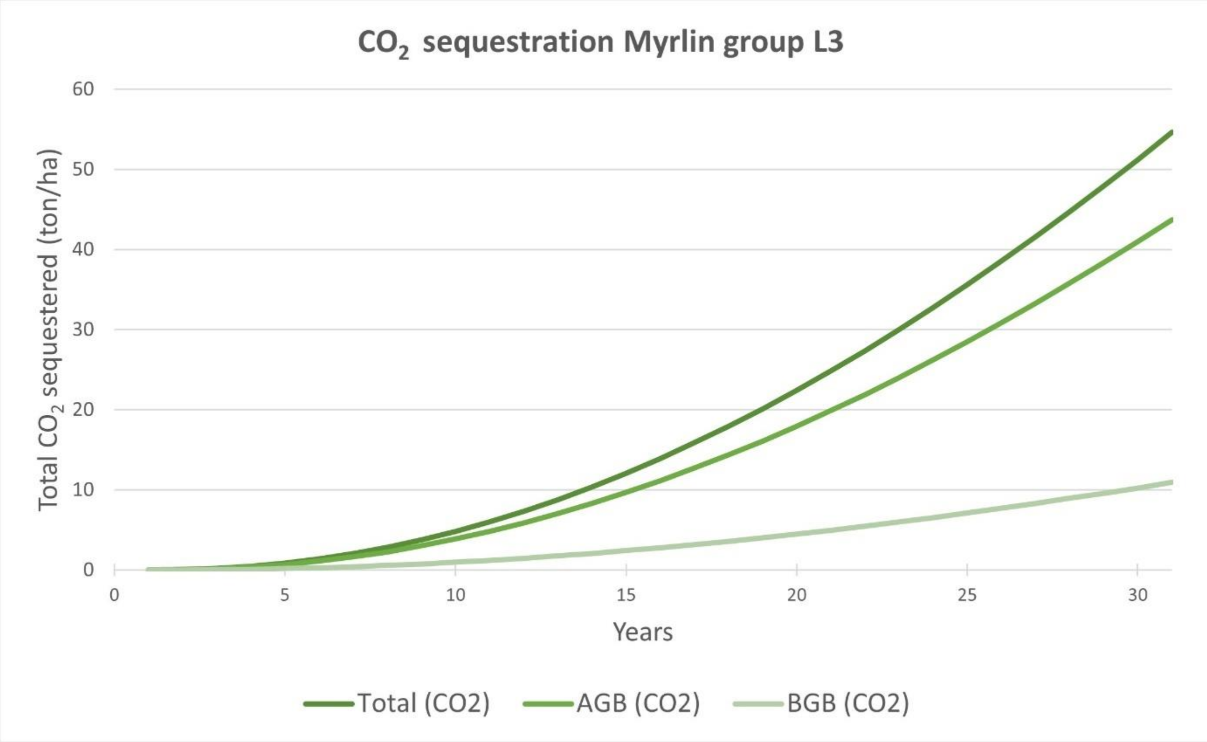


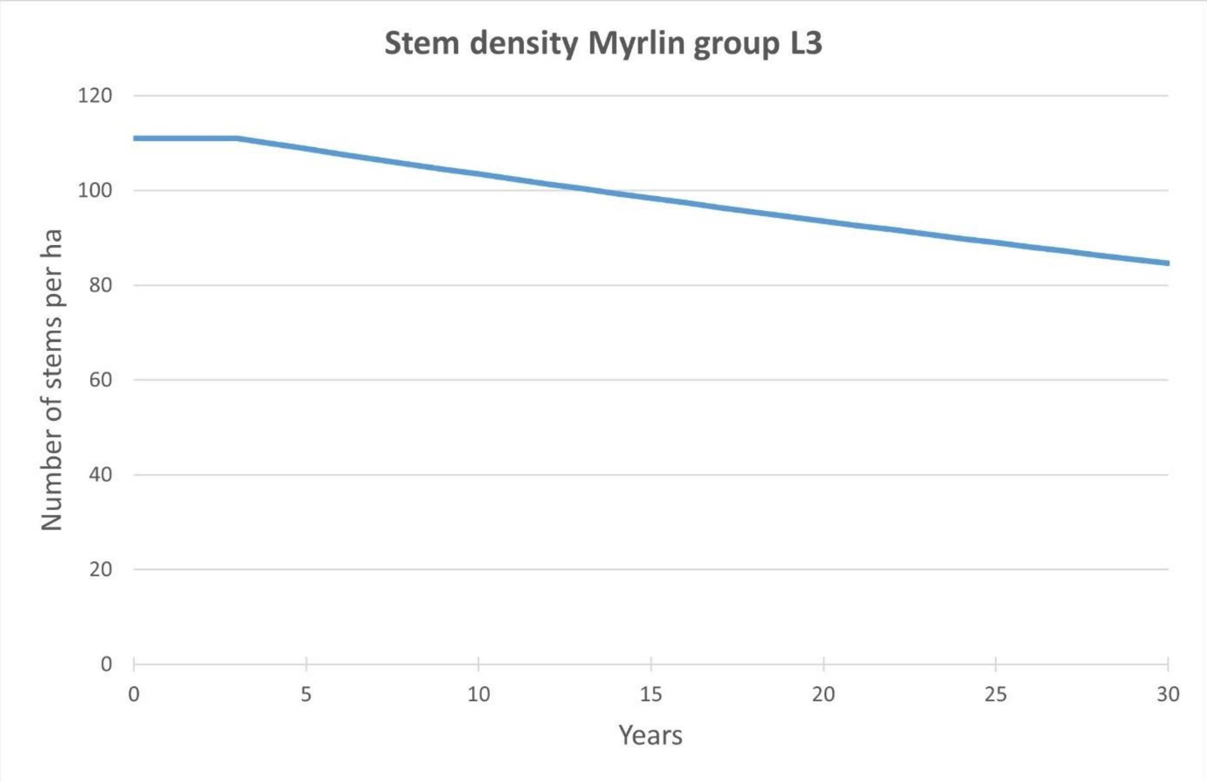




| L2 outcome | Value at year 0 | Value at year 30 |
|---|---|---|
| Stem density | 333 | 254 |
| $CO_2$ in AGB | 0 | 83 |
| $CO_2$ in BGB | 0 | 21 |
| Total $CO_2$ | 0 | 104 |

