A Training Manual

on

Wide Variety of Issues of REDD$^+$

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Acronyms

ACR	= American Carbon Registry
AD	= Activity Data (area of change in land use/land cover)
AFOLU	= Agriculture, Forestry and Other Land Use
AGB	= Above Ground Biomass
AR	= Afforestation and Reforestation
AVE	= Anthropic Vegetation in Equilibrium
BAU	= Business As Usual
BCEF	= Biomass Conversion and Expansion Factor
BEF	= Biomass Expansion Factor
BGB	= Below Ground Biomass
CCBA	= Climate, Community and Biodiversity Alliance
CDM	= Clean Development Mechanism
CER	= Certified Emission Reduction
CRGE	= Climate Resilient Green Economy
DBH	= Diameter at Breast Height
EF	= emission factor (carbon stock)
ER	= Emission Reduction
EU	= European Union
EU ETS	= European Union Emissions Trading Scheme
GHG	= Green House Gases
GPG	= Good Practice Guide
GPS	= Geographic Positioning System
IPCC	= Intergovernmental Panel on Climate Change
LA	= Leakage Area
LMA	= Leakage Management Area
LU/LC	= Land Use/Land Cover
LULUCF	=Land Use, Land-use Change and Forestry
MRV	= Monitoring Reporting and verification
PDD	= Project Design Document
PF	= Performance Factor
PIN	= Project Idea Note
QA	= Quality Assurance
QC	= Quality Control
REDD+	= Reduction of Emissions from Deforestation and Degradation
SOM	= Soil Organic Matter
tCERs	= tons of Certified Emission Reductions
tCO$_2$e	= tons of CO_2 equivalent
UNFCCC	= United Nations Framework Convention on Climate Change
VCS	= Verified Carbon Standard
VCU	= Verified Carbon Unit
WBISPP	= Woody Biomass Inventory and Strategic Plan Project
WD	= Woody Density

Contents

1. Climate change and the role of forests

Module objective: This section of the resource manual is intended to provide basic information on climate change so that the causes and impacts of climate change can easiliy be understood. In addition, the role played by forets in the climate change will be clearly explored to justify the need for measuring, reporting and verifying forest carbon stock and change. The objective of this module is to highlight the multiple relationships between forest and climate change. Forest sector related global and national initiatives to enhance its positive role and minimize its negative effect vis-a-vis climate change are also highlighted.

Learning outcomes: At the end of this module participants will be able to:

- Understand climate change, its causes and effecfs
- explain the multiple role forests play in climate change;
- understand global initiatives targeting forest sector viz-a-viz climate change;
- discuss and explain the basics of the Climate Resilient Green Economy Strategy (CRGE) design, and the place forestry will play in this CRGE strategy

Time required:

- 3 hours: 2 hrs of discussion and 1 hrs of exercise

Materials:

- Copy of the module
- Copy of CRGE document
- Copy of the Kyoto protocol regarding CDM
- Different versions of REDD, and Ethiopian REDD+
- Notebook, pen/pencil
- Flip chart and markers
- LCD

Training method:

- Start with participants sharing their knowledge/experiences about climate change (causes and impacts), as well as mitigation measures;
- Allow participants to read the module and discuss in group breakout sessions on the role of forests including global and national initiatives that target forestry;
- Group work on module exercises, and
- Summary of the module by the trainer.

1.1. Definitions of Important terminologies related to climate change

A. Climate change is a **consistent deviation** of climate pattern from historically recorded known average, and from what is considered normal temperature and rainfall fluctuation or variability. This means the deviation is in one direction -either increase or decrease – and for **long period** of time.

B. Climate variability: Variations in the climate statistics from the long term statistics over a given period of time. Variations (ups and downs) in climatic conditions on time scales of months, years and it includes droughts and floods.

C. Global warming: The gradual increase of the Earth's average surface temperature.

D. Vulnerability: The propensity or predisposition to be adversely affected and it implies the degree to which a system is susceptible to harm or unable to cope with adverse effects of climate change.

E. Resilience: the capacity of a community, or a system, to withstand and recover from changes in climate (E.g. from increased frequency and intensity of extreme weather events)

F. Mitigation: actions to reduce greenhouse gas emissions and to enhance carbon sink to curb climate change. Mitigation mainly focuses on managing the greenhouse gasses – sources and sinks of the greenhouse gasses.

G. Adaptation: The process of adjustment to actual or expected climate and its effects. It Involves adjustments to enhance the viability of social and economic activities to reduce their vulnerability to climate change

1.2. Greenhouse effect

The Earth receives most of its energy from the sun in the form of short wave radiation. Much of this incoming solar radiation passes through the atmosphere to reach the Earth's surface. The Earth absorbs some of this energy and radiates some back into the atmosphere in the form of infrared radiation. Outgoing infrared radiation has a longer wavelength than incoming solar radiation and can therefore be absorbed by certain gases in the atmosphere. The main gases that absorb infrared radiation are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and haloflourocarbons (HFCs). These gases trap some of the infrared radiation and re-radiate it back to the Earth's surface, causing a warming effect known as the "greenhouse effect" (Figure 1). Anyone who boarded a closed car in a sunny day, experiences a hot temperature inside the car because of the glass allowing light to

enter but blocking the heat energy converted from the entered light energy to escape out of the car due to changed wavelength. This is a good example of what is called '**greenhouse effect**'.

Under natural concentration, GHG in the earth's atmosphere keep the earth warm, making it conducive for living bodies to flourish on earth. However, as their concentration increases their warming effect is increasing. The natural greenhouse effect is necessary to life as it maintains the Earth's surface temperature at an average of 15ºC, 33ºC warmer than it would be otherwise (NOAA, 2007).
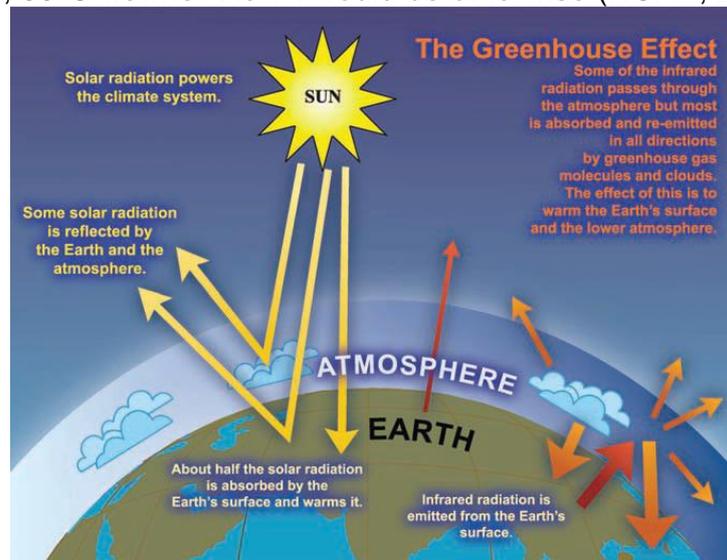
Figure 1. The Greenhouse gas effect (*Source: IPCC, 2007*)

1.3.   *Greenhouse Gasses*

Greenhouse gases (GHGs) are gases released into the atmosphere and trap heat and thereby contribute to the warming of the earth's surface. Major GHG causing global warming are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), fluorinated gases and Ozone. Over the last two conturies, the burning of fossil fuels and the destruction of forests have caused the concentrations of heat-trapping greenhouse gases to increase significantly in our atmosphere (Figure 2). With more of these gases in the atmosphere, more radiation is absorbed and re-radiated back to Earth as heat. Thus, as the concentrations of these gases continue to increase in the atmosphere, the Earth's temperature also continues to increase. In the 20th Century, global temperatures have increased by 0.7ºC (1.3ºF) (IPCC, 2007). The same source indicates that if concentrations of greenhouse gases in the atmosphere continue to increase, the average temperature at the Earth's surface could increase by more than 2ºC above 2000 levels by the end of the 21st century.
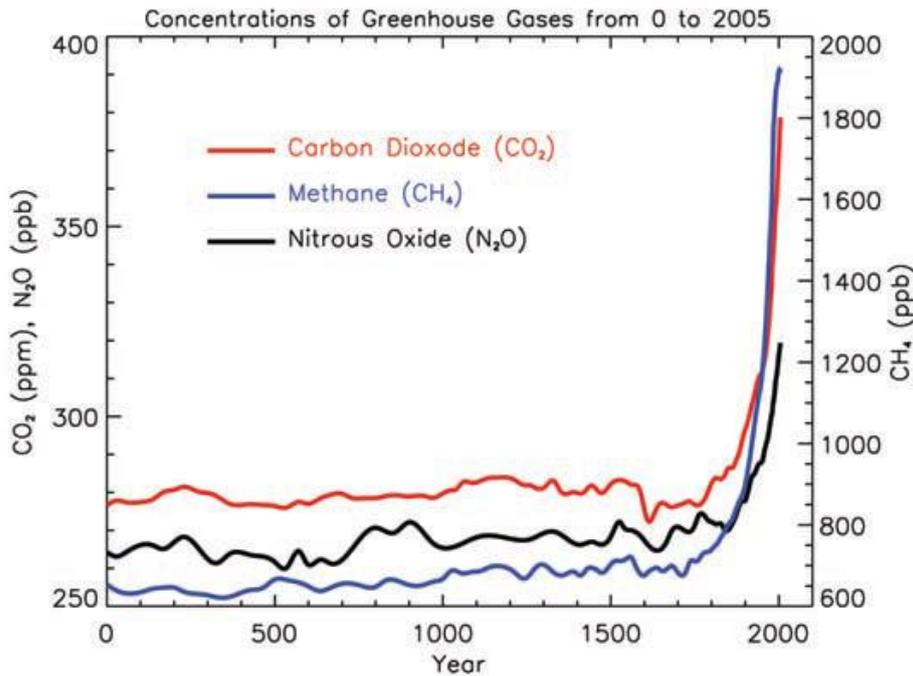
Figure 2. Concentration of GHGs from 0 to 2005.

All GHGs contribute to climate change, but not all GHGs have the same level of impact – the relative potential to contribute to global warming is based on both how long the gas will stay in the atmosphere and their ability to absorb infrared radiation (Table 1). The global warming potential indicates the level of impact each gas has on the climate relative to the impact of carbon dioxide (CO_2). Carbon dioxide is the greenhouse gas that is most often mentioned in the context of climate change. This attention is due to the fact that CO_2 is the most prevalent greenhouse gas released by human activity and 75% of the increase in atmospheric CO_2 concentration since pre-industrial times is due to fossil fuel combustion, with the largest contribution from energy, industry and cement manufacture (IPCC, 2007). Because CO_2 is so prevalent, it is one of the most important emissions to address when mitigating climate change. Other gases, however, make a significant contribution to global warming despite lower emission levels. Nitrous oxide, for example, remains in the atmosphere longer than CO_2 and it absorbs 296 times more infrared radiation than CO_2.

Table 1. Warming potential and other properties of various GHGs.

Gas name	Chemical formula	Lifetime (years)	Global warming potential (GWP) for given time horizon		
			20-yr	100-yr	500-yr
Carbon dioxide	CO_2	30–95	1	1	1
Methane	CH_4	12	72	25	7.6
Nitrous oxide	N_2O	114	289	298	153
CFC-12	CCl_2F_2	100	11 000	10 900	5 200
HCFC-22	$CHClF_2$	12	5 160	1 810	549

1.4. Sources of Greenhouse Gasses

There are two causes of climate change: **anthropogenic and natural causes**. The natural causes include volcanic eruptions that inject volcanic ashes, aerosols as well as carbon and sulphur oxides. However, the impacts such natural events have in affecting the climate is short term. Climate also changes as part of natural process but over a geological time scale. The main causes for increased GHGs concentration in the atmosphere include anthropogenic activities (See also figure 3.):

- Burning of fossil fuels: oil, gasoline, gas and coal
- Industrial processes and mining (e.g. cement manufacturing);
- Landfills, septic and sewer systems (mainly responsible for methane gas emissions)
- Agricultural practices, including fertilizer and manure management
- Forest clearance, degradation and burning
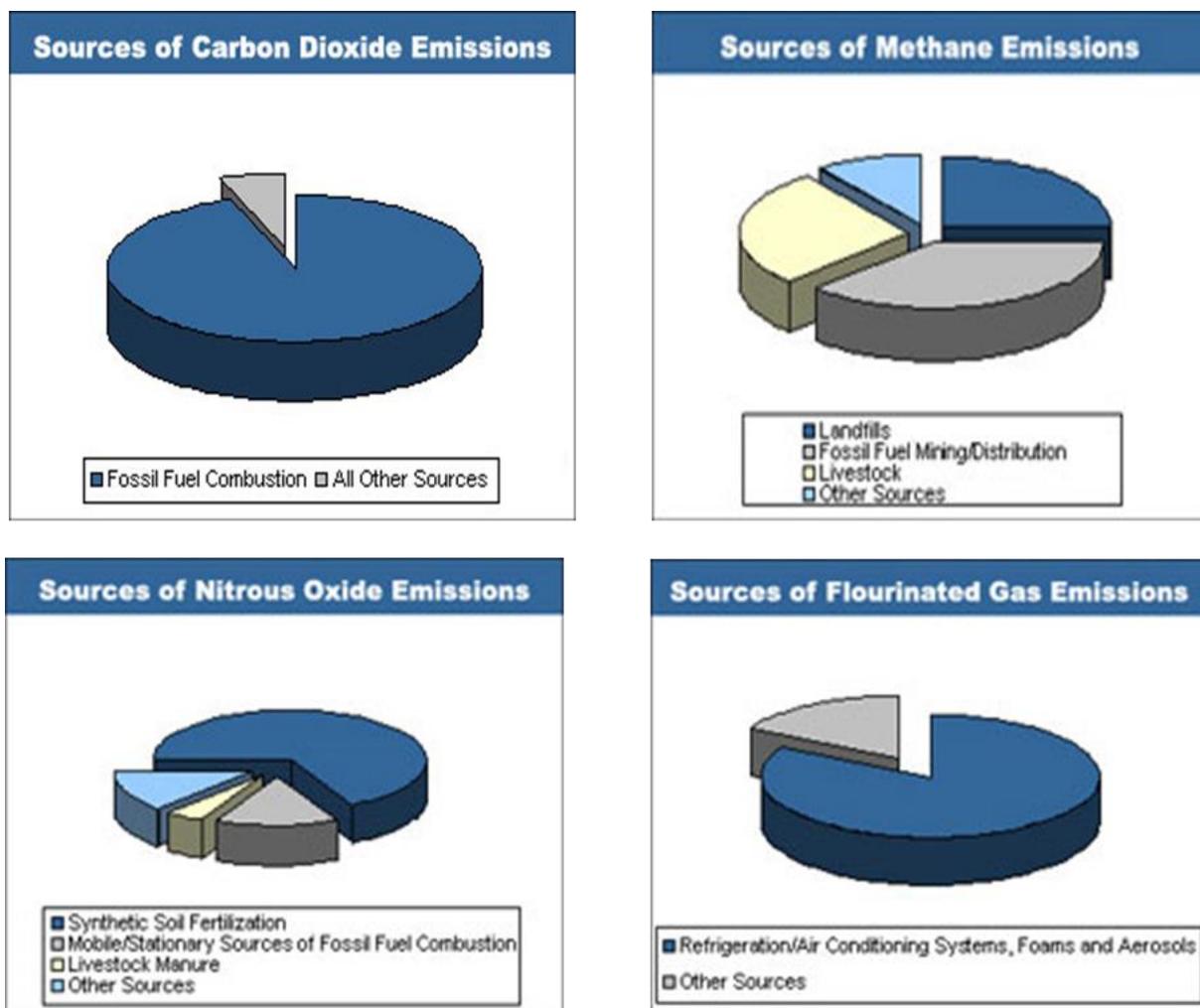
Figure 3. Sources of major GHGs (http://www.whatsyourimpact.eu.org)

