Development of a REDD pilot project in the Maringa-Lopori-Wamba Landscape

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Acronyms

ADP	Avoided Deforestation Partners	IPCC	Intergovernmental Panel on Climate Change
AFOLU	Agriculture Forestry and Other Land Uses	LCM	Land use Change Modeler
ALM	Agricultural Land Management	LULC	Land Use Land Cover
APD	Avoiding Planned Deforestation	LUP	Land use planning
AR	Aforestation Reforestation	MECNT	Ministère de l'Environnement, de la Conservation de la Nature et du Tourisme
AUDD	Avoiding Unplanned Deforestation and/or Degradation	MLW	Maringa Lopori Wamba
AWF	African Wildlife Foundation	MRV	Monitoring Reporting and Verification
BEF	Biomass Expansion Factor	N	Nitrogen
BioCF	Bui Carbon Fund	N_2O	Nitrous oxide
C	Carbon	NTFP	Non timber forest product
CBO	Community based organizations	PLUP	Participatory Land Use Planning
CARPE	Central African Regional Program for the Environment	PRA	Participatory Rural Appraisal
CBNRMA	Community Based Natural Resources Management Area	PRC	Peatland Rewetting and Conservation
CDI	Carbon Decisions International	REDD	Reducing emissions from deforestation and forest degradation
CDM	Clean Development Mechanism	REFADD	Réseau Femmes Africaines pour le Développement Durable
CH_4	Methane	SBSTA	Subsidiary Body for Scientific and Technological Advice
CIAT	International Centre for Tropical Agriculture	SDSU	South Dakota State University
CO_2	Carbon dioxide	SNV	Netherlands Development Organization
CLUE	Conversion of Land Use and its Effects	SOIL	Sustainable Opportunities for Improving Livelihoods
COP	Conference of Parties	SRTM	Shuttle Radar Topography Mission
DBH	Diameter at Breast Height (in cm)	UCL	Université Catholique de Louvain
DRC	Democratic Republic of Congo	UMD	University of Maryland
FACET	Forêts d'Afrique Centrale Evaluées par Télédétection	UNFCCC	United Nations Framework Convention on Climate Change
FAO	Food and Agriculture Organization	USAID	United States Agency for International Development
FAS	Fundação Amazonas Sustentável	VCS	Verified Carbon Standard (formerly Voluntary Carbon Standard)
G	Basal Area (in m^2)	VVB	Validation/Verification Body
G*H	Basal Area * Height (in m^3)		
GHG	Greenhouse gazes		
GIS	Geographic Information System		
H	Height (in m)		
ICRAF	World Agroforestry Centre		
IDESAM	Instituto de Conservação e Desenvolvimento Sustentável do Amazonas		
IFM	Improved Forest Management		

1. Background of the study

1.1. AWF work in the MLW landscape

AWF has been working on landscape level conservation in the Maringa Lopori Wamba (MLW) landscape (CARPE landscape 9) in the Equateur Province in northern Democratic Republic of the Congo (DRC) for the past five years, with support from two phases of the USAID-CARPE program. The AWF landscape program aims to reduce destruction of the forest canopy, improve natural resource management and reduce poverty (the Strategic Objectives of CARPE).

1.1.1. Participative Land Use Planning and zoning

One of the main components of AWF work in the landscape is Participative Land Use Planning and Zoning. AWF envisions zoning happening at two distinct levels – the 'macro' and 'micro' levels.

AWF work to date in this landscape has focused on the 'macro' zone, to propose large blocks for various uses including protected areas, production forest, community based natural resource management (CBNRM) areas, and areas for expansion of agriculture and related activities that required conversion of the forest cover.

At a more local level, 'micro zoning' refers to working with local people to plan for the future of their communities, and to address local needs and aspirations where people live. Micro zoning should be more specific and more binding as it occurs on a more manageable scale.

An agreement has been signed between the MECNT and AWF that designates the MLW landscape as a pilot site for LUP or zoning. As such, MLW is the first region in the DRC that is recognized officially as a pilot site for zoning.

The SOIL project is closely tied to the concept and practice of micro zoning. Micro zoning envisages a more definitive delineation of specific use zones. A more intense dialogue is initiated with the local communities about potential specific uses, potential management regimes for a specific zone that has to be delineated in a participative way. A mosaic of micro zones can be agreed within a macro zone.

AWF seeks to focus micro zoning activity on the distinction between areas for expansion of agriculture and areas that will not allow any human activity that requires conversion of the forest habitat.

The major weakness in the DRC Forest Code classification system at present is the fact that, while 'Forêt Classée' and 'Forêt de production permanente' are covered by management plans that reflect ecological sustainability, 'Forêt Protégée' is not subject to mandatory protection. Indeed, "Forêt Protégée" is forest that can be exploited/used by local communities and in which small-scale agriculture (<2ha) is acceptable. And thus, the Forest Code as currently written allows for a gradual conversion of all "Forêt Protégée" into agricultural areas (Art.42 and Art.53).

AWF and its partners are working to ensure that the CBNRM areas in the Forêt Protégée are clearly and appropriately designated as 'permanent forest' (pf) or 'non-permanent forest' (npf) and covered by appropriate local management plans through a micro-zoning process.

1.1.2. Livelihoods

In the MLW landscape, remote rural communities have traditionally made extensive uses of the forest, principally through collection of non timber forest products (amongst them bush meat), wood energy and slash and burn agriculture. Poverty is prevalent, livelihood opportunities are very limited and the availability of sufficient nutrition is highly seasonal.

Based on a series of socio-economic surveys in 2004, AWF and its partners (ICRAF, WorldFish, REFADD and SNV) developed a strategy for priority interventions to support livelihood alternatives in the landscape: reactivating agriculture, developing economic alternatives; access to markets; and capacity building to support strong and diverse livelihoods.

1.2. The SOIL project

The main objective of the SOIL project is to increase household well being by providing economically sustainable alternative livelihoods that mitigate and/or prevent negative environmental impacts of existing livelihoods strategies, notably forest conversion and degradation. SOIL will establish participatory micro zoning that distinguishes activities in permanent and non-permanent forest areas that have been identified as both important for secured connectivity between forest blocks and historically important for agriculture. Simultaneously, SOIL will help increase productivity for agricultural livelihoods in those communities that engage in the micro zoning process.

SOIL has three aims and three sets of related activities:

- **Participative micro zoning** of CBNRM-npf vs CBNRM-pf in the SOIL target areas, leading to agreed and formally recognised Micro Zone Land Use Plans. The CBNRM-npf should cover enough land for development of the rural complexes according to population growth. Participative mapping and household/land use surveys will be completed. The CBNRM-pf should meet local needs for non-timber forest products and socio-environmental services, as well as maintain habitat for biodiversity and its connectivity. Agreements will be signed with the organized local communities, for each Groupement, with reference to an agreed zoning process, respect for different uses in permanent vs non-permanent forest, and anticipated support for agriculture, agro-forestry and other livelihood activities.

- **Promotion of secure agricultural livelihoods** in the identified and delineated CBNRM-npf areas, including:
  - Increased productivity of traditional agricultural activities through improved agronomic practices and improved germplasm/varieties, within the CBNRM-npf; emphasis on dietary diversity (with focus on leguminosae);
  - Promotion of high value trees with focus on integrated agro-forestry, agro-biodiversity and substitution for forest wood fuels;
  - Identification of other viable alternative livelihood options in specific target areas, such as small livestock, fisheries, ecotourism;
  - Facilitation of product chain development and reactivation of access to markets;
  - Strengthening the capacity of farmer associations and platforms for joint learning and collective marketing.

- **Initiate preparedness for livelihoods aspects of forest carbon markets.**
  - Undertake appropriate carbon baselines in target areas,
  - Identifying and testing available methodologies, and investigating issues of measuring avoided deforestation, permanence and leakage;
  - Begin REDD sensitisation and capacity building with partner communities and CBOs.

SOIL focuses on extending and replicating CARPE livelihood activities in five Groupements: Bomwankoy and Likunduamba in Territory of Befale, Sector of Duale; and Lingomo, Nkole and Yolota in Territory of Djolu, Sector of Lingomo. In total, these five Groupements cover an estimated 2,000km² of land. The overall aim is to reach a total of 4,200 households in these five Groupements. The target forest area in the Territory of Befale is identified as an area of major importance to ensure the connectivity between the Faunal Reserve of Lomako Yokokala and the Luo Scientific Reserve, while the Groupements in the Territory of Djolu are mainly characterized by intensive agricultural activities. In this way, both the focus on biodiversity and livelihoods are combined, and ensure a base of experience and learning from which to rapidly extend participatory micro zoning and complementary livelihoods activities and impacts to other areas.

The partners for the SOIL project are:

- AWF, Leader and coordinator, responsible for participative mapping and delineation of the micro zones, the Public Participation Strategy and the Formal Recognition Strategy, the "enterprise" aspects of livelihoods building, notably connecting agricultural produce in the landscape with demand in urban markets, as well as investigation of non-agricultural livelihoods options.

- ICRAF, responsible for supporting the agricultural livelihoods component, notably through enabling productive tree planting, with a focus on diversity and local tree species, integrating agro-forestry aiming at re-construction of the tree canopy, or maintenance of canopy with increased production, and exploring demand and scope for substitute wood fuel trees.
- CIAT, responsible for supporting the agricultural livelihoods component, addressing issues of food security, diversification of crop production with a focus on legumes; improved germplasm, transfer of knowledge, and production monitoring against baseline values, capacity building activities with producer associations and NGO platforms, and better organization of the communities to enhance access to the market.
- UMD, responsible for assisting with spatial modelling, including identifying and interpreting satellite images to support identification of the best areas for CBNRM-pf vs. CBNRM-npf, and monitoring of the impact of the program on forest conversion.
- National NGOs functioning as platforms for local associations.

1.3. The study

AWF contracted ONF International in order to carry out the feasibility study of a REDD project in the MLW landscape. The study aims at evaluating whether the activities implemented by the Sustainable Opportunities for Improved Livelihoods (SOIL) program could generate carbon credits. It targets the potential impact of participatory land use planning and enhanced livelihoods activities in the rural development zone in the SOIL project area near Djolu.

In order to achieve this, the study focuses on (i) analysing the REDD methodologies that can be applied to the SOIL project and selecting the most appropriate, (ii) defining an appropriate method to estimate the baseline scenario and providing initial estimations, (iii) defining an appropriate protocol for carbon stocks and GHG emissions monitoring and providing initial estimations, and (iv) drafting a preliminary business plan and Project Idea Note.

The survey was realized in three phases:

- During a preparatory phase, we met with AWF and UMD staff involved in the SOIL project, collected from them relevant information and data (mainly AWF reports on the MLW landscape and GIS data collected by the UMD) and reviewed it;
- A field mission was carried out from the 23rd November to the 6th December 2010, specifically on the item (iii), in order to make initial field measurements on carbon stocks;
- Report writing on the basis of the outputs from the field mission and review of all other available information and data on the MLW landscape and SOIL project.

We would like to thank all the persons who support this work, and especially:

- The AWF staff: Florence Mazzocchetti, Jef Dupain and Charly Facheux;
- The UMD staff: Janet Nackoney and Minnie Wong.

2. Applicable methodological framework

To the contrary of aforestation/reforestation projects (which are eligible activities of the CDM of the Kyoto Protocol), projects aiming at reducing emissions from deforestation and forest degradation (REDD) are currently not included in the internationally agreed mechanisms to fight climate change.
The recent agreement reached by parties at the COP of Cancun (December 2010) includes a decision on policy approaches and positive incentives on issues related to REDD. This decision makes clear that the future REDD mechanism will be framed by policies, reference levels and MRV systems at a national scale, though allowing sub-national scale as an interim measure. It requests the SBSTA (the scientific and technical body of the UNFCCC) to develop methodological modalities related to the definition of reference levels and MRV systems.
There are still a number of unresolved issues, such as the approach for integrating activities at project scale in these national/sub-national frameworks, and whether funding should be linked to the carbon markets.

While the international framework is being defined, REDD project proponents can rely on a number of existing methodological tools:

- IPCC Guidelines[1] provide guidance on GHG inventories for forestry and land use changes;
- The REDD sourcebook[2] builds on IPCC Guidelines to provide guidance on Monitoring, Reporting and Verification systems for REDD;
- Approved methodologies and tools for CDM AR projects provide guidance on a number of relevant issues for REDD projects: additionality, uncertainties, significance of GHG emission sources and pools, etc.

A number of methodologies covering REDD activities at project scale are being developed on these methodological bases. These projects (and the related methodological works) are supported by voluntary efforts such as the BioCarbonFund and private investment funds anticipating the establishment of a future international REDD mechanism. In order to guarantee the environmental integrity of the project they support, investors and project proponents are looking for a certification with carbon standards set up by the voluntary carbon markets. Among these standards, the VCS is the standard that developed the most complete methodological framework for REDD projects. It is also considered by the majority of investors as the standard presenting the highest guarantees for ensuring quality of the projects.
We therefore based our assessment of the applicable methodologies for the SOIL project on VCS guidelines and the 7 REDD methodologies submitted to the VCS, among which 4 are officially approved by the VCS at the moment. We based our assessment on the latest available versions of these 7 methodologies[3].

2.1. Existing methodologies for REDD projects

The VCS accepts 5 broad types of activities in the domain of Agriculture Forestry and Other Land Uses (AFOLU): aforestation/reforestation (AR), agricultural land use management (ALM), improved forest management (IFM), reducing emissions from deforestation and forest degradation (REDD), and peatland rewetting and conservation (PRC).
There are 3 types of REDD activities which are eligible. As defined by the VCS (VCS, 2011a, AFOLU Requirements: VCS Version 3; Requirements Documents), they are distinguished by the level of planning and the spatial configuration of the deforestation and degradation processes. In other words, deforestation and degradation are distinguished between (i) planned or unplanned and (ii) mosaic or frontier landscape configuration.
This distinction is made in order to reflect the main different patterns of deforestation and forest degradation, which need to be targeted through distinct methodological approaches. Finally, three different types of REDD methodology enable to address three specific type of deforestation and forest degradation which are Planned

[1] IPCC 2006 Guidelines for National GHG inventories ; IPCC 2003 Good Practice Guidance Land Use Land Use Change and Forestry
[2] A sourcebook of methods and procedures for monitoring and reporting anthropogenic GHG emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation, GOFC-GOLD, November 2010.
[3] Note that the 3 methodologies that are not yet officially approved may still undergo significant changes as they progress through the VCS official double approval process. Approved methodologies can also be subjected to revision (as it is currently the case for one approved methodology for which a revision has been submitted).

Deforestation, Unplanned Mosaic Deforestation and/or Degradation and Unplanned Frontier Deforestation and/or Degradation. Avoiding planned degradation (e.g. legally sanctioned timber extraction) is an eligible activity under VCS IFM category.

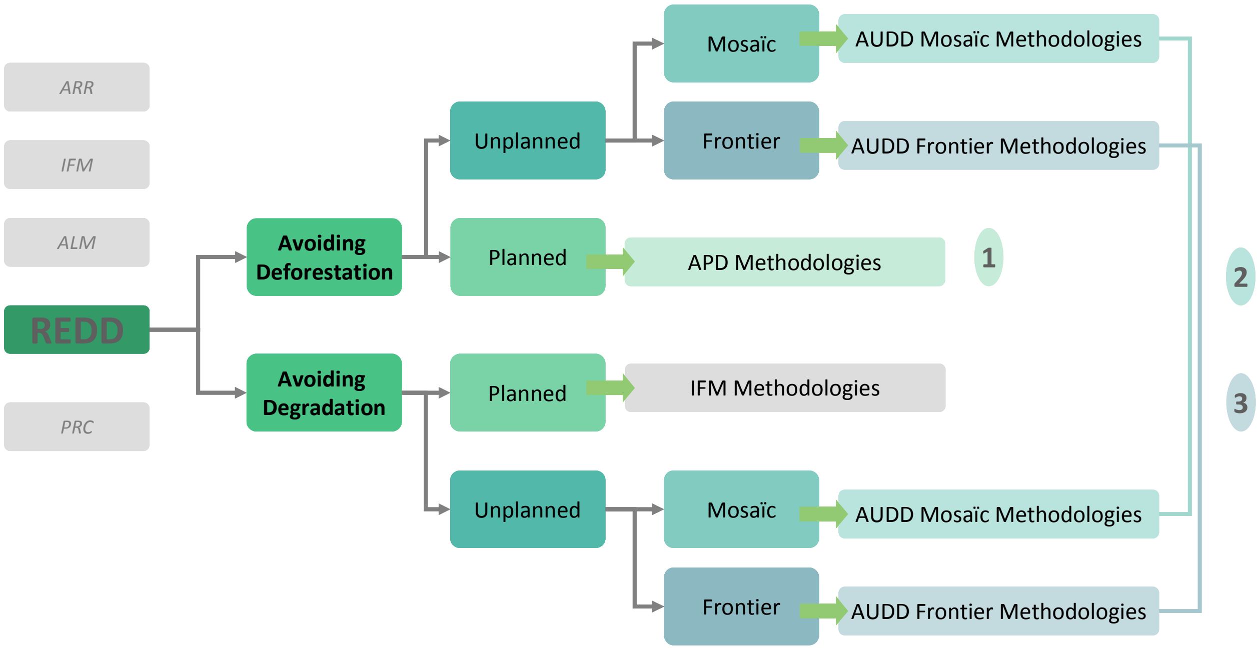


Figure 1 - VCS three REDD activities and corresponding methodology types

2.1.1. REDD activities eligible under the VCS

Planned versus unplanned deforestation and forest degradation

Planned deforestation means that the future conversion of forest to non forest areas is legally authorized and well documented. It will be the case when deforestation is due to settlement programs in forested areas, the construction of infrastructures (mines, hydropower plants) or large scale conversion for the production of agricultural commodities. The agents responsible for the deforestation are precisely defined: the State and/or local authorities, private investors and/or the landholders.
Where deforestation is planned, the baseline scenario can be argued and justified on official documents which testify the development plan of baseline activities. The management of leakage consists in (i) monitoring and discounting any increment of deforestation above the baseline level in the other areas under the agent(s) direct control and (ii) monitoring and discounting leakage due to market effects.

Planned degradation refers to legally authorized and well documented forest degradation that generates a decrease of carbon stocks in permanent forests. It targets logging activities in natural forests and the management of plantations. Projects avoiding planned forest degradation were included by the VCS in the IFM category.

Unplanned deforestation and degradation refers to deforestation and forest degradation due to a multitude of different agents whose motivations result from a complex combination of proximate drivers and underlying causes. Deforestation and forest degradation do not result from legally authorized plans. It makes more complex the baseline assessment. Moreover, the management of leakage has to take into account the potential mobility of all agents whose activities will be restrained by the project.
In this case, the VCS introduces a second distinction between mosaic and frontier type unplanned deforestation and forest degradation.

Mosaic versus frontier unplanned deforestation and forest degradation

Frontier deforestation and degradation refers to deforestation occurring in forest areas that have no current physical connection with areas already deforested. The future deforestation will occur in areas inaccessible or poorly accessible and where human activities are underdeveloped. This pattern of deforestation occurs when new transport infrastructures open the access to intact forests and attract the installation of migrants who clear the forest to establish crops and pastures.

Mosaic deforestation and degradation refers to deforestation occurring in forest patches which are surrounded by already cleared land and where human populations and associated agricultural activities and infrastructure are spread out across the forest landscape. Most forest is accessible to human activities and transport infrastructures spread over the landscape. Deforestation is manly due to the activities of already established populations.

2.1.2. 7 available methodologies for project developers

At the moment, 7 REDD methodologies were submitted to the VCS. Table 1 shows how they fit to eligible REDD activities defined by the VCS. Methodologies submitted to the VCS are subject to a double approval process. At the moment, four of these methodologies completed it successfully. The current status of each methodology is indicated in table 1.

- **RED-NM-001 - Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation (BioCF, CDI)**

This methodology has been designed for a project developed in Madagascar for the Ankeniheny – Zahamena Biological Corridor by the Ministry of Environment, Water, Forests and Tourism and Conservation International with the support of the BioCF.
It is developed to estimate and monitor greenhouse gas (GHG) emissions of project that reduce mosaic deforestation based on unplanned events. It also includes optional methods to estimate carbon stocks enhancement on regenerating forests which would have been deforested without the REDD project.

- **VM0006 - Methodology for Carbon Accounting in Project Activities that Reduce Emissions from Mosaic Deforestation and Degradation (Terra Global Capital LLC)**

This methodology has been designed for a REDD project located in the Oddar Meanchey Province in Cambodia.
This methodology is developed to estimate and monitor GHG emissions of projects that reduce mosaic deforestation and degradation linked to unplanned events. It allows taking into account the reduction of forest degradation and assisted forest regeneration.

<table>
<tr><th>Eligible REDD activities</th><th colspan="2">Available methodologies (status)</th></tr>
<tr><td>Avoiding planned degradation</td><td colspan="2">Refer to IFM methodologies</td></tr>
<tr><td>Avoiding planned deforestation</td><td colspan="2">- VM0004 - Methodology for conservation projects that avoid planned land use conversion in Peat Swamp Forest (Infinity Earth Ltd) (approved)
- VM0007 - REDD Methodology Modules, ADP (approved)</td></tr>
<tr><td rowspan="2">Unplanned deforestation and forest degradation</td><td>Mosaic</td><td>Frontier</td></tr>
<tr><td>- VM0006 - Methodology for Carbon Accounting in Project Activities that Reduce Emissions from Mosaic Deforestation and Degradation (Terra Global Capital LLC) (approved)
- RED-NM-001. Version 01, Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation (BioCF, CDI) (first assessment)
- VM0009 - Methodology for</td><td>- RED-NM-002 - Methodology for Estimating Reductions of GHG Emissions from Frontier Deforestation (IDESAM, FAS, CDI) (second assessment)</td></tr>
</table>

	Avoided Mosaic Deforestation of Tropical Semi-Arid Forests (Wildlife Works Carbon LLC) (*approved*) - Methodology for Carbon Accounting of Grouped Mosaic and Landscape-scale REDD Projects (*first assessment*)	
	- VM0007 - REDD Methodology Modules (ADP) (*approved*)	

Table 1: Eligible REDD activities and available methodologies

- **RED-NM-002 - Methodology for Estimating Reductions of GHG Emissions from Frontier Deforestation (IDESAM, FAS, CDI)**

This methodology has been developed for the Reserva do Juma Conservation Project in Amazonas (Brazil) by IDESAM, FAS and CDI. This methodology is developed to estimate and monitor GHG emissions of project that reduce frontier deforestation related to unplanned pressures. It also includes optional methods to estimate carbon stocks enhancement on secondary forests which would have been deforested without the REDD project.

- **VM0007 - REDD Methodology Modules (ADP)**

This is not really a methodology but rather a set of methodological modules that REDD project proponents may combine in order to build a methodology that suits the specific context and needs of their project.
It was not designed to serve a particular type of project but rather intend to be adaptable to a large variety of projects, thereby saving the efforts and costs of developing new methodologies.
The modules cover a wide range of REDD activities: avoided planned deforestation and avoided unplanned deforestation for both mosaic and frontier configurations. It also allows accounting carbon benefits of activities reducing forest degradation linked to fuelwood collection.
A revision to this methodology has been submitted to VCS by The Field Museum. It targets the module that enables to estimate the carbon stock changes and GHG emissions from unplanned deforestation (BL-UP) and adds an alternative approach for the quantification of unplanned baseline deforestation based on population drivers.

- **VM0004 - Methodology for conservation projects that avoid planned land use conversion in Peat Swamp Forest (Infinity Earth)**

This methodology proposes methods to estimate the avoided net greenhouse gas emissions resulting from project activities implemented to stop planned land use conversion in tropical peat swamp forest.

- **VM0009 - Methodology for Avoided Mosaic Deforestation of Tropical Semi-Arid Forests (Wildlife Works Carbon LLC)**

This methodology was designed for the Kasigau Corridor REDD project in Kenya. It is applicable to projects that reduce mosaic deforestation of topical semi arid forests.

- **Methodology for Carbon Accounting of Grouped Mosaic and Landscape-scale REDD Projects (TGC LLC)**

This methodology is derived from the “VM0006 - Methodology for Carbon Accounting in Project Activities that Reduce Emissions from Mosaic Deforestation and Degradation”. It may be combined with IFM, ALM and AR methodologies to achieve a landscape-scale REDD project that addresses land and resources issues in a holistic way.

2.2. Selection of the most appropriate methodology for the project

This part aims at evaluating which of the 7 methodologies already submitted to the VCS could be applied to the specific context and needs of the SOIL project.

2.2.1. Definition of the relevant eligible REDD activity for the SOIL project

We first define the deforestation pattern as it has been occurring up to now and is expected to occur in the future in the SOIL project area, in order to determine the eligible type of REDD activity into which falls the SOIL project.

The MLW landscape spans 74 000 km^2, and covers the four territories of Basankusu, Befale, Bongadanga, and Djolu. Forest cover dominates over 90% of the landscape. Rural complexes, i.e. human transformed areas, are composed of farms and plantations. They represent less than seven percent of the landscape. Human density is on average 8 people per km^2[4]. The total human population is estimated at 587 000 people.

Around 56,000 hectares (about 0.9%) of the forest were converted during the 1990-2000 period for the expansion of slash and burn agricultural activities. Over half of the observed conversion occurred within two kilometers of a road[5]. Villages are found stretched along road axes, with agriculture concentrated around human settlements.

Projections realized on future trends of deforestation show that the pressure will take place in the same areas by expansion of agriculture land[6] (see figure 1).

Unplanned vs. planned deforestation?

Up to now, the main deforestation and degradation pressure on the forests of the SOIL project area is slash and burn farming practiced by local communities. This process of conversion does not result from formal planning by the State, which on the contrary assigns a forest purpose to these areas, defined as “forêt protégée” in the forest code, although small scale conversion by local communities is authorized. The baseline scenario can not be argued on official plans. The conversion of the forest results from multiple stakeholders: the State, through its forest policy, traditional authorities and individuals of local communities. This situation fits in the unplanned deforestation category.

There are no planned drivers of deforestation, such as the construction of hydropower plants or large scale conversion for agri-business purpose. Therefore, the project area should continue to be only subject to unplanned deforestation in the coming years.

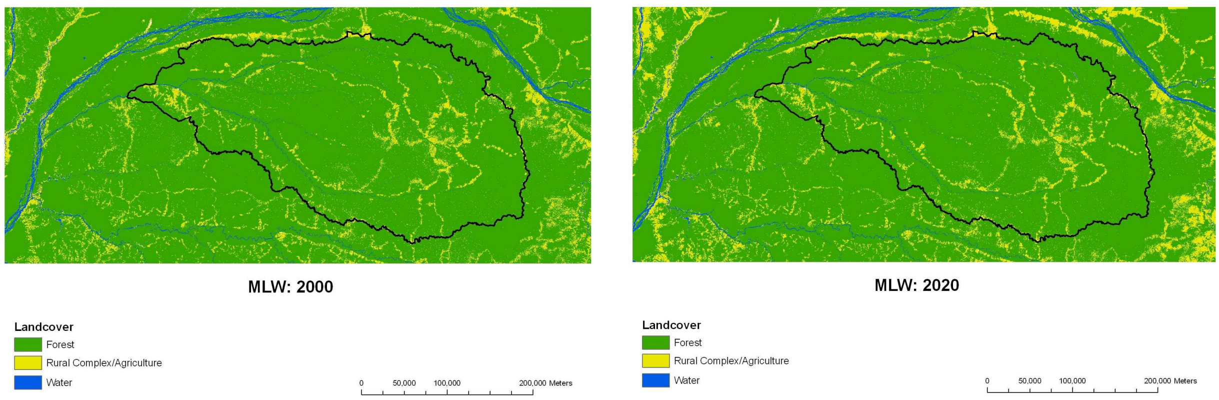


Figure 2: Localisation of the deforestation for the period 90-00 and expected trend (2020, projection by UMD with LCM)

Mosaic vs. frontier deforestation?

Deforestation is not linked to the transformation of road infrastructures improving the access to the area. It is rather a diffuse phenomenon, which spreads along communication axes such as roads and rivers. As the situation is not expected to change in the future, the situation fits with mosaic deforestation.

[4] Kimbanbe, 2007. Modélisation spatial multisectorielle des dynamiques territoriales: étude de cas à l’échelle régionale dans la RDC, DEA, Univ. Catholique de Louvain

[5] Dupain and al. 2008 Carpe-Maringa, Lopori Wamba, Lanscape, Landuse Planning – Lessons learned

[6] LCM modelling carried out by UMD on the basis of data from Hansen and al. 2007: A method for integrating MODIS and Landsat data for systemic monitoring of forest cover and change in the Congo Basin, Remote Sensing of Environment

The relevant VCS eligible activity for the SOIL project is therefore the reduction of GHG emissions from unplanned mosaic deforestation and forest degradation. Under this category, there are 5 available methodologies that the project could use (see table 1).

2.2.2. Available REDD methodologies for the SOIL project

Five methodologies could be relevant for the SOIL project:

1. VM0006 - Methodology for Carbon Accounting in Project Activities that Reduce Emissions from Mosaic Deforestation and Degradation (Terra Global Capital LLC)
2. RED-NM-001. Version 01, Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation (BioCF-CDI)
3. VM0007 - REDD Methodology Modules (ADP)
4. VM0009 - Methodology for Avoided Mosaic Deforestation of Tropical Semi-Arid Forests (Wildlife Works Carbon LLC)
5. Methodology for Carbon Accounting of Grouped Mosaic and Landscape-scale REDD Projects (TGC LLC)

However, we decided to exclude from our analysis 3 of these 5 methodologies:

- VM0006 - Methodology for Carbon Accounting in Project Activities that Reduce Emissions from Mosaic Deforestation and Degradation. One of the applicability conditions of the methodology is that historical deforestation rate in the reference area must be superior to 0.5% per year. As it is not the case for the SOIL project (see tables 6 & 7), this methodology can not be used.
- Methodology for Carbon Accounting of Grouped Mosaic and Landscape-scale REDD Projects: it is similar to the VM0006 methodology, with the potential to be combined with methodologies for AR, ALM and IFM activities. We exclude it for the same reasons than the VM0006.
- VM0009 - Methodology for Avoided Mosaic Deforestation of Tropical Semi-Arid Forests. This methodology was only recently submitted to the VCS and thus could not be considered in our analysis. As it was developed for semi-arid forests, it is not foreseen that it would suit well the context of the SOIL project.

The report is therefore focused on the comparison and selection among two methodologies (Figures 2 & 3 illustrate the respective structure of these two methodologies):

- VM0007 - REDD Methodology Modules (ADP), named ADP modules
- RED-NM-001. Version 01, Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation (BioCF-CDI), named BioCF-CDI methodology.

Throughout the report, we explained the differences between both methodologies, which are relevant to the specific context of the SOIL project. Table 2 summarizes the comparison. The conclusion gives recommendations on the most suitable methodology.

The ADP modules are approved by the VCS and could therefore be used immediately by the SOIL project.
The BioCF-CDI methodology is still in the process of double validation, at the first assessment stage. However, we anticipated most of the expected changes through consultations with the methodology lead author and reference to the RED-NM-002 - Methodology for Estimating Reductions of GHG Emissions from Frontier Deforestation (IDESAM, FAS, CDI), which is developed by the same author on comparable bases and has already passed the first assessment.

- ✓ In the absence of methodological rules defined at international level, most REDD projects developed for the voluntary carbon markets rely on the methodological framework developed by the VCS;
- ✓ Under the VCS definitions, the SOIL project is eligible as an activity reducing emissions from unplanned mosaic deforestation and forest degradation;
- ✓ Out of the 5 methodologies covering this activity that were submitted to the VCS (3 approved), we pre-selected 2 methodologies that suit best the needs of the SOIL project;
- ✓ The differences between these two methodologies that are relevant to the SOIL project are underlined throughout the report, and the conclusion recommends the most suitable one.