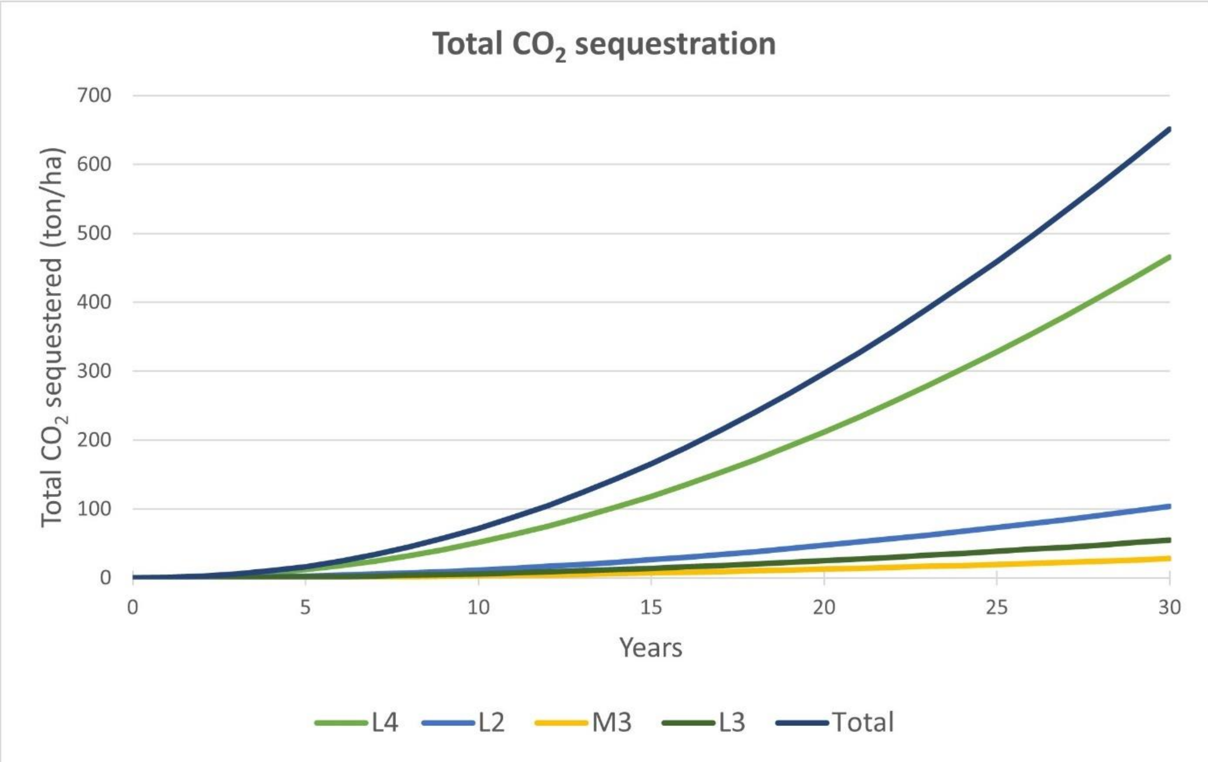



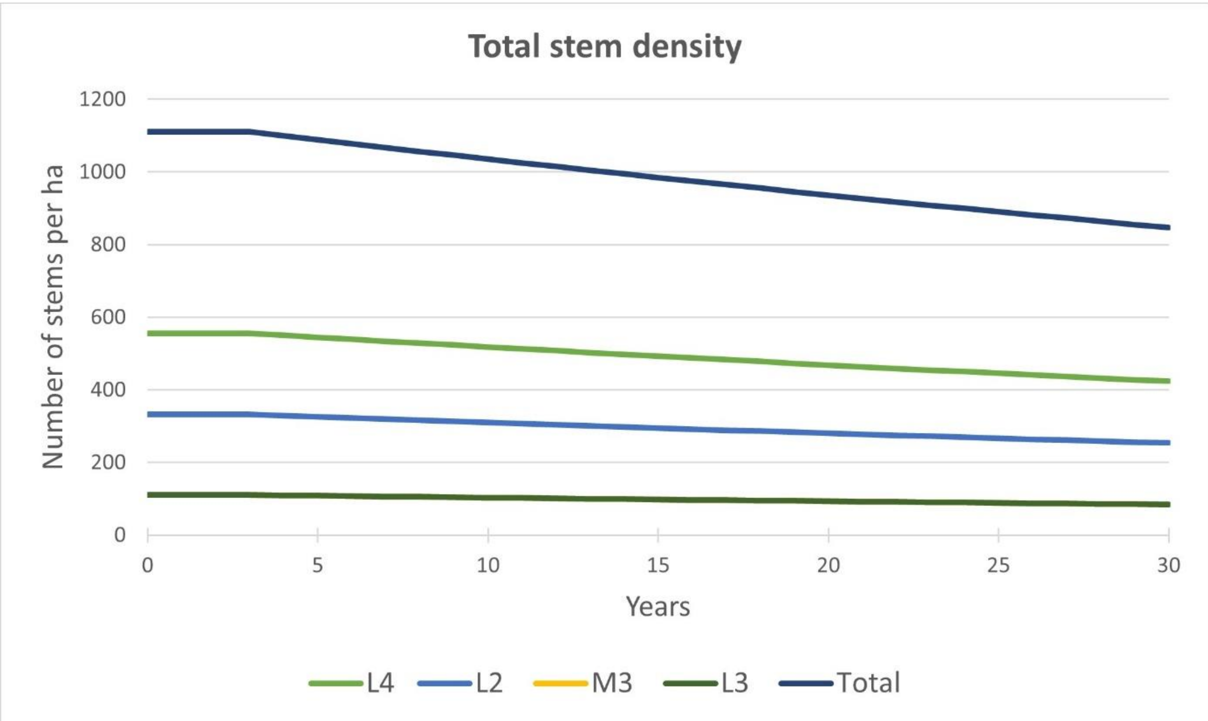

| **M3 outcome** | **Value at year 0** | **Value at year 30** |
|---|---|---|
| Stem density | 111 | 85 |
| $CO_2$ in AGB | 0 | 22 |
| $CO_2$ in BGB | 0 | 6 |
| Total $CO_2$ | 0 | 28 |