The energy sector contributes the highest GHG emission followed by forestry and land use changes (Figure 4). When agriculture and transport are added to these two sectors, they jointly contribute for over 60% of global GHG emission.
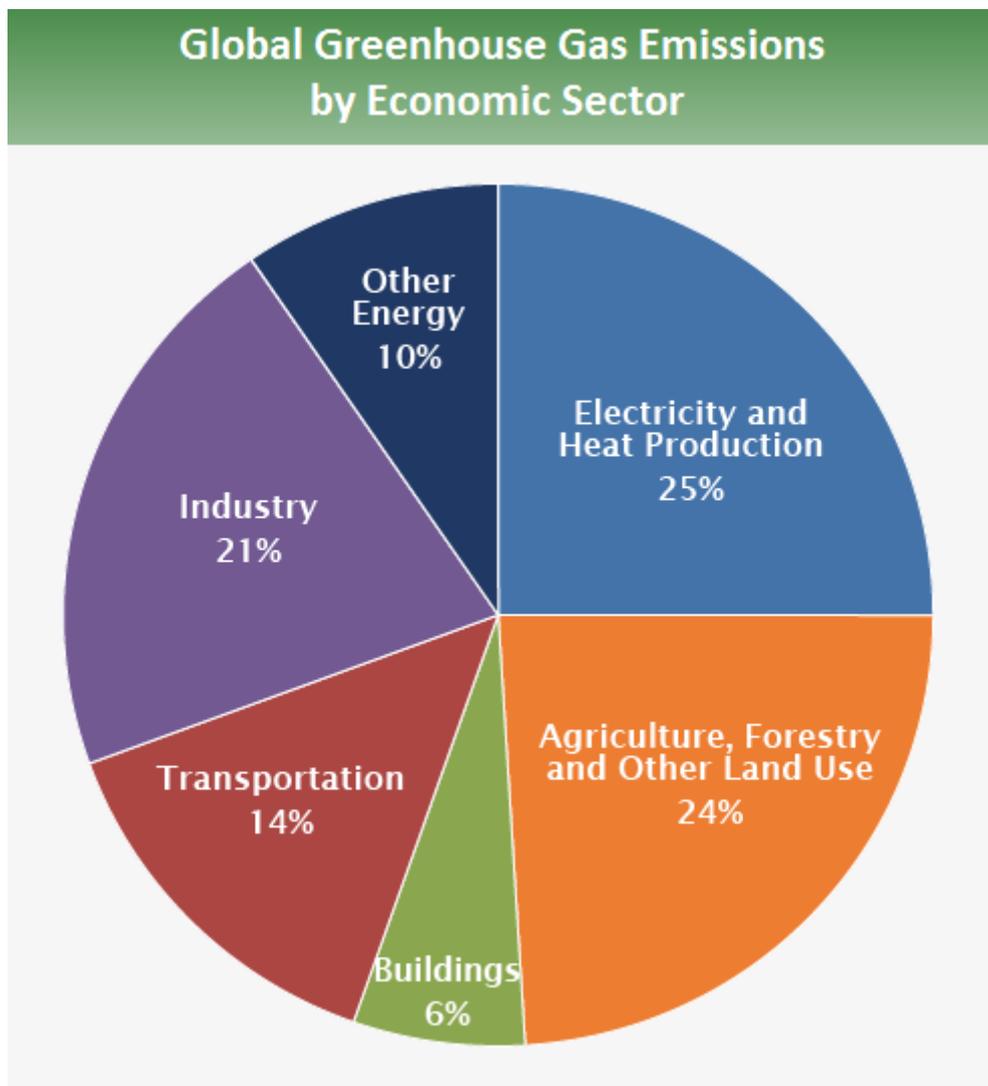
Figure 4. Relative importance of various anthropogenic activities to the GHG emissions, including forest sector (IPCC, 2014)

China is the leading top emitor of GHGs in recent years (Figure 5). However, United States is the leading country in terms of per capita emission.

Annual Emissions of Top 10 Emitters in 2011
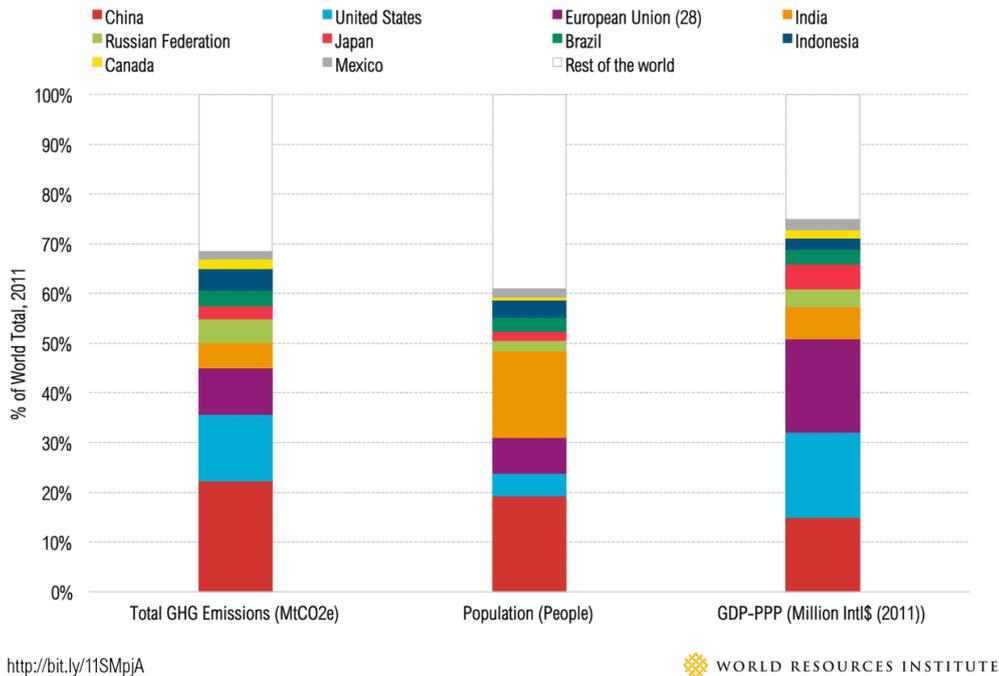
Figure 5.The top 10 emittors of GHGs (2011).

1.5. *Manifestations of climate change*

The following are the major manifestations of climate change;

A. **Temperatures are rising:** The average global temperature has warmed by more than 0.7°C over the past century, and the present warming rate is 0.2°C per decade.

B. **More extreme weather:** Extreme events (major storms, big winds) are increasing in magnitude and/or frequency with global warming.

C. **Rainfall is changing:** Based on the region precipitation increase or decrease.

D. **Flora and fauna are relocating:** shifts in their range of occurrence

E. **Decline in ice mass:** Glaciers, sea ice and ice sheets are shrinking

F. **Sea levels are rising:** There is strong evidence that global sea level is now rising at an increased rate and will continue to rise during this century. The two major causes of global sea-level rise are thermal expansion caused by the warming of the oceans (since water expands as it warms) and the loss of land-based ice (such as glaciers) due to increased melting. Records indicate a rate of rise of 0.30 cm per year (seehttp://oceanservice.noaa.gov/facts/sealevel.html).

1.6.   Climate change scenarios and its underlying principles.

Scenarios are alternative images of how the future might unfold and are an appropriate tool with which to analyse how driving forces may influence future emission outcomes and to assess the associated uncertainties. Future greenhouse gas (GHG) emissions are the product of very complex dynamic systems, determined by driving forces such as demographic development, socio-economic development,and technological change. Their future evolution is highly uncertain. They assist in climate change analysis, including climate modeling and the assessment of impacts, adaptation, and mitigation. The possibility that any single emissions path will occur as described in scenarios is highly uncertain. Acording to a sepecial report on emission scnarios (SRES) by IPCC, (2000), four storylines and six scenario families were developed (Figure 6).

Figure 6. Storylines and emission scenario families of SRES (IPCC, 2000).

Box 2. Description of the storylines and scenario families (IPCC, 2000)

Each storyline assumes a distinctly different direction for future developments, such that the four storylines differ in increasingly irreversible ways. Together they describe divergent futures that encompass a significant portion of the underlying uncertainties in the main driving forces. They cover a wide range of key "future" characteristics such as demographic change, economic development, and technological change. For this reason, their plausibility or feasibility should not be considered solely on the basis of an extrapolation of *current* economic, technological, and social trends.

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

The B1 storyline and scenario family describes a convergent world with the same global population that peaks in midcentury and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

1.7. Climate change in Ethiopia

It is stated in the CRGE (2011) the annual emission of GHGs (data 2010) in Ethiopa is 150 Mt CO_2 equivalents and that agriculture and forestry are the two major sources of GHGs (Figure 7). Compared to the global annual emission of the same year, the emission from Ethiopia is less than 0.3%. However, the impacts of climate change will reach Ethiopia since it is a global phenomenon.
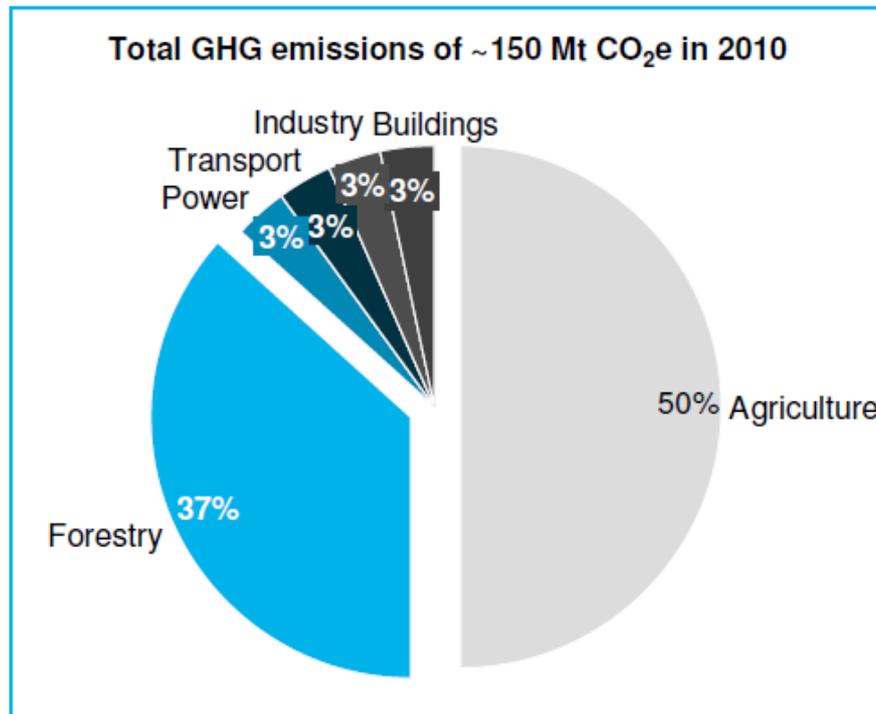
Figure 7. Sources of GHGs in Ethiopia (CRGE, 2011)

According to NMA (2007), there has been a warming trend in the annual minimum temperature over the past 55 years with about about 0.37°C every ten years (Figure 8). Projections indicate that mean annual temperature across the country will increase with a range of 1.4 to 2.9^{0}C by the 2050s (Conway and Schipper, 2011).

National average annual minimum temprature differnce compared to 1971-2000 normal

$y = 0.0372x - 1.2835$
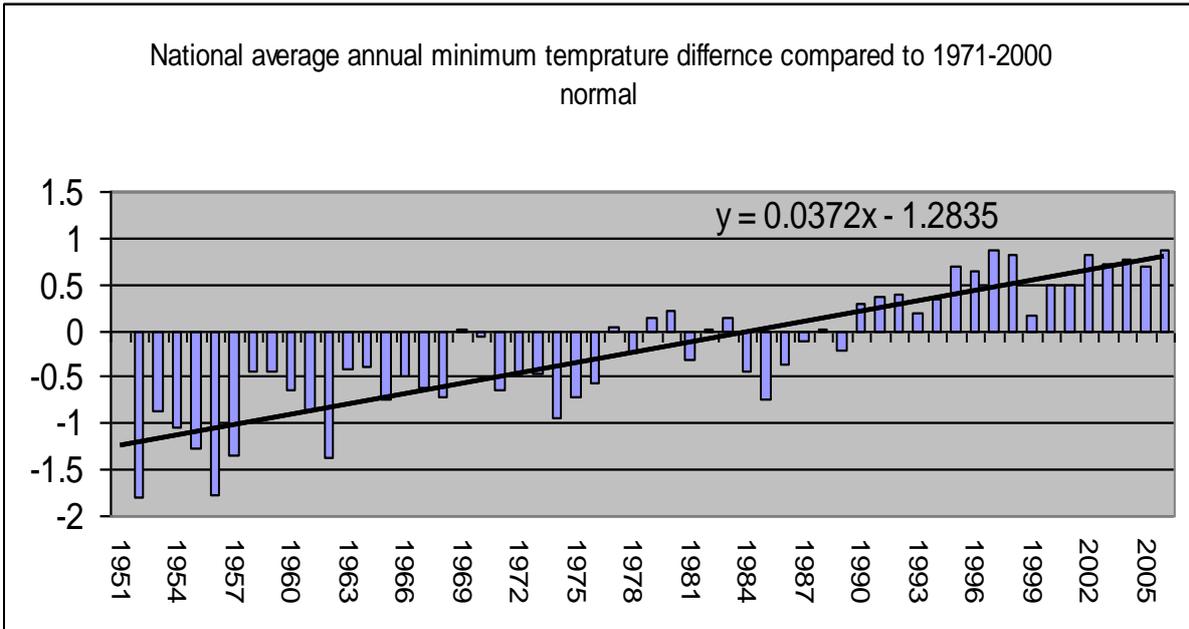
Figure 8. Year to Year Variability of Annual minimum Temperature over Ethiopia expressed in temperature (NMA 2007).

The same study (NMA, 2007) showed that the rainfall remained more or less constant when averaged over the whole country though high variability has been observed over the years (Figure 9). According to World Bank (2010), projections regarding rainfall are less certain, but suggest the possibility of more frequent and intense patterns of extreme weather.

National average of standardized annual rainfall anomaly compated to 1971-2000 normal
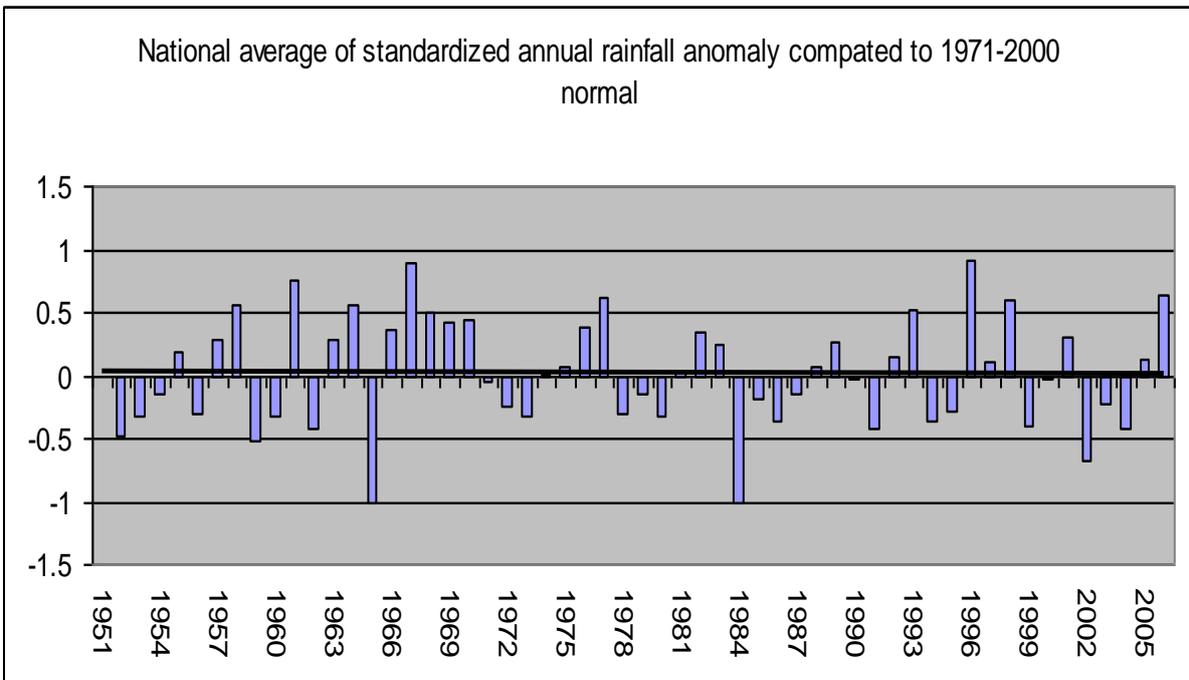
Figure 9. Year to Year Variability of Annual Rainfall and trend over Ethiopia expressed in Normalized Deviation (NMA, 2007).

Main climate change related hazards frequently occurring in Ethiopia are (NMA, 2007, Yirgu et al., 2013):

- floods,
- drought and erratic rainfall patterns
- disease/pest prevalence (crop, human and livestock), and
- wind hazards.