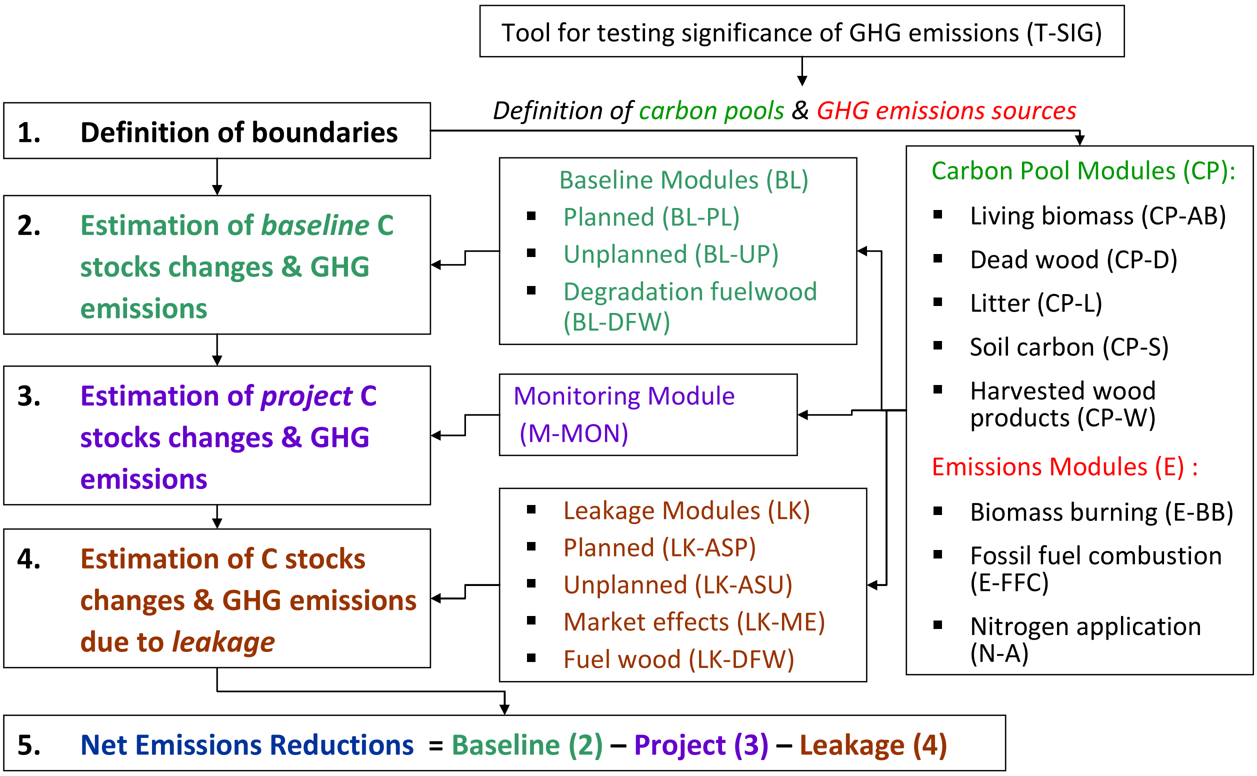


Figure 3: Structure of the ADP REDD methodological framework (estimation of net emissions reductions)

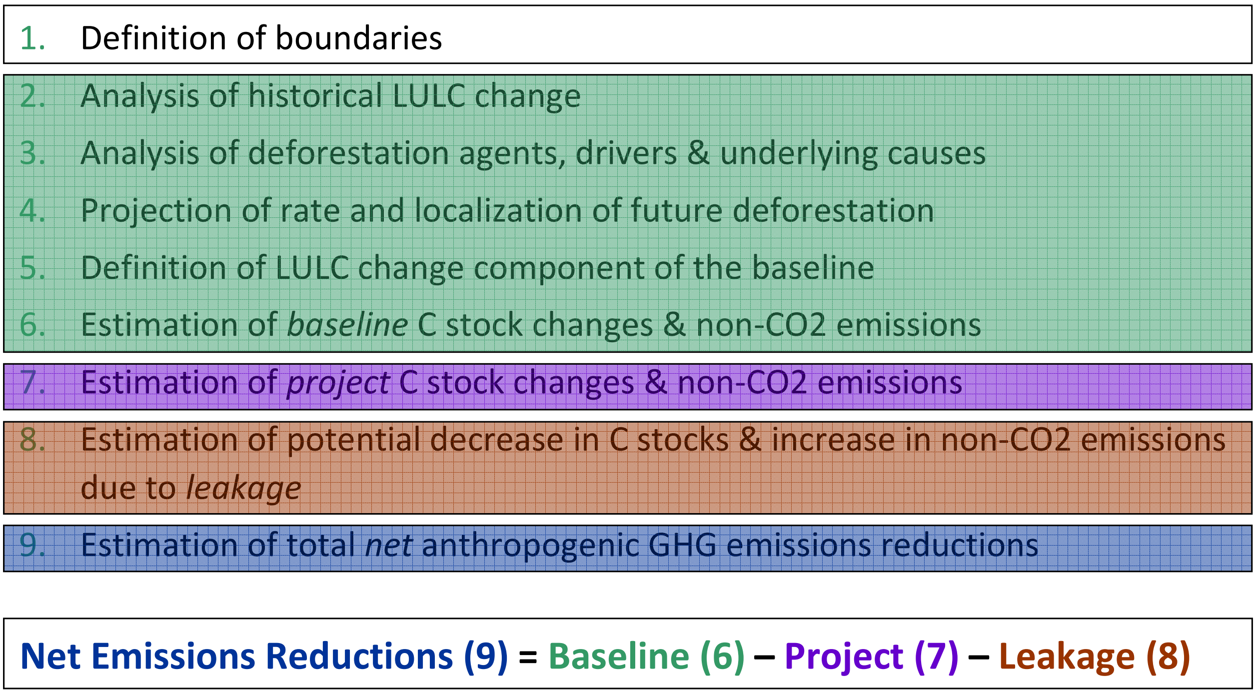


Figure 4: Structure of the BioCF-CDI mosaic methodology (ex-ante estimation of emissions reductions)

Methodologies	BioCF	ADP
Applicability conditions		
Baseline activities	▪ May include planned or unplanned logging for timber, fuel-wood collection, charcoal production, agricultural and grazing activities	▪ Post deforestation land use shall not be reforestation ▪ Forest shall not be allowed to naturally regrow after deforestation (temporarily unstocked) ▪ Large scale industrial agriculture activities are excluded ▪ Degradation caused by fuel wood extraction can be included if it is "non renewable"
Project activities	May include controlled logging, fuel wood collection or charcoal production	No Constraints
Leakage management activities	No restriction	Excludes agricultural lands that are flooded to increase production (e.g. paddy rice) and intensifying livestock production through use of "feed-lots" and/or manure lagoons
Forest types	All types, including peat lands forests as long as there are no changes of ground water table between baseline and project scenarios	The project area can include forested wetlands as long as they do not grow on peat.
Definition of boundaries		
Spatial boundaries		
Project area	▪ Includes only forest land (qualifying as forest for a minimum of 10 years prior to the project start) ▪ Under control of project participants, on which project activities will be undertaken	
Leakage management area	▪ Non-forest areas outside the project boundary in which project proponents will implement project activities that reduce the risk of displacement leakage	absent
Reference region	3 criteria ▪ Agents and drivers of deforestation ▪ Landscape configuration and ecological conditions: ▪ Socio-economic and cultural conditions Reference region shall encompass the project area, the leakage belt and any other geographic area that is relevant to determine the baseline of the project area. It must be larger than the project area.	▪ To determine baseline deforestation rate: Only forest area at the start of historical reference period Shall not encompass project area and leakage belt Minimum area required 4 definition criteria (see table 8) ▪ To determine baseline deforestation location: Min. 5% non forest & 50% forest Includes project area & leakage belt Same area (as above) +/- 25% 4 definition criteria: soils, rainfall, elevation, access to markets.
Leakage belt	Leakage belt is mandatory Two methodological approaches options to define the boundary: ▪ Opportunity cost analysis ▪ Mobility analysis	▪ Leakage belt may have to be defined, depending on the method chosen to address leakage due to activity displacement ▪ If a leakage belt is defined: Only forest area Min. size is 90% of project area

		6 definition criteria (see table 3)
Temporal boundaries		
Historical reference period	Ends as close as possible to project start; begins 10 to 15 years before project start	Starts from 9 to 12 years before project start, ends within 2 years before project start
Baseline validity	Up to 10 years	10 years, except where triggers lead to more frequent renewal (but minimum 5 years)
Project crediting period	20 to 100 years	20 to 100 years
Monitoring period	1 year to the duration of the valid baseline	1 to 10 years
Carbon pools		
Above ground biomass tree	▪ Included	▪ Included
Above ground biomass non tree	▪ To be decided on the basis of conservativeness and significance	▪ To be decided on the basis of conservativeness and significance
Below ground biomass	▪ Recommended but not mandatory	▪ Recommended but omission is conservative
Dead wood	▪ To be decided on the basis of conservativeness and significance	▪ To be decided on the basis of conservativeness and significance
Harvested wood products	▪ Included (subject to conservativeness and significance criteria)	▪ To be decided on the basis of conservativeness and significance
Litter	▪ Not included	▪ Not significant (can be omitted)
Soil organic carbon	▪ To be decided on the basis of significance, can be conservatively omitted	▪ To be decided on the basis of significance, can be conservatively omitted
GHG emissions sources		
Livestock emissions (CH_4 and N_2O)	▪ Included	▪ Need not to be included (see applicability conditions)
Biomass burning (CH_4 and N_2O)	▪ To be decided by project proponents	▪ To be included in the project case if fire occurs
Fossil fuel combustion (CO_2)	▪ Excluded	▪ Can be included in baseline accounting but will also be included in project accounting
Use of fertilizer	▪ Excluded	▪ Can be included in baseline accounting but will also be included in project accounting ▪ Must be included if use of fertilizer is enhanced by leakage prevention activities
Ex-ante estimation of baseline carbon stock changes and GHG emissions		
Analysis of historical land-use and land-cover change & deforestation drivers		
Dates & periods	▪ At least 3 dates (2 sub-periods), 3-5 years apart	▪ At least 3 dates (2 sub-periods), at least 3 years apart
Land-use land-cover (LULC) classes	▪ Forest & Non-forest (minimum)	▪ Forest & Non-forest (only)
Outputs	▪ Forest cover benchmark map (each date) ▪ Land Use Land Cover map (each date) ▪ Land Use Land Cover change map (each period) ▪ Land Use Land Cover change matrix (each period)	▪ Forest cover map (each date) ▪ Deforestation map (each period) ▪ Deforested area (each period)
Analysis of agents, drivers	▪ Identification of agents, drivers and	absent

and underlying causes of deforestation	underlying causes of deforestation ▪ Analysis of chain of events leading to deforestation ▪ Conclusions	
Projection of future deforestation rate		
Baseline approach	▪ Historical average approach ▪ Time function approach (linear or logistic regression) ▪ Modeling approach (deforestation is a function of drivers variables) Past deforestation trends and deforestation drivers analysis (from the previous section) determine the appropriate approach	▪ Historical average ▪ Linear regression against time ▪ Non linear regression against time (power or logarithmic) Non linear regressions is authorized only when 5 or more points in time (see the previous section) are used in the analysis
Analysis of constraints to the further expansion of deforestation	1. Assess forest area suitable for conversion If > 100 times average area annually deforested in the reference region during historical reference period => no constraint 2. Stratify the forest area suitable for conversion in broad suitability classes Optimal, average, sub-optimal 3. Define future periods with decreasing deforestation rates 1st period: highest deforestation rate on optimal areas 2nd period: lower deforestation rate on average areas 3rd period: drastically reduced deforestation rate on sub-optimal areas	1. Assess forest area suitable for conversion If during project implementation, remaining forest area suitable for conversion < 50 times annual projected area of deforestation in the reference region => the baseline must be revised If > 5 years have passed since the beginning of the baseline period => immediately If < 5 years have passed, exactly at 5 years after the start of the baseline period
Quantitative projection	▪ For the reference region ▪ According to selected baseline approach & constraints analysis	▪ For the reference region ▪ According to selected baseline approach ▪ If location analysis is not performed, quantity is projected on project area and leakage belt using simply area ratios (project area/reference area; leakage belt area/reference area)
Projection of future deforestation location		
Location analysis	Always required Production of a deforestation risk map on the reference region (spatial modeling)	In case of mosaic configuration, location analysis is not required; However, can be elected to avoid the conservative approach with regard to carbon stocks (see below)
Projection on the reference region	Quantitative projection X (GIS) Deforestation risk map = Location map of future deforestation per year on the reference region	Same approach as the BioCF/CDI methodology in case a location analysis is performed
Projection on the project area and leakage belt	Location map of future deforestation per year on the reference region X (GIS) Project area/leakage belt = Location map of future deforestation	Same approach as the BioCF/CDI methodology in case a location analysis is performed

	per year on project area/leakage belt & future annual quantities of deforestation in project area and leakage belt	
Estimation of carbon stock changes		
Stratification of the project area and leakage belt	▪ Stratification of pre-deforestation (forest strata) and post-deforestation (non-forest land uses) strata or ▪ Stratification per land use change category (forest → cropland, forest grazing land, etc.)	▪ Stratification of pre-deforestation (forest strata) and post-deforestation (non-forest land uses) strata ▪ If no location analysis is applied (see above), strata with lowest carbon stocks are assumed to be deforested first
Estimation of forest carbon stocks per stratum		
Estimation of post - deforestation carbon stocks per stratum		
Estimation of carbon stock changes	▪ Same method as ADP Modules or ▪ Estimation of carbon stock changes per land use change category	Total forest C stock in areas deforested - Total post-deforestation C stock in areas deforested = Baseline carbon stock changes
Estimation of greenhouse gas emissions		
Emissions (CO_2, CH_4, N_2O) due to biomass burning	▪ Optional ▪ Only in forest strata where deforestation is projected to occur ▪ Limited to non-CO_2 emissions	▪ Optional ▪ In all strata ▪ CO_2 also included in areas subject to fire but not deforested
Ex-post estimation of carbon stock changes and GHG emissions in the project area		
Estimation of carbon stock changes		
Planned activities in the project area	▪ Carbon stocks decrease (mandatory) Area of deforestation (project infrastructures) Area of forest management (timber logging, fuel wood collection) ▪ Carbon stocks increase (optional) Areas that would have been deforested in the baseline case, where significant growth is expected	▪ Carbon stocks decrease (mandatory) Monitoring of actual deforestation occurring within the project area Monitoring of actual degradation (timber logging, fuel wood collection) occurring within the project area ▪ Carbon stocks increase (optional) Areas that would have been deforested in the baseline case, where significant growth is expected
Unplanned deforestation in the project area	▪ Monitoring of actual deforestation occurring within the project area	
Estimation of carbon stock variations per activity (see above)	▪ Based on available data (project specific, literature, existing databases…) and field measurements (mandatory for initial carbon stocks & carbon stocks increase)	▪ PRAs and field measurements (mandatory for all activities)
Estimation of carbon stock changes	Area / activity X Carbon stock variation/activity = carbon stock change/activity	Area / activity X Carbon stock variation/activity = carbon stock change/activity
Estimation of greenhouse gas emissions		
Emissions (CO_2, CH_4, N_2O) due to biomass burning	▪ Optional (but mandatory if accounted in the baseline) ▪ Limited to non-CO_2 emissions	▪ Mandatory ▪ In all strata ▪ CO_2 also included in areas subject to

		fire but not deforested
Ex-post estimation of carbon stock changes and GHG emissions due to leakage		
Estimation of carbon stock changes due to activity displacement		
Ex-post estimation of carbon stock changes due to deforestation in the leakage belt	▪ Area of actual deforestation occurring within the leakage belt **X** ▪ Carbon stock variation due to deforestation (field measurements) = actual carbon stock changes due to deforestation in the leakage belt	Same as BioCF/CDI methodology
Ex-post estimation of carbon stock changes due to activity displacement in the leakage belt	= actual carbon stock changes due to deforestation in the leakage belt - *baseline* carbon stock changes due to deforestation in the leakage belt	
Ex-post estimation of carbon stock changes due to activity displacement *outside* the leakage belt	absent	▪ Baseline deforestation due to immigrants (in the project area and leakage belt) is assumed to be 100% displaced outside the leakage belt
Estimation of greenhouse gas emissions due to activity displacement		
Emissions (CO_2, CH_4, N_2O) due to biomass burning	▪ Optional (but mandatory if accounted in the baseline) ▪ Limited to non-CO_2 emissions	▪ Mandatory ▪ In all strata ▪ CO_2 also included in areas subject to fire but not deforested
Estimation of carbon stock changes and GHG emissions due to leakage prevention measures		
Carbon stock changes	▪ Any decrease of carbon stock changes due to leakage prevention measures must be estimated and accounted	Absent
Non CO_2 emissions (CH_4, N_2O) due to biomass burning	▪ Optional (but mandatory if accounted in the baseline)	▪ Mandatory
Ex-post estimation of net GHG emission reductions		
Total net GHG emission reductions	= Ex-ante estimation of baseline carbon stock changes and GHG emissions - Ex-post estimation of carbon stock changes and GHG emissions in the project area - Ex-post estimation of carbon stock changes and GHG emissions due to leakage	
Uncertainty analysis	▪ Only carbon stocks are subject to uncertainty assessment ▪ Allowable uncertainty is +/- 10% of net GHG emission reductions at the 90% confidence level - Where this precision level is met, average carbon stock value can be used - Where uncertainty exceeds 10%, lower/upper boundaries of 90% confidence interval must be used (so that estimation is conservative)	▪ Uncertainty analysis is performed for rates of deforestation, estimation of C stocks changes, estimation of GHG emissions ▪ Allowable uncertainty is +/- 15% of net GHG emission reductions at the 95% confidence level - Where this precision level is met, no deduction for uncertainty - Where uncertainty exceeds 15%, deduction = amount that the uncertainty exceeds 15%

Table 2: Comparison of REDD methodologies relevant to the context of the SOIL project

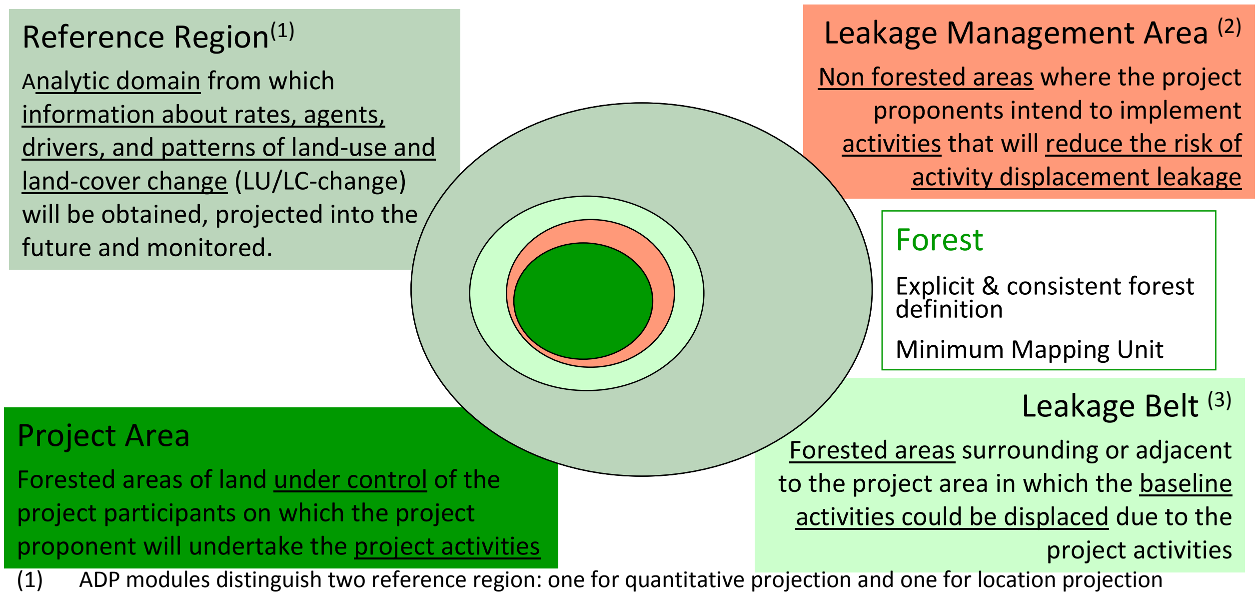
3. Definition of project boundaries

The first step of the methodology is to determine the boundaries of the project:

- Spatial boundaries
- Temporal boundaries
- Carbon pools
- GHG emissions sources

3.1. Spatial boundaries

Figure 4 shows the spatial boundaries of a REDD project.



(1) ADP modules distinguish two reference region: one for quantitative projection and one for location projection

(2) Does not exist in ADP modules

(3) Optional for mosaic deforestation in ADP modules

Figure 5: The spatial boundaries of a REDD project

3.1.1. Project area

The methodologies define the project area as the forested areas that the project intends to protect and where the reduction of deforestation will be estimated.

It is confusing because in many projects, activities will be carried out in both the forest areas (NTFP sustainable management, patrolling) and non-forest areas (agro-forestry, fuelwood tree plantations), and project proponent usually refer to both forest and non-forest areas under the term project area.

In order to avoid this confusion, we make the distinction throughout the report between:

- The project crediting area, i.e. the forested area at the beginning of the project that the project intends to protect and where the reduction of deforestation will be estimated (named project area by the methodologies);
- The project area, i.e. the whole area, whether forested or not, where project activities will be implemented.

We retained as the project crediting area the primary forest area of the five Groupements constituting the SOIL project area. According to the land cover change analysis carried out by UMD/SDSU for 2000-2010, it corresponds to 195 922 ha of primary forests in 2010.

Although the FACET product mapped secondary forests, we decided to exclude them from the project crediting area because we assumed that they are part of the rotation system of slash and burn agriculture. Rather than forests, we assumed they are old fallows that farmers let to regrowth, but that will be slashed and burnt again in the coming years. Under this assumption, such land could not be considered as forest land but as cropland, and should not be included in the project crediting area.
Our assumption is based on the following observation: the population density in the SOIL project area (2000 km²) is estimated at 8 inhab./km². The total population in the SOIL project area should be around 16.000 inhabitants, for 4 200 families as estimated by AWF.
In the FACET product, the areas of no-forest, secondary forests, and forest losses in primary and secondary forest (assumed to be cropland) sum up to 20 485 ha of land available for farming, i.e. less than 5 ha per family. Assuming that an average family cultivates from 0.5 to 1 ha of land each year, any secondary forest is likely to be slashed and burnt every 5 to 10 years. Population density and therefore farming intensity may vary spatially and decrease far from roads and settlements, which explains why fallows of up to 20 years can be (seldom) observed in the field.
Overall, it seems a reasonable assumption that all secondary forests are included in a rotation that may range from 5 to 20 years at a maximum.

It should be noted that the carbon storage in secondary forests/fallows is taken into account in the protocol for the inventory of carbon stocks (see part 5). Therefore, this definition of the project crediting area should not lead to an overestimation of baseline CO_2 emissions.

3.1.2. Leakage management area

The leakage management area consist in the areas of the rural complex where livelihoods support activities of the SOIL project will be developed: support to agriculture intensification, agroforestry. These activities are called leakage prevention measures in the BioCF-CDI methodology, which separates them from project activities, which are implemented in the project crediting area (for instance NFTP management, patrolling).
In the report, we name project activities all the activities that will be implemented by the SOIL project. We distinguish leakage management activities from project activities implemented in the project crediting area in some occasions, only when it makes a difference in the methodologies.
Note that only the BioCF-CDI methodology requires defining the exact location of leakage prevention areas.

3.1.3. Leakage belt

The leakage belt will be the forest areas under a potential threat of deforestation due to the displacement of slash and burn farming outside the project area. Its shape and extension must be determined on the basis of the potential mobility of farmers who would have practiced farming activities in the project crediting area without the project intervention.
Note that in ADP modules, an alternative approach to a leakage belt is the implementation of leakage prevention measures to maintain or increase the agents' livelihoods, such as the creation of alternative sources of fuelwood, improved crop or animal production systems, and employment.

The BioCF-CDI methodology proposes two options for the definition of the leakage belt: an opportunity cost analysis, applicable where economic profit is an important driver of deforestation, and/or a mobility analysis, where the potential mobility of deforestation agents is assessed using a GIS multi-criteria analysis. There is no specific recommendation on the number or type of criteria to include in the analysis.

The ADP Modules provide a list of precise criteria for the definition of the leakage belt (see table 3).

3.1.4. Reference region

The reference region should be representative of the deforestation patterns, rates and drivers that occur or are expected to occur in the project area. Its definition is discussed in the specific section on the baseline scenario.

Methodologies	ADP Modules
Size of the leakage belt	At least 90% of the area of the project
Landscape factors	
Forest types	Forest classes must be present in the leakage belt in the same proportion as in the project area (+/- 20%)
Elevation	Elevation classes (500 m classes) shall be in the same proportion (+/- 20%)
Slope	The ratio of gentle (<15%) to steep (>15%) slope classes shall be the same (+/- 20%)
Soils	Soil types suitable for use of main deforestation agents must be present in the same proportion (+/- 20%)
Socio-economic and cultural conditions	
Policies and regulations	Policies and regulations having an impact on land-use change patterns must be of the same type or have the same effect, taking into account the current level of enforcement
Social factors	Social factors having an impact on land use change patterns must be the same
Transportation factors	
Navigable rivers	Navigable river/stream density (m/km2) shall be the same (+/-20%)
Roads	Road density (m/km^2) shall be the same (+/-20%)
Settlements	Settlement density (settlements/km^2) shall be the same (+/-20%)

Table 3: Criteria for defining the leakage belt (ADP Modules)

3.2. Temporal boundaries

Figure 5 shows the temporal boundaries of a REDD project.

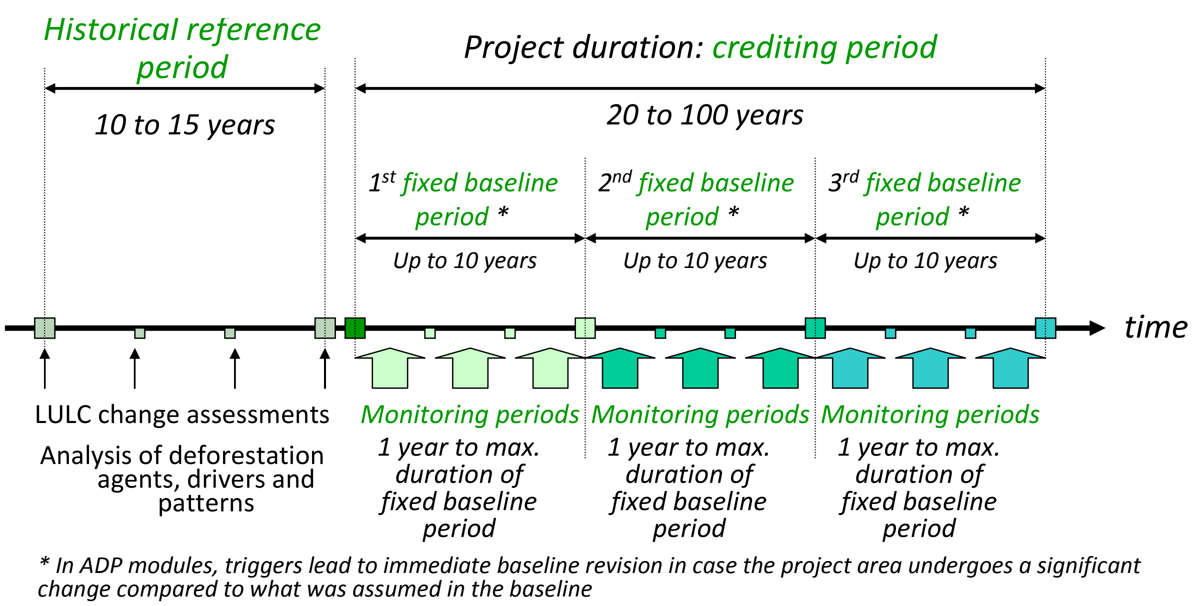


Figure 6: The temporal boundaries of a REDD project

3.2.1. Historical reference period

The baseline scenario is partly constructed through the analysis of past deforestation trends over a reference region. Necessary data (deforestation rates, deforestation drivers) will be collected over a given historical reference period. The BioCF methodology states that this period must end as close as possible before the project start and begin 10 to 15 years before project start. In the ADP Framework Methodology, it must span a period of 3 to 12 years before the start of the project and end within two years of the project start.

3.2.2. Fixed baseline period

Due to uncertainties of future evolutions of deforestation drivers, the baseline scenario is considered valid for a maximum duration of 10 years in both BioCF and ADP methodologies.
The BioCF methodology gives the latitude to project proponents to fix a shorter validity period for the baseline scenario: the fixed baseline period can not exceed 10 years but may be shorter.
The ADP Framework methodology fix the baseline period at 10 years, but set up a trigger based on forest scarcity that would lead to immediate baseline revision in case the project area undergoes a significant change compared to what was assumed in the baseline (see part 4.4.3 below).

3.2.3. Monitoring period

Monitoring is needed to report and certify emissions reductions by the VCS. The monitoring period is the time spent between two monitoring events. Project may wish to reduce monitoring period in order to certify credits and generate incomes quickly. However this entails more costs. Moreover, with a too short time span between monitoring events, changes in deforestation trends may not be observable with a sufficient level of certainty.

3.2.4. Crediting period

The crediting period is the project duration, i.e. the period of time during which the project will generate emissions reductions. It should be at least 20 years to ensure a minimum permanence of forest conservation efforts and emissions reductions. It can be extended to up to 100 years.
Most of existing REDD projects have a crediting period ranging from 20 to 30 years. In average, projects developed on areas where unplanned and mosaic deforestation will occur have a crediting period of 30 years (this is the case of both Oddar Meanchey and Ankeneny-Mantadia-Zahamena projects, for which some of the existing methodologies were developed.

There temporal boundaries are defined in the following parts of the report.

3.3. Carbon pools

Six carbon pools are eligible:

- Above ground biomass (tree and non-tree);
- Below ground biomass;
- Dead wood;
- Harvested wood products;
- Litter;
- Soil organic carbon.

The VCS tool for AFOLU Methodological Issues provides recommendations on the carbon pools to be included according to project types and baseline activities (cf. table 4).

	Living biomass			Dead organic matter			
Project type/Baseline activity	**Above ground trees**	**Above ground non-tree**	**Below ground**	**Litter**	**Dead wood**	**Soil organic carbon**	**Wood products**
REDD/Conversion of forest to non-forest with **final land cover of annual crop**	Y	O	O	N	O	O	S
REDD/Conversion of forest to non-forest with **final land cover of pasture grasses**	Y	O	O	N	O	N	S
REDD/Conversion of forest to non-forest with **final land cover**	Y	Y	O	N	O	N	S

of perennial crop								

Table 4: carbon pools to be considered for REDD activities (VCS AFOLU requirements, v3 March 2011)

- Y: pool shall be included in the monitoring plan for the baseline and project
- N: pool need not be measured because it is not subject to significant changes or potential changes are transient in nature
- O: pool is optional, although its carbon stock may increase as a result of the project, depending on the practices involved.
- S: Carbon pool shall be included where project activities may significantly reduce the pool, and may be included where baseline activities may significantly reduce the pool. The methodology shall justify the exclusion or inclusion of the pool in the project boundary.

Project proponents may decide whether to include an optional pool or not on the basis of several criteria (see figure 6 for a decision tree on whether to include or not a carbon pool and the definition of each criteria):

- Expected magnitude of change
- Ease and costs of measurement
- Conservativeness
- Significance

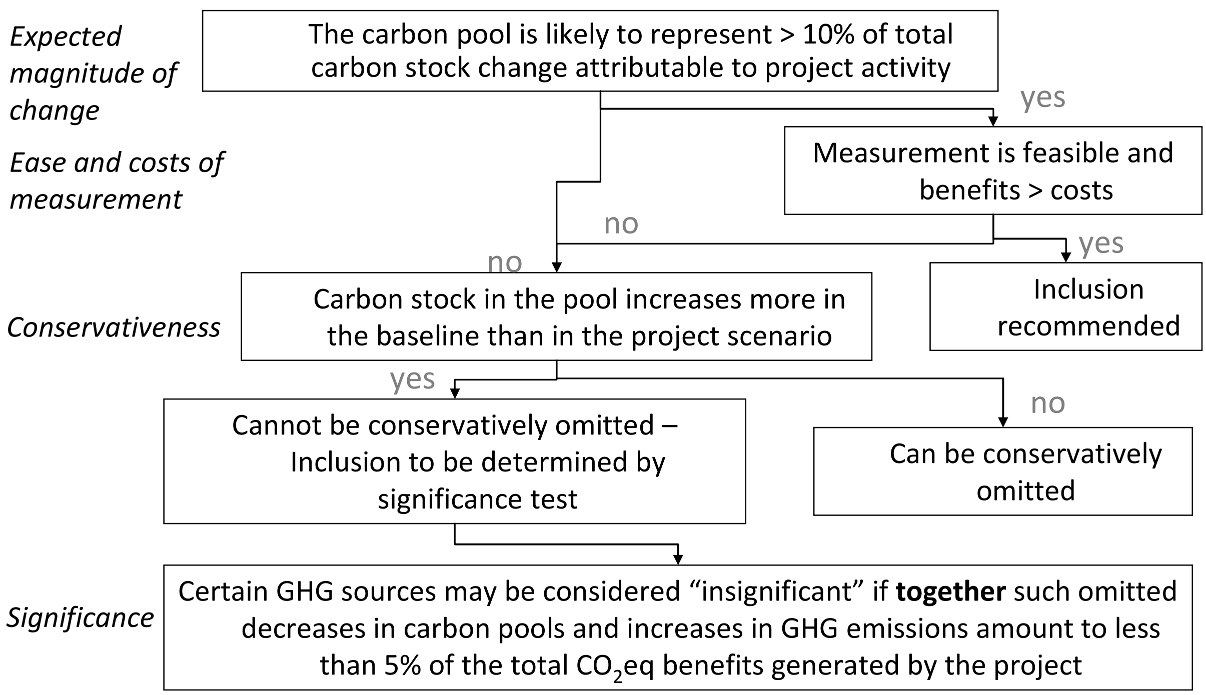


Figure 7: Decision tree for the inclusion of carbon pools

In the case of the SOIL project:

- **Above ground tree biomass:**

It will be automatically included in any REDD project.

- **Above ground non-tree biomass:**

It can not be conservatively omitted if the post – deforestation land cover is of perennial crops, e.g. oil palm, bananas, fruit trees, spice trees, etc. The reason for this is that this pool is likely to decrease in the project scenario in comparison to the baseline scenario. Indeed, the baseline scenario is the conversion of forest to croplands, where non-tree biomass may be more abundant then in forest land. The project scenario is the

reduction of conversion, thus under this scenario, the above-ground non-tree biomass pool may be reduced compared to the baseline scenario.
It is likely that post deforestation land covers in the SOIL project area include such perennial crops. Therefore, this pool has to be measured at least during the ex-ante carbon inventory. It will then be possible to ignore it only if the significance test allows its omission.

- **Below ground biomass:**

It will be included as it is always significant.

- **Litter:**

It can be neglected according to VCS recommendations.

- **Dead wood:**

As post-deforestation land use is slash and burn agriculture, it is likely that the dead wood pool will decrease because of project implementation. Thus, it can not be conservatively omitted. It has to be measured at least during the ex-ante carbon inventory. It will then be possible to ignore it only if the significance test allows its omission.

- **Soil organic carbon:**

With SOIL project implementation, it is likely that the soil organic carbon pool will be increased, because the conversion of forest will be reduced and project activities will improve soil conservation in the crop lands, through agro-forestry techniques for instance. However, the magnitude of change is uncertain. The ASB program conducted research in Cameroon in a relatively low land-use intensity area, where crops were established only one year prior to abandonment to fallow regrowth. It did not show a significant change in the soil carbon content between forest and fallows (Palm et al., 2000).
Moreover, costs of measurements are high. Thus, this pool will be conservatively omitted.

- **Harvested wood products:**

Harvested Wood Products shall be included according to VCS guidelines. However, both BioCF-CDI and ADP methodologies allow the exclusion of the pool based on conservativeness and significance. In the case of the SOIL project, as there is no timber logging on a commercial scale in the baseline situation, the implementation of the project won't lead to a decrease of this pool. Thus, it can be conservatively omitted.

3.4. GHG emissions sources

According to the VCS tool for AFOLU methodological issues, all significant GHG sources shall be measured, estimated and monitored in both the **baseline** and **project** case.
Potentially significant sources are:

- CO_2, CH_4 and N_2O emissions resulting from biomass burning (note that CO_2 emitted by biomass burning in areas deforested or degraded is taken into account through the estimation of carbon stocks variations);
- N_2O emissions resulting from the use of nitrogen fertilizer and/or manure, or the plantations of N-fixing species;
- CH_4 and N_2O emissions resulting from livestock rearing;
- Emissions resulting from fossil fuel combustion from transport.

It is important to notice that the significance/insignificance of carbon pools and GHG emissions sources is tested as a whole: certain GHG sources may be considered insignificant if **together** such omitted decrease in carbon pools and increase in GHG emissions amount to less than 5% of the total CO2eq benefits generated by the project. This may be tested with the CDM tool for testing significance of carbon pools and GHG emissions sources[7], according to both ADP modules and BioCF-CDI methodology.

[7] http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

3.4.1. Baseline case

If feasible and profitable, without overestimating emissions reductions, project proponents may take into account the reductions of CH_4 and N_2O emissions, if in the baseline scenario the project land would have been subject to cattle grazing and/or nitrogen fertilization, and/or if fire would have been used to clear the land.

In the case of the SOIL project, it is expected that emissions due to nitrogen fertilization and cattle grazing are marginal in the baseline case and thus will be ignored. Indeed, even for cash crop plantations (coffee, cocoa…), most farmers don't use chemical fertilizers[8], and cattle grazing is almost absent[9].

Emissions resulting from forest fires are expected to be significant in the baseline case, and project implementation is supposed to reduce the use of fires. This emissions source may be included if it is technically feasible and profitable for the project without overestimating emissions reductions. Note that in this case, emissions from fires shall be accounted for and monitored **in both the baseline and project** cases (as well as in the estimation of leakage).

Emissions resulting from fossil fuel combustion can always be ignored. The ADP methodological framework allows including them in the baseline, but then they should also be included in the project case. In case of the SOIL project, baseline emissions due to fossil fuel combustion should be marginal. Thus, it is recommended to ignore this source.

3.4.2. Project case

If the project implementation generates relevant sources of emissions, they should be accounted for and monitored. However, some sources are automatically considered insignificant and do not have to be accounted for:

- N_2O emissions resulting from the use of nitrogen fertilizer and/or manure, or the plantations of N-fixing species resulting **from project activities within the project crediting area**.
- Emissions from removal or burning of herbaceous vegetation, fossil fuel combustion from transport in **project activities within the project crediting area**.

In the case of the SOIL project, the only emissions sources resulting from project activities that could be considered significant are:

- CH_4 and N_2O emissions resulting from livestock rearing;
- N_2O emissions resulting from the use of fertilizers.
- CO_2, CH_4 and N_2O emissions resulting from biomass burning;

As the project activities do not include an intensification of livestock rearing, it is considered that this emissions source can be conservatively omitted.
Note that the available methodologies differ regarding this issue: The ADP methodological framework is not applicable if project activities include the creation of livestock feedlots and/or manure lagoons. Consequently, emissions sources resulting from livestock activities are ignored. On the contrary, the BioCF mosaic methodology does not have any applicability constraint on livestock. As a consequence, emissions sources resulting from livestock activities may be accounted for (if significant). There is no consequence on the SOIL project.

The BioCF-CDI methodology ignores N_2O emissions resulting from the use of fertilizers (following VCS guidance), whereas the ADP methodological framework requires that they are accounted if leakage management activities enhance the use of fertilizers. If SOIL project activities on agriculture include an enhanced use of fertilizers and the generated emissions are significant, then this emission sources must be included in the monitoring plan.

Emissions resulting from biomass burning are covered in the section on monitoring (see part 5.5).

[8] AWF. Les potentialités agricoles et les aspirations des populations pour la relance de l'agriculture. Janvier 2005.
[9] CARE. Vivre ou mourir au cœur de la forêt équatoriale. Janvier 2005.

- ✓ There are four main spatial boundaries:
  - o The project crediting area: the forest area in the SOIL project area whose protection allows receiving carbon credits;
  - o The project area: the (forest and no forest) areas where project activities will be implemented; it is the SOIL project area;
  - o The leakage belt: it is used for the monitoring the displacement of deforestation that would be attributable to the project;
  - o The reference region: see next part x.

- ✓ The project crediting area does not include secondary forests, because they are most probably fallows of the slash and burn rotations.

- ✓ There four temporal boundaries: the historical reference period, the fixed baseline period, the monitoring period and the crediting period. They are defined in the following parts of the report.

- ✓ Among eligible carbon pools, Above ground and below ground tree biomass will be included; above ground non tree biomass and deadwood can not be conservatively omitted but will be ignored if non significant.

- ✓ Under the BioCF-CDI methodology, all GHG emissions sources could be ignored; Under the ADP Modules, significance of N_2O emissions resulting from the use of fertilizers (if applicable to SOIL project) should be tested. Moreover, the ADP Modules require accounting for emissions from biomass burning (see part 5.5).

4. Methodological approach to determine the reference scenario

4.1. Review of available data

We elaborated an approach to determine the reference scenario on the basis of the data available (see table 5) for the project site and its reference area. We indicated where data is missing and how it could be completed.