| L3 outcome | Value at year 0 | Value at year 30 |
|---|---|---|
| Stem density | 111 | 85 |
| $CO_2$ in AGB | 0 | 44 |
| $CO_2$ in BGB | 0 | 11 |
| Total $CO_2$ | 0 | 55 |




| Total outcome | Value at year 0 | Value at year 30 |
|---|---|---|
| Stem density | 1 111 | 847 |
| $CO_2$ in AGB | 0 | 521 |
| $CO_2$ in BGB | 0 | 130 |
| Total $CO_2$ | 0 | 651 |

The total expected CO2 sequestration in year 30 is 651 ton CO2 per hectare. The total expected stem density in year 30 is 847 stems per hectare. We followed AR-TOOL 14, and its assumption about linearity of biomass growth for trees, to get to this estimate. The estimated stem density as a result of the annual mortality rate of 1% is relatively high, but as we will show below, the estimate of CO2 sequestration is in line with values found for this ecosystem in literature. In reality we expect density dependent and species-specific growth of trees, meaning we expect higher mortality for certain species (i.e. short-lived pioneers) and higher annual diameter increments in the future. However, AR-TOOL 14 does not allow to model the interaction between these factors. We will closely monitor the growth and stem density in the field and use these data to improve our estimates over the course of the project.

When compared to values found for primary forests in the Eastern Arc the outcome of 651 ton CO2 per hectare is conservative:

- A study by Mwampanda (2009) in the Nguru Landscape found that Above Ground Carbon stock in primary forests of the Nguru is 153.24 ton per hectare, which is equivalent to 702.3 ton CO2 per hectare.
- A study by Cuni-Sanchez et al. (2021) found that Above Ground Carbon stock in Afromontane forests, of which the forests of the Eastern Arc are part, is 149.4 ton per hectare. Multiplying this number with (44/12) and 1.25 to include C stored in below ground biomass this results in a $CO_2$ stock of 684.8 tons per hectare;
- A study by Sullivan et al. (2016) quantifies the AGC stock in African forests between 176 and 190 tons per hectare, equivalent to 807-871 t/ha of $CO_2$ including BGB;
- A study by Marhsall et al. (2012), based on plots in the Eastern Arc biome only, reports an average of 174 t AGC/ha when height is included in the allometric equations, and 229 t AGC/ha when height is excluded (equivalent to approximately 797 to 1 050 t $CO_2$/ha, including below-ground biomass).
- A study by Willcock et al. (2014), using plots in the Eastern Arc biome only, reports the following values:
  - 130 t AGC/ha for montane forests (≈ 596 t $CO_2$/ha)
  - 166 t AGC/ha for upper montane forests (≈ 761 t $CO_2$/ha)
  - 182 t AGC/ha for lowland forests (≈ 834 t $CO_2$/ha)
  - 189 t AGC/ha for submontane forests (≈ 866 t $CO_2$/ha)

  These latter two forest types (lowland and submontane) correspond to the areas where most of our planting takes place.

If we take the average of all of the values mentioned above, the expected carbon stock to be found in primary forest in our project area is 775.8 ton CO2 (AGB + BGB)per hectare. To understand if our estimate is realistic and conservative we need to know how quick the planted seedlings will grow and how fast natural succession will be. In other words, how much carbon will be stored in biomass after 30 years, compared to a primary forest. There is however no growth data of comparable reforestation projects in the Eastern Arc over a period of 30 years.

Therefore, we mainly rely on the study done by Mwampanda (2009) in our project area. In her study Mwampanda assessed the succession rate of fallow land by measuring 120 vegetation plots on fallow land of different ages and 13 primary forest plots to determine the carbon potential. All of these plots are located within the project area where our activities are implemented, meaning environmental and social conditions are equal to those we are facing. Mwampanda found that after a fallow period of 30 years, the fallow plots on average reach 62% of the basal area of that of the primary forests. Basal area is closely correlated to tree biomass and is an appropriate measure for comparing re-growth across sites (Mwampanda, 2009), and thus a good proxy for carbon sequestration.

If we take the average carbon storage in primary forests in the region (775.8 ton CO2/ha) and multiply it by 0.62, we get the expected carbon sequestration after a 30 year fallow period. Based on literature we can expect a minimum sequestration of 481 ton CO2 per hectare if the project sites would be left fallow, without any interventions. It is safe to assume that our project plots will sequester more carbon as compared to the fallow land researched by Mwampanda. The main reasons for this assumption are:

1) In her study Mwampanda points out that after abandonment of the land there were several disturbances to forest recovery, such as biomass extraction for firewood and building poles, hunting, grazing and fires. Although she was not able to reconstruct ongoing use entirely, Mwampanda expects that these activities, in particular biomass extraction, would keep BA levels low and thereby slow down BA accumulation (Mwampanda, 2009). In our project plots, as stated in the collaboration agreements with farmers, wood extraction is not permitted.
2) In our project scenario we will plant 1 111 trees per hectare. This will kickstart and accelerate biomass accumulation as compared to the fallow lands. Moreover, we also plant dispersal-limited species, often canopy-dominant pioneers, that grow into bigger, denser trees than short-lived pioneer species that are usually the first tree species to colonize a fallow field. We also plant keystone species that attract seed disperses and further accelerate natural regeneration.
3) During the first 3-5 years after planting the plant sites will be maintained regularly, between 2 and 3 times a year, facilitating growth of the planted seedlings and natural regenerating trees.
4) Plots studied by Mwampanda may have been disturbed by fire and grazing, as commonly happens in the project area, while restored plots by our project are actively protected from fire and livestock.