These hazards affect all key sectors: agriculture, health, water, energy, forestry and infrastructure. Drought and flood episodes are increasing in the country, and their impacts. For instance, major floods occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 leading to loss of life and property. According to National Metrological Agency (2006) report:

- more than 250 people died, about 250 people were unaccounted for and more than 10,000 people became homeless due to the Dire Dawa flood,
- more than 364 people died, and more than 6000 people were displaced due to flooding of about 14 villages in South Omo,
- more than 16,000 people were displaced in West Shewa,
- similar situations also occurred over Afar, Western Tigray, Gambella Zuria and the low-lying areas of Lake Tana, and
- in terms of loss in property and livestock, flood of the same year affected about 199,000 people, drowned more than 900 livestock over South Omo alone, and washed away 2700 heads of cattle and 760 traditional silos were washed away, and over Dire Dawa, the loss in property is estimated in the order of tenth of millions of dollars.

It was stated that (CRGE, 2011) climate change related impacts will increase in the future unless effective steps are taken to build resilience. World Bank (2010) suggested that climate change may reduce Ethiopia's GDP by up to 10% by 2045. Various studies have stated that climate change will influence production of various crops such as teff, wheat, Enset and Coffee (e.g. NMA, 2007; Davis et al., 2012; Yirgu et al., 2013). These declines are caused through shortening of growing season and increased prevalence of crop pests and diseases. A recent study by Funk et al. (2012) showed that the areas receiving sufficient Belg rains have contracted by 16% and the areas receiving sufficient Kiremt rains has also contracted by 20% from the observations made between 1990 to 2010.

1.8. Roles of forests in climate change mitigation and adaptation

Forests as source of GHGs and cause for climate change

Forests cover a total of 4 billion hectares worldwide, equivalent to 31% of the total land area (FAO, 2010). About 45% of the earth's terrestrial carbon is stored in these global forests. Yet, the global forests are disappearing rapidly and as a result they are emitting large carbon to the atmosphere. Between 1990 and 2010 there was a net loss of 8.3 million hectares forests per year emitting huge tons of CO2 to the atmosphere (FAO, 2010). A major consequence of this deforestation is the release of considerable heat-trapping carbon dioxide (CO_2) and other GHGs into the atmosphere, since half (50%) of the biomass in the lost forest is carbon. At the global level nearly 1/5th of GHG released into the atmosphere comes from the forest sector, and this is the second most important human induced sources of GHG after fossil fuel combustion.

While developed countries are contributing to climate change through GHG emissions from industries and transport sectors, developing countries are contributing their shares and accountable for emissions through land use change, mainly deforestation and conversion of forest land to other land uses. Unless deforestation and forest degradation is reversed, this huge stock can be released, and continue to contribute to further change in climate. In Ethiopia, the forest sector is the second largest source of national GHG emission (55 million tCO_2e) after agriculture (75 million tCO_2e) (Figure 3). Under the Business-As-Usual scenario in the country, the next 20 years would lead to emission of 90 million tCO_2 from the forest sector, making it still the second largest source of emission for years to come (CRGE, 2011).
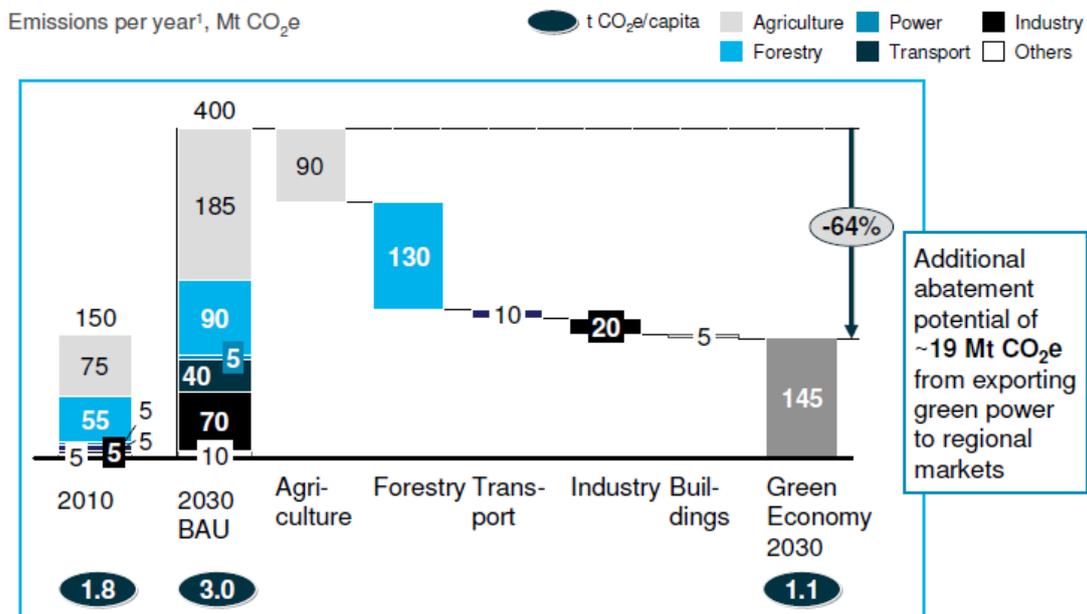
1 Rounded numbers
2 Currently estimated emissions form buildings and waste

Forests for mitigation of climate change

In a simple term, mitigation refers to reducing drivers of climate change such as reducing heat trapping gasses from being emitted to the atmosphere or sequestering back from the atmosphere those already emitted. Forests play three integrated roles in the process of mitigating climate change (Figure 10):

- First, they are important component of the terrestrial ecosystems that remove (absorb) nearly 3 billion tons of anthropogenic carbon every year (3 Pg C year−1) through net growth. They absorb about 30% of all CO_2 emissions from fossil fuel burning and net deforestation. Therefore, if existing global forests are well conserved and managed, they can continue trapping GHGs and help mitigate climate change;
- Second, the 4 billion hectares of forest ecosystems existing today in the world are storehouses of large carbon. Avoiding the loss of this stock and managing it is essential in mitigating further release of GHGs and climate change, and
- Third, reforestation/afforestation of degraded forestlands and non-forestlands and improving management of existing stands offer cheap and fast means of sequestering already emitted GHGs.

Forests also provide green energy when produced from sustainably managed forest or new forest (afforestation/reforestation balanced with harvesting) that can offset emissions from use of energy from non-green sources such as coal and fossil fuels; hence can reduce overall realise of GHG from other sources as well (Figure 10).
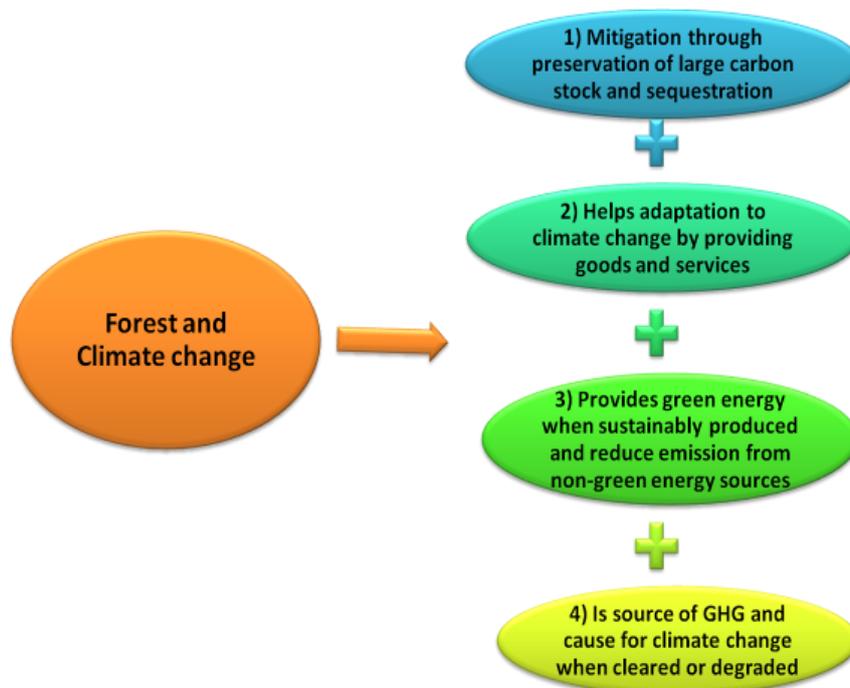
Figure 10. Multiple roles of forest in global climate change

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Ensuring these roles of forests in global carbon cycle is essential to mitigate climate change. Measures that can reduce deforestation and forest degradation, and improve management of forest ecosystems may involve a number of actions in **the forest sector as well as outside forest sector**. These include: improving institutional setups (rules, rule enforcement mechanism and organizational structural) and getting incentive mechanisms right (e.g. development of forest market, investment in forest industries, improvement on forest/tree tenure, etc) that improve sustainable forest management rather than conversion; promoting biomass energy efficiency or shifting to other sustainable green energy sources (e.g. hydropower); sustainable intensification and promoting of green agriculture, developing new forests as sustainable and carbon neutral sources of wood products and the like.

Forests for adaptation to climate change

Adaptation refers to coping with the adverse effects of climate change such as drought, flood and others. Forests play multiple roles to safeguard households and communities against climate change. First, they provide wild edible food. These foods enrich nutritional wealth but also help as coping strategies during food shortage seasons including during crop failures. A good example of edible forest product is *Moringa stenopetala*. The plant is widely consumed and its nutrient- and vitamin-rich leaves and shoots, enrich household nutritional security.

Second, forests in particular are major sources of cash income both summer and winter (Yemiru, 2010). These incomes support households to purchase food and non-food items including during slack periods. The significant income contribution from own trees and nearby forests to support local livelihoods and to serve as strategy for income diversification has been re-iterated in many recent studies (e.g. Bluffstone et al., 2008; Lemenih, 2012). Studies reports the share of forest incomes in household total income to range from 27% (e,g. in Tigray) (Babulo et al. 2008) to as high as 40% (in Chilimo) (Mamo et al. 2007). In terms of cash income alone the contribution of forests will rise sharply. Typical attribute to forest income is also its pro-poor nature. Its relative contribution to household income is always high for the poor, and because of that it plays income equalizing effects. This means it safeguards the most vulnerable and poor groups of the community, which are also most susceptible to impacts of climate change and variability. Because of this, local communities enlist forests and trees outside forests as part of the menus of options used in adaptation to climate change (e.g. Deressa et al., 2008). Deressa et al (2008) in their study within the Blue Nile basin showed that planting trees was the number one adaptation measure proposed by local communities (Figure 11). Additionally, forests play a role in normalizing extreme weather events and provide prevention of frost, flood, heat and enhances ground water recharge, which strengthen adaptation and reduce vulnerability.
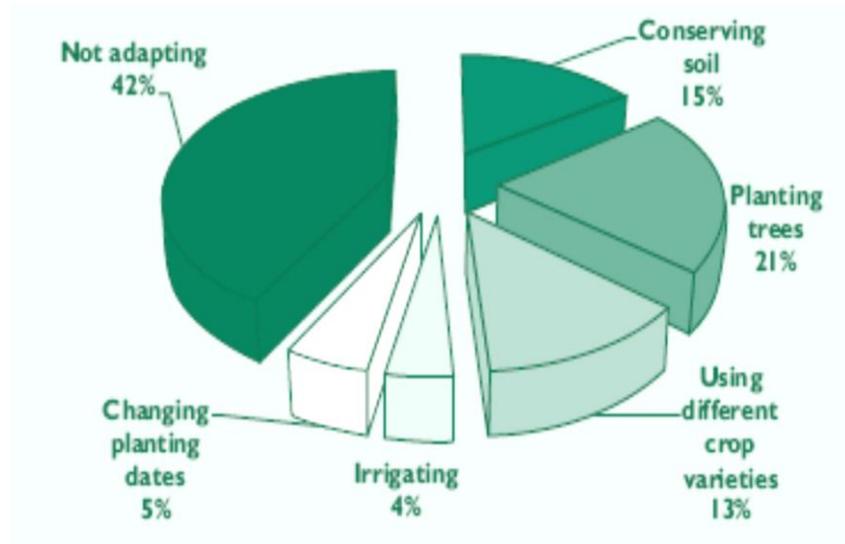
Figure 11. Farmers' preferred options for adapting to climate change in Ethiopia (**Source:** Deressa et al., 2008)

Third, forests through sustaining and improving the quality and quantity of ecosystem services supply and sustain productivity of other economic sectors such as agriculture. Forests provide protection or regulatory services to watersheds. They reduce soil erosion and run-off, which improves water flow regime. They also provide supportive services whereby they play important role in soil formation and enhance soil fertility and hence productivity.

Global initiatives related to forests and climate change

Forest is one of the major focuses in global efforts to fight climate change. It was among the components included in the Kyoto protocol signed in 1997, forming part of the Clean Development Mechanism (**CDM**) as Afforestation and Reforestation (A/R). In the Kyoto protocol, the role of forest is considered as means to absorb carbon (**emission removal**). The **CDM** is a market-based mechanism, driven by demand for credits - certified emission reductions - from private or public entities in **developed countries**, to fulfil part or whole of their emission **gaps,** by purchasing supply from offset projects in **developing countries**. CDM projects which reduce GHG emissions from sources can be carried out in many sectors including forestry. AR projects qualify as CDM projects because of their abilities to remove carbon from the atmosphere. Currently, it is the **only forest carbon** category eligible to earn credits under the **compliance markets**. Under CDM A/R, the approved methodologies give project developers options to manage and harvest forests for bio-energy and timber production.

Despite its international recognition and potential to mitigate climate change, the AR sector still remains underdeveloped. This is mainly due to two main reasons:
- Firstly, the temporary nature of carbon sequestered in such forest, i.e. impermanence (temporary nature) of its carbon, which is taken into account by special types of expiring carbon credits (tCERs). The market for such temporary credits is limited, and compounded by the EU's decision to exclude forestry

credits from the EU Emissions Trading Scheme (EU ETS), the overall market for AR base carbon offset become low (Ecosystem Marketplace, 2012), and

- Secondly, many project developers lack capacity to apply the stringent rules and complicated methodologies of AR.

In fact, the Kyoto protocol has expired officially in 2012, but there is global negotiation to continue it. Given the positive improvements in performance of the AR sector, and rise in project registrations and a significant increase in volumes contracted, there seems high chance for global community to agree to continue it. According to BioCarbon Fund (2011), scaling up A/R activities is critical to mitigating climate change, improving rural livelihoods, improving resilience to climate change, conserving biodiversity, restoring degraded lands, and strengthening the human, social, and financial capital of local communities. They consider four key areas which need to be resolved to remove bottlenecks and unnecessary obstacles:

- regulatory improvements,
- access to finance,
- strengthened capacity, and
- increased demand for credits from A/R CDM projects.

Reduction of Emissions from Deforestation and forest Degradation (REDD+) is another dimension that considers the role of forest in climate change mitigation. CDM based AR initiatives are meant to trap back the released GHGs in a growing tree biomass or forest soils (emission removal), while REDD+ initiative aims at **preserving the huge carbon stock** existing in global forests, particularly those in the developing countries that are suffering rapid deforestation and degradation, from being released. Both schemes are carbon management instruments targeting global climate change mitigation. Yet both have some degree of difference as summarized in the table2 below. Tackling deforestation and degradation of tropical forests is the way to preserve this carbon stock form release. Consequently, Reducing Emissions from Deforestation and forest degradation in Developing countries (**REDD+**) is emerging as a global initiative to deal with climate change.

Table 2. Brief comparison of CDM and REDD+ schemes

Attributes	CDM	REDD+
Scope or forest types of focus	New planted or regenerated forests (AR) on degraded lands. I.e. crediting for AR	Existing old growth forest. Crediting mainly from existing forests saved from deforestation and degradation, although the plus sign also credit conservation and carbon enhancement
Main GHG effect	Sequestration of already emitted GHG back from the atmosphere (Carbon removal)	Preservation potentially emitted carbon (carbon emission reduction) plus carbon enhancement
Legal status	Both voluntary plus compulsory (binding). It is	So far voluntary. No binding global agreement

	part of the binding Kyoto protocol agreement though it is one of the flexible mechanisms included in the agreement	so far
Additional benefits	Mainly climate, some economic benefit to the local people.	Biodiversity and community benefits also equally stressed
Methodology	Mainly CDM modalities and procedures adopted by the Parties to the Kyoto Protocol as well as methodologies and tools approved by the CDM Executive Board. New methodology can be developed but should be approved before being applied by the Executive Board	Many alternatives exist (e.g. VCS, plan-vivo, WB, etc). New methodologies can also be developed to fit to existing contexts but these should also be approved by concerned global actors such as VCS, etc.
Sectoral aspect	Mainly forestry	Multi-sector to avoid drivers of deforestation and degradation
Actors	Any legal entity (private to public)	Same
Risks to forest dependent communities	None to low. But requires analysis of socio-economic impacts.	Medium to high if not properly designed and implemented
Scale	Usually project based, hence small scale	Current argument is national or sub-national scale, Jurisdictional
Potential impact in CC mitigation	Limited and usually short term	Significant and usually long term,
Compliance & Liability	Low host country involvement	Higher host country involvement
Baseline	Land use pre-1990 (usually degraded or empty lands)	Historical reference level (10 years before the REDD+ project start date)

REDD+ is a framework through which developing countries like Ethiopia that are hotspots of deforestation are rewarded financially for any emissions reductions achieved associated with a decrease in the deforestation and degradation of forests. By identifying current and/or projected rates of deforestation and forest degradation (baseline), a country taking remedial action and effectively reduce those rates will be financially rewarded relative to the extent of their achieved reduction in forest loss or emissions reductions from it.