	MLW landscape	SOIL Project Area
Analysis of Land Use Land Cover changes		
Satellite images	Landsat composite mosaics for circa 1990, circa 2000, and circa 2003-2006.	Landsat 30m (1984, 86, 87, 94, 99, 2000, 03, 04, 06, 07, 08, 09) Aster 15m (2000, 01, 04, 06, 07) Quickbird <1m (2009)
Fires monitoring	FIRMS (UMD) from MODIS terra and Aqua satellites (2002 to 08)	
Land cover analysis	UMD/SDSU land covers for 1990, 2000	
Land use land cover changes analysis	Forest Change Map 90-00 SDSU Forest Change Map 00-10, elaborated by SDSU, OSFAC & UMD (FACET product)	
Spatial drivers of deforestation		
Rivers (navigable)	FAO-Africover	Derived from SRTM 90 meters elevation data
Roads	UCL	
Settlements	DRC GIS working group, revised by UMD	
Elevation and slope	SRTM 90m elevation data	
Rainfall	No data[10]	No data
Soils	Soil (1960)	
Socio-economic data on deforestation drivers		
Demography, agricultural production, energy consumption, etc.	▪ CARE micro-socio-economic survey; ▪ AWF Updated participative landscape land use planning strategy document (MOV.1.1.A) ▪ AWF Updated participative landscape land use plan design (MOV.1.1.B) ▪ AWF Les potentialités agricoles et les aspirations des populations pour la relance de l'agriculture (IR.1.1 ALL 2 Livelihood and Market) ▪ AWF Report on study on land use patterns vs active fire points vs population's migratory movement (MOV 1.2. CBNRM5 E) ▪ AWF Report on study: active fire points for monitoring of impact of a conservation program on canopy destruction (MOV 1.1.F)	
General GIS data		
Administrative boundaries	Protected Areas Logging concessions	"Groupements" polygon of the SOIL project site

[10] There is general data on the rainfall for this part of RDC of course, but it is not useful for comparing the project area with other areas of the MLW landscape and determining a reference area. We could not find any separate data for the project area on one hand and the MLW landscape on the other hand. However, we assume there is not significant variation of the rainfall throughout the landscape.

	"Groupements" MLW landscape	
Zoning	Proposed macro-zones for MLW landscape	

Table 5: Available data for estimating the baseline scenario

An important source of information for this part is the available map products on land covers and land cover changes for the MLW landscape (all elaborated by UMD and SDSU):

- Land cover map for the year 2000;
- Forest loss map for the period 1990-2000;
- Forest loss map for the period 2000-2010.

The 2000 land cover map discriminates two forest types (dense moist forest and swamp forest), a rural complex mixing farmed areas and regrowth areas of secondary forest, and urban and wetland areas. The forest loss map 1990-2000 doest not distinguish areas deforested in the primary forest (i.e. dense moist forest and swamp forest) from areas deforested in the secondary forest.

Land cover 2000	SOIL Project Area		MLW landscape	
	Area (ha)	%	Area (ha)	%
Swamp forest	29 328	13.5	1 871 665	25.9
Dense moist semi-deciduous and evergreen forest	168 759	77.9	4 864 709	67.2
Rural complex and young secondary forest	18 291	8.5	464 409	6.4
Urban	0	0.0	572	0.01
Water	48	0.02	32 820	0.5
Total	**216 424**	**100.00**	**7 234 175**	**100.00**
Forest loss 1990-2000 (in swamp forest and dense moist semi-deciduous and evergreen forest)	1 196	0.6	61 429	0.9

Table 6: Land cover 2000 and forest loss 1990-2000 in the SOIL project area and MLW landscape (from UMD/SDSU)

The 2000-2010 forest loss map discriminates woodlands, primary forest, secondary forest, no-forest areas and wetland. It estimated deforestation both in the primary forest and the secondary forest.

Forest loss 2000 - 2010	SOIL Project Area		MLW landscape	
	Area (ha)	%	Area (ha)	%
No forest	1 454	0.67	63 690	0.88
Wetlands	28	0.01	33 920	0.47
No data	12	0.01	1 458	0.02
Woodlands	1	0.00	401	0.01
Primary tropical forest	195 922	90.52	6 647 142	91.89
Secondary tropical forest	13 735	6.35	376 215	5.20
Forest loss in woodlands 2000-2005	1	0.00	15	0.00
Forest loss in primary forest 2000-2005	453	0.21	10 472	0.14
Forest loss in secondary forest 2000-2005	1 579	0.73	39 333	0.54
Forest loss in woodlands 2005-2010	0	0.00	14	0.00
Forest loss in primary forest 2005-2010	1 016	0.47	19 153	0.26
Forest loss in secondary forest 2005-2010	2 248	1.04	42 358	0.59
Total	**216 450**	**100.00**	**7 234 170**	**100.00**

Table 7: Land cover 2010 and forest loss 2000-2010 in the SOIL project area and MLW landscape (from UMD/SDSU)

The land cover map for the year 2000 was used for the stratification of the project area in potential carbon density classes and the design of the protocol for carbon stock inventory.
The forest loss map for 2000-2010 was used for the estimation of the baseline.

4.2. Definition of the reference region

The reference region is the analytic domain from which information about rates, agents, drivers, and patterns of land-use and land-cover change (LU/LC-change) will be obtained, projected into the future and monitored. It is therefore essential that the reference region be as representative as possible of the project area. This is evaluated by methodologies on various criteria (see table 8):

1. Size of the reference area
2. Agents and drivers of deforestation
3. Landscape configuration and ecological conditions: forest/vegetation classes, elevation, slope, rainfall and soils (only in ADP methodology for this last criteria)
4. Socio-economic and cultural conditions: legal status of the land, land tenure, land use, enforced policies and regulations
5. Transportation networks and human infrastructure, such as roads, navigable rivers and settlements (only in ADP REDD methodology modules)

Methodologies	BioCF	ADP
Size of the reference area	Should be larger than the project area and include the project area	▪ Projection of deforestation rate: Minimum size of the reference region = $7500*(\text{Project Area})^{-0.7}$ ▪ Projection of deforestation location: Equal to the area of the reference region for projection of deforestation rate +/- 25%
Agents and drivers of deforestation	Those existing or expected to exist in the project area must exist elsewhere in the reference area	▪ Proportion of agriculturalist versus ranchers is the same +/- 20% ▪ Lack of legal rights to use land is the same ▪ Proportion of agents resident versus immigrants is the same +/- 20%
Landscape configuration and ecological conditions		
Forest/vegetation classes	At least 90% of the project area must have forest classes or vegetation types that exist in at least 90% of the rest of the reference region.	Forest classes must be present in the reference region in the same proportion as in the project area (+/- 20%)
Elevation	At least 90% of the project area must be within the elevation range of at least 90% of the rest of the reference region	Elevation classes (500 m classes) shall be in the same proportion (+/- 20%)
Slope	The average slope of at least 90% of the project area shall be within $\pm$10% of the average slope of at least 90% of the rest of the reference region	The ratio of gentle (<15%) and steep (>15%) slope classes shall be the same (+/- 20%)
Rainfall	The average annual rainfall in at least 90% of the project area shall be within $\pm$10% of the average annual rainfall of at least 90% of the rest of the reference region	none
Soils	none	Soil types suitable for use of main deforestation agents must be present in the same proportion (+/- 20%)
Socio-economic and cultural conditions		
Legal status of the land	The legal status of the land in the baseline case within the project area must exist elsewhere in the reference	Policies and regulations having an impact on land-use change patterns must be of the same type or have the

	region	same effect, taking into account the current level of enforcement
Land tenure	The land-tenure system prevalent in the project area in the baseline case is found elsewhere in the reference region	
Land use	Current and projected classes of land-use in the project area are found elsewhere in the reference region.	Areas of planned deforestation shall be excluded
Enforced policies and regulations	The project area shall be governed by the same policies, legislation and regulations that apply elsewhere in the reference region.	See above
Social factors	none	Social factors having an impact on land use change patterns must be the same
Transportation network and human infrastructure		
Navigable rivers	none	Navigable river/stream density (m/km2) shall be the same (+/-20%)
Roads		Road density (m/km^2) shall be the same (+/-20%)
Settlements		Settlement density (settlements/km^2) shall be the same (+/-20%)

Table 8: Criteria for defining the reference area (reference region for projecting rate of deforestation in ADP Modules)

Note that ADP modules two reference regions:

- One for projecting the rate of deforestation
- One for projecting the location of deforestation

The criteria for the definition of the reference region for projecting the rate of deforestation are detailed in the table 8. It should also be noted that, in the ADP modules, this reference region for projecting the rate of deforestation must be forested land at the start of the historical reference period.

The reference region for projecting the location of deforestation shall consist of a minimum of 5% of non-forest and a minimum of 50% forest. Its area of forest shall be equal to the area of the reference region for projecting the rate of deforestation (+/- 25%). It must have the same proportion of forests suitable for conversion as the project area (+/- 30%) as demonstrated by soil suitability, precipitation regime, elevation and access to markets.

We designed the reference region on the basis of the above-mentioned criteria, as detailed below.
If used in the ADP modules, it can suit the requirements for the determination of both the rate and localization of deforestation.

4.2.1. Agents and drivers of deforestation and forest degradation

Agents and drivers of deforestation and forest degradation that exist or are expected to exist in the project area must be similar to those existing in the reference region.
The main driver of deforestation in the project area and MLW landscape is slash and burn agriculture practiced by local communities.
Forest degradation may be caused by two main factors/agents:

- Local communities collecting firewood and timber for domestic use, especially around population centers such as Djolu;
- Logging of timber at commercial scale in logging concessions.

As there are no logging concessions and thus no commercial logging in the SOIL project area, the reference region shall exclude areas where commercial logging occurs. Therefore, logging concessions located in the MLW landscape shall not be part of the reference area (which is also consistent with the criteria on socio-economic conditions, see below).

4.2.2. Landscape configuration and ecological conditions

The BioCF and ADP methodologies retain five sub-criteria:

- forest/vegetation classes
- elevation
- slope
- rainfall (BioCF only)
- soils (ADP only)

Both methodologies define acceptable ranges of differences between project area and reference region (+/- 10 to 20% of the averages/proportions).

The SOIL project area and the MLW landscape seem quite similar in terms of ecological conditions. However, one of the vegetation classes, i.e. swamp forests, may be over represented in the MLW landscape compared to the SOIL project area. When defining the reference region; it may be necessary to exclude areas of the MLW landscape where swamp forests are abundant.

The reference area was designed in order to comply with criteria on land cover, soil types, elevation and slopes for both methodologies. This led to exclude most of swamp forests on gley soils lying in the south of the project area along the river Maringa (see figure 7).
Rainfall was not tested due to lack of data but it is not expected that the rainfall would vary significantly from across project and reference region.

Land cover	SOIL Project Area		Reference Area	
	Area (ha)	%	Area (ha)	%
Swamp forest	29 328	13.55	100 455	14.79
Dense moist semi-deciduous and evergreen forest	168 759	77.98	515 592	75.89
Rural complex and young secondary forest	18 291	8.45	63 027	9.28
Water	48	0.02	287	0.04
Total	**216 424**	**100.00**	**679 360**	**100.00**
Soil types	**SOIL Project Area**		**Reference Area**	
	Area (ha)	**%**	**Area (ha)**	**%**
Ferrallitic soils on clayey sands	193 644	89	570 741	84
Gley soils on alluvial deposits	22 781	11	108 565	16
Total	**216 424**	**100**	**679 305**	**100**
Elevation classes	**SOIL Project Area**		**Reference Area**	
	from 364 to 488 m		from 346 to 526 m	
Slopes	**SOIL Project Area**		**Reference Area**	
	Area (ha)	**%**	**Area (ha)**	**%**
Rainfall	**SOIL Project Area**		**Reference Area**	
	Area (ha)	**%**	**Area (ha)**	**%**
	No data		No data	

Table 9: Landscape configuration and ecological conditions in the SOIL project area and reference area

4.2.3. Transportation networks and human infrastructure

Only the ADP methodology framework includes this criterion, with three considered variables: density of navigable rivers, density of roads and density of settlements. The reference region shall not differ from +/- 20% of the project area.

Transportation networks and human infrastructure	SOIL Project Area	Reference Area
Roads density	52.21 m/km^2	42.61 m/km^2
Navigable rivers density	13.97 m/km^2	14.13 m/km^2
Settlements density	0.0037 settlements/km^2	0.0043 settlements/km^2

Table 10: Transportation networks and human infrastructure in the SOIL project area and reference area

The designed reference region complies with those three criteria.

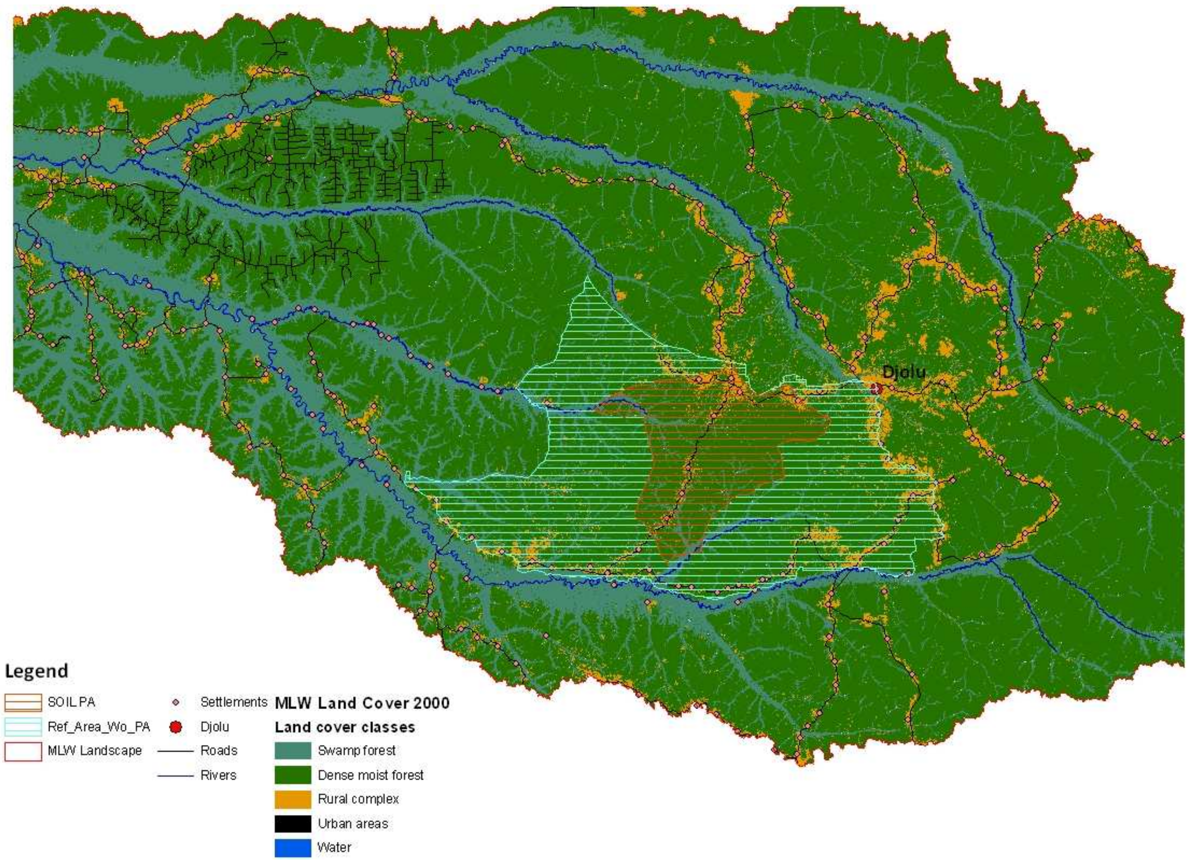


Figure 8: land covers (2000) of the SOIL project area and reference area (land cover UMD/SDSU)

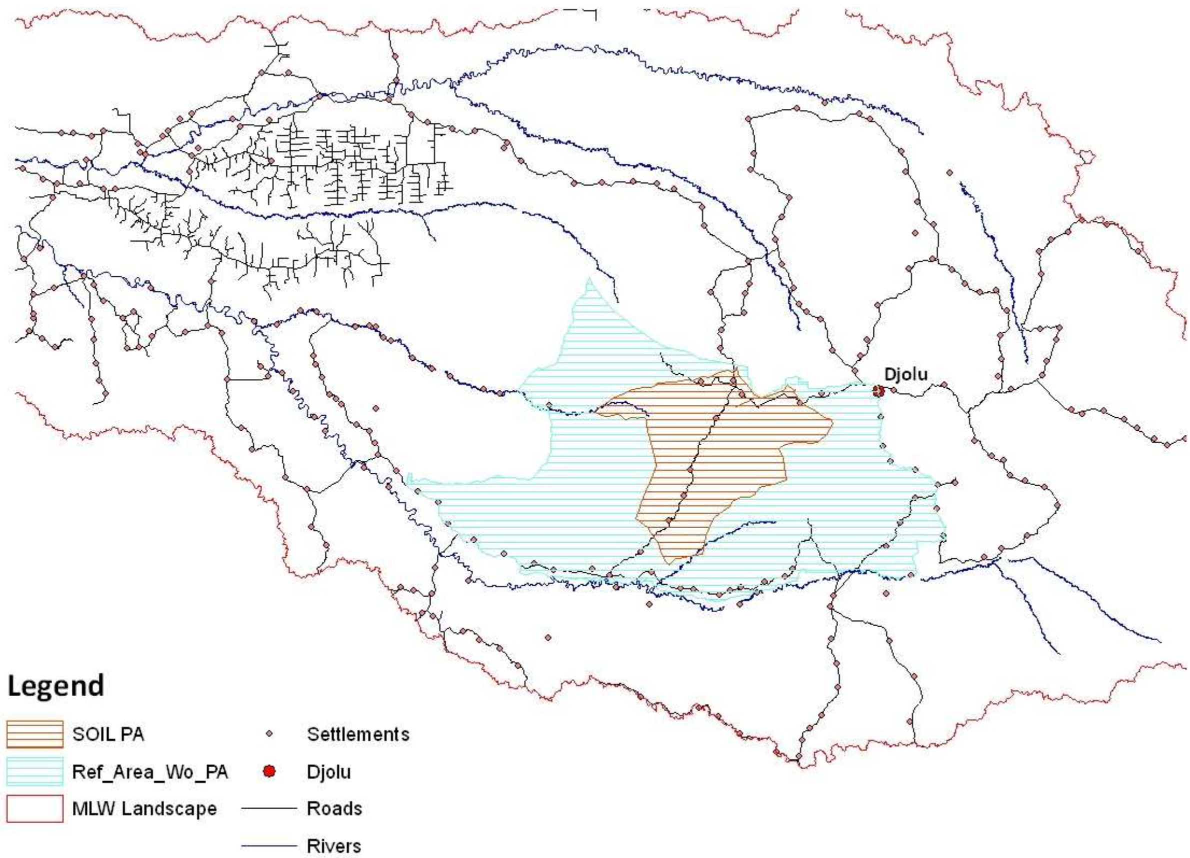


Figure 9: Road network, rivers and settlements in the reference area and SOIL project area (FAO Africover, UCL)

4.2.4. Socio-economic and cultural conditions

In the BioCF methodology, this criterion refers to 4 issues:

- legal status of the land;
- land tenure;
- land use;
- Enforced policies and regulations.

The ADP methodology framework says that "policies and regulations having an impact on land-use change patterns within the reference region and the project area must be of the same type or have the same effect, taking into account the current level of enforcement".

In order to fulfill this criterion, the reference region excludes areas which are or will be governed by different legal status and land use regulations than the project area (see figure 9):

- Protected Areas: Lomako Faunal Reserve, Lopori Congo Area, Luo Scientific Reserve
- Logging concessions: SIFORCO K2, SIFORCO K7
- Wetlands (if allowed land use is different than for CBNRMAs)

Indeed, such areas won't be subject to the same deforestation and degradation pressures than the SOIL project area and therefore can not be considered as representative, for distinct reasons:

- Protected areas: because they are protected by law and deforestation/degradation is forbidden
- Logging concessions: because conversion for agriculture (allowed agricultural series in the management plan) and commercial logging (according to officially approved forest management plans) are supposed to be strictly controlled.

Conversely, the designed reference region includes macro zones similar to the ones that are encountered in the project area:

- Community Based Natural Resources Management Areas (CBNRMA): Corridor and Cadjobe;

- Agricultural areas (SAP): surrounding Corridor and Cadjobe CBNRMA;
- Areas not classified in the macro-zoning: between Corridor CBNRMA, SIFORCO K7 concession and Lomako Faunal Reserve.

4.2.5. Size of the reference region

The BioCF methodology does not provide any guideline on the size of the reference region: "it may include one or several discrete areas; it should be larger than the project area and include the project area".
The ADP methodological framework defines a formula to calculate the minimum area of the reference region. If we retain the SOIL project area, this gives a REDD project area of around 216 327 ha. In this case, the size of reference region should be at a minimum of about 350 000 ha.
The designed reference area is much larger: 679 360 ha.

In conclusion, the reference area surrounds the SOIL project area and is limited by (see figure 9):
- The SIFORCO K7 concession to the north;
- The boundary of the Corridor CBNRMA to the west;
- The road from the boundary between Lomako and Corridor CBNRMA to the boundary between Corridor CBNRMA and wetlands and the river Maringa to the south;
- The Luo Scientific Reserve to the south-east;
- The road from Yakiri (north of the Luo scientific Reserve) to Djolu to the east.

Note that the reference area for projecting the deforestation rate in the ADP modules should be only forested land at the start of the historical reference period, i.e. 2000 (see part 4.4.1 below). Therefore, if ADP modules are used, areas that were not forested in 2000 should be excluded from this shape (it should have only minor impacts on the criteria for reference area definition).

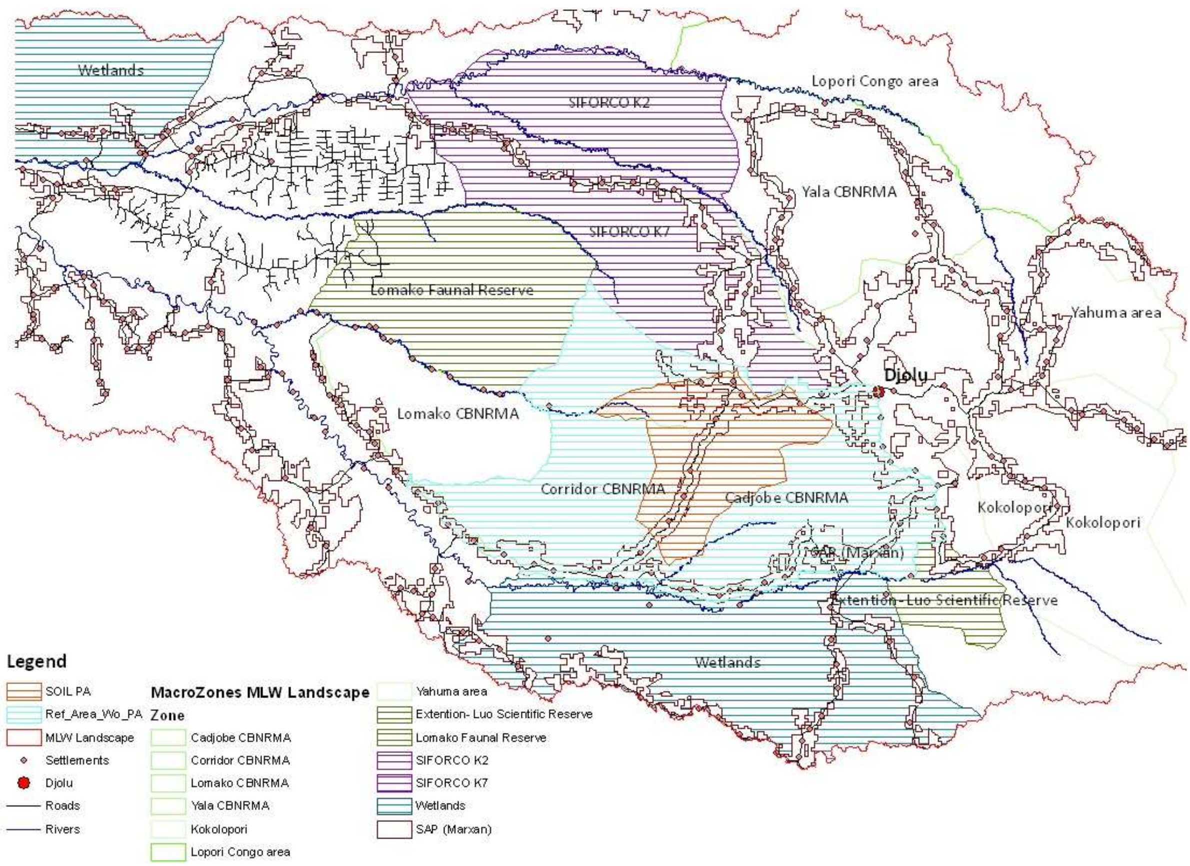


Figure 10: SOIL project area and reference area, and proposed macro zones for the MLW landscape (UMD)

4.3. Deforestation trends and factors in the project and reference areas

We reviewed the available information and data (see table 5) on the SOIL project area, MLW landscape and DRC in order to describe the main trends in terms of deforestation rates and the factors that explain them.
Assessing past deforestation rates on the reference area through remote sensing is mandatory in both methodologies.
The detailed analysis of deforestation agents, drivers and underlying causes is only required in the BioCF-CDI methodology.

4.3.1. Past and current land use changes

The estimation of historical deforestation rates during the historical reference period within the reference area and the project area is the first step for the determination of the baseline.
Both BioCF and ADP methodologies recommend analyzing the land cover for at least 3 time points, at least 3 years apart.
At the moment, there are:

- a land cover analysis for the year 2000, and a forest cover change map 1990-2000, elaborated by UMD and SDSU;
- A forest cover change map for 2000-2005-2010, elaborated by UMD and SDSU.

Those two sets of data are not meant to be compared: they were made with different methodologies and algorithms[11].
The 2000 land cover map discriminates two forest types (dense moist forest and swamp forest), a rural complex mixing farmed areas and regrowth areas of secondary forest, and urban and wetland areas. The forest cover change map 1990-2000 does not distinguish areas deforested in the primary forest from areas deforested in the secondary forest. However, given the limited number of has deforested during this period (see table 12), our assumption is that the forest loss that is detected concerns mostly primary forests.
The 2000-2010 data set discriminates primary forest, secondary forest, no-forest areas and wetland. It estimates deforestation both in the primary forest and the secondary forest. However, deforestation in the secondary forest is probably part of the rotation between crops and fallows of slash and burn farming, where a piece of land is cultivated one or two years and then let as a fallow for years before being cut and burnt again (see part 3.1.1 above). We therefore assimilate secondary forests as fallows of the slash and burn rotations and consequently, clearing of these secondary forests is not included in the baseline deforestation.

Historic deforestation is therefore obtained from forest loss estimates of 1990-2000 and primary forest loss estimated of 2000-2005-2010, and concerns only forest loss in the primary forest, when a piece of land is slashed and burnt for the first time and enters a cycle of clash and burn farming. Results for the reference area and project area are presented in figure 10 and table 11.
In the reference area the rate was of 455 ha/year between 1990 and 2000, then decreased to 257 ha/year between 2000 and 2005, and increased to 451 ha/year between 2005 and 2010.
In the project area, was of 120 ha/year between 1990 and 2000, then decreased to 91 ha/year between 2000 and 2005, and increased to 203 ha/year between 2005 and 2010.
These irregular trends may be partly explained by the fact that the 1990-2000 and 2000-2010 assessment were done with different methodologies. If we retain only the 2000-2010 period, we observe an increase of the deforestation rates from 2000-2005 to 2005-2010. However, it is not possible to draw conclusions on only two points in time.

[11] The area of primary forest in 2000 in the FACET product (deducted from primary forest area in 2010, and forest loss in primary forest for 2000-2005 and 2005-2010) is 197.391 ha, whereas it is 198.087 ha in the 2000 land cover map (dense moist forest and swamp forest area).

	1990-2000		2000-2005		2005-2010		1995-2010		2000-2010	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
SOIL project area	120	-0.06%	91	-0.05%	203	-0.10%	138	-0.07%	147	-0.07%
Reference area	455	-0.07%	257	-0.04%	451	-0.07%	388	-0.06%	354	-0.06%

Table 11: Historical annual deforestation rates in the project and reference area

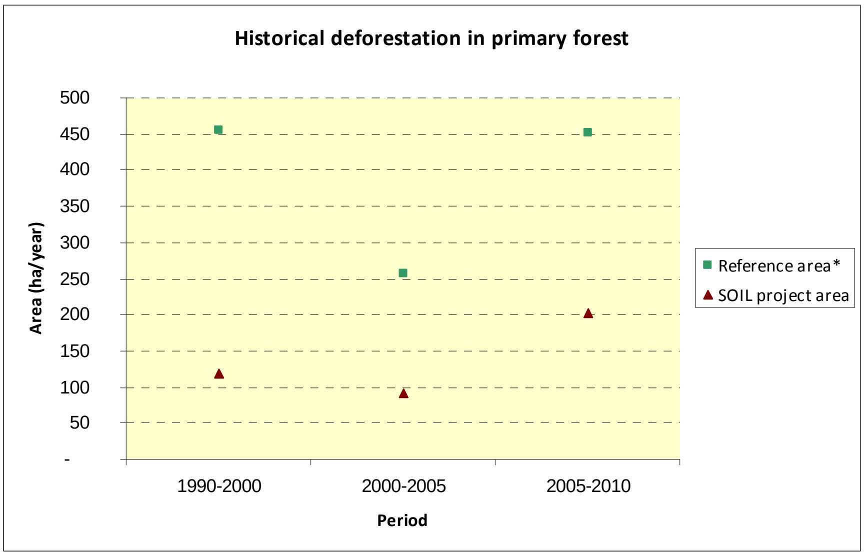


Figure 11: Historical deforestation rates (ha/year) in the project and reference areas

4.3.2. Drivers and underlying causes of land use changes: past and current trends

Deforestation usually results from a combination of proximate causes, such as infrastructure extension, agricultural expansion and wood extraction, and underlying causes such as demographic, economic, technological factors, etc. (See figure 11). We used the analysis developed by Geist and Lambin (2001) in order to describe deforestation drivers in the SOIL project area.

Slash and burn farming is the main direct cause of deforestation in the project area and its region.
Historically, plantations of perennial crops (coffee, cocoa, hevea, oil palm) played an important role in agricultural activities of the MLW landscape. The productions were supported by the State (guaranteed price, access to credit). Nowadays most of these plantations are abandoned: transport infrastructures were destroyed during war time, cutting the access to markets for local producers. The few active plantations deliver low yields, due to a lack of access to operating capital. Most of the production is sold locally at low prices.

Farming is the main activity of the majority of inhabitants (8 to 9 out of 10). With the decline of plantations, farmers tuned themselves towards the production of food crops, mainly cassava and maize. Rice, groundnuts, bananas and tubers (yam, sweet potatoes) are also cultivated. Cassava is the staple food and main crop. It is cultivated in association with short cycle crops such as maize and groundnuts. Most of the production is consumed by the family; few surpluses are sold or exchanged locally for consuming goods.
Farmers practice slash and burn agriculture, either on new primary forest land, either on fallows of varying ages (from 5 to 20 years). Usually one hectare of cassava is cultivated per family (with a yield of 5 tons/ha).
Farmers keep small livestock (poultry, pigs, sheep, and goats). Animals are divagating and usually don’t exceed 10 heads/family. They are used as a saving in case of urgent needs for cash (health cares, scholarship, etc.). Incomes are completed with hunting, fishing, boats fabrication, etc.
According to national statistics of the Ministry of Agriculture, agricultural production in the Equator Province has been stable between 1999 and 2009.

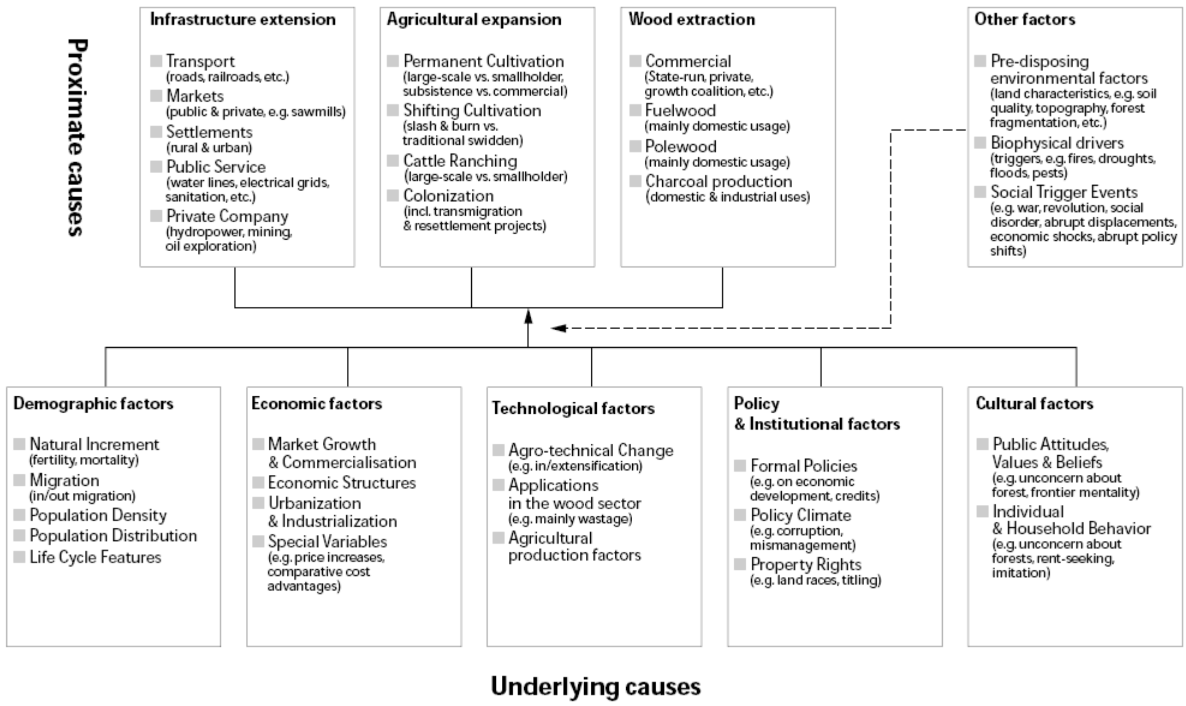


Figure 12: Proximate and underlying causes of deforestation (source H J Geist & E F Lambin, 2001)

Families are completely dependent on fuel wood to supply domestic energy. However, fuel wood is mainly collected from deadwood and residues in slash and burned fields. Given the large forest cover and low population density, it is not expected that the collection of fuel wood may have an impact in terms of deforestation or forest degradation.
According to data collected by AWF (MOV 1.2.CBNRM5: E: Report of study on land use patterns vs active fire points vs population's migratory movement), annual consumption of fuel wood per habitant would be around 2 tons. With a population density of 8 hab./km² over the project area, total consumption of fuelwood would be around 35 000 tons/year. Let's assume that this fuel wood is collected in primary and secondary forests at a maximum distance of 3.5 km from roads and settlements. The dry above-ground biomass annual increment of these accessible forests (based on IPCC default values 2006) is around 180 000 tons, which is large enough to cover fuelwood needs of the population.
However, such assumptions should be ground checked with local surveys and more accurate and systematic data on population density, fuelwood consumption and biomass stocks.

Settlements expansion also contributes to deforestation, but marginally because settlements are mostly composed of the houses of rural population dedicated to farming. There is no urban expansion in the project area.

The main underlying causes of deforestation are:

- Lack of land use planning and open access conditions in protected forests:

The national forest code that is being developed distinguishes three main land use policies in forests:

- Classified forests (*Forêts classées*) are protected areas, where forest conversion is prohibited;
- Permanent production forests (*Forêts de production permanente*) are forests dedicated to logging under sustainable management plans;
- Protected forests (*Forêts protégées*) are forests that can be used by local communities and in which they can practice slash and burn farming (<2ha).

In practice, protected forests function as an open access reserve of farming land for local communities under the authority of community leaders. Therefore, the forest code as currently written allows for a gradual conversion of all protected forests into agricultural areas.

- Demography:

Population growth increases needs for food and income. In the absence of agricultural yields improvements, other sources of incomes than agriculture, and good connection to food markets, population growth is likely to lead to the increase of cultivated areas to the detriment of forests.

There is no accurate evaluation of the population density in the project area and its region. The micro-socio-economic survey carried out by CARE in 2005 utilizes UNDP statistics of 2001 for the Province of Equator (see table 12), but the data seems inaccurate:

- Areas per territory are conflicting with the data on territories from the "Référentiel Géographique Commun".
- Densities per km² (right column) do not correspond to the figures of areas and population (left and central columns).

AWF updated participative landscape land use planning strategy document (MOV.1.1.A, 2009) evaluated the human density in the MLW landscape to be about 3-6 inhabitants/km².
AWF updated participative landscape land use plan design (MOV.1.1.A, 2009) also refers to spatial modeling conducted by the UCL, which give a density of 8 inhab./km², with densities of 7, 7, 10 and 9hab./km² in the territories of Befale, Djolu, Basankusu and Bongandanga respectively.

Territories	Area	Population	Density (inhab./km²)
Basankusu	24.787 km²	369.747	7
Bongandanga	33.910 km²	329.503	8
Befale	16.797 km²	98.531	5
Djolu	17.494 km²	215.060	8

Table 12: Population density in the MLW landscape (source UNDP, 2001 in CARE report 2005)

All these estimations show a rather low density in the MLW landscape (compared to other territories of the Equator Province, 20 to 60 inh./km²) ranging from 5 to 8 inhabitants/km².
The population growth is estimated to be 2.9% per year. However, there are no consistent estimations of human populations across time to verify whether this growth rate is accurate.

- Poverty

Poverty is an underlying cause of deforestation in the project area for diverse reasons linked to the various aspects of poverty: lack of income opportunities outside the agriculture sector, lack of available resources to invest in more sustainable farming practices, lack of safety nets that could allow farmers taking risks and testing new technologies.