It is difficult to quantify the impact of these factors on the forest development, compared to the 62% from Mwampanda's study. However, with a maximum average sequestration of 775 ton/ha (primary forest) and minimum of 481 ton/ha after 30 years (fallow land), we believe our estimate of 651 ton/ha using the methodology explained above, is realistic. Even more when taking into account that 30% of the estimated carbon sequestered will be attributed to buffer reserves. If we withhold the 30% buffer from our estimate the total expected CO2 in AGB+BGB is 456 ton/ha, which is lower than the 481 ton/ha for fallow land found by Mwampanda.

During the course of the project we will monitor the growth of the planted trees closely and make changes to our growth model when needed.

**Conclusion: during the crediting period total stem density will decrease from 1 111 to 847 stems per hectare and $CO_2$ sequestration will increase from zero under the baseline to 651 tons of $CO_2$ per hectare stored in above ground and below ground biomass.**

<u>Step 2 – Non-woody biomass</u>

Compared to the baseline non-woody biomass is expected to increase during the crediting period. Since non-woody biomass is expected to change during the different stages of forest succession it is difficult to model. In initial stages non-woody biomass will consist of grasses and herbs whereas in the final stages non-woody biomass will consist of herbs in the understory and epiphytes higher up. To be conservative we do not include removals by non-woody biomass in the calculation of project removals.

Step 3 – Belowground biomass

Belowground biomass is only considered for woody biomass. We use a root-to-shoot ratio of 0.25 as published by Cairns et al (1997). As shown above this leads to 130 tons of $CO_2$ per hectare stored in belowground biomass.

Step 4 – Project removals in dead wood and litter

We assume part of the dead wood in the project scenario will still be collected by community members, therefore we conservatively assume the removals from deadwood and litter will be zero under the project scenario.

Step 5 – Project removals in Soil Organic Carbon (SOC)

Change in SOC Stock during the crediting period is estimated using AR-TOOL 16 "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities". The tool is applicable to this project activity because it matches the following applicability conditions:

- The project area does not fall into wetland category;
- The project area does not contain organic soils as defined in "Annex A: glossary" of the IPCC GPG LULUCF 2003 (see below). Only valley bottoms within the project area could be classified as organic soils if they contain more than 20 percent of organic carbon. Valley bottoms are however unlikely to be included in the project because they tend to be the most productive agricultural fields. Farmers will most likely not use these plots for forest restoration activities.
- Are not subject to any of the land management practices and application of inputs as listed in the Tables 1 "Baseline cropland management practices under which the tool is not applicable" and 2 "Baseline grassland management practices under which the tool is not applicable". Since the project area is cropland (ie not grassland), is located in a tropical ecosystem and inputs and manure used by farmers in the project area are absent or very little, based on Table 1, AR-TOOL-16 is applicable;
- Litter remains on site and is not removed in the A/R CDM project activity;
- Soil disturbance attributable to the A/R CDM project activity is limited to land preparation (digging holes) before planting and is not repeated within the next 20 years, expect for the purpose of beating up:
- Site preparation and planting take place within a year of each other;

AR-TOOL 16 assumes that SOC will linearly increase from the baseline state to a steady state, for a period of 20 years from the year of planting. The steady state SOC content depends on the ecosystem and type of soil, as presented in Table 3 on page 7 of AR-TOOL16. Since the project area is classified as tropical moist and contains predominantly LAC soils the reference SOC stock is 47 ton C per hectare at 0-30 cm depth. The initial SOC stock at the start of the project can be estimated using the following formula:

$SOC_{INITIAL} = SOC_{REF} * f_{LU} * f_{MG} * f_{IN}$

Using the tables of AR-TOOL 16 this results in the following values:

- $SOC_{REF}$ = 47 ton C per hectare corresponding with the tropical, moist climate region and predominant LAC soils.

- $f_{LU}$ = relative stock change factor for baseline land-use in stratum i of the areas of land = 0.48 corresponding with tropical moist temperature region and long-term cultivation. From the analysis of old satellite photos and empirical observations in the field we can conclude that the majority of land has been cultivated for over 20 years.
- $f_{MG}$ = relative stock change factor for baseline management regime in stratum i of the areas of the land = 1.00 since the vast majority of farmers in the area applies full tillage.
- $f_{IN}$ = relative stock change factor for baseline input regime (e.g. crop residue returns, manure) in stratum I of the areas of land = 0.92. It is common practice to remove and burn pre and post-harvest residues and no use of fertilizers by project participants. Only a small percentage of farmers pile up residues and leave it in field.

This leads to an initial SOC value of 20.76 ton C/ha under the baseline scenario. Since the project intervention are not expected to create additional loss of SOC the $SOC_{LOSS}$ factor mentioned in AR-TOOL 16 is not taken into account. The annual increase in SOC per year is calculated as follows:

$(SOC_{REF} – SOC_{INITIAL})/20$ = (47 – 20.76)/20 = 1.312 ton C per ha per year.

However, considering uncertainties and inherent limitations of the precision of a factor-based estimation used in AR-TOOL16, the value of the rate of change of SOC is put to a maximum of 0.8 ton C per hectare per year. Taking into account a baseline SOC change of zero (as determined previously) and this maximum annual increase of 0.8 ton C per hectare per year, the total amount of SOC content during the crediting period will be:

SOC = 20 * 0.8 = 16 ton C per hectare

(44/12) * 16 = 58.7 ton $CO_2$ per hectare

**Total increase in $CO_2$ in the soil during the crediting period is expected to be 58.7 ton per hectare.**

Step 6 – Wood products / Step 7 – Harvesting

No felling or harvesting will take place during the crediting period. Therefore there are no expected removals or emissions from wood products or harvesting.