In addition to reducing emissions from deforestation and forest degradation, the REDD negotiations have evolved to include the conservation of forest carbon stocks,

sustainable management of forests and enhancement of forest carbon stocks; REDD+, where the plus sign refers to this enhancement actions. The five eligible activities under REDD+ are shown in figure 12 below:
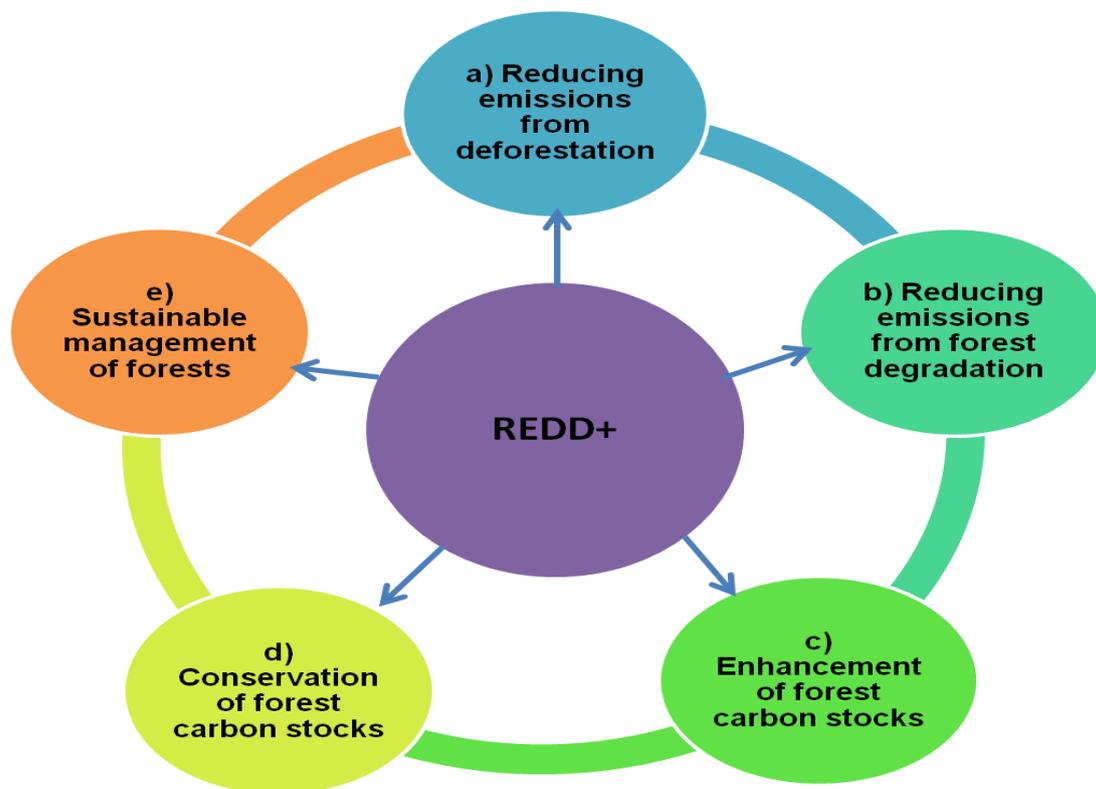
Figure 12. Eligible activities under REDD+ project

National Initiatives and forest related projects/programs

Ethiopia is experiencing impacts of climate change and is likely to be affected more if the change is not mitigated. The vulnerability of Ethiopia emanates from its poor and susceptible economy, which is predominantly climate dependent such as agriculture. The far reaching impacts of climate change are well recognized in the country, and the necessary institutional setup is being in place. Several projects, programs and strategies to mitigate and/or adapt to it are developed. Many of the initiatives recognize the roles of the forest sector. One such example is the national REDD+ initiative through the World Bank's Forest Carbon Partnership Facility. A bold national initiative towards climate change is the CRGE strategy, which aims to ensure climate resilient and green growth in the country. One of the four pillars of the CRGE is forestry.

Under the forestry pillar of CRGE, the following initiatives are proposed:
• Reduce demand for fuelwood via the dissemination and usage of fuel-efficient stoves and/or alternative-fuel cooking and baking techniques (such as electric, LPG, or biogas stoves) leading to reduced forest degradation,
• Increase afforestation, reforestation, and forest management to increase carbon sequestration in forests and woodlands. These initiatives would result in an increased storage of carbon in Ethiopia's forests, provide a basis for

sustainable forestry, and even allow the forestry sector to yield negative emissions, i.e., store more carbon in growing forests than are emitted from deforestation and forest degradation.

- Promoting area closure via rehabilitation of degraded pastureland and farmland, leading to enhanced soil fertility and thereby ensuring additional carbon sequestration (above and below ground).

Table 3. GHG emissions and abatement potentials of the various sectors as presented in the CRGE strategy (Source: CRGE, 2011)

Economic sector	Current emission (million tCO$_2$e)	BAU emission For 2030 (million tCO$_2$e)	CRGE emission By 2030 (million tCO$_2$e)	Emission reduction (million tCO$_2$e)
Agriculture	75	185	95	90
Forestry	55	90	-40	130
Power	5	5	5	10
Transport	5	40	20	20
Industry	5	70	65	5
Others	5	10	0	0
Total	**150**	**400**	**145**	**145**

As indicated in table 3, forestry sector is expected to contribute the largest abatement potential to ensure the envisaged green growth in the country. The sector is expected not only to neutralize its sectors emission, but to offer about 40 million tCO2e emission reduction to neutralize the emission from other sectors, which can ultimately be traded as payments for mitigation efforts. Therefore, the role of the sector in ensuring green economy via mitigating and adapting to climate change is huge.

At project level there are several initiatives in the country, both CDM and REDD+. A number of CDM projects are recognized today in Ethiopia that comprises:

♦ Humbo Assisted Natural Regeneration Project targeting an area of 2,728 hectares;
♦ Abote District Afforestation/Reforestation project with an area of 2,000-3,000 hectares;
♦ Ada Berga District Afforestation/Reforestation project with an area of 4,500-6,000 hectares;
♦ Sodo Farmers Managed Natural Regeneration & Agro-forestry project with an area of 2,200 hectares, and
♦ An Afforestation/Reforestation project in Amhara National Regional State under discussion, and comprising over 20,000 hectares.

The Humbo CDM project is the first A/R project to be registered in Africa. The carbon credit of the project is purchased by the World Bank's Bio-Carbon Fund, creating an important revenue stream for project participants. The expected total carbon sequestration of the project is about 200,000 million tons of CO2e by 2017. The Bank's Bio-Carbon Fund purchased 165,000 tons worth of the carbon credits and will provide an income stream of more than US$700,000 to the local communities over a minimum of ten years. Further revenue will be available to the community from the

sale of the remaining carbon credits not purchased by the World Bank, as well as from the sale of timber products from designated woodlots in the Project. Similarly, Ethiopia is also making good progress with REDD+ initiatives. The Oromia Forested Landscape REDD+ project and the Bale REDD+ pilot projects are worth mentioning. The **Oromia Forested Landscape REDD+ project** is estimated to generate 260 M CO_2e by GHG emission reduction by 2030. **The Bale Eco-Region REDD+ project** is estimated to achieve 37 million tCO2e emission reductions in 20 years. The Bale REDD+ project is already in the process of validation and the PDD of the project uploaded on VCS and CCBA web pages (http://www.climate-standards.org/2014/05/27/bale-mountains-eco-region-redd-project).

While these progresses in the country are encouraging supports from the international community, research in the area have been weak. Supports from research and academic institutions need to be intensified to make Ethiopia more and more integrated into carbon market as well as realize its green growth vision. Most priority areas where research should address include among others: the carbon sequestration potentials of the various forests and vegetation types in the country (whether planted or natural), how forest management (e.g. tree species planted, stocking, density, logging and the like) affects carbon uptake and release and modeling carbon dynamics in the different ecosystems need to be researched and understood to guide effective implementation of the CRGE strategy.

Module Exercise

1. Download and read thoroughly the CRGE document of Ethiopia. After reading it
    a) Identify the main sectors contributing to GHG emission in the country, and the amount of their current emissions and projected 2030 emissions;
    b) Indicate under the CRGE scenario the amount of emission reduction achievable in 2030 for each sector;
    c) Discuss the role forest plays as indicated in the CRGE document.

2. Identify CDM and REDD+ projects in Ethiopia and for each identify the amount of verified carbon credit they are expected to generate.

2. History of REDD+ and its design basics

Module objective: The development of REDD+ concept and practice has undergone several years of discussion, negotiation and learning at global level. Methodological limitation was the main challenge for integrating of REDD+ early into climate negotiation for compliance market. However, over the years REDD+ concept and methodologies have advanced though its market and finance remained vaguely defined. It is essential to understand the history and design basics of REDD+ in order to effectively implement REDD+ projects of any scale. This module is prepared to provide a detail coverage of the history and design basics of REDD+ including some of the major standards.

Learning outcomes: At the end of this module participants will be able to:
- explain the historic perspective of REDD+
- explain most of the design basics of REDD+ such as additionality, non-permanence, leakage and the like
- the current financing status for REDD+ particularly in relation to the Paris agreement;
- Explain history of REDD+ in Ethiopia

Time required:
- 2 hours of discussion

Materials:
- Copy of the training material
- Notebook, pen/pencil
- Flip chart and markers
- LCD

Training method:
- Start with participants sharing their knowledge/experiences about REDD+
- Allow participants to read the module and discuss in group breakout, and
- Summary of the module by the trainer.

2.1. History of REDD+

The history of REDD+ is more or less the same as the history of global initiative to tackle climate change that was started in Rio de Janeiro in 1992. At the Earth Summit held in Rio, the United Nation established a 'Framework Convention on Climate Change (UN-FCCC) to address the issue of climate change globally. In this framework causes of climate change were discussed including land use change and deforestation.

There are three categories of countries/parties to the UN FCCC. The categories are: **Annex 1 countries**: industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

Annex 2 countries: consist of the OECD members of Annex I, but not the EIT Parties. These are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries.

Non-Annex 1 countries: These are mostly developing countries. Certain groups of developing countries (about 49 of them) were recognized by the Convention as being especially **vulnerable to the adverse impacts of climate change**, including countries with low-lying coastal areas and those prone to desertification and drought.

Following the ratification of the Rio convention by many countries, the first global initiative for practical action against climate change took place in 1997 when powerful and legally binding protocol called the **Kyoto Protocol** was signed. The protocol recognizes that developed countries share the main responsibility for the current high levels of GHG emissions, and places a heavier burden on them under the principle of "**common but differentiated responsibilities**." Under this protocol industrialized countries are allowed to meet part of their emission reduction targets abroad through "market-based mechanisms" such as the Clean Development Mechanism (CDM). It was during this period that the issue of forest sector based solution mainly Afforestation/Reforestation (AR) as part of CDM and **reduction of emission from deforestation** were discussed. However, while the AR CDM idea received acceptance, the RED (as it was called then) did not. The main reason for exclusion of REDD+ from the protocol was related to methodological challenge at the time rather than lack of understanding of the significance of it. The main challenges then were issue of **permanence and leakage** and how to address these dimensions. Yet, it can be said that the first seed for REDD+ was planted at the Kyoto during the Kyoto protocol.

Since the Kyoto protocol, global community has made significant move in understanding better and developing methodologies to address well the issue of REDD+. Among the evolution of the concept the progress from RED -Reduction of

Emission from Deforestation to REDD+, Reduction of Emission from Deforestation and forest Degradation and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks in Developing countries. Since the inception of the concept in Kyoto, several rounds of discussions have been conducted during various Conference Of the Parties (COP) (Table 3). Yet, the global community has not reached a formal agreement (legally binding) on how to deal with it. A significant decision in terms of its formal recognition was made in Paris, but its financing mechanism has yet remained vaguely defined. Because the contribution of deforestation and forest degradation to GHGs emission is so significant, globally it accounts for 18-20 of GHG emissions or about 5.8 billion tonnes of CO2e each year, the world cannot ignore it (Meridian Institute, 2009). In fact, reducing deforestation is stressed by some as the "single largest opportunity for cost-effective and immediate reductions of carbon emissions. The benefit of REDD+ over AR is that it causes large changes in carbon stocks over a short period of time, whereas AR generally cause small annual changes in carbon stocks over long periods of time. In other words, most emissions from deforestation take place rapidly, whereas carbon removal from the atmosphere through AR is a slow process.

2.2. REDD+: what is it?

Degradation and deforestation of the world's tropical forests are cumulatively responsible for about 18-20% of net global carbon emissions. Therefore, tackling the destruction of tropical forests is core to any concerted effort to combat climate change. **Traditional approaches** to halting tropical forest loss have typically been unsuccessful, as can be seen from the fact that deforestation and forest degradation continue unabated.

REDD+ is an incentive mechanism, like any other PES, that attempted to incentivize those that reduce deforestation/degradation; hence emission reduction. REDD+ is therefore, a break from historic trends of increasing deforestation rates and greenhouse gases emissions using market mechanism. It is a framework established to make developing countries also through which developing countries are rewarded financially for any emissions reductions achieved associated with a decrease in the conversion of forests to alternate land uses. Having identified current and/or projected rates of deforestation and forest degradation, a country taking remedial action to effectively reduce those rates will be financially rewarded relative to the extent of their achieved emissions reductions.

At early stage, REDD+ focused on reducing emissions from deforestation; hence RED. Then, degradation was also recognized to contribute hugely to emission in the forest sector that led to the coining of the initiative as REDD. Furthermore, in 2007 the Bali Action Plan, at COP-13 stated that a comprehensive approach to mitigating climate change should include "policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries". Finally, in 2010, at COP-16, as set out in the Cancun Agreements, REDD became REDD-plus (REDD+) to reflect the new components. REDD+ now includes:
     (a) Reducing emissions from deforestation;

(b) Reducing emissions from forest degradation;
(c) Conservation of forest carbon stocks;
(d) Sustainable management of forests;
(e) Enhancement of forest carbon stocks (AR).

The whole history of REDD+ is compiled in table 4 below from Rio to Paris.