- Economic downturn, crisis conditions

The war crisis caused the destruction of many transport infrastructures, isolating the area from markets. Consequently, perennial crops plantations (hevea, coffee, oil palm) of the area were abandoned, pushing farmers to few remaining alternatives, such as slash and burn farming and hunting.

- Low level of technological inputs, no access to credits

Farmers do not have access to the technological inputs that could allow them investing in sustainable farming practices and intensified and diversified agricultural production. This lack of technological inputs is due to a lack of access to credits and the isolation of the area from commercial markets. Isolation from markets makes the access to inputs more costly and disadvantages the area in terms of productions marketing. Overall, there are poor incentives for farmers to invest in technological innovations.

- Tradition/continuation of inherited modes of resource use:

Slash and burn farming is part of the culture of local communities. Changing practices may require difficult social evolutions on cultural issues (such as the repartition of labor tasks between men and women for instance).

4.3.3. Future trends

Up to now, deforestation in the project area has been limited and mainly due to the cultivation, through slash and burn farming, of food crops for domestic consumption, with poor connection to the markets. This trend is likely to continue in the near future. In this case, the major underlying factor that will have an impact on future deforestation rate is the population density. It is therefore expected that the deforestation trend will be closely linked to the population growth.
However, the data on past trends do not allow verifying this assumption. It is not possible to deduct a clear trend from past deforestation rates (see above) and there are no accurate estimations of population growth.

The history of the area shows that it has an important potential for cash crop productions such as coffee, hevea and oil palm. If the production of these commodities were reactivated, the future deforestation trend would probably be very different from the current and recent past.

4.4. Methodological approach to establish the baseline

BioCF mosaic methodology and ADP methodological framework follow similar approaches, based on 5 common issues:

- Step 0: Analysis of historical deforestation trends
- Step 1: Determine the future quantity of deforestation that will take place in the reference region
- Step 2: Determine constraints to the future progression of deforestation
- Step 3: Project the localisation of future deforestation
- Baseline monitoring and revision

4.4.1. Step 0: Analysis of historical deforestation trends

Step 0.1: Complete the available data on historical land cover and land cover changes

Both methodologies require project proponents to develop for the reference region a land cover map for at least 3 points in time, and produce a land cover change matrix (see table 13).
The FACET product, in the form we received it, does not allow to discriminate land covers for 2000, 2005, 2010, nor to produce a land cover change matrix between those dates[12]. If the FACET product was made from separate land cover maps for the years 2000, 2005 and 2010, then such matrix can be completed easily. If not, then the methodology may need some adjustments in order to produce this data.

Land cover classes		Forest land			Non forest land		Final area, in ha (2010)
		Primary forest	Secondary forest	Woodlands	No forest	Wetlands	
Forest land	Primary forest						195922
	Secondary forest						13 735
	Woodlands						1
Non forest land	No forest						1 454
	Wetlands						28
Initial area, in ha (2005)							
Net change (in ha)		- 1 016	- 2 248	0			

Table 13: Example of a land-use / land-cover change matrix for the SOIL project

The land cover changes after the project start shall be monitored regularly with the same methodology than the one used for the historical reference period.

12 Only the primary forest area for 2000 may be deducted from the primary forest area in 2010 and forest loss in the primary forest for 2000-2005 and 2005-2010.

Step 0.2: Complete the qualitative analysis and collect quantitative data on deforestation drivers and underlying factors

In a first instance, there is no other option than to establish the project baseline on the basis of historical trend of deforestation (as explained in part 4.4.2 below). However, the baseline shall be revised, at least after ten years of project implementation. In order to allow more accurate approaches when revising the baseline, the project ought to carry out a more detailed analysis of deforestation drivers and collect and monitor accurate data throughout the first phase of its implementation.

Figure 12 presents main deforestation drivers and underlying factors in the SOIL project area and reference area. The following issues require more in depth studies and data collection:

- The impact of fuelwood collection on the forest cover. Rough assessment in this report (see part 4.3.2) point to a very low impact. However, this needs to be confirmed.

- The dynamic of slash and burn agriculture. In theory, slash and burn agriculture can be a stable system, where long fallows are used to restore fertility and eliminate weeds. However, when the population density reaches a certain level, the needs for farming land increase. There are two options to deal with this issue: expand the cultivated area to the detriment of primary forests and/or reduce the length of fallows. Because the travel time from the house of farmers to their fields can not increase without limits, the first option leads to the expansion of settlements in the primary forest and a deforestation frontier. When this expansion is constrained (by biophysical, i.e. lack of adequate areas for farming, or social, i.e. isolation from basic infrastructures such as schools and health centres, factors), the second option can be used. In practice, both trends are often observable at the same time: the lengths of fallow are reduced in most accessible areas (near old settlements and roads) and the deforestation front expands in the primary forest. It seems that this is the situation in the reference region: deforestation is taking place in the primary forest and the lengths of fallows range from 5 to 20 years. However, it is necessary to understand better the dynamic of this system, qualitatively and quantitatively, and how it is linked with demographic evolutions. A part from the baseline deforestation rate, such information will also be helpful to determine baseline carbon stock changes (see part 5.3).

- The demography. There is no accurate data on population residing in the reference area. Such data should be available at the start of the project and be monitored regularly. Residing populations and migrants shall be differentiated.

- The economic situation. The economic and war crisis led to the abandonment of cash crop plantations (coffee, cocoa, hevea, oil palm) in the area around Djolu. With the rehabilitation of the economy of DRC, some of these plantations may be reactivated. This could have contrasting impacts on the forest cover: shift small scale farming for food crops to the forests but also generate incomes outside slash and burn farming; improve the access to farm inputs and markets and increase productivity, with potentially bad or good impacts on the forests. Whatever the potential impacts, trends in the plantation sector should be monitored in order to be able to account them when revising the baseline if relevant.

- The access to technological inputs, credits, connection to markets. Significant changes of these underlying factors shall be monitored, with an initial diagnostic at the start of the project and regular monitoring before baseline revision.

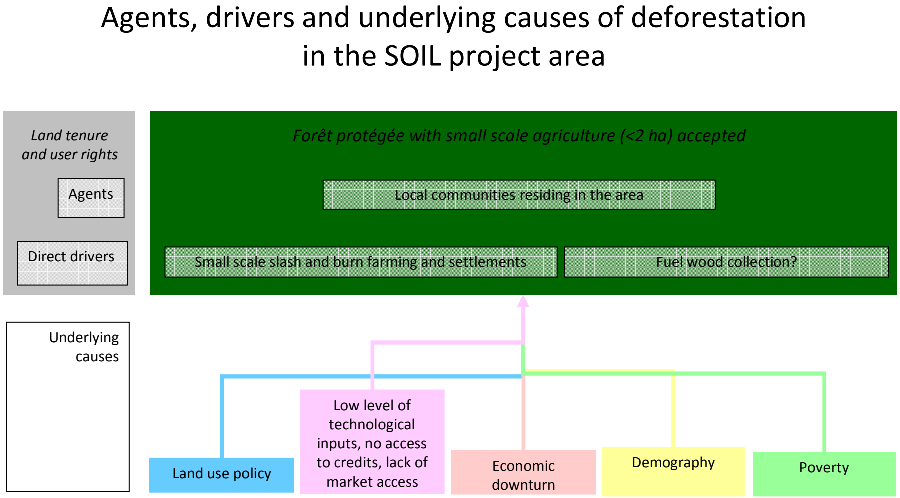


Figure 13: Proximate and underlying causes of deforestation in the SOIL project area

4.4.2. Step 1: Determine the future quantity of deforestation that will take place in the reference region

This step relies on conclusions that can be drawn from the analysis of past deforestation rates in the reference region and deforestation drivers. The methodologies provide guidance on whether this historic trend may be projected into the future and how to do this projection (projection of the average rate, linear or exponential time regressions). The BioCF methodology offers the additional possibility to develop an econometric model linking deforestation to socio-economic variables, which can be useful when the past deforestation trend is unstable and sufficient data is available in order to allow modelling.

Two options could be foreseen for determining the baseline of the SOIL project:

- 1st option: adopt the period 2000 to 2010 as the historic reference period and extrapolate the baseline on the basis of the historical average deforestation rate over this period (as given by the FACET product). Under the BioCF methodology, a discount factor must be applied in order to account for uncertainties. Under the ADP modules, the average historical rate can be used without discount (uncertainty is assumed to be null).
- 2nd option: carry out a forest cover and deforestation analysis for more points in time in the past, in order to get a more detailed picture of deforestation trends and allow different approaches than the simple extrapolation of the historical rate. In order to use this kind of approach, whether based on statistical regression against time or modeling (see below), a minimum standard in terms of statistical robustness must be reached, and uncertainties must be discounted. However, the methodologies have different requirements regarding this issue:

BioCF methodology
If the past deforestation trend is explained by the analysis of deforestation drivers, then it can be extrapolated in the future, either through a function of time using a statistical regression (linear or logistic), either though a model that expresses deforestation as a function of driver variables (such as population density, price of agricultural commodities, transport infrastructure density, etc.).

An analysis of the period 1995-2000 could be added to the FACET product. This would give three points in time, and could in theory allow a statistical regression against time. However, it is unlikely that such regression on 3 points would give statistically significant results.
A model does not seem either a realistic option: to be statistically robust, a model must be based on the analysis of a sufficient number of observations, at least 30. Thus, the impact of any variable, such as population density, on deforestation can be tested statistically only if data is available on this variable and the deforestation rate for 30 points, across time, across space, or across both time and space. It seems that such data do not exist for the SOIL project area (see part 4.3.2 above).

ADP modules:
Two approaches are proposed: linear regression against time and non-linear regression against time. In practice, only the fist approach seems realistic. Indeed, the second approach requires 5 or more points in time, over an historical reference period spanning a maximum of 12 years before project start.
To be tested, a linear regression would need at least 3 points in time over this 12 years period, which means re-assessing deforestation rates for the periods 1998-2002, 2002-2006 and 2006-2010. This would be costly, without assurances that the outputs would give a regression meeting minimum statistical requirements.

In conclusion, we recommend adopting 2000-2010 as the historical reference period for the project and establishing the baseline deforestation rate as the average deforestation rate over this historical reference period.

4.4.3. Step 2: Determine constraints to the future progression of deforestation

This step aims at identifying the forest area in the reference region that is really suitable for future deforestation, taking into account bio-physical and socio-economic constraints. The maximum potential forest area suitable for deforestation is then estimated.
In the BioCF-CDI mosaic methodology, of this area is less than 100 times the annual historical rate of deforestation in the reference region, then the projected future quantity of deforestation must decline gradually, in order to take into account the forest scarcity.
In the ADP modules, the baseline must be automatically reassessed (during project implementation) when the forest area suitable for deforestation falls below 50 times the projected annual deforestation quantity in the reference region.

In the reference area of the SOIL project, swamp forest can be considered unsuitable for deforestation: no slash and burn farming is practiced in this type of forest, except rice farming which remains marginal.
Apart from swamp forest, the total extent of dense moist forest may be considered suitable for deforestation: there are no constraints (in terms of soils, elevation, slopes or climate) to the future progression of deforestation other than the distance from settlements and roads. The maximum potential forest area suitable for deforestation is then equal to 515.592 ha, i.e. the area of dense moist forest (according to MLW Land Cover 2000).
The annual historical rate of deforestation (2000-2010) in the reference area is 354 ha: the maximum potential forest area suitable for deforestation is more than 1400 times the annual historical rate.
Even if the baseline annual deforestation quantity in the reference area would be ten times higher than this annual historical rate of deforestation, the forest scarcity would not be an issue.

4.4.4. Step 3: Project the localisation of future deforestation

This step consists in producing a deforestation risk map over the reference region indicating which pixels will be deforested first (a forest pixel closed to roads on goods soils with gentle slope will be at a higher risk of being deforested than a forest pixel far from roads, with poor soils and steep slopes). A GIS modelling software, such as LCM or Geomod, must be used for this.
The future annual quantity of deforestation is then projected over the reference region according to this deforestation risk map: pixels with highest risk of deforestation are deforested first, and then follow the less risky ones. By projecting annually the future deforestation quantity, one obtains annual deforestation maps

over the reference region. The future quantity of deforestation for the project area can then be determined from these maps.

The ADP methodological framework allows bypassing this step in case of mosaic configuration. The future quantity of deforestation in the project crediting area is then simply estimated as a proportion of the total future deforestation in the reference region multiplied by the ratio between the project crediting area and the reference region. However, if project proponents find this method too conservative, localization modelling is always possible.

Note that the last version of VCS requirements for AFOLU projects, which was published in March 2011 after the approbation of ADP modules establishes criteria on whether localization is obligatory or not in the case of mosaic configuration.

According to this last version, spatial projections are not required where no patch of forest in the project area exceeds 1000 ha and the forest patches are surrounded by anthropogenically cleared land, or where it can be shown that 25% or more of the perimeter of the project area is within 120m of land that has been anthropogenically deforested within ten years prior to the project start date. In the SOIL project area, 67.5 % of the project boundary is within 50m[13] of land that has been deforested between 2000 and 2010 (according to GIS analysis on FACET product). Therefore, even if ADP modules are revised following the last VCS requirements version, spatial modeling would still be optional.

If the SOIL project wants to avoid localization modelling, the baseline deforestation rate (providing that an historical average approach is adopted) would be set as 354 ha/year * the ratio project area/reference area, i.e. about 32%., which is equal to 113 ha/year.

However, the historical rate of deforestation for the period 2000-2010 in the project crediting area is 147 ha/year. Therefore, localization modelling is recommended, because it is likely to show a higher baseline rate of deforestation in the project crediting area than the “without modelling” option would do.

Spatial modelling was carried out by UMD with LCM (Land use Change Modeller), on the basis of 1990 and 2000 land covers. It produced deforestation maps up to 2050.

The same methodology can be used for the REDD project but it should be applied on more recent land covers, for instance 2000, 2005 and 2010.

The methodologies require that the quality of the model output is assessed through calibration and validation. To perform this task, one can use two historical sub-periods (2000-2005 and 2005-2010) or divide the reference region into two sub-regions. The first sub-period/sub-region is used to calibrate the model, the second sub-period/sub-region serves for the validation of the model output.

[13] We did the analysis with 50 m value because it was this value that was first adopted by the VCS,which changed to 120 m afterwards. As land within 50m of deforested areas is also within 120 m of deforested areas, it is not necessary to repeat the analysis with this new value.

The numerous existing land-use models can be allocated to three categories:

- Geographic models, analyzing land suitability and spatial interactions (Geomod, LCM, Dinamica, CLUE);
- Economic models, analyzing land use change drivers (markets, population, etc.);
- Integrated geographic and economic models, combining both approaches.

In both BioCF and ADP methodologies, the baseline is estimated in two distinct steps: the estimation of future quantity of deforestation and the estimation of future localization. Therefore, integrated models are not appropriate.
Economic models can be used for the estimation of the future deforestation quantity, when modeling is authorized by the methodology (such as in the BioCF-CDI methodology).
Geographic models must be used when localization analysis is required by the methodology.

	Geomod	LCM
Quantity of deforestation modeling	Linear extrapolation or (entered by the user)	Calculated by the model (Markov Chain)
Spatial allocation modeling	Empirical frequency	Logistic regression Multilayer perceptron
Multiple transition modeling	no	yes

Table 14: Comparison of Geomod and LCM modeling tools

Figure 14: Available tools for baseline modeling

4.4.5. Baseline monitoring and revision

In the BioCF-CDI methodology the frequency of baseline revision is entirely left to the decision of the project proponent. The baseline validity shall not exceed 10 years but project proponents may opt for a shorter duration.
In the ADP modules, the baseline must be renewed every 10 years after the start of the project, except where forest scarcity has led to a trigger for baseline revision (see above part 4.4.3).

Projects which expect rapid changes in deforestation drivers may have an interest in setting up a short fixed baseline period, but this entails additional costs (the baseline must be reassessed and validated by the VCS more frequently) and increases uncertainty on future project benefits: once a baseline is validated, it is considered valid for the entire fixed baseline period and can't be reviewed retrospectively. The longer is the fixed baseline period, more certainties will have investors on the potential project benefits.
Therefore, except when significant changes in deforestation drivers that could not be taken into account in the baseline are expected, it is not recommended to reduce the length of the fixed baseline period.

In the case of the SOIL project, a short fixed baseline period (5 years for instance) could be justified by:

- An increasing deforestation rate due to an increased demographic pressure, if demonstrated by additional data collected on deforestation drivers and underling factors;
- An expected significant reactivation of the production of cash crops plantations in the region in the coming five years;
- An expected construction of important transport infrastructures in the region in the coming five years.

If none of these 3 justifications is verified, a fixed baseline period of 10 years is recommended (note that it is anyway mandatory if ADP modules are used).

Baseline revision should follow the same process than for the first estimation at the project start. During the first fixed baseline period, forest cover changes and deforestation drivers must be monitored. These data will then be used for the baseline revision. If new deforestation drivers appear, they should be included in the monitoring plan.
Note that it is important to link the dates and frequency of data monitoring on deforestation drivers with the dates and frequency of monitoring of forest cover change: this will allow conducting statistical analysis when the baseline will be revised.

- ✓ The report defines a reference region that suits criteria of both methodologies and suggests adopting 2000-2010 as the historical reference period of the project;

- ✓ The available data on historical land cover and land cover changes for this reference period needs to be completed to reach the requirements of both methodologies;

- ✓ At the moment, applying the historical average of deforestation rate is the only possible option for the baseline determination;

- ✓ The project sought to collect and monitor data on deforestation drivers and underlying factors in order to allow alternative approaches for the baseline deforestation rate (time regression, modelling) when the baseline will be revised;

- ✓ Although optional in one of the methodologies, we recommend modelling the localization of baseline deforestation.

5. Methodological approach for the monitoring of carbon stocks and GHG emissions

Estimations of carbon stocks are necessary for different land cover classes at different steps of a REDD project:

- Forest cover classes:
    - Before the project start (ex-ante): forest carbon stocks need to be estimated in order to calculate an emission factor per unit area of land deforested (tCO_2/ha); these estimations remain valid throughout the project life (BioCF-CDI methodology) or first baseline period (ADP modules).
    - After the project start (ex-post):
        - Potential decrease of forest carbon stocks need to be estimated in order to discount it from project benefits;
        - Optionally, forest carbon stocks increase in areas that would have been deforested in the baseline case can be accounted.
- Post-deforestation land use[14] classes:
    - Before the project start (ex-ante): Post-deforestation land use carbon stocks need to be estimated in order to calculate an emission factor per unit area of land deforested (tCO_2/ha); these estimations remain valid throughout the project life (BioCF-CDI methodology) or first baseline period (ADP modules).

We first deal with the approaches to stratify areas of forest and post-deforestation land uses, and sampling procedures.

We then describe recommended methods for ex-ante estimations of carbon stocks in forest and post-deforestation land uses and ex-post monitoring of carbon stock changes.

Monitoring of GHG emissions due to biomass burning is also treated in this chapter.

Methodologies are compared on relevant issues (see table 20).

5.1. Stratification and sampling procedures

5.1.1. Approaches to stratify the forest areas

Stratification allows separating the project area into discrete, relatively homogenous units to improve accuracy and precision of carbon stock estimates.

The stratification has to be performed prior to field measurements: by separating the project area in strata of homogenous carbon stocks, the sampling intensity in each stratum can be reduced. In other word, fewer measurements are needed to reach the desired level of accuracy, and the carbon stocks inventory results less costly.

Various factors may influence the variations of carbon stocks in forests: forest types, soils, elevation, slopes, human disturbances, etc. Two types of forest, corresponding to variations of soils and elevations, can be found in the SOIL project area:

- Dense moist semi-deciduous and evergreen forest on "sols ferralitiques", corresponding to highest elevation areas;
- Swamp forest on "sols à gley", corresponding to lowest elevation areas.

[14] Post-deforestation land use is the immediate land use that takes place on a given land parcel where the forest has been cleared in the baseline scenario. In the case of the SOIL project, there is only one post-deforestation land use: slash and burn farming.

The field mission allowed making initial measurements of carbon stocks variability in the two forest types. Two series of measurements were done in the south of Djolu, along the road leading to Dongo, and in the east of Yambayo (see figure 14).

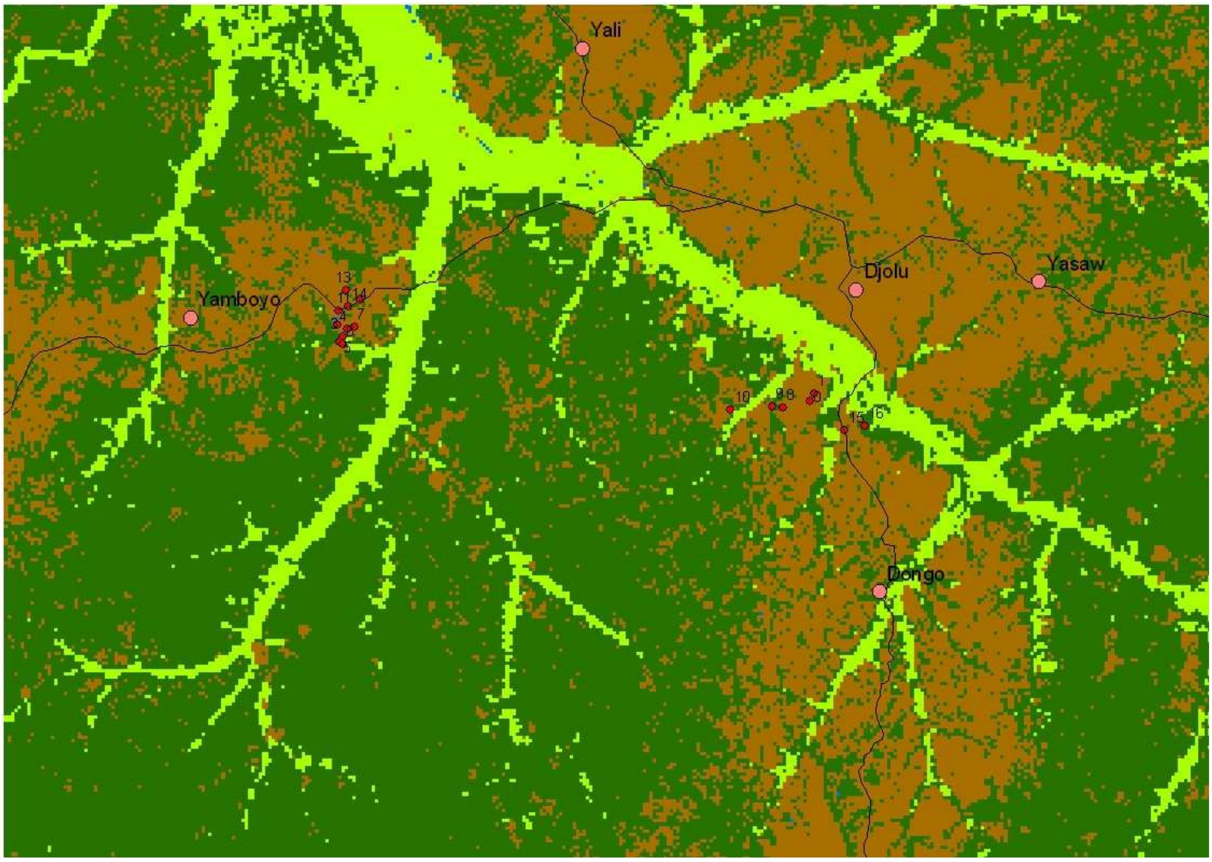


Figure 15: Localization of measured sample points during the field mission

Table 15 presents the outputs of the field measurements. 11 and 25 points were sampled respectively for the swamp forest and the dense moist forest. At each sample point, average basal area and height were estimated using a relascope and a clinometer. The basal area * height (G*H) is used as a proxy of the volume, hence the content of biomass and carbon. What is interesting here is not the value obtained for G*H but its variability for each forest type, represented by the coefficient of variation (CV), which is presented in the table 15.

	CV	Number sample points
Swamp forests	33.9%	11
Dense moist forests	32.0%	25
All forests	33.3%	36

Table 15: Field measurements results in the forests land use classes

The measurements show a similar variability of carbon stocks in the two forest types: 32 % for dense moist forests and 33.9 % for swamp forests.

Based on these initial measurements, it is possible to determine the sampling intensity for each forest type, using the formulas proposed by Pearson et al. 2005 or Wenger 1984 (for an allowable error of 10% of a 95% confidence interval, see annex 4 for detailed calculations):

- Swamp forests: 6 sample plots[15]
- Dense moist forests: 39 sample plots
- All forests: 45 sample plots

[15] Note that these sample plots are different and should not be confused with the sample points measured during the field mission

During the field mission, we noticed that the dense moist forest is often degraded. In certain areas, degradation is caused by the harvest of trees to supply timber locally, which is proved by the presence of stumps. Other areas seem to be secondary forests, which have re-grown on land cleared a long time ago. Before the 90's, there were 16 coffee plants in Djolu and probably many more coffee plantations that can be observed nowadays. Therefore, it seemed that the many areas dedicated to plantations were abandoned and returned to a secondary forest state.

All field measurements were carried out in accessible forest areas, thus areas potentially degraded. This is for practical reasons (logistic and time limitations of the field mission) but also because these accessible forest areas are the ones that are under deforestation pressure and for which estimation of carbon stocks is most needed.

However, we observed during the field measurements in the dense moist forest strata[16] that 5 (out of 25) sample points showed clear signs of degradation (unexpected basal areas and heights for this forest type). If we separate these 5 degraded points from the 20 other "intact" sample points, we can discriminate two strata with reduced variability of biomass (see table 16).

	CV	Number sample points
Dense moist forests "intact"	18.3%	20
Dense moist forests "degraded"	21.0%	5
All Dense moist forests	32.0%	25

Table 16: Field measurements results in the dense moist forests land use classes

It is not possible to detect this degradation through remote sensing. However, the collection of timber and the farming activities are certainly restricted to a buffer of few kilometers around existing villages and roads. Thus, a stratum of potentially degraded forest could be defined based on the accessibility of forests. This could allow pre-stratifying the dense moist forest area in potentially intact and degraded strata, and reduce the sampling intensity in the intact stratum, because it has a coefficient of variation of G*H of 18.3% compared to 32% when both degraded and intact strata are mixed.

The size of the buffer should be evaluated based on a Participative Rural Appraisal (PRA) conducted with local communities, in order to determine how far wood is harvested and fields are cultivated. Analysis of the rural complex extension on GIS show that most deforestation takes place within 4.5 km of roads and 6 km of settlements. We adopted these values in order to demonstrate the potential impact of pre-stratifying the dense moist forest. On these basis, only 29 sample plots would be necessary (using the formulas proposed by Pearson et al. 2005 or Wenger 1984, for an allowable error of 10% of a 95% confidence interval, see annex 4 for detailed calculations):

- Swamp forests: 5 sample plots
- Dense moist forests intact: 13 sample plots
- Dense moist forests degraded: 11 sample plots

- All forests: 29 sample plots

We therefore recommend the following approach:

1. Conduct a PRA in order to evaluate how far villages go into the forest in order to collect wood and cultivate crops;
2. On the basis of the PRA outcomes, determine a buffer along roads and villages: dense moist forest within the buffer is assigned to a potentially degraded stratum, dense moist forest outside the buffer is assigned to a supposed intact stratum;
3. Estimate the number of needed sample plots with this pre-stratification (29 as described above under our assumptions on maximum distances for wood collection and slash and burn farming);
4. Conduct a first phase of inventory on these bases and analyze the results:
    a. If plots in the intact stratum show significant higher level of carbon stocks and reduced variability than plots in the degraded strata, keep the same stratification; the exact number of plots may be

[16] The swamp forest has not been cultivated up to now and is less accessible to communities. Thus, it is considered that observed variations of carbon stocks are mainly not due to human activities but rather to varying ecological conditions.

adjusted depending on the actual coefficient of variation measured during the inventory (which may differ from our early field measurements, especially for degraded forest for which only 5 sample points were measured);

   b. If there is no significant difference between the degraded and intact plots, then the dense moist forest should be treated as one single stratum, and the number of sample plots should be increased (from 24 to 39 in the dense moist forest according to the coefficients of variation observed during our field measurements).

5. In case of option b, the dense moist forest may still be stratified after the realization of complete inventory, with the following method suggested by ADP modules: “After the inventory, if there are discrete clusters of sample plots representing more than 10% of samples in the project area that consistently differ (i.e. each sample plot estimate) from the overall project mean by +/- 20%, a new stratum has to be delineated, encompassing the cluster”. However, a careful analysis should be carried out in order to confirm whether the +/- 20% difference is actually explained by an issue of stratification. Raw data from the carbon inventory may reveal that the difference is in fact explained by errors in data collection and/or treatment, or unexpected natural events (fire, landslide). In this case, stratification shall not be modified.

It should be noted that the coefficient of variation presented in this report were obtained through field measurements made during the field mission on a limited number of sample points (especially for degraded forest). Once the inventory haw been carried out, the actual coefficients of variation of carbon stocks in each stratum may differ from these measurements, and the number of sample plots be readjusted accordingly.

5.1.2. Approaches to stratify the post-deforestation areas

Post-deforestation carbon stocks are assumed to be the long-term average stocks on the land following deforestation.
In the SOIL project area, post-deforestation land use is shifting agriculture with 1 to 2 years of crops followed by fallows, ranging from 5 to 20 years, according to the observations made during the field mission.
In such a cyclical system, the long term average carbon stock is the time-weighed average of stocks in a cycle. Therefore, shifting agriculture systems of different durations have to be treated distinctly.
Values of G*H were collected in 57 sample points in fallows ranging from 1 to 20 years. The distribution of G*H values according to the age of fallows (see figure 16) conducted us to discriminate 3 theorical cycles of different ages:

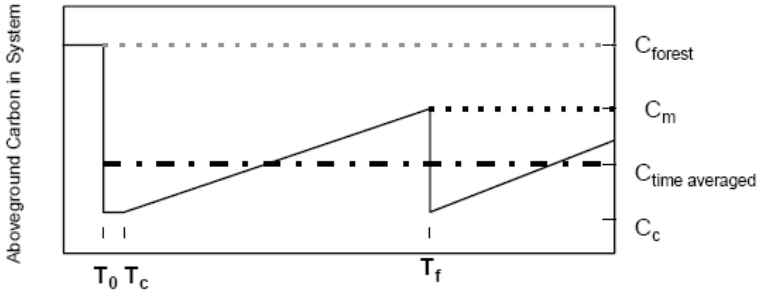
- Cycle of 6 years: 2 years of crops are followed by 4 years of fallows;
- Cycle of 12 years: 2 years of crops are followed by 10 years of fallows;
- Cycles of 22 years: 2 years of crops are followed by 20 years of fallows.

G*H is again used as a proxy of trees C stock. Two parameters were calculated, using the method developed by Palm et al. 2000 (see figure 15):

- The annual increment rate of G*H;
- The time-weighed average over the cycle of G*H.

The results (see table 17 and figures 16) are expressed as a % of the initial G*H value in the dense moist forest. We use the dense moist forest as a reference because it is the forest type in which most if not all slash and burn farming has been practiced so far.

Cycles of 6, 12 and 22 years show respective time-weighed average of tree biomass of 6.9, 20.4 and 42.7 % of the initial tree biomass of the dense moist forest.



C accumulation rate = $I_c = (C_m - C_c)/(T_f - T_c)$, or if T_c and C_c are small then,
$I_c = C_m/T_f$.

Time averaged C = $(I_c * T_f)/2$, assuming T_c and C_c are small.

C_m= carbon in fallow at time of clearing
C_c= carbon in crop, assumed to be negligible
C_{ta} = Time averaged carbon
T_f = Time (years) in fallow phase
T_c = Time in crop phase, asumed short compared to T_f .

Figure 16: Aboveground C losses and regrowth in a shifting cultivation system (Palm et al. 2000)

	Dense moist forests	Fallows 1 to 4 years	Fallows 5 to 10 years	Fallows > 11 years
Average G * H (in %)	100%	7%	35%	61%
Annual inc. G * H (in %)		3.5%	5.7%	3.9%
Time-weighed average G*H (in %)		6.9%	20.4%	42.7%

Table 17: Field measurements results in the rural complex

No measurement of dead wood could be done during the field mission, but it was observed that dead wood is abundant during the first 5 to 10 years after the first forest clearing and burning. After 10 years of fallows, or when the fallow is again slashed and burnt to begin a new cycle, the deadwood pool does not seem significantly more abundant than in the forest.
During the carbon inventory, measurements of the deadwood pool in various ages of fallow will allow to determine average annual decay rate of deadwood and time-weighed average dead wood content of the fallows according to the cycle duration.

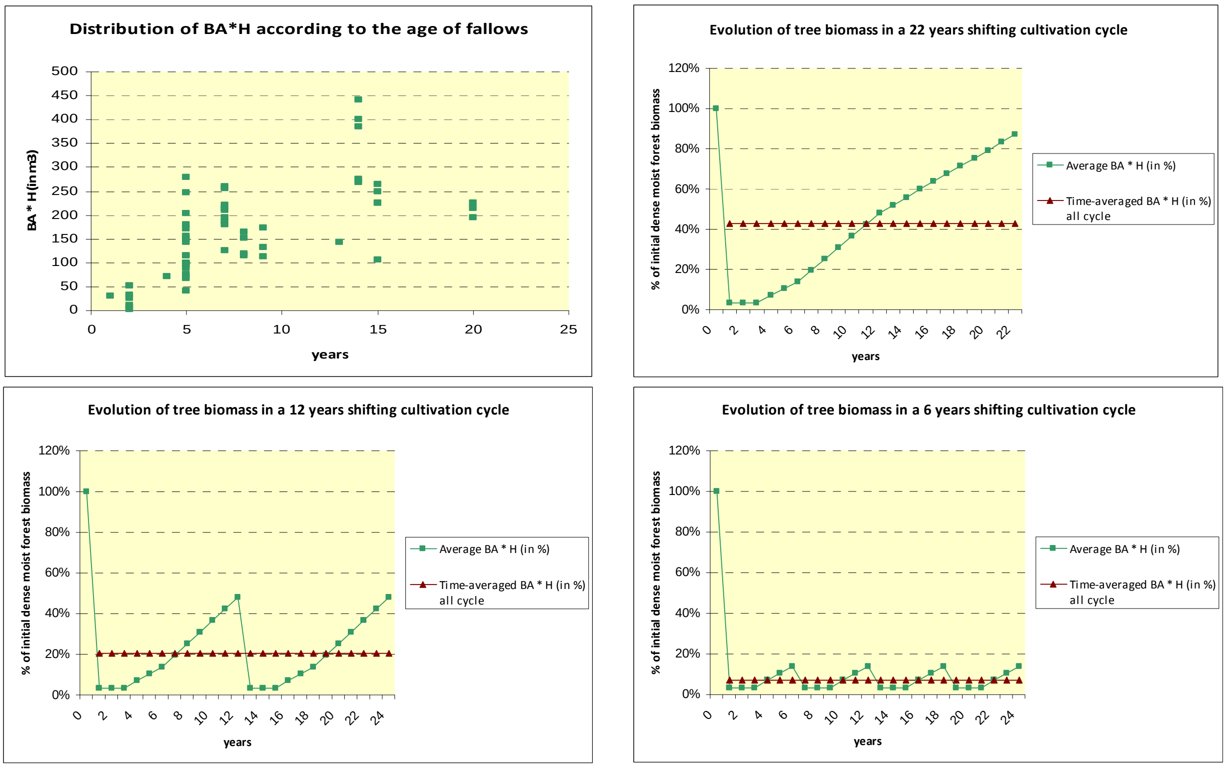


Figure 17: Evolution of tree biomass in theorical shifting cultivation systems of 6, 12 and 22 years.

Out of the 57 sample points measured during the field mission, 9 were in fallows of 1 to 4 years, 35 in fallows of 5 to 10 years, and 13 in fallows of more than 11 years. The objective of the mission was to sample a sufficient number of each age range. A priority was also given to the 5 to 10 years fallows because they seemed more abundant (field observations and discussions with the CIAT). However, this may not be representative of the actual situation in the field. Moreover, the theorical distinction between 6, 12 and 22 years rotations may not fully reflect the actual practices of farmers.

The fallows constitute a mosaic of patches of various ages and areas. Stratification, either through remote sensing, or through ground mapping, would be too fastidious and costly. The suggested approach is therefore to carry out a PRA, such as the one already realized in the territory of Basankusu[17], in a few villages in order to determine:

- The most common practices in terms of length of rotations between crops and fallows;
- The respective proportions of these different fallows lengths in the rural complex.

Then field measurements will be done, in sample plots representatives of the range of ages reached by fallows, selected with the assistance of villagers.

In order to calculate the required number of sample plots, we applied the same formulas than for forest land uses to a theorical situation where:

- There are three shifting cultivation cycles of 6, 12 and 22 years;
- Proportion of 6, 12 and 22 years rotation cycle is given by the repartition of sample points measured during the field mission.

This gives the following results:

- 6 years cycle: 4 sample plots
- 12 years cycle: 37 sample plots
- 22 years cycle: 23 sample plots
- All rural complex: 64 sample plots

However, the calculation will have to be done again on the basis of the actual situation reflected by the PRA.