**Conclusion: the total expected removals under the project scenario are made up by $CO_2$ stored in Above Ground Biomass (521.2 ton/ha), Below Ground Biomass (130.3 ton/ha) and in the soil (58.7 ton/ha). This brings the total expected removals of $CO_2$ under the project scenario to 710.2 ton $CO_2$ per hectare.**

As demonstrated previously the module PU003 can be applied for calculations of project emissions. The following emission sources are assessed:

Step 8 - Nitrogen fertilisers

Synthetic fertilisers are being used on a small scale in the nursery and after planting. We have used two types of fertilisers so far: 1) YaraMila Power and 2) YaraMila 16-16-16. YaraMila Power has a nitrogen content of 11%, YaraMila 16-16-16 of 16%. To be conservative we will use 16% in the calculations to follow.

Fertiliser use in the nursery is approximately 100 kgs per year, which equals 0.5 kgs per hectare for the pilot project. After planting we consider to apply 30-60 g of fertiliser per seedling, equalling 33.3-66.6 kgs per hectare. The maximum total amount of fertiliser used will therefore be 67.1 kgs per hectare. In following phases of the project, when the total area of planting will be increased, the amount of fertilizer used per hectare will remain the same. Emissions resulting from fertilizer use are calculated using the following formulas from AR-TOOL07 “Estimation of direct nitrous oxide emission from nitrogen fertilization”:

$N_2O_{direct\ N,t} = (F_{SN,t} + F_{ON,t}) * EF_1 * MW_{N2O} * GWP_{N2O}$

With:

- $N_2O_{direct\ N,t}$ = Direct emission as a result of nitrogen application within the project boundary, in ton $CO_2$
- $F_{SN,t}$ = mass of synthetic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$. The default values for the fractions of synthetic fertilizer nitrogen that are emitted as $NH_3$ and $NO_X$ ($Frac_{GASF}$) are 0.2 and 0.1 respectively. These values are derived from IPCC 2006 Guideline (table 11.3). The nitrogen content ($NC_{SFi}$) of the fertilizer we use is 16%. The combined mass of nitrogen ($F_{SN,t}$) in synthetic fertilizer applied is calculated using the following equation:

$F_{SN,t} = M_{SFi,t} * NC_{SFi} * ( 1- Frac_{GASF})$

= 0.0671 * 0.16 * (1 – 0.3) = **0.0075152** tonnes of N per hectare

- $F_{ON,t}$ = mass of organic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$. Not applicable, since only synthetic fertilizer is used.
- $EF_1$ = emission factor for emissions from N inputs, tonne $N_2O$-N (t-N input)$^{-1}$. IPCC 2006 Guideline (table 11.1) give a default emission factor of 1%, thus $EF_1$ = 0.01.
- $MW_{N2O}$ = ratio of molecular weights of $N_2O$ and N = (44/28)
- $GWP_{N2O}$ = Global Warming Potential for $N_2O$, kg-$CO_2$-e (kg-$N_2O$)$^{-1}$. IPCC default value is 310.

Hence the direct emissions as a result of nitrogen application are as follows:

(0.0075152 + 0) * 0.01 * (44/28) * 310 = **0.03660976 ton $CO_2$ per hectare**

<u>Step 9 - Nitrogen fixing species</u>

Nitrogen fixation in reforestation projects is a complicated process and there are examples for both increased and decreased soil $N_2O$ emissions under N-fixing trees relative to non-fixing trees (Kou-Giesbrecht et al, 2021). We will illustrate the difficulty using the line of argumentation in Kou-Giesbrecht et al (2021). In our planting mix there is only one nitrogen fixing tree species, *Afzelia quanzensis*. The tree is planted in a relatively low density of 10% and is expected to be planted in a similar density during the next phases of the project. Nitrogen fixing species convert atmospheric N gas into a plant available form of nitrogen, which can fuel primary production, driving CO2-sequestration and mitigating climate change. However, nitrogen fixing species can also exacerbate climate change through N fixation, which can simulate nitrous oxide ($N_2O$) emissions from the soil. According to Kou-Giesbrecht et al (2021) reforestation with 10% N-fixing species would lead to an increase of the $N_2O$ source in the soil of approximately 0.5% as compared to the $N_2O$ source in reforestation project with exclusively non-fixing species.

The hypothesis that the $N_2O$ source will be higher because of N-fixing species does however not mean that $N_2O$ emissions will increase. This depends on how the $N_2O$ source in the soil will be used by the (other) trees that are planted. N-fixing trees are generally useful for reforestation based on the theory that they relieve N limitation of plant growth and facilitate neighbouring trees, which would counteract their stimulation of $N_2O$ emissions (Kou-Giesbrecht et al, 2021). In conclusion, it is difficult to determine and quantify the sequestration and emission resulting from the use of N-fixing species in a low density. Using the species can either lead to (slightly) higher or lower emissions when compared to the baseline scenario.

Based on the following three arguments, we decide to exclude nitrogen fixing species as a relevant emission source in this technical specification:

1) It is unsure, and heavily dependent on the context, if nitrogen fixing species will lead to an increase in N-storage (in case sequestration of N gasses exceeds the emission of N gasses from the soil) or decrease in N-storage (vice versa). There is empirical evidence for both cases.
2) Research by Kou-Giesbrecht et al (2021) shows that differences in $N_2O$ source in the soil between reforestation projects with 100% non-fixing species and reforestation projects with 10% N-fixing species are expected to be small (0.5%). The effect, regardless if positive (higher storage) or negative (higher emissions), is expected to be small.
3) It is unsure if a relatively higher $N_2O$ source in the soil will lead to an increase in $N_2O$ emissions or if the $N_2O$ is used by other species to facilitate their growth.