Table 4. History of REDD+ from a global perspective

Year	Occasion	Action
1992	Earth Summit	UN-FCCC
1997	Kyoto protocol	The first seed of REDD+ planted. It was discussed but excluded from consideration due to methodological immaturity
2003	Marrakesh Accord (COP 7)	RED was removed from LULUCF
2005	Coalition for Rainforest Alliance formed	These are strong advocate for REDD+ and worked hard for REDD+ recognition in compliance market
2005	Montreal, COP 11	REDD issue was brought back for discussion in 2005 by the UNFCCC at its 11th COP by Coalition for Rainforest Nations,
2007	COP 13, The Bali Action Plan	The first significant move on REDD+ was made in 2007 at Bali COP where an Action Plan was agreed. Decision 1/CP13 Para 1 (b) (iii) "Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" The Bali Action Plan also established a subsidiary body to conduct the process, the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA).
2009	COP 15, Copenhagen	Heads-of-state-negotiated on a non-binding political statement known as the 'Copenhagen accord'. The accord notes ''We recognize the crucial role of reducing emission from deforestation and forest degradation and the need to enhance removals of greenhouse gas emission by forests and agree on the need to provide positive incentives to such actions through the immediate establishment of a mechanism including REDD+, to enable the mobilization of financial resources from developed countries.' The Accord explains that the Copenhagen Green Climate Fund will be worth US$10 billion a year from 2010-2012, which also include forestry. Six countries namely the US, UK, France, Japan, Australia and Norway, pledged US$3.5 billion over the next three years to kick-start REDD
2010	COP 16, Cancun-Mexico	Emphasized phased approach to REDD+, starting with readiness (Paragraph 73 of Decision 1/CP.16). The Cancun Agreements (Decision 1/CP.16) affirmed that "in the context of the provision of adequate and predictable support to developing country Parties, Parties should collectively aim to slow, halt and reverse forest cover and carbon loss" (14), The Green Climate Fund (GCF) was established in Cancun and it was decided that it would be designated as 'an operating entity of the financial mechanism of the Convention' (Paragraph 102 of Decision 1/CP.16). At this COP, REDD became REDD-plus (REDD+), to reflect the new components. REDD+ now includes:

		(a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forests; (e) Enhancement of forest carbon stocks
2011	COP 17, Durban	Outcomes for REDD+ from COP-17 at Durban related to financing options, safeguards and reference levels
2012	COP-18, Doha	The main areas of debate on REDD+ at COP-18 were measurement, reporting and verification (MRV) and REDD+ financing
2013	COP-19, Warsaw,	Produced the 'Warsaw Framework for REDD+'; a package of decisions, which along with those adopted at previous COPs completes the 'REDD+ Rulebook' and gives guidance for the full implementation of REDD+
2014	COP-20, Lima,	Dealt with further guidance on safeguards, and decisions on non-carbon benefits and non-market mechanisms.
2015	Cop-21, 2015 Paris Climate Conference	REDD is dealt with in the two paragraphs of Article 5 of the Paris agreement: • Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention, including forests. • And paragraph 1(d) reads as follows: Promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems; • Para2. Parties are encouraged to take action to implement and support, including through results-based payments, the existing framework as set out in related guidance and decisions already agreed under the Convention for: policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries; and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests, while reaffirming the importance of incentivizing, as appropriate, non-carbon benefits associated with such approaches. Paragraph 55 is about financing REDD: • 55. Recognizes the importance of adequate and predictable financial resources, including for results-based payments, as appropriate, for the implementation of policy approaches and positive incentives for reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks; as well as alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests; while reaffirming the importance of non-carbon benefits associated with such approaches; encouraging the coordination of support from, inter alia, public and private, bilateral and multilateral sources, such as the Green Climate Fund, and alternative sources in

		accordance with relevant decisions by the Conference of the Parties;

2.3. History of REDD+ in Ethiopia

Ethiopia has engaged in REDD+ very early on. Two initiatives mark the early engagement of the country in REDD+. These are the submission of Project Idea Note by the then EPA to the FCPF of the World Bank and the Bale Eco-Region REDD+ initiative by Farm Africa and SoS Sahel. Simultaneously, Ethio wetland and Natural Resources Association also initiative project level REDD+ in Sheka and Benchi Maji zones of southern Ethiopia.

In 2011 REDD+ was given a more policy level recognition and was firmly embedded in the country's long term development strategy called CRGE, and in an increasingly enabling political environment, especially at higher levels. The CRGE, recognized REDD+ as one of the strategy to reduce emission from the forest sector and contribute to the green growth strategy of the country.

This recognition also matched with institutional development such as the establishment of the national REDD+ Secretariat, and then MEFCC. The former is undertaking various activities to pave the way for the country's preparedness, policy, institution and capacity wise, to fully implement a national scale REDD+ implementation in Ethiopia. In fact, the establishment of both institutions was as a fulfilment of the requirements put forwards in the Readiness Preparation Proposal (R-PP).

Milestones:
- Ethiopian Readiness Plan Idea Note (R-PIN) was developed and submitted on July 30th 2008 to FCPF of WB followed by of its approval by the FCPF
- FCPF allocated USD 200,000 towards R-PP development on September 2, 2009
- Readiness Preparation Proposal (R-PP), which was finalised in May 2011 (April 2010 to February 2012)
- The R-PP was approved at PC8 of March 25, 2011 in Da Lat, Vietnam through Resolution PC/8/2011/4 with conditions to undertaking adjustments on some of the components • The R-PP was revised as per Resolution PC/8/2011/4 and was submitted to the FCPF FMT on May 25, 2011
- A Ministerial Steering Committee (MSC) was established in year 2010 by the Government of Ethiopia (GoE) to oversee the development and the realization of Climate Resilient Green Economy (CRGE)Strategy
- REDD+ Secretariat (NRS) under the previous Environmental Protection Authority in 2012, which was then moved to Ministry of Agriculture in 2012.
- Ministry of Environment, Forest and Climate Change (MEFCC) in July 2013
- Bale eco-region REDD+ pilot project PIN was prepared in 2007
- Bale Eco-region REDD+ pilot officially embarked as a project 2011
- Bale REDD+ validation 2013-2015

REDD+ finance or its marketing system

The finance for REDD+ is still unclear. REDD+ finance has remained to be fund based through bilateral or multilateral cooperation. The fact that REDD+ is not in the compliance market makes it more vulnerable to lack of clear financing mechanism for it. Despite being recognized as one of the major international climate change mitigation strategies, financing REDD+ remained a major challenge to its successful delivery. There is also no agreed way forward to financing REDD+ whether it will be integrated into part of a compliance market or not.

Theoretically two financing options are available for REDD+. These are: market based or fund based. At idea level, harnessing carbon market based mechanisms to support REDD+ has attracted substantial interest. However, the structure and future of such a potential market remains uncertain, a large share of REDD+ finance remained in the form of fund based. One main issue that has challenged REDD+ financing is a scale issue. The UN-FCCC has negotiated always for national scale REDD+, making market based approach rather a bit tough.

In a national based initiatives for REDD+, two general phases are recognized: readiness phase and implementation phase. REDD+ finance so far has been spent on "readiness" activities to prepare countries for funding based on demonstrated reductions of deforestation and associated emissions. In 2009, at COP-15 in Copenhagen, the Copenhagen Accord was reached, noting in section 6 the recognition of the crucial role of REDD+ and the need to provide positive incentives for such actions by enabling the mobilization of financial resources from developed countries. The Green Climate Fund (GCF) was established at COP-17, principally to function as the financial mechanism for the UNFCCC, so including for REDD+ finance. The Warsaw Framework on REDD+ makes various references to the GCF, instructing developing country Parties to apply to the GCF for result-based finance. In this fund based approach, Annex I countries would deposit money into a fund administered by some multi-lateral entity (e.g. World Bank) and/or GCF.

Under the market-based approach, REDD+ would act as an "offset scheme" in which verified results-based actions translate into some form of carbon credits, more-or-less analogous to the market for Certified Emission Reductions (CER) under the CDM of the Kyoto Protocol. Such carbon credits could then offset emissions in the country or company of the buyer of the carbon credits. This would require Annex I countries to agree to deeper cuts in emissions of greenhouse gases in order to create a market for the carbon credits from REDD+, which is unlikely to happen soon given the current state of negotiations in the COP.

Some developing countries, such as Brazil and China, maintain that developed countries must commit to real emissions reductions, independent of any offset mechanism. Recent studies indicate that an offset approach based on projects would significantly increase the transaction costs associated to REDD+ and would actually be the weakest alternative for a national REDD+ architecture as regards effectiveness, efficiency, its capacity to deliver co-benefits (like development, biodiversity or human rights) and its overall political legitimacy. Since COP-17, however, it has become clear that the COP is opting for a **fund-based financing** of REDD+, with the GCF as the trustee for management of the fund and disbursement of **result-based finance** to developing countries that submit verified reports of

emission reductions and enhanced removals of greenhouse gases. This fund is only available to developing country Parties to the UNFCCC.

2.4. REDD+ design basics

REDD+ design basics comprises several aspects beginning with the definition of several terminologies. This concerns about the definition of forest, deforestation, forest degradation, additionality, permanence, leakage, standards and methodologies, all of which are essential features of REDD+ project design.

Forest: The central focus of REDD+ design is a forest. The first and most important aspect in REDD+ project design is therefore to define what we mean by a 'forest.' According to the IPCC, each REDD+ project host country is required to select and submit its official forest definition when submitting REDD+/CDM projects. This is because, deforestation reduced or carbon enhancement and the associated GHG emission removal or reduction depend on what is defined as a forest.

UN-definition of forest:
> *According to UN-REDD, forest definition must specify minimum levels for each of the following parameters:*
> - Minimum land area: 0.05–1.00 hectare
> - Minimum tree crown cover: 10–30%
> - Minimum tree height: 2–5 meters

(UNFCCC host country forest definitions can be found at: http://cdm.unfccc.int/DNA)

FAO- definition of forest:
- The FAO definition is useful to project developers in those cases where the host country has not submitted an official forest definition to the UNFCCC. FAO specifies its definition when collecting forest data (e.g., as part of the Global Forest Resource Assessment) from countries. According to FAO, forests are defined to meet all of the following criteria *in situ*:
  - Land Area: > 0.50 hectare
  - Tree Crown Cover: > 10 percent
  - Tree Height: > 5 meters

FAO also specifies that forests do not include land that is predominantly under agricultural or urban land use. Therefore, using the FAO definition, lands used for agro-forestry that otherwise meet the above definitions are not considered forests (e.g. Gedeo and Sidama Agroforestry system).

Ethiopia has developed its own forest definition and included in the draft forest proclamation under appraisal. This new definition has been included in its national forest reference level submitted to UN-REDD by MEFCC 2015. According to this definition, 'forest is land spanning more than 0.5 ha covered by trees (including bamboo) with a minimum width of 20m or not more than two-thirds of its length attaining a height of more than 2m and a canopy cover of more than 20% or trees with the potential to reach these thresholds in situ in due course'. Ethiopia is in the process of approving this as its national legal definition when the proclamation is ratified.

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2.5. REDD+ scale: national verse project

REDD+ can be implemented at various scale, form a national or sub-national level to a small scale project level. The scale of REDD+ affects several aspects of REDD+ design basics such as reference emission level, leakage, additionality and the like. Examples of scale of REDD+ design in Ethiopia are:

- Project level   = Bale eco-region REDD+
- Jurisdictional/sub-national = Oromia Forested Landscape Program
- National scale   = Ethiopia REDD+ program of the UN

A national level REDD+ program is implemented at a jurisdiction of a country and is governed by a national accounting system (MRV) based on a national baseline. Credits are issued to the national government based on performance against this national baseline. National projects are implemented across the country and performance is assessed and measured in terms of achievement at national scale.

A national monitoring system and credit registry would also be part of the program. REDD+ country should submit its REL/FRL to the UNFCCC, and specifying the scope, carbon pools etc.

The national reference level would likely be based on methodological guidance from the UNFCCC or other guidance that represents international Good practice, taking into account recent historical emissions and, in line with the specific circumstances of each country, a credible assessment of future emissions. In the absence of additional guidance from the UNFCCC, different approaches would be tested based on national priorities and circumstances, building on IPCC 2003 Good Practice Guidance and1996 and 2006 Guidelines. Readiness would require that such a Reference Scenario has been established.

National REDD+ requires three elements:

- **National REDD+ strategy**: a broad guideline on how much, how, where, and at what cost a country intends to implement its national REDD+ initiatives.
- **MRV system**: A basic system for monitoring and verifying REDD+ would be designed and implemented. Countries will report emission reduction and removals based ion this MRV system.
- **National registry**: Registries are usually electronic databases that register, track and hold verified or recognized emission reductions enabling the transfer between sellers and buyers. It is where verified carbon units are displayed.

A sub-national level REDD+ differs from project level as it is implemented at a jurisdiction of a state or a region within a country governed by a similar institutional and governance arrangement. Example is Oromia REDD+ program. The MRV of such REDD+ is either the jurisdiction or national. If national reference level does not exist, a jurisdictional reference level can be developed.

A national scale REDD+ is favoured in international negotiations as it is expected to yield a sustainable and large scale emission reduction without leakage. As national governments own the project, sustainability is not a question.

These three levels can also be implemented in parallel and can be interlinked by what is called **nested approach**. Nesting is defined as a system of integrating different local level initiatives into a sub-national or national level actions. In fact, nesting is variously used to refer to regional (state) and province-level accounting integrated into national level systems, as well as to project-level activities sitting within broader national (or subnational) systems.

Nesting helps to effectively involve various actors and stakeholders of REDD+ projects including a private sector. It is a system that creates an environment of decentralized accountability to manage forests, and distribution of resultant carbon based incentive. Despite a slight complexity of managing it, nested approach to REDD+ offers a number of advantages over a purely national or one big sub-national projects. The advantages include:
1) Engagement of multiple actors: national and regional governments, communities, NGOs and other actors;
2) Creates more transparent environment for distribution of REDD+ benefits since local actors could own and transact credits directly rather than relying on a national system of benefit-sharing.
3) Disaggregates big and sometimes difficult to handle kind of initiatives into smaller sub-units each being managed or addressed by different actors effectively. If such activities are guided by a similar framework (MRV), the aggregated output could be much bigger than managing one very bulky project at jurisdictional scale such as Oromia or national scale such as Ethiopia;
4) Small project level initiatives are likely to be effectively managed and likely to deliver results, and also effective in creating opportunities for private sector to engage, and
5) Last but not least nested projects are critical pieces for generating lessons for what works and what notes as they involve diverse techniques of implementation; hence serve as stepping stones for effective national frameworks for REDD+ management and accounting.

Its disadvantage is that it is a bit complex compared to just one project or program in terms of carbon accounting, systems for risk and benefit sharing between actors. It is also complex in terms of defining institutional arrangement that can bring together the different actors involved for managing and transacting benefits. Yet, in a context where sub-national or national institutions for managing to REDD+ are at infancy like the case in Ethiopia, nesting offers the opportunity for different actors to involve; hence to assist in developing successful REDD+.

2.6. Scope of REDD+

Scope refers to the **eligible activities** to include in a REDD+ project. REDD+ eligible activities are those that **avoid deforestation**, **forest degradation** and **enhance forest carbon**, which in theory comprise the following five activities based on the breakdown of REDD+ under the UNFCCC:
(a) Reducing emissions from deforestation;
(b) Reducing emissions from forest degradation;

(c) Conservation of forest carbon stocks;
(d) Sustainable management of forests;
(e) Enhancement of forest carbon stocks (AR).

The common eligible activities included in most REDD+ project design are **avoided deforestation** and **enhancement of forest carbon stock** (AR). For instance, Ethiopia's FRL included these two activities. Although degradation in most countries is significant, it is excluded mainly due to the absence of methodology.

Deforestation: is the direct, human induced conversion of forest to non-forest land. *For example, deforestation occurs when forests are converted to agricultural or to developed lands.*

Forest Degradation: the persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuel-wood extraction, timber removal or other such activities, but which does not result in the conversion of forest to non-forest land (which would be classified as deforestation), and qualifies as forests remaining as forests, such as set out under the IPCC 2003 Good Practice Guidance."(AFOLU Requirements, Section 4.2.5, italics added for emphasis).
  – *For example, degradation occurs when trees are selectively cut and used for fuel-wood, but the area where the trees were removed still meets the definition of forest*

Degradation is easy to consider when it is planned such as known volume of selective logging in a forest. Degradation is somehow considered in REDD+ projects during forest monitoring by conducting forest inventory, either in permanent plots or temporary plots, every 10 years to see changes in carbon stock and to adjust emission factors. However, inclusion of it as project activity in the design of REDD+ as far as it remains unplanned is, not recommended just due to lack of simple methodologies today to account for it (Table 5).

Table 5. Eligible activities for REDD+

Drivers in baseline scenario	Baseline activities				
	Deforestation	degradation	Forest conservation	SFM	AR
Planned	Legal conversion of forest to a non-forest land use (e.g., agri-business). There must be intent from the authorized body to convert to qualify as REDD project	Legal conversion of forest to a managed tree plantation with lower carbon stocks; Legal selective logging	This is not considered in most cases as it maintain status quo, it is carbon neutral by nature.	Not common as change in carbon stock is often minimum	Included as carbon removal option

Unplanned	Unauthorized (Illegal) conversion of forest to a non-forest land use (e.g.,, agriculture) • Road construction • Introducing SFM in a forest area liable to deforestation	Illegal, unsustainable logging and fuelwood collection that reduces carbon stocks; • Illegal selective logging, etc		Not common	Included particularly when jurisdictional or national

Forest conservation: conservation in this context refers to the conservation of forests that have not historically, and are not currently, under threat. Since these forests are not facing deforestation or degradation, there is no way to reduce emissions from deforestation and degradation and earn compensation as described above. However, many of these forests may face increasing future threats and it is important to provide incentives to continue to conserve them. A REDD+ policy framework will include some **type of incentives, not ER payment,** to maintain non-threatened standing forests.