[17] MOV.1.2. CBNRM 5 E. The mean fallow age was estimated at 5 years, but it is note sure whether this area is representative of the SOIL project area because it seems to be located in a more densely populated area, at the confluent of the Lopori and Maringa rivers.

5.1.3. Sampling scheme: location, size and shape of sample plots

Location of sample plots

ADP modules don't provide any guidance on plot location. We follow hereunder recommendations of the BioCF-CDI methodology.

To avoid subjective choice of locations, the plots should be located randomly and distributed as evenly as possible.

However, areas with poor accessibility may be excluded for the location of sample plots, using a transparent and conservative procedure such as creating a buffer zone along roads, paths or navigable rivers. In that case, the representativeness of the plots for the corresponding stratum must be ensured.

In the case of the SOIL project, the accessibility to forests is limited to few kilometers from settlements, roads and paths. Allocating sample plots throughout the forests of the project area in a random or systematic way would oblige to access to plots distant of up to 25 km from a road. Unless a footpath already exists, more than 10 days of walk in the forest would be necessary to reach such plots. And the opening of pathways deep into the forest would also increase the risk of deforestation and/or hunting in the forest. We therefore recommend constraining the allocation of plots to areas accessible at a reasonable cost.

These accessible areas are the ones that are under risk of being deforested, and therefore, for which knowledge of carbon stocks is most important. However, more distant areas should also be included in the inventory, in order to be able to discriminate potentially degraded and intact forests (see above). The PRA suggested in part 5.1.2 will give an estimation of the maximum distance to roads and settlements of potentially degraded forests.

Assuming this distance is about 4.5 to 6 km, the plots of the intact forest stratum should be located in a buffer ranging from 4.5-6 km to 8 km from roads. It is assumed that this buffer is representative of the most distant forest because there is neither ecological nor anthropological variation between forests located at 7 km or at 20 km from the a road (exact distances need to be confirmed with a PRA).

Even with this limitation of distance, distributing all 29 plots evenly in the forest would mean opening 29 pathways in the forest. In order to reduce the impact of the inventory on forests, we recommend to group sample plots in clusters of 4 plots, thus reducing the number of pathways to open to around 7 to 8.

One sample plot in a neighboring swamp forest stratum (selected at random) will then be added to each cluster in order to cover the 5 to 6 plots required in this stratum.

In conclusion, in order to conciliate methodological requirements with reduced impact on forest and control of logistic and costs, we recommend the following approach (see figure 17):

1. Exclude areas that are considered inaccessible, for reasons of costs and logistic feasibility: for instance areas more than 8 km from any road and settlement;
2. Group sample plots in clusters of 5 plots (4 in the dense moist forest - degraded or intact - stratum, and 1 in a randomly selected neighboring area of the swamp forest stratum);
3. Distribute the cluster of sample plots randomly (using a GIS) throughout the accessible areas.

Regarding the post-deforestation land use stratum, sample plots representative of the range of ages reached by fallows need to be selected with the assistance of villagers. Therefore, the plot location doesn't have to be random. Plots will also be grouped in clusters of 4 to 6 plots in order to reduce travel costs.

Size and shape of sample plots

There is no recommendation on size and shape of sample plots in the methodologies. They must be selected according to the specific needs of each project.

The stands to measure contain a wide range of tree diameters and have varying diameters and stem densities. It is therefore recommended to use nested plots, taking the form of nested circles or rectangles (see figures 18 & 19).

Circular plots require distance measuring equipment (such as a laser telemeter): then, actual boundary around the plot need not be marked and such plots are quicker to inventory than rectangle ones. However, in dense forest stands, rectangular plots, although more fastidious because they need to be laid out with tape measure and stakes, are easier to inventory and offer less sources of error.

For sample plots in the forest strata, we recommend to use rectangular plots. For sample plots in the post-deforestation land use stratum, circular plots seem preferable in order to save time. However, mixing two shapes of plots may also be a source of complexity for the training of inventory teams and the treatment of data. If it seems preferable to keep a single shape, then the rectangular plots should be favored.

We follow the size recommended by Pearson *et al.* (2005) and Ravindranath *et al.* (2008):

- Trees with a diameter > 2 cm & < 5cm are measured in a circle of 1m radius around the plot center (on a plot area of 3.1 m²), or a rectangular plot of 2m x 2m (4m²);
- Trees with a diameter > 5 cm & < 20cm are measured in a circle of 4m radius around the plot center (on a plot area of 50 m²), or a rectangular plot of 7m x 7m (49m²);
- Trees with a diameter > 20 cm & < 50cm are measured in a circle of 14m radius around the plot center (on a plot area of 615 m²), or a rectangular plot of 25m x 25m (625m²);
- Trees with a diameter > 50 cm are measured in a circle of 20m radius around the plot center (on a plot area of 1257 m²), ²); or a rectangular plot of 35m x 35m (1225m²).

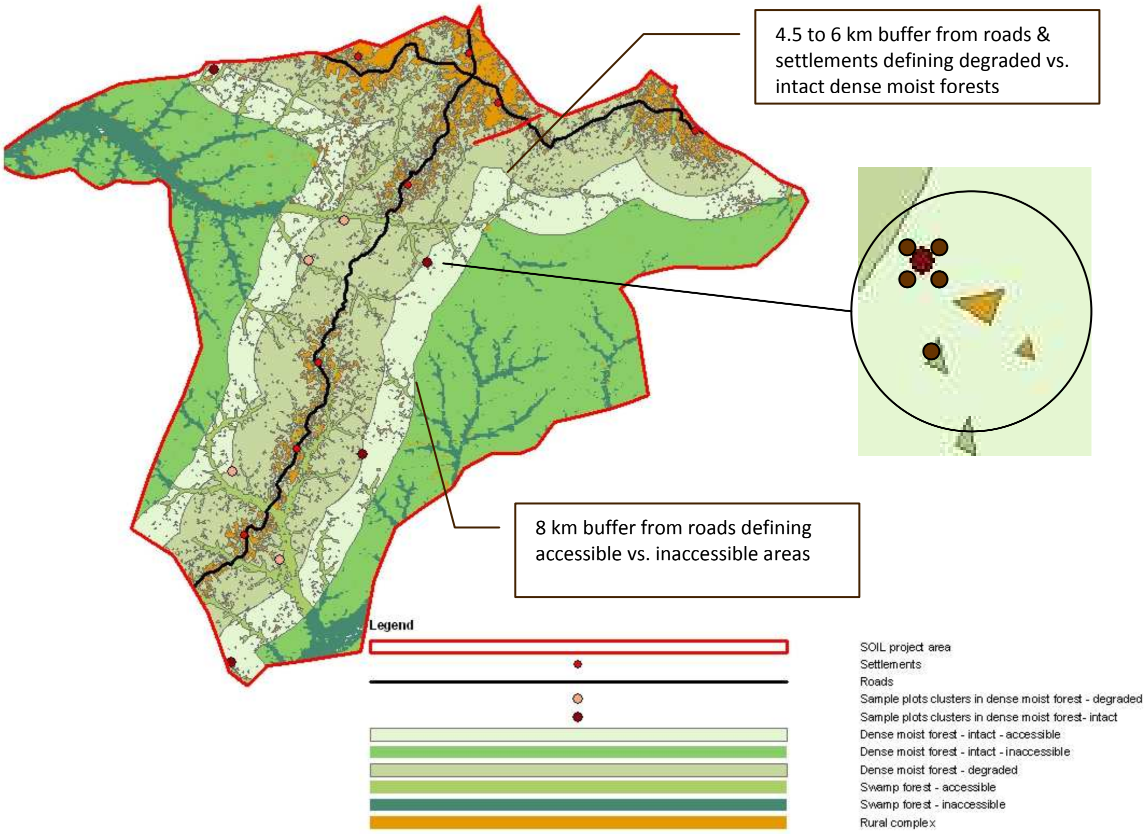


Figure 18: Stratification and sampling

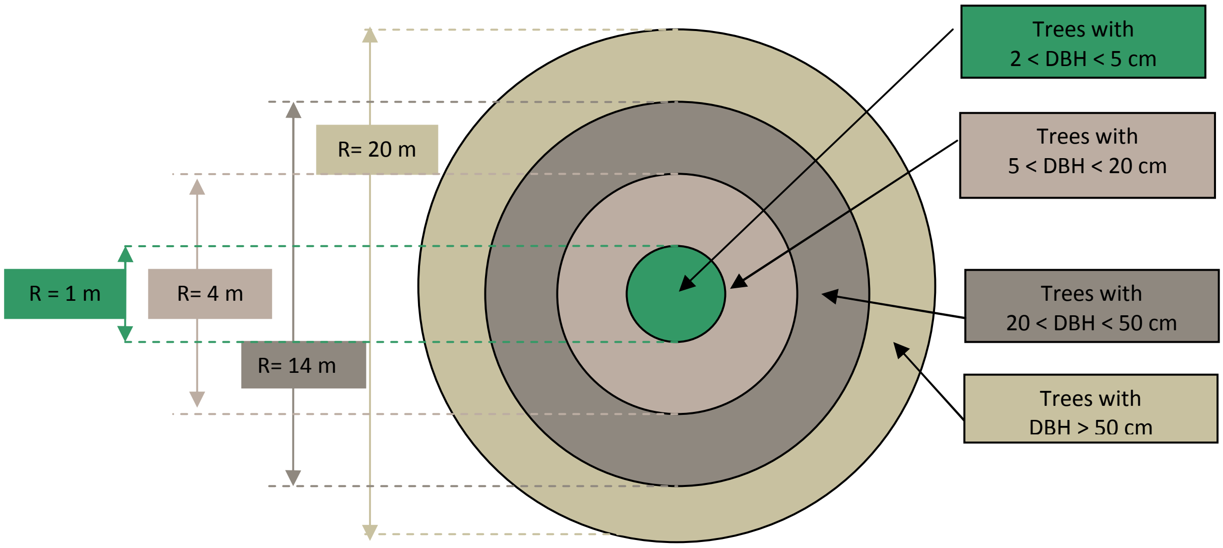


Figure 19: Circular sample plots

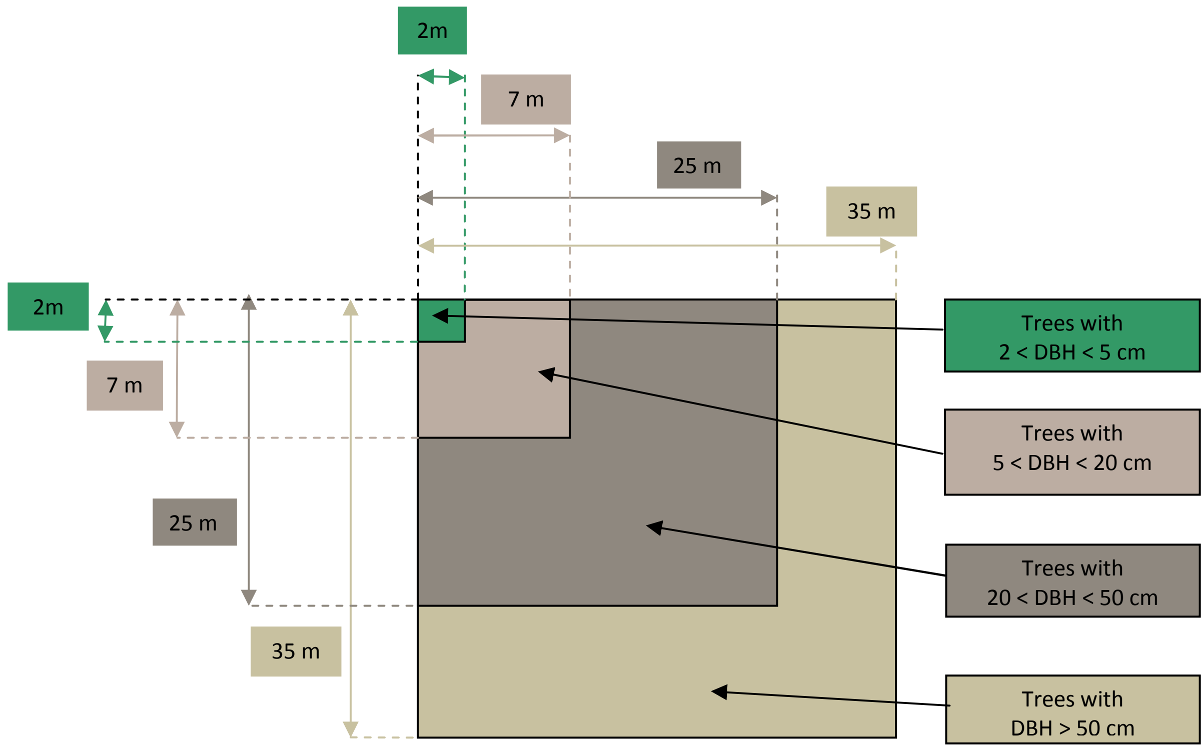


Figure 20: Rectangular sample plots

5.2. Estimation of carbon stocks in forest strata carbon pools

5.2.1. Estimation of carbon stocks in the aboveground and belowground biomass in live trees

Two main methods can be used to estimate carbon stocks in the above ground biomass:

- Indirect method: use existing forest inventories, under the form of stand tables or stock tables, and appropriate expansion factors (Volume Expansion Factor, Biomass Conversion and Expansion Factor) to calculate the total biomass (diameter classes => volumes => biomass);
- Direct method: collect field data - Diameter at Breast Height (DBH), Height (H) - and use an allometric equation that expresses directly the biomass as a function of DBH and/or H (diameters/heights => biomass).

In the SOIL project area, there is no existing forest inventory. Therefore, an allometric method will be preferable. It is recommended to use the allometric equation that is most specific to the project local conditions: ideally, an equation developed specifically for the forests within the project area. If not available, project proponents may use equations sourced from similar forest types in the country or the region, and as a last option, pan-tropical equations such as those provided by the IPCC.
The ADP modules require validating the chosen equation with limited field measurements or destructive sampling. This is mandatory in the BioCF methodology only if IPCC default equations are used. Depending on the chosen/developed equation, only the DBH or both DBH and H must be collected with field measurements. Practical procedures for field measurements are presented in annex 5. Table 18 details available data for the estimation of above ground tree carbon stocks in the forest strata.

At the moment, the only allometric equation developed on forests of the Congo Basin is the one of Ibrahima et al. (2002), in the South-West of Cameroon. It was developed on tropical rainforest under the following ecological conditions:

- Equatorial climate (2 wet seasons, 2 dry seasons) with average yearly rainfall of 2131 mm;
- Plateaus with gentle slopes and low elevation (440 m a.s.l.);
- Ferralitic soils, developed on gneiss and migmatites;

Looking at ecological conditions, this equation could be suitable to the project. However, it was developed on trees of small diameters, with only one tree above 50 cm of DBH.

Another allometric equation is being developed (Samba et al., to be published in 2011) by ONFI in collaboration with the University of Paris XII Val de Marne in the South-East of Cameroon. It was developed on tropical rainforest under the following ecological conditions:

- Equatorial climate (2 wet seasons, 2 dry seasons) with average yearly rainfall of 1500 mm;
- Plains at low elevation: 600 to 850 m a.s.l.);
- Ferralitic soils, developed on gneiss and granite;

The equation was developed on 55 trees ranging from DBH of 10 to 120 cm. It is planned to be completed with highest DBH in 2011. It covers a wider range of DBH than the one of Ibrahima et al. (2002) but ecological conditions differ a bit from the ones of the project area (lowest rainfall, highest elevation).

Other equations (Brown 2007, Chave et al. 2005) are pan-tropical and are meta-studies that were developed with samples that do not include any tree from Africa.

We recommend testing the applicability of these equations to the project (ADP modules provide methods to test the applicability of allometric equations) with the following order:

1. Samba et al. (2011)
2. Ibrahima et al. (2002)
3. Chave et al. (2005)
4. Brown (2007)

If none of the previous equations is applicable, a specific allometric equation has to be developed for the forests of the project area.

	Value	Source
Carbon fraction of dry matter	0.47 t C/t dry matter	IPCC 2006 Guidelines for National GHG inventories Ch.4 Table 4.3
Root to shoot ratio		
If aboveground biomass < 125 t/ha	0.20	IPCC 2006 Guidelines for National GHG inventories Ch.4 Table 4.4
If aboveground biomass > 125 t/ha	0.24	
Allometric equations for Tropical moist forests		
Pan tropical (without sample from Africa)	$Y = \exp[-2.289 + 2.649 \cdot \ln(DBH) - 0.021 \cdot (\ln(DBH))^2]$	IPCC 2003 GPG-LULUCF Table 4.A.1, updated from Brown (2007)
Pan tropical (without sample from Africa)	$\langle AGB \rangle_{est} = \exp(-2.977 + \ln(\rho D^2 H)) \equiv 0.0509 \times \rho D^2 H$ $\langle AGB \rangle_{est} = \rho \times \exp(-1.499 + 2.148 \ln(D) + 0.207(\ln(D))^2 - 0.0281(\ln(D))^3)$	Chave et al. (2005)
Cameroon (South East)	*To be published*	Samba et al. (2011)
Cameroon (South West)	$0{,}05378909 * D^{2{,}828851}$	Ibrahima et al. (2002)
Existing estimations for above ground tree biomass	310 t dry matter/ha	IPCC 2006 Guidelines for National GHG inventories Ch.4 Table 4.7
	460 t dry matter/ha	State of Congo Basin Forests 2008 (based measurements in sample plots)
	268 t dry matter/ha	State of Congo Basin Forests 2008 (based on forest inventories data)

Table 18: Available data for the estimation of aboveground and below ground tree carbon stocks in the forest strata.

Estimations of the above ground tree biomass (see table 18) in forests of the Congo Basin are given in the Congo Basin Forest State 2008. We used these data to make initial estimations of the carbon benefits of the SOIL project (see chapter 6.2.1).

Below ground tree biomass (see table 18) is directly deducted from above ground biomass by applying a Root to shoot ratio. Project specific data is preferable but is not available in most cases. It is therefore accepted to use IPCC default values in accordance with the methodologies.

5.2.2. Estimation of carbon stocks in the aboveground and belowground non-tree biomass

Biomass in the non-tree pool is composed of palms, bamboos, shrubs, lianas and other epiphytes. It is conservative to ignore it: as the project will reduce deforestation, forest cover will decrease less in the project scenario than in the baseline scenario; therefore, the non-tree carbon pool in forests will increase with the project.

However, biomass of the non-tree pool can't be ignored in the post-deforestation land use stratum (for opposite reasons: as the project will reduce conversion, cropland will be reduced in the project scenario and so will be the non-tree carbon pool).

Therefore, it may be to the interest of the project to include this pool in the forest strata if it is significant.

The field mission observed that lianas and palms can be abundant and represent a significant proportion of the biomass of the forest. Three measurements were done in 100 m² sample plots in the forest strata, showing a fresh weight ranging from 7.5 to 50 tons per ha for lianas.

It is therefore recommended to include this pool in the inventory. Practical procedures for field measurements are presented in annex 5.

There are neither data nor allometric equations (for palms and lianas) available for the forests of the Congo Basin. Therefore, we could not include this pool in the initial estimations of the carbon benefits of the SOIL project (see chapter 6.2.1).

5.2.3. Estimation of carbon stocks in the dead wood pool

In forests of the project area, timber collection is limited to harvests by local communities. Degradation is observable but it is not expected that such local harvest of timbers produce a significant quantity of dead wood through collateral damages.
However, because the dead wood pool could be significant in the post-deforestation land use (see below), it must be measured in the inventory at least for the post-deforestation land use class. We therefore recommend measuring it as well in the forest class, in order to be able to take it into account in project benefit.
Practical guidelines for field measurements of the dead wood pool are presented in annex 5.

There are no data available for the forests of the Congo Basin. Therefore, we could not include this pool in the initial estimations of the carbon benefits of the SOIL project (see chapter 6.2.1).

5.3. Estimation of carbon stocks in post-deforestation land use stratum carbon pools

5.3.1. Estimation of carbon stocks in the aboveground and belowground biomass in live trees

The protocol is the same than for the forest strata. Table 19 details available data for the estimation of above ground tree carbon stocks in the post-deforestation land use stratum.

Palm et al. (2000) observe that allometric equations developed for mature forests often include trees with DBH greater than 25 cm, and trees with higher wood densities than in young re-growing systems. Therefore, these equations may overestimate (by up to 100%) the carbon content of trees with DBH inferior to 25 cm, which constitute most of the trees in fallows. It is therefore recommended to use an allometric equation developed on trees of small DBH. If applicable, the equation of Ibrahima et al., which was developed on trees with small DBH, could be used, and if not, a specific equation of trees in fallows should be developed.
Palm et al. (2000) made estimations of the mean time-averaged above ground carbon stock in rotations of 6, 11 and 25 years in study sites of Cameroon. Mean values are presented in table 19. Forest of the study sites contain an average above ground biomass of 228 tC/ha.

Measurements carried out during the field mission can also provide preliminary estimates. In rotations of 6, 2 and 22 years, the time-averaged BA*H are respectively 6.9, 20.4 and 42.7 % of the initial (forest) BA*H. Applying these ratios to the default value for above ground forest carbon stocks taken from the State of Congo Basin Forest 2008, i.e. 156 tC/ha, we obtain values of 11, 32 and 67 tC/ha.
We can deduct from these data that the field measurements in the MLW landscape show a higher regeneration rate of biomass than those in Alternative to Slash and Burn (ASB) study sites in Cameroon (which could be explained by factors such as soil quality, climatic conditions, farming practices, etc.). This observation is preliminary and need to be confirmed by the realization of the carbon inventory. For the estimation of carbon benefits of the SOIL project, we adopted the most conservative data, i.e. obtained with field measurements.

5.3.2. Estimation of carbon stocks in the aboveground and belowground non-tree biomass

Non tree vegetation in the post-deforestation land use is composed of bananas, palms, bamboos, shrubs, lianas and other epiphytes.
This pool can not be conservatively omitted: it will decrease in the project case compared to the baseline case (because deforestation is reduced). It must be included in the inventory and the significance will be tested to decide whether it should be included in the project monitoring.

Initial measurements during the field mission show that the lianas and palms may represent a significant amount of biomass in the old fallows (lianas were weighed in a 7 years fallow, giving a fresh weight of 26.5 tons per ha).
Practical procedures for field measurements are presented in annex 5.

There are neither data nor allometric equations (for palms and lianas) available for the Congo Basin. Therefore, we could not include this pool in the initial estimations of the carbon benefits of the SOIL project (see chapter 6.2.1).

	Value	Source
Carbon fraction of dry matter	0.47 t C/t dry matter	IPCC 2006 Guidelines for National GHG inventories Ch.4 Table 4.3
Root to shoot ratio		
If aboveground biomass < 125 t/ha	0.20	IPCC 2006 Guidelines for National GHG inventories Ch.4 Table 4.4
If aboveground biomass > 125 t/ha	0.24	
Allometric equations for Tropical moist forests		
Pan tropical (without sample from Africa)	$Y = \exp[-2.289 + 2.649 \cdot \ln(DBH) - 0.021 \cdot (\ln(DBH))^2]$	IPCC 2003 GPG-LULUCF Table 4.A.1, updated from Brown (2007)
Pan tropical (without sample from Africa)	$\langle AGB \rangle_{est} = \exp(-2.977 + \ln(\rho D^2 H)) \equiv 0.0509 \times \rho D^2 H$ $\langle AGB \rangle_{est} = \rho \times \exp(-1.499 + 2.148\ln(D) + 0.207(\ln(D))^2 - 0.0281(\ln(D))^3)$	Chave et al. (2005)
Cameroon (South East)	*To be published*	Samba et al. (2011)
Cameroon (South West)	$0{,}05378909 * D^{2{,}828851}$	Ibrahima et al. (2002)
Existing estimations for above ground tree biomass		
Time-averaged C stocks in Alternative to Slash and Burn (ASB) study sites in Cameroon (Yaoundé, Mbalmayo, Ebolowa)		
Forest (selectively logged)	228 t C/ha	Palm et al. (2000)
6 years rotation (2 years crops + 4 years *chromalaena* fallow)	5 t C/ha	
11 years rotation (2 years crops + 9 years bush-tree fallow)	32 t C/ha	
25 years rotation (2 years crops + 23 years bush-tree fallow)	77 t C/ha	
Time-averaged C stocks in MLW landscape		
Dense moist forest	156 t C/ha	State of Congo Basin Forests 2008 (based on forest inventories data)
6 years rotation (2 years crops + 4 years *chromalaena* fallow)	11 t C/ha	Deducted from field measurements and State of Congo Basin Forests 2008
12 years rotation (2 years crops + 10 years bush-tree fallow)	32 t C/ha	
22 years rotation (2 years crops + 20 years bush-tree fallow)	67 t C/ha	

Table 19: Available data for estimation of above and below ground tree carbon stocks in the post-deforestation land use stratum.

5.3.3. Estimation of carbon stocks in the dead wood pool

When a forest land is slashed and burnt for the first time, a lot of burnt dead trees with diameters reaching 40 to 50 cm remain. This dead wood takes around 10 years to decay. In this case, the dead wood pool can't be ignored conservatively and need to be measured.
When the land is cleared and burnt for the second time (after a cycle of annual cultivation and various years of fallows), remaining burnt dead trees reach no more than 10 cm of diameter, and decay in two years. In this

case, it is probably not significant. Practical guidelines for field measurements of the dead wood pool are presented in annex 5.

There are no data available for the forests of the Congo Basin. Therefore, we could not include this pool in the initial estimations of the carbon benefits of the SOIL project (see chapter 6.2.1).

In the inventory, the post-deforestation land use classes will be grouped in one stratum, composed of a mosaic of fields and fallows of various ages (see part 5.1.2). Sample plots representative of the range of ages reached by fallows will be measured. The aboveground and below ground tree and non tree biomass and the deadwood pools will be measured in these plots. Practical guidelines for field measurements are presented in annex 5.

Methodologies	BioCF	ADP
Sampling procedures		
Forest strata		
Stratification guidelines	▪ Pre-stratification: guidelines on sample size and allocation, sample plot size and plot location	▪ Pre-stratification (prior to inventory) is optional ▪ Post-stratification is required
Location, number, size and shape of sample plots	▪ Formulas to determine number and size of plots ▪ Recommendations on location of plots	▪ no recommendation
Post-deforestation land use strata		
Stratification guidelines	▪ No stratification: sampling areas selected at locations that represent a chrono-sequence of 10 to 30 years since the deforestation date	▪ No stratification: average post-deforestation stock values over the post-deforestation land use stratum
Ex-ante estimation of carbon stocks		
Estimation of carbon stocks in the above and belowground biomass in live trees		
Aboveground tree biomass/ha	▪ Existing forest inventory data: stand/stock tables with VEF (Volume Expansion Factor) & BCEF or ▪ Field measurements in sample plots with allometric equations/Biomass Expansion Factors (BEF)	▪ Field measurements in sample fixed area plots or sample points using prisms ▪ Allometric Equations method to estimate biomass
Allometric equations	▪ If derived from biome-wide database (IPCC default values), applicability of equations must be validated with destructive sampling	▪ Applicability of equations must be validated with limited field measurements or destructive sampling
BEF	▪ Only if local commercial volume equations and BEF exist (if not, allometric equations are preferable)	absent
Belowground tree biomass/ha	Same as ADP Modules	= Aboveground tree biomass/ha * Root to shoot ratio
Root to shoot ratio		▪ Site specific data or IPCC default values
Estimation of carbon stocks in the above and belowground non – tree biomass		
Above ground non-tree biomass/ha	Same as ADP Modules	▪ Published/default data or field measurements in sample fixed area plots ▪ Sampling frames and/or allometric equations (for vegetation types where individuals can be clearly delineated)
Sampling frames method		▪ Laboratory analysis of a sub-sample to determine wet to dry mass ratio

Allometric equation method		▪ Applicability of equations must be validated with data sources review or destructive sampling
Estimation of carbon stocks in the deadwood pool		
Dead wood	▪ Field measurements in sample fixed area plots and line transects ▪ Two components: standing dead wood & lying dead wood	▪ Field measurements in sample fixed area plots or sample points using prisms or relascopes, and line transects ▪ Two components: standing dead wood & lying dead wood
Standing dead wood	▪ Four decomposition classes & a key distinction: with/without outward signs of decomposition	▪ Two decomposition classes: with/without outward signs of decomposition
Standing dead wood without outward signs of decomposition	▪ Allometric equation or BEF method, same as for live trees ▪ Subtraction of leaves biomass (default proportions)	▪ Allometric equation or Biomass Conversion Expansion Factor (BCEF), same as for live trees
Standing dead wood with outward signs of decomposition	▪ Volume of a cone/cylinder using diameters and heights ▪ 1 wood density class	▪ Volume of a cone/cylinder using diameters and heights ▪ 3 dead wood density classes: sound, intermediate, rotten
Lying dead wood	Same as ADP Modules	▪ Line intersect method ▪ 3 dead wood density classes: sound, intermediate, rotten
Dead wood density classes		▪ Published data/IPCC default values or project specific field measurements (laboratory analysis to determine dry mass per unit green volume)
Ex-post monitoring		
Carbon stocks decrease due to deforestation		
Validity of ex-ante estimations	▪ Ex-ante estimates are treated as constant ▪ Re-estimation is optional	▪ Ex-ante estimates are treated as constant for 10 years, after which they must be re-estimated from new field measurements ▪ If re-measured estimate is similar to the ex-ante estimate (within 90%confidence interval) the latter takes precedence
Carbon stocks decrease due to forest degradation		
Area degraded and related carbon stock variations	▪ Areas subject to planned harvest activities (logging, fuelwood collection, charcoal production), according to project management plans and monitoring	▪ PRA to determine whether degradation occurs and delineate potentially degraded areas; ▪ Limited sampling (>1%) of potentially degraded areas to confirm PRA outputs (presence/absence of new tree stumps) ▪ Measurements in systematically sampled plots (> 3% of potentially degraded areas) of above and below-ground carbon stocks of harvested trees
Frequency of measurements	▪ At least once after each harvest event	▪ PRA: every 2 years ▪ Limited sampling: each time PRA indicates potential degradation ▪ Systematic sampling; if limited

		sampling confirms degradation, every 5 years
Carbon stocks increase		
Area in regeneration and related carbon stock variations	- Only areas that would have been deforested in the baseline case are eligible - Permanent sample plots recommended	- Only areas that would have been deforested in the baseline case are eligible - Carbon stock increase captured by re-measured estimates after 10 years
Frequency of measurements	No recommendation	- Every 10 years

Table 20: Estimation of carbon stocks – comparison of ADP modules and BioCF-CDI methodology.

5.4. Ex-post monitoring of carbon stock changes within the project area

5.4.1. Carbon stock decreases due to deforestation

Both methodologies require projects to monitor actual deforestation occurring within the project area after the project start using comparable remote sensing data and processes.
The BioCF/CDI methodology separates planned deforestation by the project (e.g. if needed to build project infrastructures) and unplanned deforestation (e.g. deforestation that the project was unable to prevent). ADP modules don't. It does not make any difference: at the end, any deforestation that occurred within the project area must be recorded, whether planned or unplanned by project proponents[18].
Carbon stock changes due to deforestation are estimated ex-post by multiplying the area deforested by the variation of carbon stocks due to deforestation, i.e. the difference between forest carbon stocks and carbon stocks of the post-deforestation land use.

5.4.2. Carbon stock decreases due to forest degradation

Both methodologies require projects to monitor actual forest degradation (through timber logging and/or fuelwood collection) occurring within the project area after the project start, but they use diverging approaches.
The BioCF/CDI methodology targets forest management activities planned by project proponents: the areas dedicated to these activities must be clearly identified. The carbon stock variations due to these activities are estimated on the bases of the corresponding forest management plans (quantities of timber/fuelwood collected & harvest co-damages vs. potential regrowth). Unplanned collection of timber or fuelwood by local communities is considered lower in the project case compared to the baseline scenario and thus can be ignored.
ADP modules require project proponents to monitor actual degradation occurring in the project area: PRAs with local communities must be conducted every two years in order to define potentially degraded areas. Measurements in sample plots (every five years) allow verifying whether degradation actually occurred and is significant, and if it is the case, the related carbon stock variations.

In the case of the SOIL project, there are not planned activities potentially leading to forest degradation. If the BioCF methodology is adopted, carbon stock variations could thus be ignored. If ADP modules are adopted, actual degradation would have to be monitored through PRAs and field measurements in sample plots.

5.4.3. Carbon stock increases

Both methodologies allow taking into account carbon stocks enhancement in areas that would have been deforested in the baseline scenario and where the potential for biomass growth is significant.

[18] The term planned/unplanned used here do not refer to the distinction made between planned and unplanned deforestation for the selection of the eligible REDD activity under the VCS scheme.

If project proponents wish to do so, they have to monitor forest carbon stocks enhancement in these areas (which is mandatory every 10 years in the ADP methodology, but optional in the BioCF-CDI methodology).

This could be interesting for the SOIL project; in particular in areas of the moist dense forest which were cleared a long time ago to establish plantations, and then were abandoned and retuned to a forest state. These secondary forests still show reduced basal area and heights and thus could have the potential to increase their carbon stocks if protected. Among the 25 sample points measured, 5 in particular showed important signs of degradation. Table X details BA*H values for degraded and "intact" or, better said, less degraded dense moist forest: in average, degraded points contain less than half of the carbon content of "intact" points.

The realization of the carbon inventory will allow checking whether the accessible forest areas, which are at risk of deforestation and will be protected by the project, contain less carbon stocks than inaccessible areas, and thus have the potential to gain carbon stocks if protected.

5.5. Monitoring of GHG emissions from biomass burning within the project area

5.5.1. Guidance on whether to include the source in the project perimeter

Biomass burning is the source of CO_2, CH_4 and N_2O emissions. It can result from:

1. Conversion of forest to non-forest
2. Periodical burning of grassland or cropland
3. Burning in forest land

Those two sources seem relevant in the context of the SOIL project:

1. Slash and burn agriculture, where fire is used for deforesting primary forest (1^{st} cycle) and beginning a new cycle on vegetation regrowth
2. Hunting (using fire)

In the first two cases, CO_2 emissions need not to be accounted, because they are already captured when monitoring changes of carbon stocks due to deforestation.

The BioCF-CDI methodology requires monitoring emissions from biomass burning only if project participants wish to account these emissions in the baseline. Indeed, emissions resulting from biomass burning are expected to decrease in the project case compared to the baseline case, because slash and burn farming and hunting will be reduced. Thus, this source of emissions can be conservatively omitted.
However, it can also be included to the benefit of the project. If included in the baseline, emissions from biomass burning must also be accounted in the project and leakage estimation, and have to be included in the monitoring plan.
In any case, only biomass burning linked to deforestation is taken into account, and consequently, CO_2 emissions are ignored (because already accounted through changes in carbon stocks).

Under the ADP modules, accounting of emissions resulting from biomass burning in the project case is mandatory. Accounting in the baseline case is optional.
All sources of biomass burning shall be taken into account. It can represent an important quantity of emissions, especially for fires in forests (without forest conversion), for which CO_2 emissions must be accounted (around 153 tCO_2e/ha, applying Congo Basin Forest State lowest estimations for above ground carbon stocks and default IPCC 2006 combustion factor for tropical forests) if they are not captured by estimations of carbon stock variations. However, this source may be omitted if project developers can prove that it is not significant.

At the moment, fires are monitored through the Fire Information for Resources Management System (FIRMS). FIRMS is an active fire product, that provides the location of fires within a radius of 1 km. However, many fires are not detected by FIRMS for various reasons: small burnt areas and intensity, small duration of fires, cloud cover, smoke, etc... AWF collected data on fire points in part of the MLW landscape (Basankusu) and compared it with the active fires points detected by FIRMS[19]: from the 177 fire points in a period of 31 days, only 32 were localized in a 1km radius around an active fire point detected by FIRMS. But, the dates of data collection in the field and by the satellites were different for all these 32 points.

FIRMS detected 155 fire points over 2002-2008 in the SOIL project area: 89 were in the rural complex (no forest areas and secondary forests) and 66 in the primary forests. However, FIRMS does not provide the exact location of fire points: the fire may actually have taken place within a radius of 1 km around the point detected by FIRMS. The figure 20 shows that most (all except three) the active fire points detected by FIRMS are close (less than 1 km) to the rural complex and correspond probably to fires actually located in the rural complex and linked to slash and burn farming. This is confirmed by the calendar distribution of fire points, which is centered on the farming season for all active fire points (see figure X), whether FIRMS detected them in the rural complex or in the primary forest. Only 3 active fire points were detected by FIRMS out of the December to May period: one is clearly isolated in the primary forest, the two others are close to the rural complex (less than 1 km).

We can conclude from this that fires in forest remaining forest rarely reach a sufficient intensity to be detected by FIRMS. It is likely that they don't reach the canopy level or do it too rarely or during a too brief time span to be detected at the time the satellite images are captured for the SOIL project area (one image is captured each day). The presence of clouds or smoke could also explain this.

Overall, the impact of GHG emissions due to fires in forest remaining forest, i.e. when there are not associated to slash and burn farming, should be very low.