Step 10 - Biomass burning

Under the project scenario there will be no use of fire for site preparation of post-harvest clearings. In this sense we expect a decrease in fires as compared to the baseline, in which continued use of fire as an agricultural practice is expected on the project land. Historically, forest fires are mainly caused by the spread of fire from farms. However there is a risk for the occurrence of natural fires, this risk is expected to remain similar or lower as under the baseline scenario. Possible damage resulting from natural forest fires however will be accounted for by the Plan Vivo and/or Project risk buffer.

In general, fire occurrence is expected to be higher under the baseline scenario. To be conservative, we do not include emissions from burning biomass under the baseline and project scenario.

Step 11 - Fossil fuel combustion

AR-TOOL05 "Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities" is used to calculate the fossil fuel combustion under the project scenario. The sources of emissions that are included are vehicles and mechanical equipment (e.g. portable such as chainsaws and stationary such as generators or water pumps).

Within the project the following emission sources are included:

- International flights (6.3 ton $CO_2$): based on two international return flights from Milano to Kilimanjaro for the nursery manager and one international flight for the project manager. In total three return flights with an emission of 2.1 t $CO_2$ each.
- National site visits (3.6 ton $CO_2$): site visits normally include transport from PAMS office in Arusha to the project site in Pemba. The distance to be covered is 600 kms, and site visits take place approximately 10 times a year. Considering 299 grams of CO2 per kilometer for a Land Rover Defender total emissions will be 3.6 tons of $CO_2$.
- Project logistics on site (6.2 ton $CO_2$): on average the project car drives 30 972 km per year. For a Toyota Land Cruiser an average of 200 grams of $CO_2$ per kilometre can be used.
- Project logistics on site, motorbike (2.3 ton $CO_2$): on average the project motorbikes drive a total of 22 330 km per year, with a 150 cc bike averaging 101 grams of $CO_2$ per kilometre.

Total yearly project emissions account for 18.4 tons of $CO_2$ in year 1.

After year one the emissions are expected to decrease significantly because (1) the intensity of project activities will decrease and (2) the project area will increase over the coming years, meaning the emissions per hectare will decrease. The entire project area, as described in the PDD, consists of

6.200 hectares which is planned to be reforested (partly forest restoration, agroforestry and natural regeneration in the corridor) over a period of 7 years.

We assume fossil fuel combustion for the coming year will increase linearly with the number of hectares reforested. Since project logistics will be more efficient over time we expect that project activities from planting sites from the previous years will be combined with project activities from the current year. For example, a project visit to the 2023 plantings, can be done during the implementation of project activities for the 2028 plantings. After planting, between 2029 and 2069 it is important to have a presence in the project area and to have regular visits by project staff. We used an estimate of 5 ton/year for this period, which should be enough for local and national project staff to visit the project area.

Total emissions due to fossil fuel over the project period are expected to be as follows:

| **Planting year** | **Planted area (in ha)** | **Fossil fuel combustion (ton $CO_2$)** |
|---|---|---|
| 2023 | 200 | 18.4 |
| 2024 | 300 | 27.6 |
| 2025 | 800 | 73.6 |
| 2026 | 1 050 | 96.6 |
| 2027 | 1 250 | 115 |
| 2028 | 1 300 | 119.6 |
| 2029 | 1 300 | 119.6 |
| 2030 - 2069 | - | 39 x 5 = 195 |
| Total | 6200 hectares | 765.4 ton $CO_2$ |

In line with this argumentation we can argue that the emissions due to fossil fuel combustion are *(765.4/6 200) = 0.12 ton* $CO_2$ */ hectare*.

However, since we are currently in the pilot phase it is not certain yet if the entire project area of 6.200 hectares will be planted in the foreseen period of 7 years. We therefore would like to use a more conservative estimate. For 2023, 200 hectares have been planted and in 2024 we are taking preparations for another 300 hectares. If we only take these two planting rounds into account the fossil fuel combustion would be as follows:

| **Planting year** | **Planted area (in ha)** | **Fossil fuel combustion (ton $CO_2$)** |
|---|---|---|
| 2023 | 200 | 18.4 |
| 2024 | 300 | 27.6 |
| 2025 | - | 20.7 |
| 2026 | - | 15.5 |
| 2027 | - | 11.6 |
| 2028 | - | 8.7 |
| 2029 -2065 | - | 35 x 2.5 = 87.5 |
| **Total** | **500 hectares** | **190 ton $CO_2$** |

In this scenario, we assume that fossil fuel combustion in the planting years is similar to what we have calculated before. After planting there will still be a need for project activities within the project area. During the first 5 years after planting we expect that the fossil fuel combustion due to project movements decreases by 25%. For the last 35 years of the monitoring period local project staff and national staff still would pay visits to the project area. This would however be less that the 5 tons per hectare for the 6 200 hectares area, conservatively estimated 2.5 tons of $CO_2$ per year. In line with this argumentation, we can argue that the emissions due to fossil fuel combustion are *(190/500) =* ***0.38 ton $CO_2$ / hectare***.

Step 12 - Enteric fermentation / step 13 – Manure decomposition

The numbers of livestock in the project area are very limited and are not expected to change under the baseline scenario, nor the project scenario. Emissions resulting from enteric fermentation and manure decomposition therefore are not taken into account in the calculations for the baseline and project scenario. The project itself will not use beasts of burden.

Step 14 - Soil methanogenesis

The project area is not subjected to conditions of flooding or saturation, due to elevation and height differences, and therefore emissions from soil methanogenesis are not taking into account in the calculations for the baseline and project scenario.