Sustainable Management of Forests: Sustainable management of forests means that forest areas designated for the production of timber are managed in such a way as to effectively balance social, economic and ecological objectives. Improving the management of those forests to avoid net degradation offers a significant opportunity to reduce emissions. In order to include sustainable management of forests within a REDD+ program, project developers would need to calculate emissions from existing forest management practices, and these should be significant. Those actors can then implement activities to **reduce emissions**, while continuing to harvest timber. Such strategies may include reduced impact logging, reduction in harvest levels, and increased protection of high-value areas such as riparian zones.

Enhancement of Forest Carbon stocks: Enhancement of forest carbon stocks has not yet been fully defined within the international negotiations on REDD+. However, it will likely include **forest restoration** (enrichment planting, regeneration management, etc), **afforestation** and/or **reforestation**. Forest restoration is the process of assisting the recovery of the carbon stocks of an existing forest that has been degraded or damaged. Afforestation is the process of planting trees on land that has not been forested within the last 50 years (or has never been forested). Reforestation is the process of planting trees on land that was previously forested but has recently (within the last 50 years) been converted to other uses.

2.7. REDD+ feasibility assessment

For REDD+ projects, the project area is the area of forestland under the control of the project developer that will be protected by the REDD project activities, and where the generation of GHG emission reductions or removals may take place. The project area need not be a single contiguous area, but can be composed of a collection of dispersed tracts.

Feasibility of an area for REDD+ is usually checked by preparing what is called Project Idea Note (PIN). This is a brief assessment of an area, in terms of its size, extent of deforestation, approximate size of GHG emission reduction, and the like. PIN is usually prepared based on desk study, and it is essential to do before embarking on full-fledged project design document preparation. An area qualifies for REDD+ when:

- There is considerable size of forest in the area
- The forest is experiencing severe deforestation and/or degradation
- And that there is no on-going or planned action to protect or manage it other than the REDD+ project

In terms of size of forest area, UN-REDD+ always consider a national scale REDD+ initiative, while other project levels have what they call micro and mega projects. For instance, VCS classifies forest area with 5000 tCO2-eq per year emission or removal as micro project, and those with greater than 1 000 000 tCO2-eq per year as mega projects.

2.8. Additionality

Any REDD+ project must demonstrate that they are additional to what would have occurred under a business as usual scenario. That is to say that the REDD+ project activity would not have occurred in the absence of carbon finance. If other initiatives are on-going, e.g. conservation effort, and that the REDD+ will not add extra value in reducing GHG emission, such areas do not qualify for REDD+ project development. Additionality is about two things: economic additionality and climate benefit additionality.

- *Climate additionality: there must be additional ER that could not have happen without the project*

Several means are employed to check whether REDD+ project yield true additionality. However, the most standard of these technique is the use of Reference level. A reference level is the bench mark that shows what would have happened to the forest based emission without the REDD+ project. It is a projected deforestation and emission based on historic deforestation level. More detail in Chapter 7.

- *Economic additionality: REDD+ project must add up to make forest management attractive compared to other alternatives. i.e. opportunity cost of abandoning deforestation is so high that agents of deforestation will not switch to conservation unless carbon payment is provided.*

People clear and People clear forest or log it because they gain from doing so. While gains can be unsettlingly small or impressively large, short-term or sustainable, there is one economic rationale that applies to all forest actors: landholders or claimants will deforest when it **offers higher returns** (of course also provides better tenure security) than maintaining the land as forest. Therefore, for any REDD+ to be successful it should make forest management and conservation economically competent with alternative land uses to be forsaken (Table 6).

Table 6. Example of economic additionality from Bale eco-region

Land use alternative	Products	Dry forest case			Moist forest case		
Forest use		NPV@5%	NPV@10%	NPV@15%	NPV@5%	NPV@10%	NPV@15%
	Honey	881	881	881	881	881	881
	Timber	881	881	881	10447	9443	8604
	Total forest	47987	32921	21341	84326	69281	57298
Alterative land use (agriculture)	Enset				16659	13112	10454
	Coffee				3520	3520	3520
	Maize	11315	11315	11315			
	Wheat	11690	11690	11690			
	Barely	881	881	881	881	881	881

2.9. Permanence/non-permanence and buffer credits

Any GHG emission reduction or removal achieved due to REDD+ project should remain for long period of time. This refers to the longevity and stability of forest carbon pools once credited for. Permanence is the very reason for REDD+ project periods (crediting periods) to be long, at least 20 years. It is also one of the reasons why REDD+ could not find its way into the compliance market. This refers to the risk that GHG emission reductions that have been credited will be reversed or lost in the near future due to several risks: internal, external and natural. In any operational REDD+ projects, credited emission reductions can be **reversed** if GHG emissions in the project area exceed the baseline rate in future periods. To control for such non-permanence related risks, REDD+ project designs incorporate what is called **buffer for credit**.

Buffer credits refers to reserving a portion of GHG emission reductions (15% usually) to as a buffer to protect against the risk of non-permanence. If GHG reversal occurs, an equivalent amount of credits from the buffer pool will be cancelled to ensure the permanence of the credits that were originally issued to the project while maintaining atmospheric integrity.

In some standards (e.g. VCS), risk of permanence are critically assessed: internal external and natural, and presented. These are also used in the decision making to **assess REDD+ project feasibility.**

Another means to safeguard permanence is the use of **temporary crediting. Temporary REDD+ credits** would be valid for one or more commitment period(s), after which they would expire and new credits would be issued if re-verification showed that deforestation rates stayed below the baseline rate. Increases in deforestation rates would be met with decreases in the number of credits issued finally.

2.10. Leakage and leakage management

REDD+ is all about net contribution to climate change mitigation by avoiding deforestation and the associated emission of GHGs. This can be achieved if and only if deforestation avoided in one area is not driving equal or greater amount of deforestation in other nearby places. **Leakage** is the increase in GHG emissions outside the project boundary **as a result of the project** under consideration. A major problem with leakage is that it considers displacement only within the same country (i.e. jurisdiction). International leakage is not accounted for.

Leakage are either activity shift and/or market leakage. By activity shifting leakage it means when agents of deforestation shift their deforestation/degradation activities outside the project area (to forests in the vicinity of project area) as a result of improved management of the forest in the project forest. Activity shifting should be accounted for, and anything above the business as usual must be deducted from the reported performance by the project. Similarly, market leakage occurs when the project activity reduces the production of a commodity that results in an increase in production elsewhere to meet continuing market demand. Due to a high chance of leakage, UN-REDD and WB REDD+ project always focus at national or jurisdictional level. In national or jurisdictional level REDD+, displacement outside the jurisdiction is assumed little and therefore unaccounted for. This is why project level REDD+ are discouraged globally. However, wherever it exist, a project scale REDD+ must manage leakage properly.

2.11. REDD+ standards and methodologies

Several standards exist to develop REDD+ projects. These include: VCS, plan vivo, CCBA, carbon fix, CCAR, WB and Un-REDD. Each standard has its own requirements

Verified Carbon Standard (V-C-S.org): This is the world's most widely used voluntary GHG program. More than 1300 certified VCS projects have collectively reduced or removed more than 185 million tonnes of GHG emissions from the atmosphere. Projects developed under the VCS Program must follow a rigorous assessment process in order to be certified. VCS projects cover a diverse range of sectors, including renewable energy (such as wind and hydroelectric projects), forestry (including the avoidance of deforestation), and others. Emission reductions certified by this program are eligible to be issued as VCUs, with one VCU representing one metric tonne of greenhouse gas emissions reduced or removed from the atmosphere. VCS involves three components one after the other: i) selecting appropriate accounting methodology; ii) independent auditing and iii) registry system.

Plan vivo (http://www.planvivo.org): The Plan Vivo System was developed in 1994 by the Edinburgh Centre for Carbon Management in partnership with El Colegio de la Frontera Sur. Plan vivo projects generally originate with a small community or group of landowners, following a bottom-up approach to increase the number of participating communities and land over time. Plan Vivo accepts a range of land use, land use change and forestry (LULUCF) projects, including afforestation and reforestation, agroforestry, restoration, conservation, improved forest

management and REDD. Plan Vivo sets a goal for at least 60% of carbon revenues directed towards communities with a minimum of US$6/tCO2 needed to achieve this.

Plan Vivo accepts a range of land use, land use change and forestry (LULUCF) projects, including afforestation and reforestation, agroforestry, restoration, conservation, improved forest management and REDD. Projects are issued a Plan Vivo Certificate with a unique serial code for each tonne of carbon dioxide sequestered or reduced. In addition, Plan Vivo has begun to use the Market Environmental Registry to issue, track and retire certificates.

CCB (http://www.climate-standards.org): this standard supports projects that simultaneously address climate change, support local communities and smallholders, and conserve biodiversity. The CCB Standards can be applied to any land management project, including projects also certified under the VCS Program. The two have what is called combined templates or standards. The CCB Standards require projects to generate net reductions in GHG concentrations, but do not result in the issuance of emission reduction certificates, and combination with a carbon accounting standard is recommended. The standards comprise 14 required criteria and 3 optional 'Gold Level' criteria. Once a project has been designed, a third-party evaluator will use indicators to determine if individual criteria are satisfied. Only projects that use best practices and deliver significant climate, community and biodiversity benefits will earn CCB approval. Gold status is awarded to projects that also satisfy one of the optional criteria by providing exceptional benefits including explicit design for adaptation to climate change, benefits for globally poorer communities or conservation of biodiversity at sites of global conservation significance.

CCB Standards criteria ensure that projects:
- Identify all stakeholders and ensure their full and effective participation
- Recognize and respect customary and statutory rights
- Obtain free, prior and informed consent
- Assess and monitor direct and indirect costs, benefits and risks
- Identify and maintain high conservation values
- Demonstrate net positive climate, community and biodiversity benefits

Over 100 projects have been validated to the CCB Standards, over 40 of which have achieved full verification. CCB projects span over 40 countries on every continent except Antarctica. Projects validated and verified to the CCB Standards encompass more than 10 million hectares, an area the size of Iceland

American Carbon Registry Forest Project Standard (http://americancarbonregistry.org): This is forest carbon project standard details requirements and specifications for the quantification, monitoring, and reporting of forest project-based GHG emissions reductions and removals, methodological acceptance, verification, registration, and issuance of offsets for trade in the global voluntary and U.S. pre-compliance carbon markets. Requirements are provided for Afforestation/Reforestation (AR), Improved Forest Management (IFM), and Reducing Emissions from Deforestation and Degradation (REDD) projects. Currently there is version 2.1 of the standard to be filed by project developers. This standard

establishes the requirements that every forest project must meet in order for ACR to register its GHG emission reductions and removals as tradable environmental assets (ERTs) for the voluntary and pre-compliance carbon markets. The Forest Carbon Project Standard includes requirements for afforestation and reforestation (AR), improved forest management (IFM), and reducing emissions from deforestation and degradation (REDD). Additional eligible forest carbon project types may be added in the future. The standard does not include guidance on agricultural, grazing, or other land use projects, which will be addressed in separate ACR standards and methodologies.

The CarbonFix Standard (CFS): is a product of the non-profit association CarbonFix, which was founded in 1999 and registered in Germany in 2007 to support the potential for climate forestation projects. The standard applies to afforestation and reforestation, but not to improved forest management or avoided deforestation (i.e. REDD) activities. In terms of methodology, CFS only accepts its own, which is based on IPCC good practice guidelines and aligned to the greatest extent possible with the CDM. For those project developers that want to maximise environmental and social benefits without duplicating validation costs, CFS recognises the certification schemes of the Forest Stewardship Council (FSC) and the CCB. CarbonFix has its own registry and delivers a unique certificate ID for each project.

Climate Action Reserve (CAR): emerged from the California Climate Action Registry (CCAR), a non-profit organisation which emerged in 2001 through an initiative by the State of California to oversee entity emissions reporting and offsets in that state. In September 2009, CAR's Forest Project Protocol 3.0 was adopted to verify the carbon sequestration benefits of forestry projects in avoided conversion of forest land to other uses, improved forest management and reforestation of land. Credits verified to the standard are branded Climate Reserve Tonnes (CRTs), or 'carrots' for short. CRTs are only issued ex-post, and are held in the Reserve's own registry powered by APX. The CAR forest protocol takes a deliberately standardised approach, relying heavily on US Forest Service regional data and other official data sets for the calculation of baselines and establishing additionality.

World Bank REDD+ methodology: the World Bank is also a leading organization in REDD+ and other carbon project development. The Forest Carbon Partnership Facility (FCPF), is the largest REDD+ initiative in the world. Carbon fund methodological framework is the World Bank's REDD+ methodology. The methodological framework is a set of 37 criteria and related indicators (C & I), associated with five major aspects of Emission Reductions Programs. An important aspect of WBG REDD+ method concerns the reference level. It specifically uses a historic average and nothing else. The framework emphasizes that ER should be conservatively measured and reported relative to a transparently presented and clearly documented Forest Reference Emission Level or Forest Reference Level for the ER Program Measures Area, following the guidance of the Carbon Fund Methodological Framework. The framework believes that one of the means to ensure conservativeness is by using average historic deforestation rate. The MF approach allows a limited set of ER Programs to **adjust Reference Levels** above average historical rates, states what adjustments may be made, and defines quantitative

limits on adjustments. Adjusted Reference Levels is allowed only for countries with a long-term history of minimal deforestation to contribute to mitigation and access finance as well.

The framework can be found at https://www.forestcarbonpartnership.org/carbon-fund-methodological-framework. Methodological Framework for the Carbon Fund (CF) does not consist of detailed calculation methods or protocols. It rather provides the overarching guidance and act as a standard that is designed to achieve a consistent approach to carbon accounting and programmatic characteristics.

The ambition of the Carbon Fund, and therefore the target of the MF, is a large-scale approach to REDD+ that require a mix of policies and investments, integration with national development strategies, use of innovative financial structures, and involvement of multi-stakeholder approaches. This is because large-scale accounting is expected to likely capture the wide range of REDD+ drivers, provide ER Programs with incentives to establish comprehensive REDD+ strategies, and generally enhance the environmental integrity of the system.

UN-REDD Program: The UN REDD+ Programme was created in September 2008 to assist developing countries to build capacity to reduce emissions and to participate in a future REDD+ mechanism.
The UN-REDD Programme builds on the convening power and expertise of its three participating UN organizations, called UN-REDD Programme agencies: FAO, UNDP and UNEP. It is established in response to the UNFCCC decisions on the Bali Action Plan and REDD at COP-13. The UN-REDD Programme also works in close partnership with other REDD+ initiatives, especially those operated by the World Bank, and supports the implementation of UNFCCC decisions.
The UN-REDD Programme supports nationally led REDD+ processes and promotes the informed and meaningful involvement of all stakeholders, in national and international REDD+ implementation. Clearly UN-REDD program supports national initiatives, not project level initiatives that target voluntary carbon markets.

The UN-REDD Programme supports its partner countries through;
- Direct funding and technical support to the design and implementation of National REDD+ Programmes;
- Complementary tailored funding and technical support to national REDD+ actions; and
- Technical country capacity enhancing support through sharing of expertise, common approaches, analyses, methodologies, tools, data, best practices and facilitated South-South knowledge sharing

UN-REDD Programme – is not a methodology by itself. Rather the program partners with developing countries to support them in establishing the technical capacities needed to implement REDD+ and meet UNFCCC requirements for REDD+ results-based payments. It does so through a country-based approach that provides advisory and technical support services tailored to national circumstances and needs.

2.12. Drivers of deforestation and strategic options

Among REDD+ design basics is the need to identify and assess what drives deforestation and forest degradation and agents behind these on one hand and the design of actions and interventions, including policies and institutions, to effectively address these (also called strategic options) on the other. Any REDD+ project developer should conduct detail study of the direct and underlying causes of deforestation and forest degradation, agents and design how to address these so as to reduce deforestation. Investing in forest conservation projects without understanding the causes of deforestation can result in wasted resources with no impact on deforestation rates.

Causes of deforestation and forest degradation are multi-faceted, complex and vary from place to place. The drivers are often categorized as proximate (direct) causes and underlying causes.
- Proximate causes are human activities that directly impact the environment at the local level, and
- Underlying drivers are social, economic, political, and/or cultural processes that indirectly impact deforestation.

Direct drivers are underpinned by a complex set of underlying drivers that need to be tackled if efforts to address the direct drivers are to be successful over the long-term. Direct drivers of deforestation include conversion to agriculture, infrastructure expansion and mining, long-term overharvesting of forest products (including unsustainable fuel wood harvest), poor harvesting practices and overgrazing. Underlying causes are the broader **economic (market, price)**, **political/institutional (agricultural incentives, forest/land tenure, etc)**, technological (inputs, profitability), cultural, and demographic factors - the fundamental social processes that underpin the proximate factors of deforestation. These are what create the enabling environment for proximate drivers to unfurl.