<table>
<tr><th></th><th>Value</th><th>Source</th></tr>
<tr><td>Area burnt/LULC strata</td><td>No data available</td><td>No data available</td></tr>
<tr><td>Average above ground biomass stock before burning (= ABG tree biomass + litter + deadwood)/burnt LULC strata</td><td>See tables 18 &19</td><td>See tables 18 &19</td></tr>
<tr><td>Combustion factor/burnt LULC strata</td><td>
TABLE 2.6
COMBUSTION FACTOR VALUES (PROPORTION OF PREFIRE FUEL BIOMASS CONSUMED) FOR FIRES IN A RANGE OF VEGETATION TYPES
(Values in column 'mean' are to be used for quantity C_f in Equation 2.27)
<table>
<tr><th>Vegetation type</th><th>Subcategory</th><th>Mean</th><th>SD</th><th>References</th></tr>
<tr><td rowspan="4">Primary tropical forest (slash and burn)</td><td>Primary tropical forest</td><td>0.32</td><td>0.12</td><td>7, 8, 15, 56, 66, 3, 16, 53, 17, 45,</td></tr>
<tr><td>Primary open tropical forest</td><td>0.45</td><td>0.09</td><td>21</td></tr>
<tr><td>Primary tropical moist forest</td><td>0.50</td><td>0.03</td><td>37, 73</td></tr>
<tr><td>Primary tropical dry forest</td><td>-</td><td>-</td><td>66</td></tr>
<tr><td colspan="2">All primary tropical forests</td><td>0.36</td><td>0.13</td><td></td></tr>
<tr><td rowspan="3">Secondary tropical forest (slash and burn)</td><td>Young secondary tropical forest (3-5 yrs)</td><td>0.46</td><td>-</td><td>61</td></tr>
<tr><td>Intermediate secondary tropical forest (6-10 yrs)</td><td>0.67</td><td>0.21</td><td>61, 35</td></tr>
<tr><td>Advanced secondary tropical forest (14-17 yrs)</td><td>0.50</td><td>0.10</td><td>61, 73</td></tr>
<tr><td colspan="2">All secondary tropical forests</td><td>0.55</td><td>0.06</td><td>56, 66, 34, 30</td></tr>
<tr><td colspan="2">All tertiary tropical forest</td><td>0.59</td><td>-</td><td>66, 30</td></tr>
</table>
</td><td>IPCC 2006 Guidelines for National GHG inventories Ch.2 Table 2.6</td></tr>
<tr><td>Emission factor/burnt LULC strata/GHG</td><td>
TABLE 2.5
EMISSION FACTORS ($g\ kg^{-1}$ DRY MATTER BURNT) FOR VARIOUS TYPES OF BURNING. VALUES ARE MEANS ± SD AND ARE BASED ON THE COMPREHENSIVE REVIEW BY ANDREAE AND MERLET (2001)
(To be used as quantity 'G_{ef}' in Equation 2.27)
<table>
<tr><th>Category</th><th>CO_2</th><th>CO</th><th>CH_4</th><th>N_2O</th><th>NO_X</th></tr>
<tr><td>Savanna and grassland</td><td>1613 ± 95</td><td>65 ± 20</td><td>2.3 ± 0.9</td><td>0.21 ± 0.10</td><td>3.9 ± 2.4</td></tr>
<tr><td>Agricultural residues</td><td>1515 ± 177</td><td>92 ± 84</td><td>2.7</td><td>0.07</td><td>2.5 ± 1.0</td></tr>
<tr><td>Tropical forest</td><td>1580 ± 90</td><td>104 ± 20</td><td>6.8 ± 2.0</td><td>0.20</td><td>1.6 ± 0.7</td></tr>
<tr><td>Extra tropical forest</td><td>1569 ± 131</td><td>107 ± 37</td><td>4.7 ± 1.9</td><td>0.26 ±0.07</td><td>3.0 ± 1.4</td></tr>
<tr><td>Biofuel burning</td><td>1550 ± 95</td><td>78 ± 31</td><td>6.1 ± 2.2</td><td>0.06</td><td>1.1 ± 0.6</td></tr>
<tr><td colspan="6">Note: The "extra tropical forest' category includes all other forest types.
Note: For combustion of non-woody biomass in Grassland and Cropland, CO_2 emissions do not need to be estimated and reported, because it is assumed that annual CO_2 removals (through growth) and emissions (whether by decay or fire) by biomass are in balance (see earlier discussion on synchrony in Section 2.4.</td></tr>
</table>
</td><td>IPCC 2006 Guidelines for National GHG inventories Ch.2 Table 2.5</td></tr>
<tr><td>Global Warming Potential/GHG (CO_2, CH_4, N_20)</td><td>CO_2 = 1; CH_4 = 21; N_20 = 310</td><td>IPCC SAR default values</td></tr>
</table>

Table 21: Available data for estimation of GHG emissions due to biomass burning.

When fire is used for the conversion of primary forest to cropland and subsequent burning of vegetation regrowth, CO_2 emission must not be accounted (they are already taken into account through the estimation of carbon stock variations) but CH_4 and N_20 emissions may be accounted. According to our estimation, they would

[19] AWF (MOV 1.1.F) : report on study: active fire points for monitoring of impact of a conservation program on canopy destruction, 11/2009

represent from 33 to 44 tCO_2e per ha over the entire cycle of slash and burn farming, depending on the length of rotations (indicative value estimated on the basis of the assumptions presented in part 5.1.2 on slash and burn rotations).

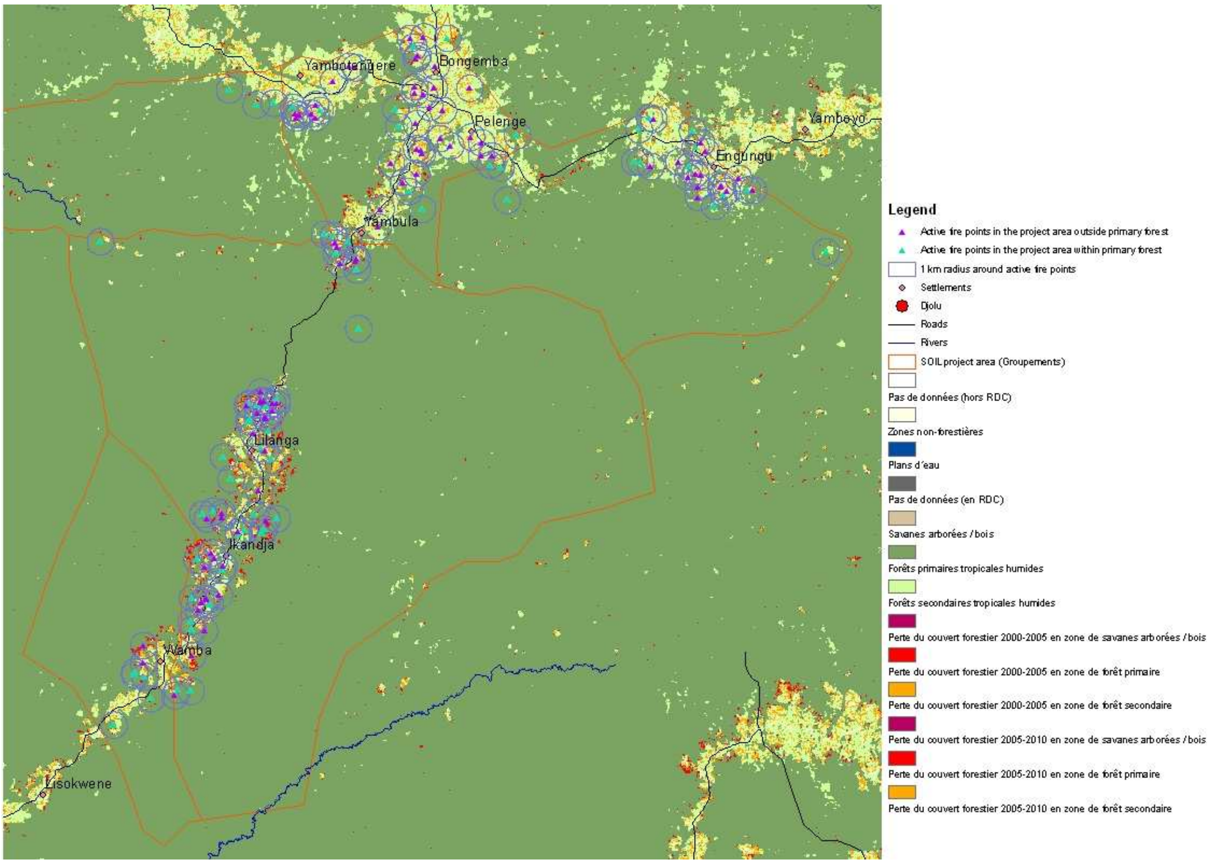


Figure 21: Localisation of active fire points detected by FIRMS in the SOIL project area (between 2002 and 2008)

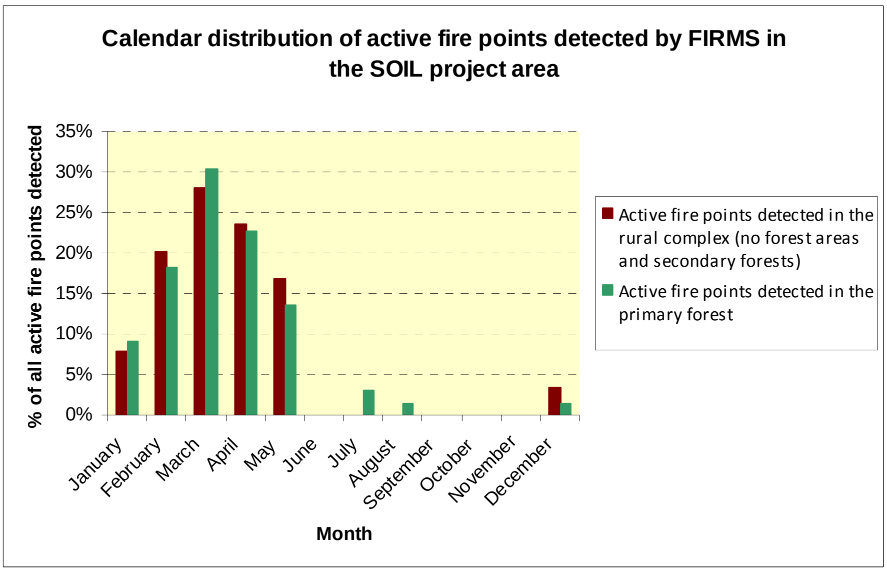


Figure 22: Calendar distribution of active fire points detected by FIRMS in the SOIL project area (between 2002 and 2008)

5.5.2. Monitoring methods

Both methodologies provide equations to estimate emissions from biomass burning (see annex 5). Those equations use IPCC default factors and parameters to be collected by the project (see table 22).

Parameters to estimate emissions from biomass burning	Ex-ante measurements (baseline estimation)	Ex post measurements (baseline revision, project monitoring)
Area of forest burnt each year	Baseline projections + data on fires	To be included in the monitoring plan
Average aboveground biomass stock, in 3 pools: - Above ground biomass - Dead wood - Litter	From carbon stock inventories	When revising the baseline
Average proportion of biomass burnt in each pool (above ground biomass, deadwood, litter)*	Field measurements	To be included in the monitoring plan

* only in BioCF-CDI methodology; ADP modules accept IPCC default factors.

Table 22: Parameters to estimate emissions from biomass burning

Estimating emissions from biomass burning require at a minimum being able to estimate burnt areas in each stratum over the historical reference period and to keep monitoring this data during the project implementation. Furthermore, the areas burnt must be characterized in terms of fire behavior (surface fires vs. crown fires) and land use (forest/secondary vegetation clearing vs. forest fires).

When the fire is used for slash and burn farming, monitoring is carried out through the monitoring of deforestation in primary forest, assuming that fire is systematically used when the forest is cleared. If IPCC default values for the combustion factor seem too conservative or generate too much uncertainty, field measurements may be done on a sample of burnt areas in order to estimate specific factors for the project.

When fire is used in the forest for hunting, the issue is much more complex. FIRMS does not allow estimating the extension of burnt areas neither their exact localization. Therefore, in order to monitor forest fires, high resolution imagery (Landsat or higher resolution) should be combined with FIRMS and field surveys in order to confirm that the fire took place in the forest, and estimate burnt areas. However, such forest fires seem marginal in the case of the SOIL project (as seen above). Therefore, it is likely that the corresponding emissions are insignificant and can be ignored. Significance can be tested using the relevant CDM tool (see part 3.4).

5.6. Ex-post monitoring of carbon stock changes and GHG emissions within the leakage belt

Carbon stock changes and GHG emissions within the leakage belt are estimated ex-ante and monitored ex-post using the same methods than for the project area.

5.7. Monitoring work plan and budget

5.7.1. Ex-ante estimations of carbon stocks: field measurements

Work plan:

The first series of field measurements should be performed preferably during the dry season (February – March) so that the access to forests (especially swamp forests) is facilitated.
The exact time needed to complete the inventory will depend on the definitive number and location of sample plots. Sample plots located in the territory of a single settlement shall be measured in a row, from a base camp established in the settlement. Field workers can be recruited locally and trained on site. 3 days should be

planned for the travel to the site, installation in the settlement, presentation to local authorities, training of field workers, and travel back.
A field team of 6 people should be able to inventory 3 plots per working day in the fallows of the rural complex and 2 plots per working day in the forest. Sufficient time should be allowed for travels from one plot to the next one: up to half day per km in the forest if the footpath must be opened, 0.2 day/km otherwise.
Taking into account these parameters and a theorical distribution of sample plots such as the one presented in figure 17, we estimate that 8.5 weeks are necessary for two field teams to inventory a first set of 29 plots in the dense moist forest (24), swamp forest (5) and 64 plots in the rural complex. After this, results should be analyzed. If the measurements of more plots is needed (15 in the dense moist forest as estimated in part 5.1.1), an additional month with two field teams must be foreseen.

Phase	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
PRA to refine pre-stratification						
Adjustment of pre-stratification & sampling according to PRA outcomes	X					
1st series of field measurements in dense moist forest (degraded and intact) and swamp forest						
Analysis of intermediate results						
2nd series of field measurements in dense moist forest if needed						
PRA to refine knowledge on slash and burn rotations						
Sampling in the rural complex according to PRA outcomes	X					
Field measurements in rural complex						
Analysis of final results						

Table 23: Time schedule of the carbon stocks inventory

Staff requirements:

- Carbon inventory coordinator: in charge of field works supervision, continuous training of field teams and data entry supervision. Must have a thorough understanding of the goals of the carbon inventory and preferably practical experience of forest/carbon inventories .Must master the utilisation of GPS, clinometer and compass, and field data collection procedures (does not use those equipments directly but must be able to train continuously team leaders and field workers and verify their work).
- Team leaders: in charge of leading a team of 5 field workers and guaranteeing field work quality. Must master the utilisation of GPS, clinometer and compass, and field data collection procedures. Responsible for fulfilling the inventory sheet for each plot.
- Field workers: in charge of field data collection under control of the team leaders. Must be trained in field data collection procedures and the utilisation of relevant material. Ideally, field workers (or at least two of them) are able to recognise tree species and to give their name (local names). To be recruited locally in the village where plots must be measured.
- Support staff: in charge of entering the data in excel files. Must master the utilisation of a computer and excel, and be able to identify and isolate abnormal data for future verification by team leaders.

We recommend AWF to recruit the Carbon inventory coordinator, preferably a forestry specialist with practical experience of forest inventories. Team leaders and field workers can be employed among local communities for this specific task. Team leaders should have a secondary level of education and be trustful persons, well-known by AWF. Field workers should be selected among local communities where the field works will be conducted: preference should be given to community members with a good knowledge of forest species. At least one of the field workers should have a very good knowledge of forest species and be able to identify inventoried tree species.

Each field team is composed of 1 team leader and 5 field workers (see table 25).

Name of function	Number of persons	Description of tasks
Team leader	1	▪ Organize and supervise team works ▪ Ensure field works quality ▪ Register data collected by field workers
Botanist, tree measurer	1	▪ Identify tree species for trees with DBH > 10 cm ▪ Measure DBH and H for trees with DBH > 10 cm
Regeneration measurers	2	▪ Measure DBH and H for trees with DBH < 10 cm) ▪ Measure litter with frames (if included)
Dead wood measurers	2	▪ Measure dead wood on line transects

Table 24: Measuring team for the carbon stocks inventory

Material requirements:

- GPS (1)
- Clinometer (1)
- Compass (1)
- Laser telemeter (1)
- Decameter (1)
- Tape measurer (4)
- Local materials: rope, wood planks, wood frames, machetes
- Chainsaw (1) for measuring the non-tree biomass
- Working materials for workers (boots, raincoats, mosquito nets, tents, cooking material)

Budget:

Item	Unit Cost	nb Unit	Total Cost
Working days inventory team (in US$, including wages and food)	68 USD	123	8 364 USD
Logistic costs (village meetings, oil for motorbikes, lump sum in US$)	280 USD	1	280 USD
Material costs (technical equipments & other, lump sum in US$)	1 500 USD	2	3 000 USD
Working months carbon inventory coordinator (wages in US$)	1 500 USD	6	9 000 USD
Working months typist for data entry (wages in US$)	500 USD	2	1 000 USD
Total			**21 644 USD**

Table 25: Carbon stock inventory budget

This budget was estimated with the following assumptions on unit costs:

Item	Unit Cost
Wages for field workers/working day	5 USD
Wages for team leaders/working day	25 USD
Wages for inventory coordinator/working month	1 500 USD
Wages for typist/working month	500 USD
Village meeting/meeting/day	20 USD
Transport costs (in US$/km)	0.10 USD
Materials (1 set as described above)	1500 USD

Table 26: Carbon stock inventory budget (assumptions on unit costs)

5.7.2. Ex-ante estimations of carbon stocks: allometric equation development

Developing an allometric equation requires destructive harvesting methods, where trees (at least 30) representing the full range of diameters classes existing and dominant species are harvested to the ground and weighed. DBH and H of the trees are measured before and a statistically valid equation linking the above-ground biomass to DBH or DBH and H is developed.
It is therefore a resource-expensive operation. With the involvement of DRC in the REDD mechanism and the multiplication of REDD pilot projects and initiatives in the country, it is very likely that allometric equations for

the forests of DRC will be available in the near future. We recommend AWF to maintain close contacts with the National REDD Coordination and other project developers on this issue.
If the project needs specific allometric equations, it would be useful to develop them in collaboration with the neighboring forest concessions of SIFORCO, by taking advantage of the opening of logging roads in the forest. The forest areas that will be destroyed by these roads can be prospected before: interesting trees for the development of an allometric equation are selected, harvested and weighed before the construction of the road (see the work carried out by ONFI with Alpicam in Cameroon in Samba et al. 2011).

5.7.3. Ex-ante estimations of carbon stocks: laboratory analyses

Laboratory analyses may be needed in order to determine ratios of dry matter to fresh weight (for non-tree vegetation), carbon fractions (carbon content /dry matter for non-tree vegetation) and basic wood densities (dry matter/volume for the different dead wood classes).
Capacities to carry out these analyses are limited in DRC. For instance, the aforestation/reforestation project of Ibi-Bateke had to import laboratory material in order to determine dry matter/fresh weight ratios and send samples to the University of Louvain-la-neuve in Belgium to determine carbon fractions.
Here again, such analyses may be conducted by other project developers and in the context of the national REDD strategy development. It is therefore important to monitor what will become available in the future regarding these carbon parameters.

5.8. Uncertainties

Both methodologies require estimating uncertainties of carbon estimations and discounting them when they reach a given threshold.
ADP modules provide a tool for the estimation of uncertainties[20]. Three sources of uncertainty are targeted:

- Determination of rates of deforestation and degradation

In the case of the SOIL project, uncertainty on rates of deforestation is considered null by the ADP modules because the rate is deducted from historical averages. This is not the case in the BioCF-CDI methodology (see part 4.4.2).

- Estimation of stocks in carbon pools and changes in carbon stocks

The uncertainty can be minimized through pre and post stratification (see part 5.1), and planning of a sufficient number of sample plots. The calculations made in this report are for an allowable error of 10% of a 95% confidence interval, in order to limit uncertainties.

- Assessment of GHG emissions

This may be the major source of uncertainties for the SOIL project if emissions from biomass burning are accounted. In this case, specific field measurements of the combustion factor may be necessary (see part 5.5.2).

In the BioCF-CDI methodology, uncertainty must be estimated for the determination of rates of deforestation (as seen above) and estimation of carbon stocks.

[20] Approved VCS Module VMD0017 – REDD Methodological Module: estimation of uncertainty for REDD project activities (X-UNC)

- Pre-stratification of the forest areas will allow decreasing the number of sample plots to measure. Pre-stratification should be based on forest types (dense moist forest vs. swamp forest) and potential degradation (estimated through the proxy indicator of distance to roads and settlements, to be refined with a PRA);
- Carbon stocks of the post deforestation land uses are estimated as the time average carbon stocks over the slash and burn cycle (crops and following fallows): farming practices (types of rotations, proportion of the different types) should be better known (through a PRA) in order to determine a representative sampling scheme;
- Localization of the plots shall be random and systematic, but issues of accessibility and logistic burden are also taken into account in the design of the protocol;
- For the estimation of tree carbon stocks, some allometric equations are available and can be tested; if none is applicable, a new equation shall be developed; allometric equations may also be developed by other projects or within the national REDD strategy development;
- For the estimation of non-tree and dead wood carbon stocks, laboratory analysis are necessary but do not seem available in Kinshasa; other projects could provide such services or capacities may be built with the national REDD strategy development;
- Apart from carbon stock variations, the only other potentially significant source of GHG emissions is biomass burning.

6. Preliminary business plan

6.1. Estimation of project costs

There are three categories of project costs:

- Development costs: studies necessary to develop the project, including the drafting of the Project Design Document and validation by a validation/verification body;
- Implementation costs: costs of project activities, i.e. micro zoning, agriculture intensification, CBNRM plans, etc.;
- Monitoring and certification costs: monitoring of emissions reductions achieved by the project, and verification by a validation/verification body.

In order to reduce development costs, we recommend relying as much as possible on institutions that are already involved in the SOIL project and have working experience in the SOIL project area.
We therefore made the assumptions that any new works relating to remote sensing/cartography/spatial modeling would be performed by SDSU/UMD/OSFAC, and that AWF would be responsible for conducting any necessary PRA in the field. Costs of these works can be best estimated by these institutions on the basis of their previous experience in the area.

There are some issues where the partners currently involved in the SOIL project will need technical support:

- The carbon stock inventory and monitoring of carbon stocks changes: apart from direct field activities (costs estimated in the section 5.7.1.), technical assistance for the training of field teams, supervision of works and data treatment.
- The elaboration of project documents allowing the validation (PDD) and the verification (monitoring report) by VVB.

We assumed these tasks would be sub-contracted to forest carbon project experts, and indicated corresponding costs in the item PDD consolidation.

6.1.1. Development costs

Regarding the carbon credit component of the project, development consist in elaborating a Project Design Document following an approved methodology by the VCS and having it validated by a validation/verification body (VVB) officially accredited by the VCSA for this purpose.

- Elaboration of the Project Design Document:
    - Historical land use changes analysis: production of a land use land cover change matrix for 2000, 2005 and 2010 in the reference region:
        - Check with UMD-SDSU-OSFAC whether it can be deduced from FACET or whether an adaptation of the methodology is needed (and what would be the cost in the latter case).
    - Analysis of deforestation/degradation drivers, agents and underlying causes
        - Assessment of the dynamic of slash and burn agriculture (PRA to determine most common practices in terms of length of rotations between crops and fallows, and respective proportion of these different length of crops-fallows cycles);
        - Assessment of the impact of fuelwood and timber collection on the forest: PRA to determine volumes of fuelwood and timber consumption and collection practices (from farms, secondary forest, primary forest);
        - Socio-economic baseline, including demographic data: data aiming at the monitoring of social impacts of the project as well as the re-assessment of baseline scenario.

Iitem	Costs	Observation
PDD Elaboration	**347.000 US$**	
▪ Historical land use changes analysis	80.000 US$	To check with FACET actors (SDSU, UMD, OSFAC)
▪ Analysis of deforestation/degradation drivers, agents and underlying causes	75.000 US$	Costs of 3 PRAs, according to experience of AWF
▪ Baseline Modeling	50.000 US$	Costs to check with UMD
▪ Carbon stocks inventory	22.000 US$	See section 5.7.1
▪ PDD consolidation	120.000 US$	Expertise of forest carbon project specialists
PDD Validation (one time)	**50.000 US$**	
Monitoring (costs for 1 monitoring period of 5 years)	**197.000 US$**	
▪ Land use land cover changes	80.000 US$	To check with FACET actors (SDSU, UMD, OFAC)
▪ Deforestation/deforestation drivers	75.000 US$	Costs of 3 PRAs, according to experience of AWF
▪ Carbon stocks changes	22.000 US$	Assuming all plots in forest areas are permanent plots to re-measure and new measurements are done in the rural complex to account for possible changes in the length of rotation cycles.
▪ Monitoring report consolidation	20.000 US$	Expertise of forest carbon project specialists
Monitoring report verification (every 5 years)	**30.000 US$**	
VCUs issuance	**0.10 US$/VCU**	
Baseline revision (every 5 to10 years)	**80.000 US$**	
▪ Baseline modelling	50.000 US$	Costs to check with UMD
▪ PDD adjustment (for the baseline part)	30.000 US$	Expertise of forest carbon project specialists
Revised baseline Validation (every 5 to 10 years)	**30.000 US$**	

Table 27: Project costs (except implementation costs)

- o Baseline modeling
    - ▪ Localization modeling with LCM: validation on 2000-2005-2010 data sets and projections

- o Carbon stocks inventory
    - ▪ Sample plots measurements, data entry and analysis

- o Project Design Document consolidation
    - ▪ Writing of the PDD integrating outputs from above-mentioned works/studies.

- Validation by a VVB:

The VVB shall assess the project for compliance with the VCS rules and produce a validation report and validation representation (the official proof of validation delivered by the VVB).

Development costs shall also include legal advice for the establishment of contractual agreements regarding carbon credits ownership and rights of sales among project stakeholders (see section 7.2.1.). It was included in the PDD consolidation budget in the table 27 above.

The costs presented in the table 27 above are rough assessments that need to be refined with relevant SOIL partners.

6.1.2. Implementation costs

We estimated implementation costs on the basis of activities and budget of the SOIL project. The SOIL project targets 4.200 households, for a period of 30 months, with a total budget of 917.338 US$.

6.1.3. Monitoring, verification and issuance costs

The monitoring plan is composed of 3 main components

- Monitoring of LULC changes in the project area and leakage belt and reference area:
  - Estimation of actual deforestation having taken place in the project area and leakage belt in order to estimate ex-post actual emissions reductions achieved by the project;
  - Estimation of actual deforestation having taken place in the reference region for future baseline re-assessment.
- Monitoring of carbon stocks changes in the project area and leakage belt (if needed):
  - Estimation of carbon stocks variations due to forest degradation (collection of fuelwood and timber) through PRAs and measurements in sample plots;
  - Estimation of carbon stocks regeneration (growth of secondary forest), through permanent sample plots.
- Re-assessment of the baseline scenario:
  - Monitoring of deforestation/degradation drivers, agents and underlying causes: regular repetition (at least every 5 years) of baseline studies carried out for the PDD elaboration.

The implementation of this monitoring plan aims at preparing monitoring reports, every 3 to 5 years, which assess the quantity of GHG emissions reductions achieved by the project. The monitoring report is then assessed by a VVB before VCUs can be issued by the VCS.

The baseline must be reviewed at the end of the each fixed baseline period (every 5 to 10 years). In order to do this, land use land cover changes and deforestation drivers must be monitored regularly throughout the project implementation. The revised baseline must be re-validated by a VVB.

- Verification by a VVB:

The VVB shall assess the GHG emission reductions for compliance with the VCS rules and produce a verification report and verification representation (the official proof of verification delivered by the VVB).
It shall in particular assess the non permanence risk of the project and decide the quantity of buffer credits that should go to (and be released of) the AFOLU pooled buffer account at each verification event.

Note that validation and verification can be performed by the same VVB at the same time at the end of the first monitoring period.

The VCS charges an issuance fee of 0.10 US$ per VCU.

6.2. Estimations of carbon credit flows

6.2.1. Baseline emissions

Baseline deforestation rate

If no localization modeling is performed the baseline deforestation rate for the SOIL project area will be 113 ha/year. However, the historical rate of deforestation for the period 2000-2010 in the project area is 147 ha/year. Therefore, it is likely that localization modeling would raise this rate.
For the purpose of this initial estimation, we retain the mean value of the 113-147 range: 130 ha/year.

Carbon stocks and GHG emissions parameters

Carbon stocks in forests strata

We use the lowest estimate (for conservativeness) of above ground tree biomass given by the State of Forests 2008: 268 tonnes of dry matter/ha, equivalent to 126 tonnes of carbon/ha. We apply this estimation to both forest strata (dense moist and swamp) in the project area.
Below ground tree biomass is obtain by multiplying this value by a root to shoot ratio of 0.24.
Biomass in non tree vegetation and dead wood is ignored.

Carbon stocks in post-deforestation land use stratum

We use the estimations deducted from the measurements carried out during the field mission: respectively 11, 32 and 67 t C/ha for rotations of 6, 12 and 22 years.
The relative proportions of these rotations and their exact duration should be confirmed through a PRA. Meanwhile, we assume that the proportion of 6, 12 and 22 years rotations in the sample points measured during the field mission is a good proxy of what actually happens throughout the rural complex:

- 16% of cleared forest land pertains to a 6 years rotation;
- 61% of cleared forest land pertains to a 12 years rotation;
- 23% of cleared forest land pertains to a 22 years rotation.

Applying these proportions, we obtain a mean value of 36.5 tC/ha for aboveground and belowground biomass.
Biomass in non tree vegetation and dead wood is ignored.

Estimation of GHG emissions due to biomass burning

CH_4 and N_20 emissions relative to biomass burning should range from 33 to 44 tCO_2e per ha over the entire cycle of slash and burn farming, depending on the length of rotations (see part 5.1.2 above). We retain a conservative value of 33 tCO_2e per ha

Based on these data, the deforestation of 1 ha of forest generates the emission of 472 tCO_2e, i.e. 439 tCO_2e due to carbon stock variations and 33 tCO_2e due to GHG emissions from biomass burning.
Total baseline emissions are estimated at around 61 350 tCO_2e/year.

6.2.2. Project scenario

Like for the baseline emissions, there are two potential sources of GHG emissions in the project scenario:

- Carbon stock variations (due to deforestation)
- GHG emissions due to biomass burning

Emissions due to carbon stock variations depend on the effectiveness of project implementation. If a project is completely successful in stopping deforestation, i.e. 100% effectiveness, these emissions are null. In the reverse situation, 0% effectiveness, they are equal or superior to baseline emissions, and the project does not generate any reduction of emissions.
The same apply to GHG emissions due to biomass burning when the fire is used in the slash and burn farming process.

At this stage of project development, it is not possible to anticipate the level of effectiveness of the project. We present hereunder the potential carbon credit flows according to various assumptions on project effectiveness.

6.2.3. Leakage

The only source of leakage that is expected is the displacement of slash and burn farming activities outside the project crediting area. This may happen if the SOIL project does not provide adequate incentives to farmers or if the agreed micro-zoning is contested by local communities.
We assumed in the estimations hereunder that limited leakage would take place, leading to the displacement of no more than 25% of baseline emissions in the worst scenario.

6.2.4. Monitoring and verification

Carbon credits, named Voluntary Carbon Units (VCU) are issued on the basis of monitoring reports estimating emissions reductions achieved by the project, which must be verified by a third party.
The frequency of monitoring and verification is a trade-off between the cash flow requirements of the project and the cost of monitoring. It is reasonable to assume that monitoring and verification will take place every 3 to 5 years.

6.2.5. VCS pooled non permanence buffer

The VCS approach for addressing non-permanence[21] requires that projects maintain adequate buffer reserves of non-tradable carbon credits to cover unforeseen losses in carbon stocks. The buffer credits for all projects are held in a single pooled buffer account (VCS AFOLU Requirements, March 2011).

The given amount of carbon credits that a specific project must deposit on the pooled buffer is assessed on the basis of non-permanence risks rating. A self assessment by the project proponents is double verified by the VCS.

The risks factor applicable to REDD project are : land ownership/land management type, technical capabilities of project developer/implementer, net revenues/financial returns from the project to all relevant stakeholders, infrastructure and natural resources, population surrounding the project area, incidence of droughts, flooding or pests/diseases, project financial plan.

For REDD projects avoiding unplanned mosaic deforestation, the risk rating may range from 10% to 30-40%.

At this stage of project development, it is not possible to anticipate the risk rating of the project. We present hereunder the potential carbon credit flows according to various assumptions on risk rating.

Project proponents who monitor and verify emissions reductions periodically and thereby demonstrate overtime the permanence of emissions reductions can claim a growing percentage of the carbon credits held in the buffer.

Figure 22 and table 29 show how the number of VCUs that the SOIL project could generate vary in function of assumptions made on project effectiveness, leakage and non permanence risk. With the most favourable assumptions, the project could generate around 50 000 tCO_2e per year.

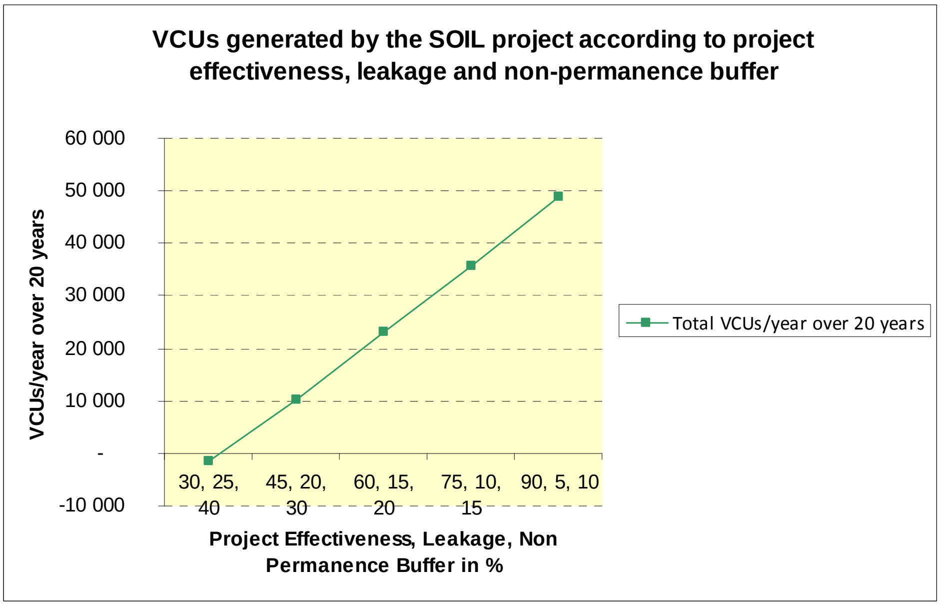


Figure 23: Voluntary Carbon Units generated by the SOIL project in function of project effectiveness, leakage and non permanence risk.

	Worst		to		best scenario
Project Effectiveness	30%	45%	60%	75%	90%
Leakage	25%	20%	15%	10%	5%
Non permanence buffer	40%	30%	20%	15%	10%
Nb VCUs/year	- 1 454	10 251	23 086	35 639	48 757

Table 28: Voluntary Carbon Units generated by the SOIL project in function of project effectiveness, leakage and non permanence risk.

[21] the non permanence risk is the potential reversibility of protected carbon: the carbon protected during the first years of project implementation, which allowed the issuance of carbon credits at the first monitoring and verification, may be later released in the atmosphere for various reasons: unforeseen human pressure on the forest, ecological disaster, etc.

6.2.6. Other potential sources of incomes

In a complete economic and financial analysis, other sources of income than carbon credits should also be taken into account. These sources are the additional outputs (compared to the baseline scenario) that the project will generate:

- Increased agricultural production in value;
- Increased valorization of NTFP;
- Other sources as relevant (eco-tourism?).

6.3. Financial analysis

We limit the financial analysis for the first 10 years of project implementation, for several reasons:

- The baseline is valid for a maximum of 10 years and must be updates beyond this period: consequently, the potential of emissions reductions of the project is very uncertain beyond this first fixed baseline period of 10 years;
- Potential investors are likely to consider carbon benefits for this first 10 years period, but not beyond, because of the uncertainty on the baseline and reluctance for long time returns on investment;
- Project implementation costs are difficult to anticipate beyond 10 years.

We assumed that the project would be implemented in two phases:
Installation phase of 2.5 years, corresponding to the concentration of investments (supplies and technical support for agriculture, micro-zoning development);
Consolidation phase of 7.5 years, corresponding to follow-up activities.
We assumed that the implementation costs for the first phase would be similar to the budget of SOIL project activities, and that the second phase would require an equal amount of funding, but spread over 7.5 years.

We adopted the following assumptions for the financial analysis:

- Inflation rate on price of VUC: 3% per year;
- Inflation rate on costs: 3% per year;
- Actualization rate: 12%.

Then, we estimated the financial performances for the 3 best scenarios of project performance (see table 28). Results are presented hereunder in table 29.