**Conclusion: under the project scenario $CO_2$ emissions will increase due to fertiliser use (0.0366 ton/ha) and fossil fuel combustion (0.38 ton/ha). The total emissions due to project activities is thus 0.4166 ton $CO_2$ per hectare.**

**Based on removals and emissions under the baseline and project scenario the total carbon benefits under the forest restoration activity are as follows:**

***Carbon benefits = (Project removals – Project Emissions) – (Baseline removals – Baseline emissions)***

**= (710.2 – 0.4166) – (0 – 0) = 709.8 ton $CO_2$ per hectare**

**Potential Leakage**

Leakage is defined as the unintended loss of carbon stocks outside the boundaries of the project resulting directly from project activities. To determine potential leakage we follow the guidelines described in module PU004 "Estimation of GHG emissions from leakage in Plan Vivo projects". This module is used to provide values for:

- Net GHG emissions due to carbon pool leakage, and;
- Net GHG emissions due to emission source leakage.

The majority of lands included in the project were previously used for agricultural purposes. Since these lands will be reforested, and thus cannot be used for agricultural anymore, it is very important to assess if this can lead to an increase in agricultural activities outside the project boundary. For this we will use AR-TOOL15 "Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity". Our project does not cause any drainage of wetlands or peat land, thus AR-TOOL15 is applicable.

Displacement of agricultural activities is defined as 'the shifting of the agricultural activities from areas of land within the project boundary to areas of land outside the project boundary'. Leakage emission attributable to the displacement of agricultural activities is estimated as the decrease in carbon stocks in the affected carbon pools of the land receiving the displaced activity. Important to note: [1] displacement of an agricultural activity by itself does not result in leakage emissions. Leakage emission occurs when the displacement leads to an increase in GHG emissions relative to the GHG emissions attributable to the activity as it exists within the project boundary. In our case this means that an incident qualifies as leakage if participating farmers compensate the 'loss' of their parcel, used for forest restoration under the project, with clearing of areas that are currently not under agricultural use. These areas are most likely to be located in the Mkingu Forest Reserve or community forests. [2] Increase in GHG emission occurring outside the project boundary attributable to the secondary effects of the project activity (e.g. changes in demand, supply or price of goods) is considered insignificant for the purpose of this tool and hence accounted as zero.

Within the project we implement several mitigation measures to prevent leakage, see section 3.12 of the PDD for more details. Even though these measures are in place we cannot be entirely sure that the project does not cause any leakage by taking significant pieces of agricultural land out of production. Therefore we continue with the application of AR-TOOL15 to our project activities.

<u>Step 1 - Carbon pool leakage</u>

Leakage emission resulting from displacement in agricultural activities is calculated as follows:

$LK_{AGRIC,t} = (44/12) \times (C_{BIOMASS,t} + SOC_{LUC,t})$

We have to quantify the loss in carbon from [1] biomass and [2] Soil organic carbon:

1) Decrease in carbon stock in the carbon pools of the land receiving the displaced activity:

$C_{BIOMASS,t} = [1.1 * b_{TREE} * ( 1 + R_{TREE}) + b_{SHRUB} \times (1 + R_S)] * CF * A_{DISP,t}$

- $b_{TREE}$ = the areas where leakage is most likely to occur is within Mkingu Forest Reserve or other (degraded) forest pockets such as community forests within the participating communities. The average Above Ground Carbon content in intact old-growth forests in the Eastern Arc is 149.4 ton C/ha (Cuni-Sanchez et al, 2021). However, leakage is expected to be lower than this figure for two reasons: 1) most targeted forests, especially on the reserves borders, are considered (partly) degraded; 2) leakage is expected to be for the cultivation of cardamom, meaning the understory will be completely cleared and only a part of the trees will be cleared. We therefore assume only half of the AGC of an intact forest will be lost due to leakage. For $b_{TREE}$ we therefore assume 75 ton C/ha.
- $R_{TREE}$ = root-shoot ratio for trees in the land receiving the displaced activity. There is no scientific data on root-shoot ratios specifically for the Eastern Arc, therefore we use the IPCC default value of 0.25.
- $b_{SHRUB}$ = the areas dominated by shrubs in the project area, are fallow lands. These areas will be used for agriculture after the fallow period. The areas where we expect leakage are dominated by trees. We therefore leave AGB of shrubs out of the equation.
- $R_S$ = root-shoot ratio of shrubs. Not applicable since we leave AGB of shrubs out of the equation.
- CF = since we used the AGC instead of AGB for $b_{TREE,}$ there is no need to apply a carbon fraction in the equation.
- $A_{DISP,t}$ = area of land from which agricultural activity is being displaced. To be conservative, next to the mitigating measures presented in the PDD, we assume that project activities will lead to leakage equalling 5% of the project area. Meaning that for each hectare of forest restoration we expect 0.05 hectares of leakage to take place in forested areas outside the project area.

The decrease in carbon stock in biomass in the land receiving the leakage will thus be:

$C_{BIOMASS,t}$ = [1.1 * 75 * (1 + 0.25)] * 0.05 = 5.15625 ton C / hectare

2) Change in soil organic carbon (SOC) stock due to land-use change in land receiving displaced activity:

$SOC_{LUC,t} = SOC_{REF} * (f_{LUP} * f_{MGP} * f_{INP} – f_{LUD} * f_{MGD} * f_{IND}) * A_{DISP,t}$

- $SOC_{REF}$ = SOC stock corresponding to the reference conditions in native lands by climate region and soil type applicable to land receiving displaced activity. Value can be taken from Table 3 of AR-TOOl16. For the reference SOC of intact ecosystem we take the value of 47 ton C/ha for a tropical moist climate regime and LAC soils.
- $f_{LUP}$ / $f_{MGP}$ / $f_{INP}$ = relative SOC stock change factors for land-use, management practices, and inputs respectively, applicable to the receiving land **before** the displaced activity was received. Values can be taken from Tables 4, 5 and 6 in AR-TOOL16. The receiving land consist of forests and in general has not undergone any cultivation, management or received inputs. Therefore we take a value of 1 for $f_{LUP}$ , $f_{MGP}$ and $f_{INP}$. In other words we assume that the SOC in the receiving land is equal to the $SOC_{REF}$ as presented in table 3 of AR-TOOL16.
- $f_{LUD}$ / $f_{MGD}$ / $f_{IND}$ = relative SOC stock change factors for land-use, management practices, and inputs respectively, applicable to the receiving land **after** the displaced activity was received. Values can be taken from Tables 4, 5 and 6 in AR-TOOL16. For $f_{LUD}$ we take the value of 0.82 since the area is considered tropical moist/wet and will be used for short-term cultivation. For $f_{MGD}$ we take the value of 1.15, meaning reduced tillage in tropical moist/wet climate as the cultivation of cardamom only results in shallow soil disturbance without full soil inversion. For $f_{IND}$ we take 0.92 since inputs are expected to be low and the tropical moist/wet climate.
- $A_{DISP,t}$ = area of land from which agricultural activity is being displaced. To be conservative, next to the mitigating measures presented in the PDD, we assume that project activities will lead to leakage equalling 5% of the project area. Meaning that for each hectare of forest restoration we expect 0.05 hectares of leakage to take place in forested areas outside the project area.

The decrease in carbon stock in SOC in the land receiving the leakage will thus be:

$SOC_{LUC,t}$ = 65 * (1– 0.81 * 1.15 * 0.92) * 0.05 = 0.464815 ton C/hectare

The total leakage emission resulting from shifting agricultural activities is thus:

$LK_{AGRIC,t} = (44/12) * (C_{BIOMASS,t} + SOC_{LUC,t})$

= (44/12) *(5.15625 + 0.454815) = 20.573905 ton $CO_2$ per hectare.

<u>Step 2 - Emission source leakage</u>

The main impact of leakage will be in the removal of AGB and SOC. We do not expect increased emissions from emission sources outside the project area due to the shifting agricultural activities.

<u>Step 3 – Leakage discount factor</u>

Based on the carbon pool leakage and emissions source leakage calculated above we calculated a leakage discount factor that we will apply to reduce the expected carbon benefits of the project accordingly. The leakage discount factor in removal projects is calculated as follows:

$LD_{CP,a} = pLE_{CP,a} / (PR_{a,t} + BR_{a,t})$

- $pLE_{CP,a}$ = potential net GHG emissions from carbon pools caused by activity shifting from the project area. As demonstrated before this figure is equal to 20.57 ton $CO_2$ per hectare.

- $PR_{a,t}$ = expected total net GHG removals under the project scenario (PM001)
- $BR_{a,t}$ = total net GHG removals under the baseline scenario. As show before we assume the total net GHG removals under the baseline scenario to be zero.

Hence, the leakage discount factor is calculated as follows:

**20.57 / (709.8 + 0) = 0.0290**

**We will apply a leakage discount factor of 0.03 to account for possible leakage events, meaning the expected total net $CO_2$ removals under the project scenario will be decreased by 3%. This means that the expected carbon benefit is 709.8 * 0.97 = 688.51 $tCO_2e$.**

**Uncertainty**

PU005 "Estimation of uncertainty of carbon benefit estimates in Plan Vivo projects" helps to determine an uncertainty correction. All calculations above are based on the best available information on this moment. If different studies provided varying parameters, models or data, we consistently choose the most conservative study. We understand the risks associated with an inflated estimate for the future of the project and deliberately choose to strive for a conservative estimate of the carbon benefits. Still, estimates are based on models and data is not always specific to the project area. This means we cannot exclude uncertainties completely. The uncertainties that could influence the estimates are:

- Leakage assumptions: although leakage is mitigated by project activities we cannot be entirely sure that farmers will not try to exploit areas that are not in agricultural use under the baseline.
- Expected tree growth vs. measured tree growth in the field: although we consistently choose the most conservative parameter values, many of those were not specific to the Nguru Mountains. Additionally, tree species that we plant are rare and not studied extensively. We cannot completely exclude the risk that tree growth in the field is lower than conservative estimates from similar regions.
- Expected SOC vs. measured SOC in the field: for the SOC we choose the most conservative default value. This value is not site specific, meaning there is still a small chance that SOC removals will be lower than expected.

It is not possible to eliminate all sources of uncertainty in estimates. However, we decide to not apply an uncertainty correction because the main uncertainties described above are accounted for through the following measures:

- Leakage assumptions are accounted for through applying the leakage discount factor of 0.03, as described in the previous section;
- The risk of expected removals (AGB/BGB & SOC) being higher than realized removals is accounted for through the instalment of an Achievement Reserve of 10%. Forest development and SOC changes will be monitored thoroughly throughout the crediting period to build a solid database on species performance for future project interventions. In case monitoring results in different values, the technical specification will be revised.

**Expected Carbon Benefits**

| **Project intervention** | **Carbon Benefit (t $CO_2e$/ha)** | **Project Area (ha)** | **Total Carbon Benefit (t $CO_2e$)** | **Risk Buffer (20%, t$CO_2e$)** | **Achievement Reserve (10%, t$CO_2e$)** | **Potential PVCs (t $CO_2e$)** |
|---|---|---|---|---|---|---|
| Forest restoration (with tree planting)<br><br>(per hectare) | 688.51* | 1 | 688.51 | 137.7 | 55.08 | 495.73 |
| Forest restoration (with tree planting)<br><br>(200 ha pilot) | 688.51* | 200 | 137 702 | 27 540 | 11 016 | 99 145 |

*as mentioned before, the Leakage Discount Factor of 3% is already deducted from the total carbon benefit of 709.8 t$CO_2e$.

The total expected fPVC issuance for the forest restoration activity will thus be 495.7 fPVCs per hectare. For the 200 hectare pilot of 2023 this means an issuance of 99 145 fPVCs.

**Monitoring**

For the monitoring we would like to refer to paragraph 4.2 (Carbon Indicators), 4.7 (Carbon Monitoring and Annex 13 (Monitoring Plan).

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