Strategic options: Addressing drivers of deforestation and forest degradation is a major goal of REDD+ projects. Actions and intervention designed to reverse the drivers and change the behaviour of agents of drivers are called **strategic options**. Carefully and systematically analysing and comprehensively addressing all direct and underlying drivers of deforestation and degradation of forests is the priority and key prerequisite to effectively reducing emissions from deforestation and forest degradation and thus enhancing forest carbon stocks in every REDD+ country. While drivers of deforestation vary in different places, particular attention should be given to addressing the **conversion of forests to agricultural land**, which is by far the greatest driver globally and in Ethiopia as well. Measures and strategies to address drivers should seek to harmonize different development objectives taking into account the need for increased food production and improved livelihoods as well as climate change mitigation and adaptation and enhanced environmental conservation.

It is important to remember that strategic options to address drivers of deforestation are not basically different from what forest managers and governments have been employing for decades to reduce deforestation and promote reforestation. REDD+ is not an entirely new system of forest conservation, it is primarily a new way of

financing that conservation. Example, PFM, which is introduced to Ethiopia before REDD+ discussion began is still one of the best scheme adopted to ensure REDD+

Example of direct drivers of deforestation and its agents in Oromia for the design of the OFLP is shown in Table 7 and underlying, and their agents (Figure 11). The study also confirmed that agriculture is the main driver of deforestation both in forests and woodlands, with small-scale agriculture farmers being the main agents. Woodfuel (firewood and charcoal production) is the main driver of forest degradation today in the region in forests and woodlands followed by livestock, whose significant share is predicted to increase in the future.

Table 7. Agents and direct drivers of deforestation and forest degradation in Oromia

Category	Specific driver	Scale of impact	Agents	Planned/ unplanned
1) Agricultural expansion	Small holder permanent cultivation (cereals)	All over forested landscape in Oromia	Smallholder farmers	Unplanned
	Small holder permanent cultivation (perennials - coffee)	Mostly in southwest	smallholder farmers	Unplanned
	Large scale agri-investment (Coffee, sugar cane, oil seeds, etc)	Mostly in southwest and also in woodlands	Investors	Planned
	Shifting cultivation		Smallholder farmers	Unplanned
	Cattle ranching (grazing)	Woodlands	pastoralists	Planned/unplanned
2) Wood extraction (degradation)	Unsustainable logging	Common across		Unplanned
	Fuelwood and charcoal production	Common across, but serious in woodlands		Unplanned
3) Others (infrastructure extension)	Road construction	Limited	Govt	Planned
	Mining	In south	Govt/investor	Planned
	Hydropower	Limited	Govt	Planned
	Forest fire	Limited		Unplanned

The agents and underlying causes of deforestation/degradation operating in Oromia and their direction of development over time is summarized in the diagram below.

Underlying drivers →		Demographic	economic	Technology	Policy/ institution	Social/cultural	environmental
Proximate drivers	Agents						
Agriculture	Small scale farmers	→ (red)	↗ (yellow)	→ (yellow)	↗ (yellow)	→ (yellow)	→ (yellow)
	Medium scale farmers	↗ (green)	↗ (red)	↘ (yellow)	→ (red)	→ (green)	↗ (yellow)
	Coffee farmers	→ (red)	↗ (yellow)	↘ (green)	→ (yellow)	→ (red)	↗ (yellow)
	Livestock herders	→ (red)	↗ (yellow)	↘ (yellow)	→ (yellow)	→ (red)	↗ (yellow)
Fuelwood (firewood and charcoal)	Producers and traders	→ (yellow)	↗ (red)	↘ (yellow)	→ (yellow)	→ (green)	↗ (yellow)

Current impacts of underlying causes

- High impact (red)
- Medium impact (yellow)
- Low impact (green)

Projected future trend of underlying cause on agents

- ↗ Increasing
- → Business as usual
- ↘ Decreasing impact

Figure 11. proximate and underlying drivers of deforestation and forest degradation in Oromia

To address the prevailing drivers of deforestation and forest/land degradation the OFLP will implement three categories of interventions in an integrated and coordinated manner. These categories of activities comprise i) project level actions and activities; ii) coordination of natural resources programs/projects implemented within Oromia implemented by government and non-government organizations, and iii) interventions at the State level to create enabling environments.

Project level actions: using the grant fund obtained from Bio-Carbon fund OFLP will implement the following activities in selected project woredas for the program:
- Land use and watershed planning at woreda and community levels;
- Extension support in each woreda or zone to coordinate on-ground implementation of landscape management such as agriculture, natural resource management, forest, livestock and household energy and income generation;
- On-ground action on forest: afforestation and reforestation (A/R), participatory forest management (PFM), and assisted natural regeneration (ANR);
- Marketing and demonstrations to stimulate demand for alternative household energy; and
- Seed capital and advisory services for community natural resource based enterprises.

2.13. REDD+ co-benefits

A REDD+ project is primarily about climate related benefit, reduction of emission and removal of GHGs to mitigate climate change. However, properly effected REDD+ project also generate many other benefits for local communities and national governments. These are often called REDD+ co-benefits. The two prominent co-benefits of REDD+ projects are: community benefits and biodiversity conservation (ecosystem service benefits).

2.14. REDD+ finance

REDD+ finance remains still unclear. Potentially it could be market-based approach, where REDD+ activities would generate credits that could be acquired by governments or traded by private entities in international carbon markets. Companies or entities that face emissions reductions commitments under a cap-and-trade system could possibly use REDD+ credits to meet part of those commitments. Proponents of a market-based REDD+ mechanism emphasize the huge potential revenue generation of the carbon markets. A market-based mechanism is considered by many to be the only means of raising sufficient funding to make meaningful reductions in deforestation in developing countries. Opponents of market based mechanism are concerned that including REDD+ credits in the current market may result in unpredictable volumes of credits, substantially lower prices, windfall profits, and reduce the incentives for Annex-I countries to meet their commitments domestically. In fact, creating market requires Annex-I countries to raise their commitment level as well to create demand for REDD+ credits.

A non-market-based approach to REDD+ finance is the most discussed at UNFCCC level, and this could include a number of funding sources. In the fund based approach UNFCCC suggests that REDD+ implementation should proceed in a phased approach "beginning with the development of national strategies or action plans, policies and measures, and capacity-building, followed by the implementation of national policies and measures and national strategies or action plans that could involve further capacity-building, technology development and transfer and results-based demonstration activities, and evolving into results-based actions that should be fully measured, reported and verified". The initial phase of the development of national strategies and action plans and capacity building is typically referred to as the "**Readiness phase**". By February 2016 no developing countries had entered into the phase of results-based actions that are fully measured, reported and verified.

Following the Warsaw Framework on REDD+, by February 2016, only Brazil has submitted a Biennial Update Report with a Technical Annex containing the details on emission reductions from REDD+ eligible activities. Brazil submitted its first Biennial Update Report on 31 December 2014.

Ethiopia has also submitted its national REL/RL to the UNFCCC in March 2015, as part of its final steps of its Readiness phase.

Questions for the module

- Explain the scale and scope of REDD+

- What do you think can ensure permanence of GHG emission reduction in REDD+?

- Discuss about the pros and cons of various scales of REDD+

- Discuss about drivers of deforestation in Ethiopia and suggest strategic options to address them

3. Measuring Forest Carbon Stock

Module objective: Forest Carbon measurement is the practice of conducting scientifically robust and verifiable quantification of stock of carbon in a given forest ecosystem. Carbon credit and subsequent financial compensation is based on precise and verifiable assessment protocol. Project developers need to understand and apply standard carbon stock assessment methods and procedures. If the method used is not of credible standard, emission trading will not be possible or acceptable. It is mandatory that most forest carbon projects, before being registered as carbon trading scheme should be validated by a third party for compliance to internationally accepted methodologies. This module aims to present options of forest carbon stock assessment methods that are internationally accepted.

Learning outcome: At the end of this module, participants, will be able to
- define and differentiate the different carbon pools and their relative importance in forest carbon stock;
- justify and decide on which carbon pool to include or exclude in a particular project;
- understand and share their experiences on the principle of conservatives and verifiability of methods applied in forest carbon stock measurements;
- differentiate between the various methods of carbon assessment, and
- choose method of forest carbon assessment for their own project.

Time required:
- 1.52 days

Materials:
- Copy of the module;
- Computer/calculator;
- Flip chart, pen, square paper, markers, post-it;
- Printed copies of module exercises, and
- Other supporting documents such as IPCC good practice guidance.

Method of training:
- Class discussion guided by brief PPT by the trainer;
- Group discussion and group exercises
- Class and take home assignments
- Group work presentation

3.1. Carbon pools and gasses

Forest carbon stock refers to the amount of carbon stored in a given forest ecosystem. Carbon is stored in various components in a forest ecosystem, mainly in living biomass (above ground and below ground (20-40%) and soil (up to 60%), but to a lesser extent also in dead wood (6%) and litter (4%). These stores of carbon are called **carbon pools**. The total carbon stock of a forest ecosystem is the sum of carbons in these different pools expressed in tons or kilograms per unit area. The pools are classified into two major categories: living and non-living pools each of which are sub-classed as indicated in Figure 12.
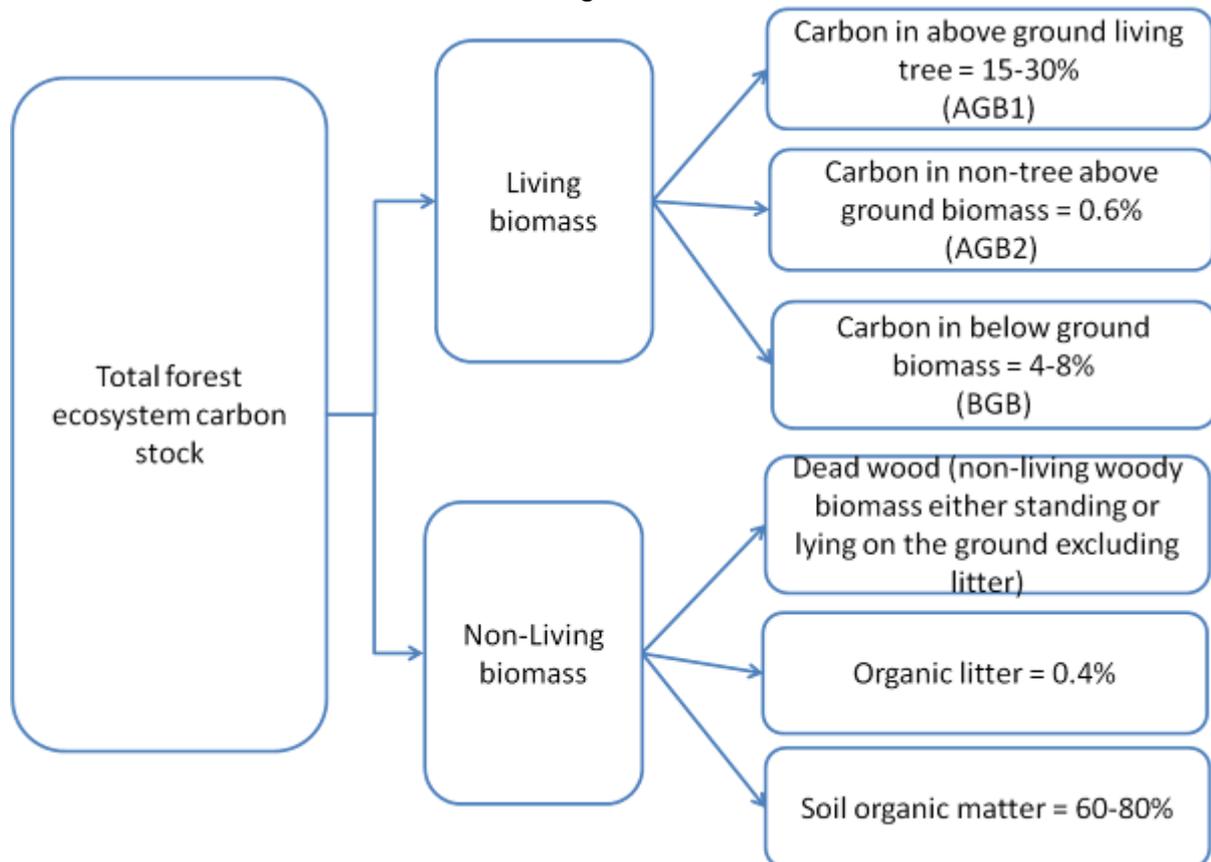
Figure 12. Different forest carbon pools and their relative importance (% are of the total pool) (Source: Watson, 2008).

The explanation for the different pools is presented below and figure 13 also shows each pool diagrammatically.

- **Aboveground biomass (AGB)**: This is of two types: above ground living biomass and above ground non-living biomass, Above Ground Living Biomass (AGLB) comprises all living tree stems, branches, leaves, bark, seeds including climbers and epiphytes as well as understory living plants (grasses, seedlings, saplings etc.) and herbaceous growth. The **Above Ground Non-Living Biomass (AGNLB)** also called **Above Ground Dead Organic Wood (AGDOW)** includes dead standing or fallen trees and stumps, other coarse woody debris, the litter layer and charcoal (or partially charred organic matter) above the soil surface. The proportion of AGDOW depends on forest condition.

- **Belowground biomass (BGB):** this component represents 4-8%. It refers to living and dead roots, soil fauna and the microbial community. Living biomass of live roots includes fine roots (< 2 mm diameter), small roots (2 – 10 mm diameter), and large roots (> 10 mm diameter).

- **Organic litter** (**DOM**) (0.4%): these comprise non-coarse dead materials leaves, small branches and twigs.

- **Soil Organic Matter** (**SOM**) (60-80%): comprises humus and other soil organic C pools in the mineral soil.

- **Harvested Wood Product (HWP):** comprises timber and other wood materials harvested and transported out of the forest ecosystem.
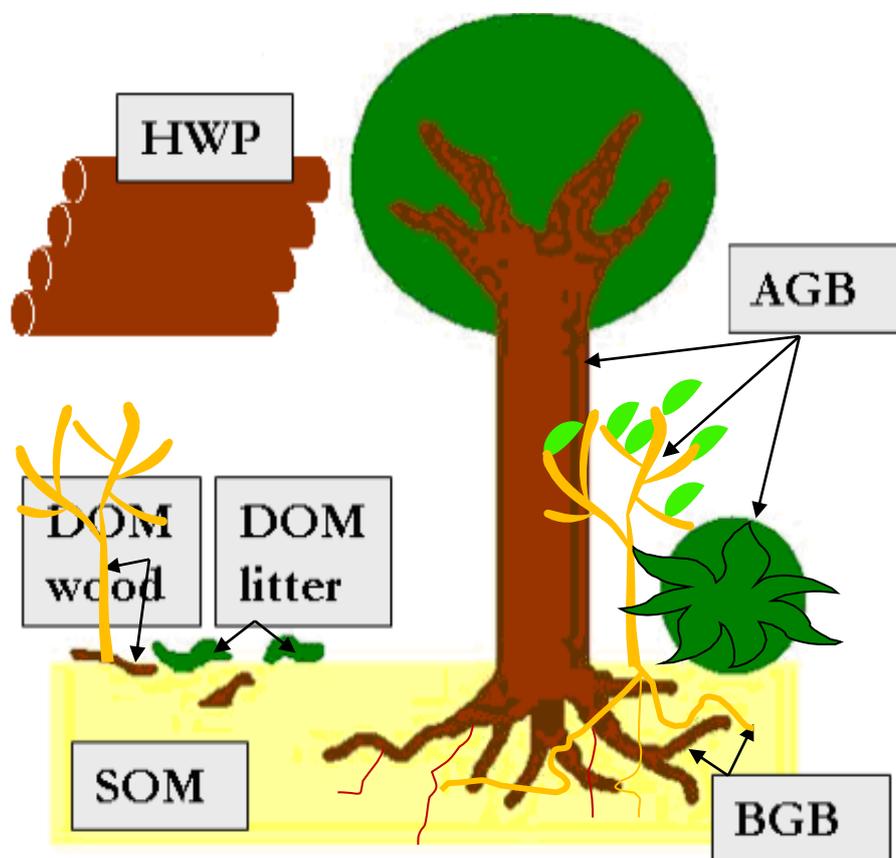
Figure 13. Components of forest carbon pools in picture (modified from Watson, 2008)

Which carbon pools to consider in carbon projects and why?