	Worst to best scenario		
	Scenario 1	Scenario 2	Scenario 3
Project Effectiveness	60%	75%	90%
Leakage	15%	10%	5%
Non permanence buffer	20%	15%	10%
Nb VCUs/year	23 086	35 639	48 757
Price/VCU	**16.9 USD**	**10.6 USD**	**7.6 USD**
Inflation rate VCU	3.0%	3.0%	3.0%
Inflation rate costs	3.0%	3.0%	3.0%
Actualization rate	12.0%	12.0%	12.0%
Project Incomes	4 401 098 USD	4 390 609 USD	4 388 074 USD
Project Costs	2 985 190 USD	3 000 568 USD	3 016 885 USD
Project Profits	1 415 908 USD	1 390 041 USD	1 371 188 USD
Net Present Value	9 145 USD	9 284 USD	7 825 USD
Investment Return Rate	12.14%	12.14%	12.12%

Table 29: Financial performances in function of project effectiveness, leakage and non permanence risk.

- Under scenario 2 (corresponding to rates of project effectiveness of 75%, leakage of 10% and non permanence buffer of 15%), the project needs to sell VCUs at **10.6 US$/VCU** in order to cover all the costs and generate 12% of return rate on investments;
- Under scenario 1, (corresponding to rates of project effectiveness of 60%, leakage of 15% and non permanence buffer of 20%), the project needs to sell VCUs at **16.9 US$/VCU** in order to cover all the costs and generate 12% of return rate on investments;
- Under scenario 3, (corresponding to rates of project effectiveness of 90%, leakage of 5% and non permanence buffer of 10%), the project needs to sell VCUs at **7.6 US$/VCU** in order to cover all the costs and generate 12% of return rate on investments.

A conservative assumption for the price of issued VCU is 10 US$. This means, that the project needs to reach at least performances of scenario 2 to be viable financially.

Note that this estimation should be refined, in particular regarding project implementation costs, on the basis of first lessons learnt by the SOIL project team on the field: Is the impact of SOIL activities sufficient to drive the expected changes in farming practices by local farmers? In particular, is the incentive in the form of support to agricultural intensification and improved livelihoods enough? Or do local communities expect a direct payment in cash for conserving the forest?

✓ The level of VCUs, and therefore the incomes, generated by the project will ultimately depend on project effectiveness in reducing deforestation, leakages caused by project implementation, and the amount of buffer credits set aside to account for non permanence. A reasonably successful project in those 3 issues would generate around 35.000 VCUs/year, a total income of 4.39 millions US$ at a selling price of 10 US$/VCU (with inflation)

✓ Project costs are divided into development, implementation, monitoring, verification and issuance costs. According to the estimations presented in the report, total costs would be 3 millions US$ (with inflation).

✓ The preliminary financial analysis over the first 10 years of implementation show that, with good performances, the project is viable for a selling price of 10.6 US$/VCU. However, it is based on many assumptions that need to be confirmed.

✓ In particular, it will be important, based on the first lessons learnt from SOIL project implementation in the field, to evaluate more precisely the adequate level and forms of incentives that could drive the expected changes in local farming practices.

✓ A more complete economic analysis would also be needed in order to capture the full economic impact of the project on the communities living in the SOIL project area and for the local and national economy.

7. Conclusions and recommendations

7.1. Potential of the SOIL project on the voluntary carbon market

7.1.1. Potential to bring the project to the market

Developing a carbon project for the voluntary market is costly. Private investors are willing to finance up front this development cost but require a share of generated carbon credits in return, generally a given amount or % of credits at a given price. The offered price per VCU is usually well below the price of issued VCUs, reflecting the fact that the investor is taking several risks: on project validation and VCU certification, on project performance, on project costs, etc. Most investors are also looking forward to trade the VCUs on carbon markets and integrate their margin in the price. In order to secure their investment, investors are therefore looking for projects generating large volumes of carbon credits at low prices.

On this voluntary carbon market, the SOIL project will be in competition with other projects which offer better perspectives to investors in terms of volume of VCUs to be generated and financial performances. Therefore we foresee that the SOIL project won't be attractive to such investors and will not be able to attract upfront investment.

Upfront finance for project development may be more easily obtained through ODA funding, such as the CBFF or CARPE.

7.1.2. Environmental and social co-benefits

The project would be very attractive in terms of environmental and social co-benefits.

- Environmental co-benefits

The project area is an important zone to ensure long term connectivity of forest habitats for emblematic species present in the MLW landscape, such as the Bonobo.

Besides the protection of forest habitats, the project also contributes to reduce the pressures on wildlife.

- Social co-benefits

The project is expected to bring positive impacts on the livelihoods of local communities. It targets an important deforestation driver in the context of DRC, that offers good opportunities to associate local communities to the benefit of REDD in the country.

Besides incentives to reduce their impact on forests, the project also supports the social organization in the area, through supporting civil society organizations.

These characteristics could be valued through a CCBS certification on the voluntary market and bring additional income through a higher price/VCU. They also make the project particularly attractive to ODA funding.

7.2. Integration in national/sub-national REDD frameworks

7.2.1. REDD policies

The development of the national strategy is under process, with support of the two major international initiatives on REDD readiness preparation: the FCPF and UN-REDD.

The readiness preparation proposal (RPP) approved by the FCPF draws the main lines of the development of the REDD strategy in the country.

It identifies 4 main components, divided in 14 programs. Among these, those especially relevant to the SOIL project are (see figure 24) :

- Component I: transferring the management of “forêts protégées” to local communities through in particular participative micro-zoning;
- Component II: development of a performing agriculture in rural forested areas, and especially programs 9 – increased productivity and alternatives to slash and burn subsistence farming – and 10 – increase of yields and added value of small scale commercial farming;
- Component IV: a transversal component gathering necessary institutional and governance reforms, in particular the land use policy.

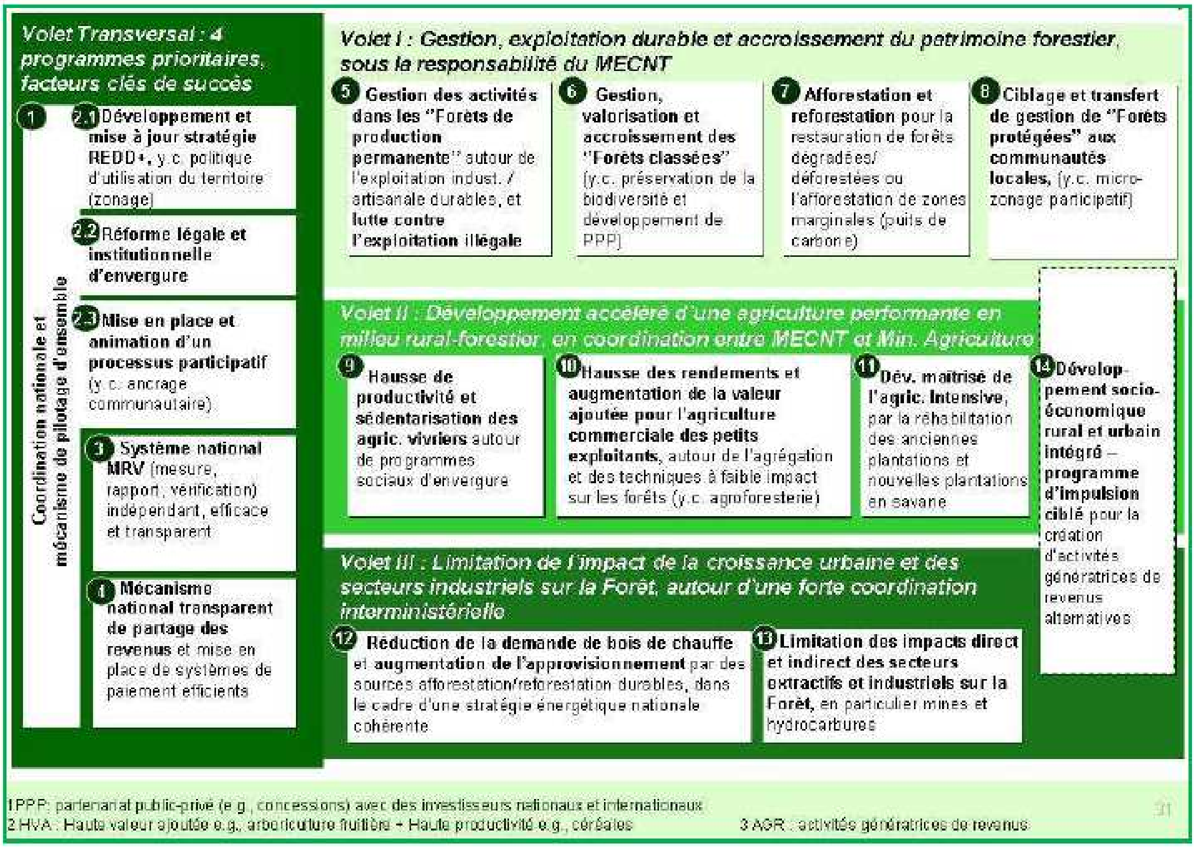


Figure 24: Components and programs of the national REDD strategy (DRC readiness preparation proposal)

The RPP foresees that these programs will be implemented in two complementary ways:

- Through reforms of the relevant sectoral policies and national programs led by the State and decentralized public authorities;
- Through projects at local scale, aiming at valorizing emissions reductions in a future international mechanism based on performance payments.

Ultimately, according to the decision on REDD made at Cancun, only the State will be responsible for measuring, reporting and verifying emission reductions achieved nationally and will be entitled to trade these emissions reductions internationally.
However this requires the country to be ready to implement such performance-based system, i.e. having developed a comprehensive national strategy, an implementation framework précising the mechanism for REDD payments distribution, a national reference level of emissions and a robust national MRV system[22].

Meanwhile, DRC welcomes the development of pilot projects in the framework of the voluntary market, as a mean of attracting private investments and gathering experience and knowledge for the development of the national strategy.

[22] As an interim measure, a country may implement this system at sub-national scale. In the case of DRC for instance, it could be implemented first in pilot provinces and then extended to cover the whole country. However, there is no sign that this approach forms part of DRC plans.

In order to ensure environmental and social integrity of these projects, and also offer guarantees on carbon credits rights for private investors, DRC plans to set up an interim implementation framework consisting in:

- Rules and criteria for official registration of REDD + projects in DRC;
- A national registry of REDD+ projects.

This registry and associated rules will ensure that registered projects are eligible activities coherent with the national REDD strategy objectives, identify project proponents, localize exactly the project,, ensure that the project address deforestation drivers and leakage issues, ensure that rights on carbon credits are clarified, etc.
Investors and project proponents who register their project will obtain two guarantees:

- The rights of trading carbon credits on the voluntary market through a contractual arrangement with the State;
- The avoidance of double accounting through an official cadastre of REDD+ projects ensuring there is no overlapping of registered project areas.

The legal framework for REDD will need to clarify carbon ownership and compensation rights associated with its sequestration or emissions prevention.
As in all countries participating to REDD, the situation remains unclear at the moment. Should carbon ownership be granted to the State, local communities? What should be the rights of project developers, investors?
More than carbon ownership, the issue is the right of trading carbon credits, on the voluntary market for the moment, and then through the State, when it will be ready to implement a nation wide performance-based system for REDD.
It is one of the purposes of the coming registry of REDD+ projects to clarify these rights to project developers and investors.
Ultimately, the State will be the only entity entitled to trade carbon assets internationally. However, it will have to delegate the production (sequestration and/or prevention of emissions) of these assets to operational stakeholders: landowners (often the State itself), local communities enjoying traditional user rights, institutions developing the projects (national and international NGOs, private companies, and public institutions), investors, technical experts. The rights of each of these actors will have to be defined according to their respective contributions to the production of the assets, and formalized through contractual agreements between parties.

As a project developer, AWF should follow closely policy developments on these issues in DRC. Moreover, consultations should be led with local stakeholders on their willingness to enter into agreement with AWF and other parties for the production of carbon assets, and what would be their expectations regarding such agreements.

7.2.2. Reference level and MRV of emissions reductions

When entering a nation wide performance based system, DRC will adopt a national reference level of emissions, against which its future performances will be measured and paid.
Reference scenarios of REDD+ projects will have to be integrated in this national reference level, which means practically that the State will have to reserve part of the total amount of emissions reductions it can achieve to assign them to the projects, if they are successful in reducing emissions.
It is therefore essential for project developers to have their projects, and respective reference scenario, approved by the State. It is therefore recommended to register the project in the national registry and keep a continuous exchange of information with the National REDD Coordination. It will ensure that the project and its development are well known by the administration, anticipate any difficulty/objection, and adapt the project development to rules and criteria applying to the registry.

The same recommendation applies to the monitoring, reporting and verification of emissions reductions.

7.2.3. The SOIL project: carbon credits or part of a national program on alternatives to slash and burn farming?

Carbon credits should not be considered as the only way to attract REDD funding. Within the national REDD strategy, providing alternatives to slash and burn farming will be an important program for the State, especially as it provides positive social co-benefits.
To implement such program, the State will need field operators implementing measures such as micro-zoning, agroforestry development or community based forest management. Rather than through projects generating carbon credits, which can be complex and costly to develop, such operators could be rewarded on the basis of proxy indicators (for instance area micro-zoned and covered by a management plan, area of forest conserved) of their impact on emissions reductions.
The interim implementation framework also foresees the registration and funding of such measures, under the name REDD+ initiatives. In our point of view, this is also a promising way of obtaining funds for SOIL, and AWF should also monitor this opportunity.

- ✓ The SOIL project doesn't seem attractive to investors of the voluntary carbon market and would have difficulties to attract upfront investment;
- ✓ However, carbon credits may constitute a valid long term funding to the SOIL project, providing that; upfront finance for project development can be obtained from philanthropic sources ; To this end, the project offers important environmental and social co-benefits, and fits well in the national REDD strategy;
- ✓ Project proponents should also pursue the registration of the SOIL project as a REDD+ initiative, aiming at developing field experience and enabling capacities on REDD+ strategies such as micro-zoning and alternatives to slash and burn farming;

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Annexes

Annex 1: Project Idea Note

Name of Project: REDD pilot project in the Maringa Lopori Wamba Landscape, Province of Equator, Democratic Republic of Congo

Date submitted:

A. Project description, type, location and schedule

General description	
A.1 Project description and proposed activities	The project area is situated in the Maringa Lopori Wamba (MLW) landscape, which harbors a diversity of protected and key species on the left bank of the Congo River, such as the bonobo, Congo peacock, , giant pangolin, Allen's swamp monkey, golden cat, forest elephant and Salongo monkey. The two most well-known and best-studied free ranging Bonobo populations are located in the Faunal Reserve of Lomako Yokokala and Luo Scientific Reserve. Increased human expansion in the landscape has posed a threat to the forest habitat of many of these wildlife species, through the expansion of slash and burn agriculture. The project will protect 195 922 ha of primary forest ensuring the connectivity between the Faunal Reserve of Lomako Yokokala and the Luo Scientific Reserve in the Province of Equateur, DRC. It is estimated that around 4200 families (~ 16000people) live in the project area, the vast majority of them depending on subsistence farming, the collection of non timber forest products and wildlife hunting for their survival. The project will increase householder well being by providing economically sustainable livelihoods that mitigate negative environmental impacts of existing livelihoods strategies, in particular deforestation and forest degradation.
A.2 Technology to be employed (mention if REDD will be undertaken)	Participative Land Use Planning and micro-zoning is the key project strategy, with the promotion of secure agricultural livelihoods.
Project proponent submitting the PIN	
A.3 Name	**African Wildlife Foundation**
A.4 Organizational category *(choose one or more)*	a. Government b. Government agency c. Municipality d. Private company e. **Non Governmental Organization**
A.5 Other function(s) of the project developer in the project *(choose one or more)*	a. Sponsor b. Operational Entity under the CDM c. Intermediary d. Technical advisor
A.6 Summary of relevant experience	
A.7 Address	African Wildlife Foundation Congo Heartland Av.Comité Urbain n°12,

	Kinshasa Gombe/DRC B.P. 2396 Kinshasa, DRCongo
A.8 Contact person	Facheux Charly
A.9 Telephone / fax	00243 994016749
A.10 E-mail and web address	cfacheux@awfafrica.org; www.awf.org
Project sponsor(s) financing the project *(List and provide the following information for all project sponsors)*	
A.11 Name	
A.12 Organizational category *(choose one or more)*	f. Government g. Government agency h. Municipality i. Private company j. Non Governmental Organization
A.13 Address *(include web address)*	
A.14 Main activities	
A.15 Summary of the financials *(total assets, revenues, profit, etc.)*	
Type of project	
A.16 Greenhouse gases targeted	**CO_2** / CH_4 / N_2O
A.17 Type of activities	Sequestration / Conservation (REDD)
A.18 Field of activities (*Select code(s) of project category(ies) from the list*)	16 (REDD)
Location of the project	
A.19 Country	Democratic Republic of Congo
A.20 Nearest city	Djolu, Equator
A.21 Precise location	Province of Equator, Maringa Lopori Wamba Landscape, Territories of Befale and Djolu, Groupements of Bomwankoy, Likunduamba, Lingomo, Nkole and Yolota.
Expected schedule	
A.22 Earliest project start date *(Year in which the project will be operational)*	2012
A.23 Estimate of time required before becoming operational after approval of the PIN	Time required for financial commitments: xx months Time required for legal matters: xx months Time required for negotiations: xx months Time required for establishment: xx months
A.24 Year of the first expected CER / ERU / RMU / VER delivery	2017
A.25 Project lifetime *(Number of years)*	20 years

A.26 Current status or phase of the project	a. Identification and pre-selection phase b. Opportunity study finished c. **Pre-feasibility study finished** d. Feasibility study finished e. Negotiations phase f. Contracting phase
A.27 Current status of the acceptance of the project by the Host Country *(choose one)*	a. Letter of No Objection is available b. Letter of Endorsement is under discussion or available c. Letter of Approval is under discussion or available
A.28 Position of the Host Country with regard to the Kyoto Protocol *(choose one)*	The Host Country **a. Is a Party to the Kyoto Protocol (i.e. has ratified or otherwise acceded to the Kyoto Protocol)** b. Has signed the Kyoto Protocol and demonstrated a clear interest in becoming a Party in due time c. Has not signed the Kyoto Protocol

B. Expected environmental and social benefits

Environmental benefits	
B.1 Estimate of carbon sequestered or conserved *(in metric tonnes of CO_2 equivalent – t CO_2e. Please attach spreadsheet.)* Provide estimated from REDD activities separately	Up to and including 2017: 180 000 t CO_2e The project will start in 2012. It is estimated that it will generate 36000 Voluntary Carbon Units per year over its 10 first years of implementation, assuming a non-permanence buffer of 15%.
B.2 Baseline scenario *(What would the future look like without the proposed project? What would the estimated total carbon sequestration / conservation be without the proposed project? Mention the baseline methodology, as per the CoP9 text.[23] Also explain why the project is additional referring to the EB16 guidelines[24]).* If REDD activity, mention the main drivers and agents for deforestation and how the project will address them[25].	The main proximate cause of deforestation in the project area is small scale slash and burn farming for subsistence, driven by population pressure, poverty, lack of economic alternatives, lack of access to markets and credits, low levels of technological inputs and inadequate land use policy. Lack of land use planning and open access conditions in the forest is a key issue. The national forest code that is being developed distinguishes three main land use policies in forests: ▪ Classified forests (*Forêts classées*) are protected areas, where forest conversion is prohibited; ▪ Permanent production forests (*Forêts de production permanente*) are forests dedicated to logging under sustainable management plans; ▪ Protected forests (*Forêts protégées*) are forests that can be used by local communities and in which they can practice slash and burn farming (<2ha). In practice, protected forests function as an open access reserve of farming land for local communities under the authority of community leaders. Therefore, the forest code as currently written allows for a gradual conversion of all protected forests into agricultural areas. In the last 10 years (2000 to 2010), this situation caused the conversion of an average of 147 ha/year of primary forest for slash and burn farming in the project area. According to existing estimations of carbon stocks, the conversion of 1

[23] http://cdm.unfccc.int/Reference/Documents/dec19_CP9/English/decisions_18_19_CP.9.pdf
[24] http://cdm.unfccc.int/EB/Meetings/016/eb16repan1.pdf
[25] The BioCF is developing a methodology for project activities reducing emissions from deforestation and forest degradation, which should be fully adopted during project preparation. It will be available by November 2007.

	ha of primary forest to a slash and burn farming system generates the emission of 439 tCO_2e through carbon stocks variations and 33 tCO_2e through non- CO_2 emissions from biomass burning. Baseline emissions are estimated at ~61.350 tCO_2e/year. Fuelwood is the only source of energy of the vast majority of households. However it is mainly collected from deadwood and clearings for farming. Given the low population density and large forest area, it is not expected that fuelwood collection may have a degrading impact on the forest. Although accurate population census are lacking, the population growth is assumed to continue at a rate of 2.9% per year. Neither significant technological change nor economic development is foreseen that could provide local communities with alternatives to their present farming practices. In the absence of project implementation, the past trend is therefore likely to continue during the ten coming years. The project will address the deforestation drivers and underlying causes through the following activities: ▪ Participatory Land Use Planning and micro-zoning; Participative LUP and micro-zoning will lead to agreed and formally recognized micro zone land use plans. Agreements will be signed with the organized local communities, with reference to an agreed zoning process, respect for different uses, and anticipated support for agriculture, agro-forestry and other livelihood activities. ▪ Promotion of secure agricultural livelihoods: - Increased productivity of traditional agricultural activities through improved agronomic practices and improved varieties; - Promotion of high value trees with focus on integrated agro-forestry, agro-biodiversity and substitution for forest wood fuels; - Identification of other viable alternative livelihood options, such as small livestock, fisheries, ecotourism; - Facilitation of product chain development and reactivation of access to markets; - Strengthening the capacity of farmer associations and platforms for joint learning and collective marketing.
B.3 Existing vegetation and land use *(What is the current land cover and land use? Is the tree cover more or less than 30%?)*	The project area is composed of 195.922 ha of primary rainforest, of which about 15% is swamp forest and 85% is dense moist forest.
B.4 Environmental benefits	
B.4.a Local benefits	
B.4.b Global benefits	
B.5 Consistency between the project and the environmental priorities of the Host Country	
Socio-economic benefits	
B.6 How will the project improve the welfare of the community involved in it or surrounding it. What are the direct effects which can be attributed to the project and which would not have occurred in a	

comparable situation without that project? *(e.g., employment creation, poverty alleviation, foreign exchange savings).* Indicate the number of communities and the number of people that will benefit from this project.	
B.7 Are there other effects? *(e.g., training/education due to the introduction of new technologies and products, replication in the country or the region)*	

C. Finance

Project costs	
C.1 Preparation costs	0.4 US$ million
C.2 Establishment costs	1.8 US$ million, over 10 first years of project implementation (without inflation)
C.3 Other costs *(monitoring, VCUs certification and issuance))*	0.5 US$ million, over 10 first years of project implementation (without inflation)
C.4 Total project costs	2.7 US$ million, over 10 first years of project implementation (without inflation)
Sources of finance to be sought or already identified	
C.5 Equity *(Name of the organizations and US$ million)*	
C.6 Debt – Long-term *(Name of the organizations and US$ million)*	
C.7 Debt – Short term *(Name of the organizations and US$ million)*	
C.8 Grants	
C.9 Not identified *(US$ million)*	
C.10 Contribution sought from the BioCarbon Fund *(US$ million)*	
C.11 Sources of carbon finance *(Has this project been submitted to other carbon buyers? If so, say which ones)*	
C.13 Indicative CER / ERU / RMU / VER price *(subject to negotiation and financial due diligence)* Please discriminate VERs from REDD	10,6 US$ per VCU

activities.	
C.14 Emission Reductions Value *(= price per t CO_2e * number of tCO_2e)* Please discriminate VERs from REDD activities.	4,4 million US$ (assuming 3% inflation rate on VCUs price per year)
Until 2012	0 US$
Until 2017	4,4 million US$
C.15 Financial analysis *(If available for the proposed CDM / JI activity, provide the forecast financial internal rate of return (FIRR) for the project with and without the CER / ERU / RMU / VER revenues. For standardization purposes, provide the financial rate of return at the expected CER / ERU / RMU / VER price above and US$4/t CO_2e and assume 20 years worth of carbon payments, even though that price and purchasing period may not be the one offered by the BioCarbon Fund. Please attach spreadsheet if available.)*	FIRR without carbon: not applicable. FIRR with carbon: 12 %, assuming: - Selling price of VCUs at 10,6 US$; - Inflation rate on price of VCU: 3% - Inflation rate on costs: 3%

Annex 2: Field mission schedule

Field mission schedule	
Tue. 23/11/2010	Travel France - Kinshasa
Wed. 24/11/2010	Travel Kinshasa - Mbandaka
Thru. 25/11/2010	Travel Mbandaka – Djolu, installation in Djolu, first meeting with AWF staff and field mission program establishment
Fri. 26/11/2010	Field work in Yambale
Sat. 27/11/2010	Field work in Ingungu
Sun. 28/11/2010	Field work in Ingungu
Mon. 29/11/2010	Field work in Yambale
Tue. 30/11/2010	Field work in Ingungu
Wed. 01/12/2010	Field work in Yambale
Thru. 02/12/2010	Field work in Yambale
Fri. 03/12/2010	Travel Djolu - Mbandaka
Sat. 04/12/2010	Travel Mbandaka – Kinshasa
Sun. 05/12/2010	Travel Kinshasa - France

Table 30: Field mission schedule

Annex 3: Proximate and underlying causes of deforestation

Table 1: List of variables (proximate causes) – I

Proximate causes		
Agricultural expansion (AGRO)	Shifting cultivation	Traditional shifting cultivation
		Colonist shifting cultivation
	Permanent cultivation	Subsistence (food, smallholder) agriculture
		Commercial agriculture (large-scale, smallholder)
		Agricultural (Integr. Rural) Development Projects
	Cattle ranching	Smallholder cattle ranching (pasture creation)
		Large-scale cattle ranching (pasture creation)
		Unspecified
	Colonization, transmigration, resettlement	Spontaneous transmigration
		Local transmigration (resettlement)
		Military transmigration (penal settlements)
		Estate settlement (agricultural, nucleus)
		Industrial forestry plantation settlement
		Unspecified
Wood extraction (WOOD)	Commercial wood extraction (clear-cutting, selective harvesting)	State-run logging (selective, clear-cutting)
		Private company logging (selective, clear-cutting)
		"Growth coalition"-led logging
		Illegal (illicit, undeclared) logging
		Unspecified
	Fuelwood extraction	Domestic uses (rural, urban)
		Industrial uses (rural, urban)
		Unspecified
	Polewood extraction	Domestic uses (rural, urban)
		Industrial uses (rural, urban)
		Unspecified
	Charcoal production	Domestic uses (rural, urban)
		Industrial uses (rural, urban)
		Unspecified
Infrastructure extension (INFRA)	Transport infrastructure	Roads (public, military, logging, mining, etc.)
		Railroads
		Rivers & tributaries
	Market infrastructure	Public infrastructure (food markets, storage, etc.)
		Private infrastructure (sawmills, food markets, etc.)
	Public services	Water & sanitation facilities, electrical grids, etc.
		Unspecified
	Settlement expansion	(Semi-)urban settlements
		Rural settlements
		Military defense villages
		Unspecified
	Private entreprise infrastructure	Hydropower development
		Oil exploration
		Mining (gold, coal, tin ore, etc.)

Table 2: List of variables (underlying causes) - II

Underlying causes (I)		
Economic factors (economic growth, change or development, commercialisation)	Market growth & commercialisation	Unspecified: rapid market growth (especially of the export-oriented sector), rise of cash economy, increasing commercialisation, incorporation into (world) economy
		Increased market accessibility (esp. of semi-urban and urban markets)
		Growth of sectoral industries (wood-related, agriculture-related, mineral-related, others)
		Lucrative foreign exchange earnings
		Growth of demand for consumer goods and services procured with cash due to a rise in well-being (unspecified, wood-related, agriculture-related, housing & transport)
	Specific economic structures	Unspecified
		Large individual (mostly) speculative gains
		Poverty & related factors (lack of income opportunities, joblessness, resource poverty, low living standard, etc.)
		Economic downturn, crisis conditions
		Indebtedness, heavy foreign debt
	Urbanization & industrialization	Urbanization: growth of urban markets
		Industrialization: rapid built-up of new basic, heavy and forest-based or –related industries
	Special economic parameters	Comparative advantages due to cheap, abundant production factors in resource extraction & use
		Special, mainly artificially low kept production conditions
		Price (value) increases (of fuel, land, cash crops)
		Price decreases (of cash crops)
Policy and institutional factors (change of political economy institutions)	Formal policies	On taxation, charges, tariffs, prices
		On credits, subsidies, licenses, concessions, (logging) bans
		On economic development (agriculture, infrastructure)
		On finance, legislation, investment, trade
		On population (migration)
		On land
		Other pro-deforestation policy (unspecified)
	Informal policies (policy climate)	Corruption, lawlessness
		Growth or development coalitions at work
		Poor performance, mismanagement
		Clientelism, vested (private) interests
		Redefinition of (forestry) policy goals
	Property rights regimes	Insecure ownership, land tenure insecurity (unspec.)
		Land race, race for property rights
		Titling, legalization, consolidation (of individual titles)
		Malfunct customary rights
		Low empowerment, deprivation, marginality
		Open access conditions

Table 3 : List of variables (underlying causes) – III

Underlying causes (II)		
Technological factors (technological change or progress)	Agro-technological change	Land-use intensification
		Land-use extensification
		Agricultural involution
		Other changes (landholding, production orientation, etc.)
	Technological applications in the wood sector	Damage & wastage due to poor logging performance
		Wastage in wood processing, poor industry performance
		Lack of cheap, technological alternatives to woodfuel; poor domestic & industrial furnace performance
	Other production factors in agriculture	Low level of technological inputs (unspecified)
		Land-related factors (landlessness, land scarcity)
		Labour –related factors (limited labour availability)
		Capital-related factors (no credits, limited irrigation)
Cultural (or socio-political) factors	Public attitudes, values, beliefs	Public unconcern or lack of (public, political) support for forest protection and sustainable use: low morale or education, frontier mentality, and dominance of other public attitudes (modernization, development, nation-building, etc.)
		Unconcern about the welfare of others and future generations, or disregard of the "sacredness of nature"
		Beliefs about how environmental conditions affect those things which individual values
	Individual and household behaviour	Unconcern by individuals about the environment as reflected in increasing levels of demands, aspirations, materials and energy consumption, commonly associated with commercialisation and increased income
		Situation-specific behaviour of actors: rent-seeking, non-profit orientation, tradition/imitation/continuation of inherited modes of resource use
Demographic factors (human population dynamics)	"Population pressure" (unspecified)	
	Population growth (unspecified)	
	Natural increment (fertility, mortality)	
	In-migration	
	Population density	
	(uneven) spatial population distribution	
	Life cycle features	

Annex 4: Calculations of sampling intensity

Pearson et al. 2005

Pearson et al. 2005

$$n = \frac{\left[\sum_{h=1}^{L} N_i \cdot st_i\right]^2}{\left(N \cdot \frac{E_1}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{L} N_i \cdot (st_i)^2}$$

$$n_j = n \times N_j.st_j / \sum N_i.st_i$$

ni	Sampling size of stratum i (number of sample plots)
n	Sampling size of the project (number of sample plots)
i	Project stratum (1, 2, 3..)
L	Total number of strata
Ni	Maximum possible number of sample plots in stratum i
N	Maximum possible number of sample plots of the project
sti	Standard deviation of stratum i
E1	Allowed error for the expected quantity Q1
Q1	Mean value of the expected quantity (here tC/ha)
p	Desired level of precision (10%, being 0,1 as default value)
Zα/2	1,9599 for α=5% (means a confidence level of 95% for the desired level of precision)

	Rural complex	Moist forest	Swamp forest	All
Area		171 177	29 329	200 506
Plots size		0.126	0.126	0.126
Average G x H		428.4	352.3	405.1
St_i		137.1	119.5	135.0
CV		32.0%	33.9%	33.3%
N_i		1 358 548	232 770	1 591 317
E		42.84	35.23	40.51

n	44.1	45 plots
Rural complex	-	0 plots
Moist forest	38.4	39 plots
Swamp forest	5.7	6 plots

Wenger 1984

Wenger, K.F. (ed). 1984. Forestry handbook (2nd edition). New York: John Wiley and Sons.

(A3-1) $$n = \frac{t_{st}^2 \cdot (CV\ \%)^2}{(E\ \%)^2 + \frac{t_{st}^2 \cdot (CV\ \%)^2}{N}}$$

(A3-2) $$n_{cl} = n \cdot \frac{N_{cl}}{N}$$

(A3-3) $$n = \left(\frac{t_{st}}{E}\right)^2 \left[\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \cdot \sqrt{C_{cl}}\right] \cdot \left[\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \Big/ \sqrt{C_{cl}} \cdot\right]$$

(A3-4) $$n_{cl} = n \cdot \frac{W_{cl} \cdot S_{cl} \Big/ \sqrt{C_{cl}}}{\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \Big/ \sqrt{C_{cl}}}$$

cl	1, 2, 3, … *Cl* LU/LC classes	
Cl	total number of LU/LC classes	
t_{st}	t-student value for a 95% confidence level, with n-2 degrees of freedom	
E	allowable error (±10% of the mean)	
S_{cl}	standard deviation of LU/LC class *cl*	
n_{cl}	number of samples units to be measured in LU/LC class *cl* that is allocated proportional to . If $n_{cl} < 3$, set $n_{cl} = 3$.	$W_{cl} \cdot S_{cl} \Big/ \sqrt{C_{cl}}$
W_{cl}	N_{cl}/N	
n	total number of sample units to be measured (in all LU/LC classes)	
N_{cl}	maximum number of possible sample units for LU/LC class *cl*, calculated by dividing the area of LU/LC class *cl* by the measurement plot area	
N	population size or maximum number of possible sample units (all strata),	$N = \sum_{cl=1}^{Cl} N_{cl}$
C_i	cost to select and measure a plot of the LU/LC class *cl*	

(A3-1) & (A3-2)		
n	44.4	45 plots
Rural complex	-	0 plots
Moist forest	37.9	38 plots
Swamp forest	6.5	7 plots
(A3-3) & (A3-4)		
n	44.1	45 plots
Rural complex	-	0 plots
Moist forest	38.4	39 plots
Swamp forest	5.7	6 plots

Annex 5: Practical guidelines for field measurements

How to measure tree diameters (DBH)

All diameters are measured at breast height (1.30 m from the ground) using a tape, perpendicularly to the trunk (even on a slope) and registered on the counting form. Figure 23 shows the way diameters are measured in some specific situations.

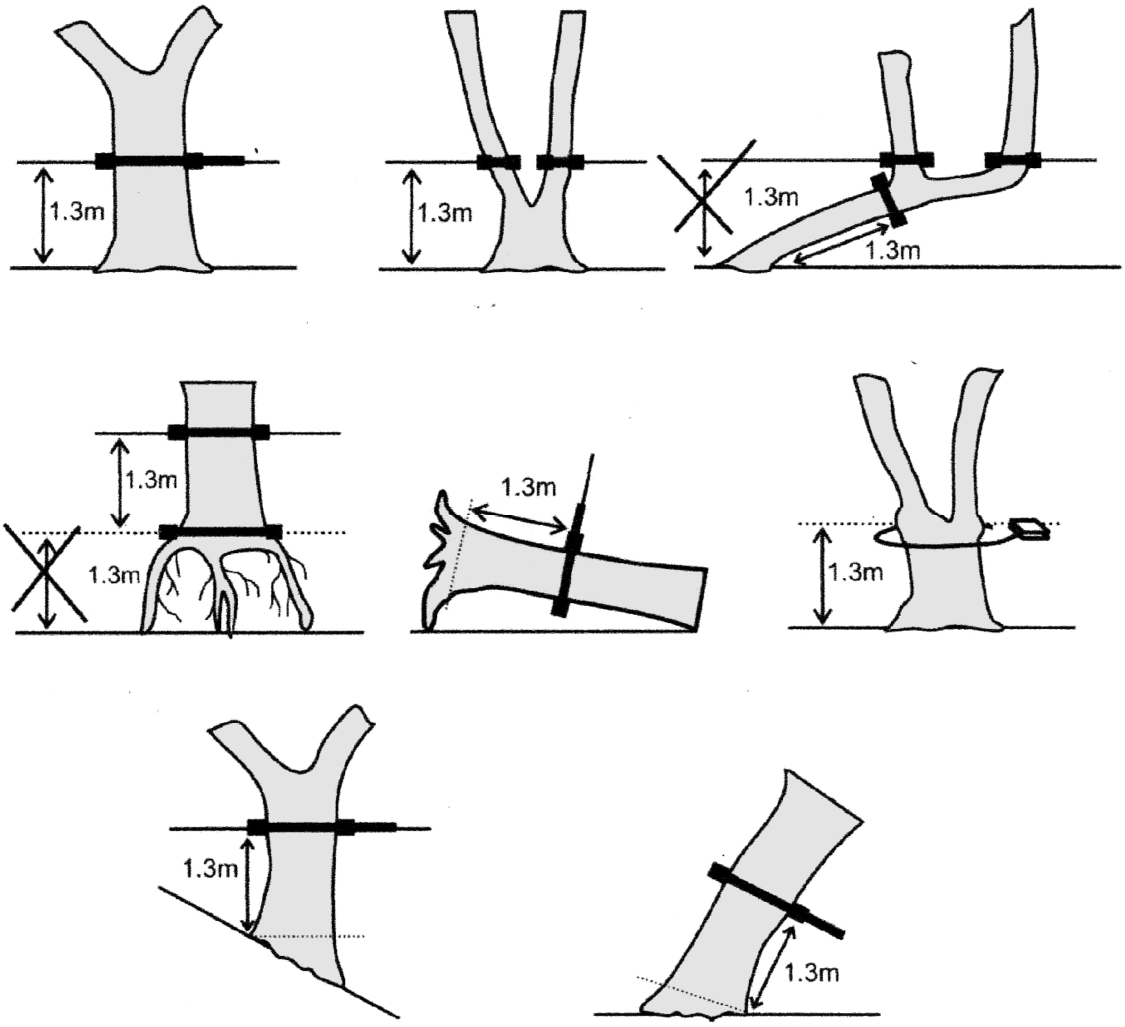


Figure 25: How to measure diameters at breast height in various situations

If there are two trunks at 1.30 m, two diameters are measured. If the trunk is divided into two trunks over 1.30 m, only one trunk is measured at 1.30 m.

In the case of buttresses, trees are measured above the buttresses if possible or with a specific wood board (see figure 24), allowing to determine the diameter class of the tree.
The dimensions of the board for the diameter measures are 150 cm x 10 cm x 1 cm; the board is painted in white and red and fixed on a pole.
Graduations and class numbers are painted in black according to the correspondences described in table 27. The average distance between the measurer and the board, for a reading height (h) between 1.5 m and 5 m (h), is 10.3 meters, corresponding to a horizontal distance of 10 m between measurer and the tree. The following table is based on this distance of 10.3 m.

Diameter classes	*Diameter class – Limits (in cm)*	*Numbers to be painted on the boards, corresponding to the inferior limits of the classes (cm)*
0	0 to 10	-
1	10 to 20	-
2	20 to 30	-
3	30 to 40	39,5
4	40 to 50	48,7
5	50 to 60	58,0
6	60 to 70	67,2
7	70 to 80	76,5
8	80 to 90	85,7
9	90 to 100	94,9
10	100 to 110	104,2
11	110 to 120	113,4
12	120 to 130	122,7
13	130 to 140	131,9

Table 31: Graduations and diameter classes to be put on the board for diameter measurements in case of buttresses

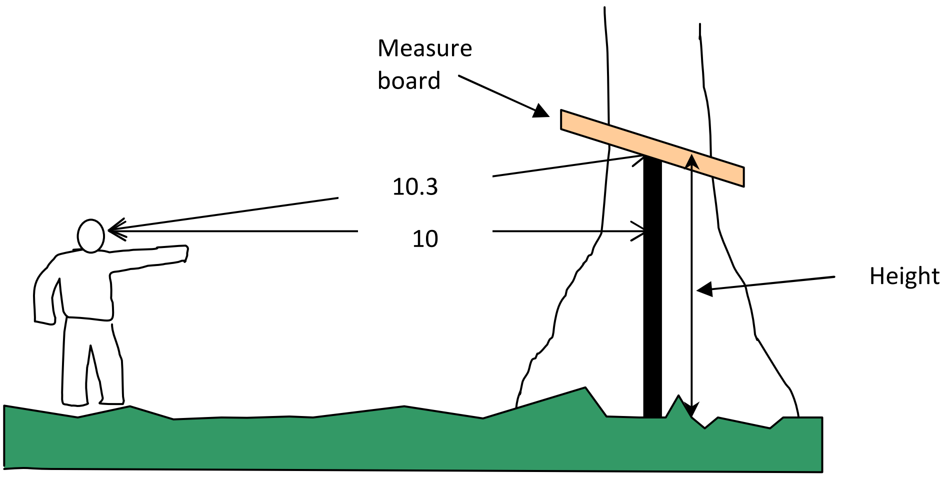


Figure 26: How to measure diameters at breast height in case of buttresses

How to measure tree heights (H)

Giving the difficulty to target the top of the trees in a tropical forest, heights will be calculated from a "height-do-diameter" relation curve, built from a sample of trees from each plot.

The height of 3 trees among the average canopy height is thus measured on each plot, among the canopy reaching trees. A clinometer is used for this purpose, at a given distance of the trunk. The trees are individually identified so that the relationship between diameter and height can be built.

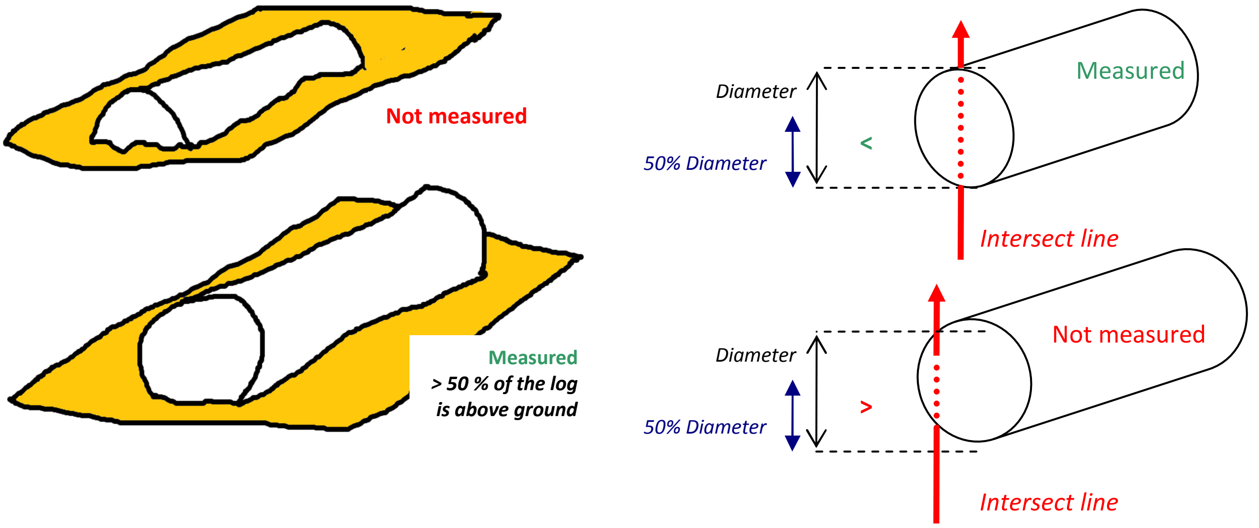
How to measure deadwood

Detailed guidelines are provided by both methodologies (see below). We discuss hereunder the main issues. Two types of dead wood are treated separately:

- Standing dead wood and
- Lying dead wood.

Standing dead wood is classified according to decomposition classes.
Trees without signs of decomposition are treated the same way as live trees (in the BioCF-CDI methodology, biomass of leaves has to be subtracted).
Trees with signs of decomposition (loss of twigs, branches or crowns) are treated differently: it is conservatively assumed that the biomass is limited to the bole of the tree. Volume of the bole is estimated as the volume of a cone or cylinder with measurements of basal diameters, top diameters (if feasible) and heights. An appropriate dead wood density (see below) is used o convert this volume into biomass.

Lying dead wood is measured using the line intersect method. Two 50 meters-long lines (ropes) intersect at 90° at the centre of the plot. Only the diameters of the lying wood superior to 10 cm intersecting the lines are measured (the smaller pieces are considered to be part of the litter pool). Figure 25 details specific rules regarding the deadwood pool measurements.



A piece of wood is only measured if more than 50% of the log is above ground

A piece of wood is only measured if the sampling line crosses through at least 50% of the diameter of the piece

Figure 27: Criteria for measurements of deadwood pool (1)

If the trunk is hollow, the inner diameter will be measured and only the difference between the two diameters will be classified in dead biomass.

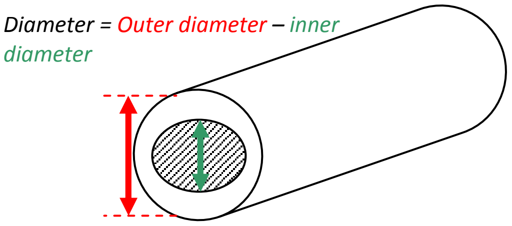


Figure 28: Criteria for measurements of deadwood pool (2)

The deadwood is classified into three different wood density categories (trough a “machete test”):

- Sound (solid, making a sound when being hit with machete)
- Intermediate (the machete is penetrating in the wood when being hit)
- Rotten (the wood has no more resistance; the machete is penetrating largely in the wood).

Wood density of each category can be sourced from relevant research publications, national or regional data and IPCC default value.
It is most likely that project specific data will be needed. Methodologies provide guidelines to measure wood densities from samples of each class. This requires measuring the dry mass in a laboratory.

Inventory charts

Biomass assessment project - AWF INVENTORY CHART				
Date	/ /	Plot nr		OBSERVATIONS :
Team leader		Coordinates		
		Slope		

Species	Diameter DBH (cm)	Height (m)	Status		Species	Diameter DBH (cm)	status		Species	Diameter DBH (cm)	status

Status: *D0 = alive, D1 = dead with all branches, D2 = dead with no more twigs, D3: dead with only big branches, D4, dead with no more branches*

Biomass assessment project - AWF INVENTORY CHART b – lying dead wood (diameter > 10 cm)				
Date	/ /	Plot nr		OBSERVATIONS :
Team leader		Sub Transect a + b		

Outer Diameter (cm)	Inner diameter if hollow (cm)	Length (cm)	Status* (S, I, R)		Outer Diameter (cm)	Inner diameter if hollow (cm)	Length (cm)	Status* (S, I, R)

S: sound; I: intermediate; R: rotten

BioCF-CDI methodology, Appendix 3, Estimation of carbons tocks in the dead wood carbon pool, pages 101 to 104

Deadwood comprises two types: standing dead wood and lying dead wood. Different sampling and estimation procedures are used to estimate the *carbon stocks* of the two components.

$$C_{l,DW} = C_{l,SDW} + C_{l,LDW} \quad \text{(A3-25)}$$

Where:

$C_{l,DW}$ = Average *carbon stock* per hectare in the dead wood carbon pool of the *LU/LC class l*; tonnes CO_2e ha^{-1}

$C_{l,SDW}$ = Average *carbon stock* per hectare in the standing dead wood carbon pool of the *LU/LC class l*; tonnes CO_2e ha^{-1}

$C_{l,LDW}$ = Average *carbon stock* per hectare in the lying dead wood carbon pool of the *LU/LC class l*; tonnes CO_2e ha^{-1}

Dead wood shall be measured using the sampling criteria and monitoring frequency used for measuring live trees. The following description of methods to measure and estimate *carbon stocks* in the dead wood carbon pool are taken from the Sourcebook for LULUCF projects Pearson *et al.* (2006).

Standing dead wood ($C_{l,SDW}$)

a. Within the plots delineated for live trees, the diameter at breast height (*DBH*) of standing dead trees can also be measured. In addition, the standing dead wood is categorized under the following four decomposition classes:

   1. Tree with branches and twigs that resembles a live tree (except for leaves);
   2. Tree with no twig, but with persistent small and large branches;
   3. Tree with large branches only;
   4. Bole (trunk) only, no branches.

b. For classes 2, 3 and 4, the height of the tree (*H*) and the diameter at ground level should be measured and the diameter at the top should be estimated. Height can be measured using a clinometer.

c. Top diameter can be estimated using a relascope or through the use of a transparent measuring ruler. Hold the ruler approximately 10-20 com from your eye and record the apparent diameter of the top of the tree. The true diameter is the equal to:

$$True\ \ diameter - (m) = \frac{Dis\tan ce\ eye\ to\ tree\ (m)}{Dis\tan ce\ eye\ to\ ruler\ (m)} * Ruler\ measurment\ (m) \quad \text{(A3-26)}$$

Distance can also be measured with a laser range finder.

d. For decomposition class 1 the carbon content of each dead tree is estimated using the allometric or *BEF* methods applied for live trees and by subtracting out the biomass of leaves (about 2-3% of the above-ground biomass for hardwood/broadleaf species and 5-6% for softwood/conifer species).

e. For classes 2, 3 and 4, where it is not clear what proportion of the original biomass has been lost, it is conservative to estimate the biomass of just the bole (trunk) of the tree.

   The volume is calculated using *DBH* and height measurements and the estimate of the top diameter. It is then estimated as the volume of a truncated cone:

$$Volume\ (m3) = 1/3 * \pi * H * \left(r_1^2 + r_2^2 + r_1 * r_2\right) \quad \text{(A3-27)}$$

   Where:

H	=	Height of the tree; meters
r_1	=	Radius at the base of the tree; meters
r_2	=	Radius at the top of the tree; meters

   The volume is converted to dry biomass using the appropriate wood density D_j and the to carbon dioxide equivalents using the carbon fraction CF_j and CO_2/C ratio (44/12), as in the *BEF* method, but ignoring the Biomass Expansion Factor.

f. To aggregate the *carbon stock* of each standing dead tree at the plot level and then at the *LU/LC class* level, continue with step a.4 of the allometric equation method.

Lying dead wood ($C_{l,LDW}$)

Lying dead wood is most efficiently measured using the line-intersect method. Only coarse dead wood above a predefined minimum diameter (e.g. > 10 cm) is measured with this method – dead wood with smaller diameter is measured with litter.

a. At each plot location, lay out two lines of 50 meters either in a single line or at right angles. The lines should be outside the boundaries of the plot to avoid damage to seedlings in the plots during measurement, and also to biasing the dead wood pool by damaging during tree measurement.

b. Along the length of the lines, measure the diameter of each intersecting piece of coarse dead wood above a predefined minimum diameter (e.g. > 10 cm). Calipers work best for measuring the diameter. A piece of dead wood should only be measured if: (a) more than 50% of the log is above-ground and (b) the sampling line crosses through at least 50% of the diameter of the piece. If the log is hollow at the intersection point, measure the diameter of the hollow: the hollow portion in the volume estimates should be excluded.

c. Assign each piece of dead wood to one of the three following density classes:

   1. Sound

2. Intermediate
3. Rotten

To determine what density class a piece of dead wood fits into, each piece should be struck with a machete. If the blade does not sink into the piece (that is, it bounces off), it is classified as sound. If it sinks partly into the piece and there has been some wood loss, it is classified as intermediate. If the blade sinks into the piece, there is more extensive wood loss and the piece is crumbly, it is classified as rotten.

d. Representative dead wood samples of the three density classes, representing a range of species present, should be collected for density (dry weight per green volume) determination. Using a chainsaw or a handsaw, cut a compete disc from the selected piece of dead wood. The average diameter and thickness of the disc should be measured to estimate volume. The fresh weight of the disc does not have to be recorded. The disc should be oven-dried to a constant weight.

e. Calculate the wood density for each density class (sound, intermediate, rotten) from the pieces of dead wood collected. Density is calculated by the following g equation:

$$Density\ (g/m^3) = \frac{Mass\ (g)}{Volume\ (m^3)} \qquad (A3\text{-}28)$$

Where:

$Mass$ = The mass of oven-dried sample

$Volume = \pi * (average\ diameter/2)^2 * (average\ width\ of\ the\ sample)$

Average the densities to get a single density value for each class.

f. For each density class, the volume is calculated separately as follows:

$$Volume\ (m^3/ha) = \pi^2 * \left(\frac{d_1^2 + d_2^2 + ... d_n^2}{8 * L} \right) \qquad (A3\text{-}29)$$

Where:

$d_1, d_2, ..., d_n$ = Diameters of intersecting pieces of dead wood; cm

L = Length of the line; meters

g. The per hectare *carbon stock* in the lying dead wood carbon pool of each *LU/LC class* is calculated as follows:

$$C_{lLDW} = \frac{\sum_{pl=1}^{PL_l} \left(\sum_{dc=1}^{DC} Volume_{dc} * D_{dc} * CF * 44/12 \right)_{pl}}{PL_l} \qquad (A3\text{-}30)$$

Where:

C_{lLDW} = Average *carbon stock* per hectare in the lying dead wood carbon pool of the *LU/LC class l*; tonnes CO_2e ha^{-1}

$Volume_{dc}$ = Volume of laying dead wood in the density class *dc*; m^3

D_{dc} = Dead wood density of class *dc*; tonnes d. m. m^{-3}

CF = Carbon fraction; tonnes C (tonne d. m.)$^{-1}$

44/12 = Ratio converting C to CO_2e

pl = 1, 2, 3, … PL_l plots in *LU/LC class l*; dimensionless

PL_l = Total number of plots in *LU/LC class l*; dimensionless

dc = 1, 2, 3 dead wood density classes

DC = Total number of density classes (3)

Part 1: Standing Dead Wood

Step 1. Estimation of biomass of standing dead trees

Step 1.1: Standing dead trees shall be measured using the same criteria (e.g. minimum DBH) used for measuring live trees. Stumps must be inventoried as if they are very short standing dead trees.

Step 1.2: The decomposition class (not to be confused with dead wood density class) of the dead tree shall be recorded and the standing dead wood is categorized under two decomposition classes:

1. Tree with branches and twigs that resembles a live tree (except for leaves);
2. Tree with signs of decomposition (other than loss of leaves) including loss of twigs, branches, or crown.

Step 1.3: Biomass is estimated using an allometric equation or Biomass Conversion Expansion Factor (BCEF) calculation for live trees in the decomposition class 1; with no outward signs of decomposition (i.e. twigs remaining) wood density is assumed to be comparable to live tree. Calculations are detailed in the module CP-AB. In decomposition class 2, the estimate of biomass should be limited to the main trunk (bole) of the tree, in which case the biomass is calculated converting volume to biomass *using the appropriate dead wood density class*. Volume is estimated as either the volume of a cone if the top diameter cannot be measured (and is assumed to be zero), or a cylinder (using Smalian's formula) if the top diameter can be measured directly or by using an instrument such as a relascope or laser inventory instrument or estimated using a taper function. Height/length is determined as either the total height in case of a standing bole or the height at the base of the crown if the crown is persistent.

For decomposition class 2, the biomass of standing dead trees is estimated either as (where top diameter is not measured):

$$B_{SDWl,sp,i} = \frac{1}{3} * \pi * \left(\frac{BDia_{SDWl,sp,i}}{200} \right)^2 * H_{SDWl,sp,i} * D_{DWdc} \quad (1)$$

Where:

$B_{SDWl,sp,i}$	Biomass of standing dead tree *l* from sample plot/point *sp* in stratum *i*; t d.m.
$BDia_{SDWl,sp,i}$	Basal diameter of standing dead tree *l* from sample plot/point *sp* in stratum *i*; cm
$H_{SDWl,sp,i}$	Height of standing dead tree *l* from sample plot/point *sp* in stratum *i*; m
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
sp	1, 2, 3, … P_i sample plots/points in stratum *i*
i	1, 2, 3, … *M* strata in the project scenario

or (where top diameter is measured):

$$B_{SDWl,sp,i} = \frac{BDia_{SDWl,sp,i} + TD_{SDWl,sp,i}}{200} * H_{SDWl,sp,i} * D_{DWdc} \quad (2)$$

Where:

$B_{SDWl,sp,i}$	Biomass of standing dead tree *l* from sample plot/point *sp* in stratum *i*; t d.m.
$BDia_{SDWl,sp,i}$	Basal diameter of standing dead tree *l* from sample plot/point *sp* in stratum *i*; cm
$TD_{SDWl,sp,i}$	Top diameter of standing dead tree *l* from sample plot/point *sp* in stratum *i*; cm
$H_{SDWl,sp,i}$	Height of standing dead tree *l* from sample plot/point *sp* in stratum *i*; m
D_{DWdc}	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
sp	1, 2, 3, … P_i sample plots/points in stratum *i*
i	1, 2, 3, … *M* strata in the project scenario

Step 2. Estimation of biomass stock per unit area in standing dead wood

Two methods are available for sampling: either Fixed Area Plots and Point Sampling with Prisms or Relascopes.

Step 2, Option 1. Fixed Area Plots

Step 2.1: Determine the biomass of each standing dead tree present in the sample plot *sp* in stratum *i* ($B_{SDWl,sp,i}$).

Step 2.2: Calculate total biomass stock in standing dead trees present in the sample plot *sp* in stratum *i*.

$$B_{SDWsp,i} = \sum_{l=1}^{N_{sp,i}} B_{SDWl,sp,i} \quad (3)$$

Where:

$B_{SDWsp,i}$	Biomass of standing dead wood in sample plot *sp* in stratum *i*; t d.m.
$B_{SDWl,sp,i}$	Biomass of standing dead tree *l* in sample plot *sp* in stratum *i*; t d.m.
sp	1, 2, 3, … P_i sample plots in stratum *i*
i	1, 2, 3, … *M* strata
$N_{sp,i}$	Number of standing dead trees in sample plot *sp* of stratum *i*
l	1, 2, 3, … $N_{i,sp,t}$ standing dead trees in sample plot *sp* of stratum *i*

Step 2.3: Calculate the mean biomass stock per unit area in standing dead wood for each stratum:

$$B_{SDWi} = \frac{1}{A_{sp,i}} * \sum_{sp=1}^{P_i} B_{SDWsp,i} \quad (4)$$

Where:

B_{SDWi} Mean biomass of standing dead wood in stratum *i*; t d.m. ha^{-1}

$B_{SDWsp,i}$ Biomass of standing dead wood in sample plot *sp* in stratum *i*; t d.m.

Asp_i Total area of all sample plots in stratum *i*; ha

sp 1, 2, 3, … P_i sample plots in stratum *i*

i 1, 2, 3, … *M* strata

Step 2, Option 2. Point Sampling

Step 2.1: Determine the biomass of each standing dead tree from sample point *sp* in stratum *i* ($B_{SDWl,sp,i}$).

Step 2.2: Calculate total biomass stock in standing dead trees from sample point *sp* in stratum *i*.

$$B_{SDWsp,i} = \sum_{l=1}^{N_{j,sp,i}} \frac{B_{SDWl,sp,i}}{(3.1415/10000)*((DBH/100)*D:RAD)^2} \quad (5)$$

Where:

$B_{SDWsp,i}$ Biomass of standing dead wood per unit area at point *sp* in stratum *i*; t d.m. ha^{-1}

$B_{SDWl,sp,i,t}$ Biomass of standing dead tree *l* from sample point *sp* in stratum *i*; t d.m.

DBH Diameter at breast height of standing dead tree *l* at point *sp* in stratum *i*, cm

D:RAD Ratio of DBH to plot radius, specific to prism Basal Area Factor (BAF) employed in point sampling

l 1, 2, 3, … $N_{j,sp,i}$ sequence number of individual standing dead trees at point *sp* in stratum *i*

i 1, 2, 3, …*M* strata

Step 2.3: Calculate the mean biomass stock per unit area in standing dead wood for each stratum:

$$B_{SDWi} = \frac{1}{N} * \sum_{sp=1}^{P_i} B_{SDWsp,i} \quad (6)$$

Where:

B_{SDWi} Mean biomass of standing dead wood in stratum *i*; t d.m. ha^{-1}

$B_{SDWsp,i}$ Biomass of standing dead wood at point *sp* in stratum *i*; t d.m. ha^{-1}

N Number of sample points in stratum *i*; dimensionless

sp 1, 2, 3, … P_i sample points in stratum *i*

i 1, 2, 3, … *M* strata

Part 2: Lying Dead Wood

Step 1: Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996)[1]. Two 50-meter lines (164 ft) are established bisecting each sample plot and the diameters of the lying dead wood (≥ 10 cm diameter [≥ 3.9 inches]) intersecting the lines are measured. The first line is oriented along a random bearing, the second line is oriented perpendicular to the first.

Step 2: The dead wood is assigned to one of the three density states (sound, intermediate and rotten) using the 'machete test', as recommended by *IPCC Good Practice Guidance for LULUCF* (2003), Section 4.3.3.5.3. Dead wood density class (*dc*) is assessed at the point of intersection with the sample line, as per measured parameters section below.

Step 3: The volume of lying dead wood per unit area is estimated using the equation (Warren and Olsen 1964)[2] as modified by Van Wagner (1968)[3] separately for each density state:

$$V_{LDWdc,i} = \frac{\pi^2 * \left(\sum_{n=1}^{N} Dia_{dc,n,i}{}^2 \right)}{8 * L} \qquad (7)$$

Where:

V_{LDWi}	Volume of lying dead wood per unit area in density class *dc* in stratum *i*; m^3 ha^{-1}
$Dia_{n,i,t}$	Diameter of piece n of dead wood along the transect in stratum *i;* cm
n	1, 2, 3, … *N* sequence number of wood pieces in density class *dc* intersecting the transect
L	Length of the transect; 100 m
dc	dead wood density class – sound (1), intermediate (2), and rotten (3); dimensionless
i	1, 2, 3, … *M* strata in the project scenario

Step 4: Volume of lying dead wood shall be converted into biomass using the following relationship. Density of each dead wood density class (D_{DWdc}) is estimated as per guidance in measured parameters section below.

$$B_{LDWi} = \sum_{dc=1}^{3} V_{LDWdc,i} * D_{DWdc} \qquad (8)$$

Where:

B_{LDWi}	Biomass of lying dead wood per unit area in stratum *i*; d.m. ha^{-1}
$V_{LDWdc,i}$	Volume of lying dead wood per unit area in density class *dc* in stratum *i*; m^3 ha^{-1}
D_{DWdc}	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
dc	dead wood density class – sound (1), intermediate (2), and rotten (3); dimensionless
i	1, 2, 3, … *M* strata

Step 5: Mean carbon stock in dead wood for each stratum is then calculated as the sum of standing and lying dead wood components, converted to carbon dioxide equivalents

$$C_{DWi} = \left(\left(B_{SDWi} + B_{LDWi}\right) * CF_{DW}\right) * \frac{44}{12} \qquad (9)$$

Where:

C_{DWi}	Mean carbon stock of dead wood in stratum *i*; t CO_2-e ha^{-1}
B_{SDWi}	Biomass of standing dead wood in stratum *i*; t d.m. ha^{-1}
B_{LDWi}	Biomass of lying dead wood in stratum *i*; t d.m. ha^{-1}
CF_{DW}	Carbon fraction of dry matter in dead wood; t C t^{-1} d.m.
i	1, 2, 3, … *M* strata
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

How to measure above and below ground non tree woody biomass

Two methods can be used:

- Sampling frame method
- Allometric equation method

In the sampling frame method, all vegetation originating from the frame is cut at the base and weighed (dry mass must be calculated on a sample in a laboratory).
The allometric equation method may be used for shrubs, bamboo, palms. It required selecting or developing an appropriate allometric equation.

Detailed guidelines are provided by both methodologies (see below).

BioCF-CDI methodology, Appendix 3, Estimation of carbons tocks in the non-tree component pages 99 & 100

Non-tree component ($C_{l,AB,non\text{-}tree}$ and $C_{l,BB,non\text{-}tree}$)

In tropical *forests* non-tree vegetation includes palms, shrubs, herbaceous plants, lianas and other epiphytes. These types of plants are difficult to measure. Unless they form a significant component of the ecosystem, they should not be measured, which is conservative as their biomass is usually much reduced in the *LU/LC class*es adopted after *deforestation*.

Carbon stock estimations for the non-tree vegetation components are usually based on destructive harvesting, drying and weighting. These methods are described in the Sourcebook for LULUCF projects (Pearson *et al*., 2006) from which most of the following explanations are taken.

For herbaceous plants, a square frame (30cm x 30 cm) made from PVC pipe is sufficient for sampling. For shrubs and other large non-tree vegetation, larger frames should be used (about

1-2 m^2, depending on the size of the vegetation). For specific *forest* species (e.g. bamboo) or crop types (e.g. coffee) it is also possible to develop allometric equations.

When using destructive sampling, apply the following steps:

a. Place the clip frame at the sampling site. If necessary, open the frame and place around the vegetation.

b. Clip all vegetation within the frame to ground level. Cut everything growing within the quadrate (ground surface not three-dimensional column) and sample this.

c. Weigh the sample and remove a well-mixed sub-sample for determination of dry-to-wet mass ratio. Weight the sub-sample in the field, then oven-dry to constant mass (usually at ~ 70 °C).

d. Calculate the dry mass of each sample. Where a sub-sample was taken for determination of moisture content use the following equation:

$$Dry\ mass = \left(\frac{subsample\ dry\ mass}{subsample\ fresh\ mass}\right) * fresh\ mass\ of\ whole\ sample \qquad \text{(A3-23)}$$

e. The *carbon stock* in the above-ground non-tree biomass per hectare is calculated by multiplying the dry mass by an expansion factor calculated from the sample-frame or plot size and then by multiplying by the carbon fraction and CO_2/C ratio. For calculating the average *carbon stock* per *LU/LC class*, average over all samples:

$$C_{l,AB,non-tree} = \frac{\sum_{pl=1}^{PL_l} DM_{pl} * EF * CF_{pl} * 44/12}{PL_l} \qquad \text{(A3-24)}$$

Where:

$C_{l,AB,non-tree}$	=	Average *carbon stock* per hectare in the above-ground non-tree biomass carbon pool of the *LU/LC class l*; tonnes CO_2e ha^{-1}
DM_{pl}	=	Dry mass of sample *pl*; tonnes of d.m.
EF	=	Plot expansion factor = [10.000 / Plot Area (m^2)]; dimensionless
CF_{pl}	=	Carbon fraction of sample *pl*; tonnes C (tonne d. m.)$^{-1}$
44/12	=	Ratio converting C to CO_2e
pl	=	1, 2, 3, … PL_l plots in *LU/LC class l*; dimensionless
PL_l	=	total number of plots in *LU/LC class l*; dimensionless

f. The *carbon stock* per hectare of the below-ground non-tree biomass is calculated by multiplying the estimated above-ground estimate by and appropriate root to shoot ratio.

ADP Modules: Module CP-AB, estimation of carbon stocks in the above and below ground biomass in non-tree pool (part 3)

Part 3: Aboveground non-tree biomass: Estimation of carbon stocks in aboveground non-tree woody biomass ($C_{AB\_nontree,i}$)

The mean carbon stocks in the non-tree aboveground biomass pool per unit area are estimated based on previously published or default data[1] or field measurements. Non-tree woody aboveground biomass pool includes trees smaller than the minimum tree size measured in the tree biomass pool, all shrubs, and all other non-herbaceous live vegetation[2].

Non-tree vegetation can be sampled using destructive sampling frames and/or, where suitable, in sampling plots in combination with an appropriate allometric equation for shrubs.

Calculate the mean carbon stock in aboveground non-tree biomass for each stratum by adding the mean carbon stock in aboveground biomass calculated using the sampling frame method to the mean carbon stock in aboveground biomass calculated using the allometric equation method.

$$C_{AB\_nontree,i} = C_{AB\_nontree-sample,i} + C_{AB\_nontree\_allometric,i} \qquad (9)$$

Where:

$C_{AB\_nontree,i}$	Mean aboveground non-tree biomass carbon stock in stratum *i*; t CO_2-e ha^{-1}
$C_{AB\_nontree\_sample,i}$	Mean aboveground non-tree biomass carbon stock in stratum *i* from sample frame method; t CO_2-e ha^{-1}
$C_{AB\_nontree\_allometric,i}$	Mean aboveground non-tree biomass carbon stock in stratum *i* from allometric equation method; t CO_2-e ha^{-1}
i	*1, 2, 3 … M* strata

Part 3, Option 1. Sampling Frame Method:

In a stratum where non-tree vegetation is spatially variable, large frames should be used (e.g. 1-2 m radius circle). Where non-tree vegetation is homogeneous, smaller frames can be used (e.g. 30 cm radius).

Generally, the frame is placed at a randomly or systematically selected GPS point or tree plot. At each location, all vegetation originating from inside the frame is cut at the base and weighed. One representative subsample of the cut material is weighed to obtain its wet mass. The collected subsample is taken to a laboratory, oven dried and weighed to determine the dry mass. The wet to dry ratio of the subsample is then used to estimate the dry mass of the original sample.

To estimate the mean carbon stock per unit area in the aboveground non-tree biomass for each stratum:

$$C_{AB\_nontree\_sample,i} = \sum_{sfp=1}^{SFP_i} \frac{C_{AB\_nontree\_sample,sf,i}}{A_{sfp,i}} * CF * \frac{44}{12} \quad (10)$$

Where:

$C_{AB\_nontree\_sample,i}$	Carbon stock in aboveground non-tree vegetation in sampling plot in strata *i* from sample method; t CO_2-e ha^{-1}
$C_{AB\_,nontree\_sample,sp,i}$	Carbon stock in aboveground non-tree vegetation in sample plot *sfp* in stratum *i* from sampling frame method; kg d.m.
CF_j	Carbon fraction of dominant non-tree vegetation *j*; t C t $d.m.^{-1}$
A_{sfpi}	Area of non-tree sampling plot *s fp* in stratum i; ha
sfp	*1, 2, 3 … SFP$_i$* sample plots in stratum *i*
i	*1, 2, 3 … M* strata
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

Part 3, Option 2. Allometric Equation Method:

This method may be used for shrubs, bamboo, or other vegetation types where individuals can be clearly delineated.

Step 1: Select or develop an appropriate allometric equation (if possible species-specific, or if not from a similar species).

Step 2: Estimate carbon stock in aboveground biomass for each individual *l* in the sample plot *r* located in stratum *i* using the selected or developed allometric equation:

$$C_{AB\_nontreealbmetric,i,r} = \sum_{j=1}^{S} \sum_{l=1}^{N_{i,r}} f_j(vegatationparameters) * CF_j \quad (11)$$

Where:

$C_{AB\_nontree\_allometric,i,r}$	Carbon stock in aboveground biomass of non-tree sample plot *r* in stratum *i* from allometric equation method; t C

CF_j	Carbon fraction of biomass for species *j*; t C t^{-1} d.m.
f_j*(vegetation parameters)*	Aboveground biomass from allometric equation for species *j* linking parameters such as stem count, diameter of crown, height, or others ; t. d.m. $individual^{-1}$
i	*1, 2, 3, …M* strata
r	*1, 2, 3, …R* non-tree allometric method sample plots in stratum *i*
j	*1, 2, 3 … S* species
l	*1, 2, 3, …* $N_{i,r}$ sequence number of individuals in sample plot *r* in stratum *i*
t	*0, 1, 2, 3 …t** years elapsed since start of the REDD project activity

Step 3: Calculate the mean carbon stock in aboveground biomass for each stratum, converted to carbon dioxide equivalents:

$$C_{AB\_nontree\_allometric,i} = \sum_{r=1}^{R_i} \frac{C_{AB\_nontree\_allometric,r,i}}{Ar_i} * \frac{44}{12} \quad (12)$$

Where:

$C_{AB\_nontree\_allometric,i}$	Mean aboveground biomass carbon stock in stratum *i* from allometric equation method; t CO_2-e ha^{-1}
$C_{AB\_nontree\_allometricr,l,t}$	Aboveground biomass carbon stock in non-tree vegetation in sample plot *r* of stratum *i* from non-tree allometric sample plots, t C
Ar_i	Area of non-tree allometric method sample plot in stratum *i*; ha
r	*1, 2, 3 …R* non-tree allometric method sample plots in stratum *i*
i	*1, 2, 3 … M* strata
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

Part 4: Belowground non-tree biomass: Estimation of belowground carbon stocks in non-tree vegetation ($C_{BBnontree,i}$)

The mean carbon stock in belowground biomass per unit area is estimated based on field measurements of aboveground parameters in sample plots. Root to shoot ratios are coupled with the aboveground biomass estimate to calculate belowground from aboveground biomass.

Step 1: Select an appropriate root to shoot ratio for non-tree biomass.

Step 2: Use the appropriate root to shoot ratio to estimate the belowground biomass from aboveground biomass carbon stock in non-tree vegetation in sample plot *sp* of stratum *i*, t C:

$$C_{BB_{nontree},i,sp} = C_{AB_{nontree},i,sp} * R \quad (13)$$

Where:

$C_{AB\_nontree,i,sp}$	Aboveground biomass carbon stock in non-tree vegetation in sample plot *sp* of stratum *i*, t C
$C_{BB\_nontree,i,sp,t}$	Belowground biomass carbon stock in non-tree vegetation in sample plot *sp* of stratum *i*, t C
R	Root to shoot ratio; t root d.m. t^{-1} shoot d.m.
I	*1, 2, 3 … M* strata
sp	*1, 2, 3 …* P_i sample plots in stratum *i*

Step 3: Calculate the mean carbon stock in belowground biomass for each stratum, converted to carbon dioxide equivalents:

$$C_{BB\_nontree,i} = \sum_{sp=1}^{P_i} \frac{C_{BB\_nontree,sp,i}}{A_{sp,i}} * \frac{44}{12} \quad (14)$$

Where:

$C_{BB\_nontree,i}$	Mean belowground biomass carbon stock in stratum *i*; t CO_2-e ha^{-1}
$C_{BB\_nontree,i,sp}$	Belowground biomass carbon stock in non-tree vegetation in sample plot *sp* of stratum *i*; t C
A_{spi}	Area of sample plot *sp* in stratum *i*; ha
sp	*1, 2, 3 … Pi* sample plots in stratum *i*
i	*1, 2, 3 … M* strata
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}