The carbon pools selected determine the emissions scope of a project, and these have to be decided early on before field inventory is conducted. The decision to include or exclude a particular carbon pool in forest carbon accounting is governed by several factors such as:
- Available financial resources for accounting the pools;
- Availability of prior data and information;

- Ease, availability of expertise, equipment and cost of measurement;
- The magnitude (sensitivity and amount) of potential change of carbon in the pool,
- Judgement from conservativeness perspective, and verifiability of methods in including the pools,
- The carbon offset standard selected, and
- Country's regulatory framework.

Generally, a carbon pool may be neglected if it is considered "insignificant." Insignificance of a pool is determined following test of significance procedure described in the various standards (the accounting methodologies adopted by a project). For instance, for CDM projects, the CDM "Tool for testing significance of GHG emissions in AR CDM project activities" should be followed. According to this tool, a pool is considered 'insignificant' when its carbon stock or emission reduction is < 5% of the total CO_2e benefits expected to be generated by the project. This is also more or less the same for REDD+ project that follows the VCS methodology. According to VCS (e.g. VM00015m) a pool can be excluded or considered insignificant when its **exclusion does not** lead to **a significant** under-estimation of the net GHG emission reductions of the project. The standard defines 'significance' as carbon pools and sources that account for > 5% of the total GHG benefits generated from a project. Therefore, the decision for **inclusion or exclusion** of a given should be determined objectively based on data collected on all pools and taking the ratio of the carbon in a given pool to that of total carbon stock expected for ER from the project. Some relatively **less significant carbon pools** can also be excluded to fulfil the conservativeness principle. There are also two additional rules to exclude or include, which are:
1. Carbon pools can be excluded if the pool will not decrease significantly because of change in land management (e.g. soil carbon), and/or;
2. Carbon pools can be excluded if the pool will not increase significantly as part of the baseline.

It is all up to the project developer to decide which pools to include or exclude but this should be decided objectively. The following are general recommendation to help project developers:
- The carbon stored in the **above ground living biomass** of trees is typically the largest pool and the most directly impacted by deforestation and forest degradation. It must always be selected both in the case of REDD+ and afforestation/ reforestation projects.
- **Below-ground carbon pool** is also always recommended, as it usually represents between 15-30% of the above ground-biomass carbon. However, while the measurement of above ground biomass (particularly that of trees' biomass) is relatively straightforward, the carbon in roots (below ground biomass) is often difficult to measure. It is estimated mostly using a suitable **root-shoot** ratio (also established as default for global applications). Root-shoot ratio is a factor that expresses root biomass in relation to aboveground biomass.

- **Above-ground non-tree or understory pools** may be worth measuring in cases where they are a significant component of the biomass, such as when the density of trees is low (e.g. savannah). Generally, the amount of biomass in non-tree living mass (commonly called understorey plants) is variable depending on level

of disturbance of the forest and forest growth stage. It is low in old growth close canopy intact tropical forest, while considerably in open canopy, disturbed or secondary forests. Under normal condition it generally represents about 3% or less biomass of the aboveground biomass in more mature forests. However, in secondary forests or disturbed forest, this fraction could be higher (e.g., up to 30%; Brown and Lugo 1990, Lugo 1992) depending on age of the secondary forest and openness of canopy. Palms are common in many tropical moist forests and they are also often ignored in forest inventories. Their contribution to total biomass density can be very variable, from nearly 100 percent to less than a few percent. In most carbon projects, however, non-tree living biomass is generally considered insignificant.

- **Above ground standing dead woods:** the amount of dead wood in tropical forests is also variable and depends on several disturbance factors. Whether it is worth measuring it or not depends on the condition of the forest, and should be determined based on a precursory examination of the forest and after understanding of whether there are sufficient quantities to merit measurement.

- **Carbon in harvested wood** must be included if removal of timber is associated with significantly more carbon stored in long-term wood products in the baseline case compared to the project scenario.

- **Soil carbon inclusion or exclusion**: In instances where total carbon stock data will be used to create emission factors resulting from changing between strata and/or land cover/land use classes, soil carbon should not be included in the sum of carbon stocks. This is because it is often assumed that the changes in soil carbon emissions resulting from deforestation will take place over a 20 year period, based on post-deforestation land use. Therefore, emissions from soil carbon will be accounted for separately.

According to VCS (VM0015 methodology) six carbon pools listed in the table 8 below are considered, and decision criteria for inclusion or exclusion also indicated together.

Table 8. Carbon pools to be included/excluded with the justification under VCS irVM0015 methodology.

Carbon pool	Included/TBD/ Excluded	Justification/Explanation of choice
Above ground	Tree: included	Carbon stock change in this pool is always significant
	Non-Tree: TBD	Must be included in categories with final land cover of perennial crop
Below-Ground[+]	TBD	Optional and recommended but not mandatory
Dead wood+	TBD	Recommended only when significant
Harvested wood products[+]	Included	To be included when significant
Littre	TBD	Recommended only when significant.
Soil organic carbon+	TBD	Recommended when forests are converted to cropland. Not to be measured in conversions to

		pasture grasses and perennial crop according to VCS Program Update of May 24th, 2010.

1. TBD = To Be Decided by the project proponent. The pool can be excluded only when its exclusion does not lead to a significant over-estimation of the net anthropogenic GHG emission reductions of the AUD (unplanned Deforestation) project activity;
2. The VCS defines "significant" as those carbon pools and sources that account more than 5% of the total GHG benefits generated (VCS 2007.1, 2008 p.17). To determine significance, the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" shall be used.

3.2. The principle of conservativeness and verifiability

As a general principle most carbon standards and good practice guidance require **conservative estimates** of forest carbon and emission reduction claims. This means only carbon pools (emission sources or removals) that contribute significantly as a source of GHG emission or removal should be accounted. Conservativeness is engraved into the various standard methodologies that project developers will adopt, and further **verified by using third party audit**. For instance, the Verified Carbon Standard (VCS) has adopted what it called "*de minimis*" regulation, which implies pools that account for less than 5% of **the total emissions reductions** generated by the project are considered insignificant; hence should be excluded (see table 3 above) . For most methodologies, "optional" pools will actually require significance testing before they may be conservatively excluded from project accounting (see below for significance test). Pools that cannot be conservatively ignored must be accounted for through field and laboratory measurements, as appropriate. This means that the project does not have discretion to forego accounting for any required or optional pools that do not justify exclusion on grounds of conservativeness or insignificance.

Verifiability of methodology and all data collected and used is another fundamental requirement to develop appropriate REDD+/CDM projects. This also includes verification of pools considered significant and included in a project design documents. As mentioned above project documents are subject to third part (external) auditing to control any flaw in the project development process. Auditors performing validation and verification will generally require rigorous documentation of inventory design, and measurement and analysis procedures applied. They expect every project to demonstrate an attempt to identify and eliminate biases, particularly those leading to over-estimation of project carbon benefits. Successful validation reinforces confidence in the overall feasibility and attractiveness of the project to credit buyers.

3.3. GHGs to consider in REDD+

Different GHGs can be considered in any REDD project (Table 9). However, the most common is usually is CO_2 emissions. Non-CO_2 emissions are included if their sources are known to exist and these are significant. To evaluate the significance of non-CO_2 gases, a calculation need to be done for each based on historic estimate of changes (e.g. fire burning of a forest; pit lands drained, etc.). The non-CO_2

emissions are calculated using equation 2.27 (IPCC 2006), using default emission factors from Table 2.5 (Tropical forest) and combustion factor values from Table 2.6 (all secondary forest).

Table 9. GHGs potentially considered in REDD+ projects including answers for each based on Bale REDD+ project

Source		Gas	Included?	Justification/Explanation
Baseline	Biomass burning	CO2	Yes	Counted as carbon stock change
		CH4	No	
		N2O	No	
		Other		
	Livestock emissions	CO2		Not a significant source
		CH4		The major baseline activity is conversion of forestland to agriculture land by small holder farmers, not to grazing land
		N2O		
		Other		
Project	Biomass burning	CO2	No	Counted for as changes in carbon stocks
		CH4	No	The BMERP is implementing activities that avoid conversion of forests to cropland and grazing / pasture land which can reduce emissions of N2O and CH4 that are associated with biomass burning used to clear the land, fertilizer use and other agricultural practices that would have occurred if the forests had been converted.
		N2O	No	Considered insignificant according to VCS Requirements Document 8 October 2013, v3.4
	Livestock emissions	CO2	No	Not a significant source
		CH4	No	Raising livestock is not a widespread baseline activity and the BMERP will not promote the raising of livestock or result in an increase of this activity compared to the baseline. Therefore, livestock emissions are conservatively excluded.
		N2O	No	Not significant

3.4. Forest Carbon Accounting Paradigm (Methods)

IPCC-Good Practice Guide (GPG) identifies two general methods to quantify change in forest carbon stock (Figure 14). These are called the flux (carbon gain and loss) method and carbon stock change method.

- **In the flux (carbon gain/loss) approach**, the quantified carbon loss due to harvest removal, fire and other disturbances is subtracted from the carbon gain though incremental yield and enrichment growth in a forest over an accounting period (Figure 14):

ΔC = A (Carbon gain from increment + enrichment) -B (carbon loss due to harvest etc.) (Figure14)

- **In the stock change approach**, the stock of carbon in a particular pool is measured over an accounting period. The difference in pools between the two time period (Figure 14) provides the net change in carbon storage:

ΔC = Ct1 (initial carbon stock or carbon at time t_1) - Ct2 (final carbon stock, carbon at time t_2) (figure 4).
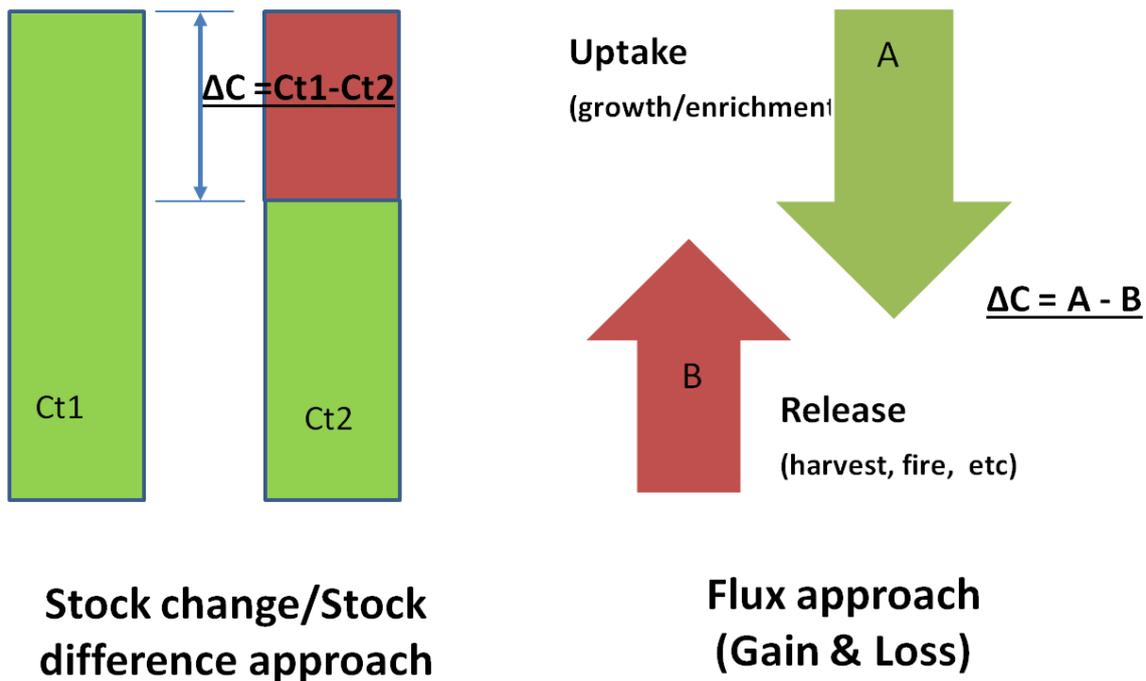
Figure 14. Stock Change and Flux methods for forest carbon accounting (modified from: Diaz and Delaney, 2011).

The two methods can also be used in combination. The specific accounting framework is usually determined by the offset methodology[1] (as specified by the standard adopted) chosen and is not usually a matter of choice for the project developer.

The **stock change approach** is the most commonly used method to quantify total or net emissions reductions, while the flux method is applied under the circumstances

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[1] Methodologies are step by step procedures developed by carbon offset standards – independent third party organizations (e.g. CDM; VCS, American Carbon Registry (ACR), Gold Standards, etc)- for quantifying the real greenhouse gas (GHG) benefits of a project and provide guidance to help project developers determine project boundaries, set baselines, assess additionality and ultimately quantify the GHG emissions that were reduced or removed. For instance, under VCS standard, there are several methodologies: VM0003, VM0004, 5,6,7,9,10,11, 15) to be used based on the local context the forest is facing.

where the stock change approach is difficult to apply. The flux approach best fits forest systems that are sustainably managed, where removals are well recorded, and growth information are well studied. It can be applied but with limited accuracy in a situation where illegal sporadic timber harvesting and unsustainable extraction of biomass for fuelwood exists by surveying the community gathering fuelwood to provide estimate of volume/mass of forest products extracted. The feasibility of such method for carbon project development and emission reduction trading depends on whether there is accepted methodology to apply or not.

A prerequisite for quantifying changes in carbon stock is to measure the initial carbon stock through forest carbon inventory and during a successive monitoring interval. Relevant forest carbon inventory guidance across forest carbon standards (e.g. CDM, VCS, gold standard, plan vivo, etc.) is usually spelled out in individual methodologies (e.g. VM0015 for VCS: www.v-c-s.org/**methodologies**). In general, the methodologies often allow many options for forest survey methods so long as the procedures and data analysis are well-documented and scientifically justified. **Project developers should download and thoroughly read, discuss and understand any methodology they intend to use to make sure their inventory design and procedures are consistent with the most current version and requirements therein**.

For **REDD+** projects, the primary emphasis of an inventory is establishing the quantity of carbon storage at the start of a project (time zero, t_0) in identified forest strata. Based on the nature of the project (e.g. if carbon enhancement is a target) subsequent inventories may be applied to track incremental growth—such as where degraded forest is recovering —but this type of accounting is not accepted in all REDD+ methodologies. Otherwise, data from the initial inventory can be used to calculate ex-ante and ex-post carbon stock, and consequently carbon stock change. The initial inventory work forms the basis for determining the expected emission level corresponding to the deforestation or degradation baseline, called baseline scenario and also that of project scenario; hence ex-ante carbon stock and stock changes of a project.

For **AR** projects, forest carbon inventories serve primarily to document the incremental growth of trees over time. A time zero (t_0) inventory will establish the starting point for incremental growth, but in most AR projects the calculation of time zero carbon storage will generally focus on measuring non-tree woody biomass (in addition to emissions associated with site preparation and clearing prior to planting) that may be required by the CDM methodology to quantify baseline carbon stocks. This initial inventory will generally not utilize the same measurement techniques or sampling intensity at later forest inventories when the primary carbon pool of interest will be **aboveground tree biomass**.

Field forest inventory is not a mandatory procedure under all conditions. The GPG-LULUCF (and the 2006 IPCC Guidelines) allows use of **three alternative methods** of forest carbon stock quantification, two of which will not require field inventory. The three methods, called 'tiers' represent methods with increasing level of data requirement and analytical complexity as described below:

Tier 1:

Typical characteristics of this tier are:

- it is simply and easy to use. It involves applying default values of forest biomes and forest mean annual increment as provided by the IPCC emission factor database (Table 10);
- requires no new data collection;
- its estimation however provides limited resolution (it is global estimate) of how forest biomass varies sub-nationally
- consequently, has a large error range for growing stock in developing countries.
- useful only for broad continental forest types (e.g. African Tropical Rainforest), and
- usually used in Project Idea Note (PIN) development cases. It is unlikely that the Tier 1 method alone is sufficient for crediting for carbon under REDD+.

Table 10. Default biomass values for various biomes in tropical and sub-tropical area under Tier 1 IPCC guidance (Source: IPCC, 2006)

Climate domain	Ecological zone	AGB in natural forest (t/ha)	AGB in forest plantations (t/ha)	AGB growth in natural forest (t/ha/yr)	AGB growth in forest plantation (t/ha/yr)
Tropical	Tropical rain forest	300	150	7	12
	Tropical moist deciduous forest	180	120	5	10
	Tropical dry forest	130	60	2.4	8
	Tropical shrubland	70	30	1	5
	Tropical mountain systems	140	90	1	5
Subtropical	Subtropical humid forest	220	140	5	10
	Subtropical dry forest	130	60	2.4	8
	Subtropical steppe	70	30	1	5
	Subtropical mountain systems	140	90	1	5

Tier 2:

- This is same as tier 1 and uses default values (static forest biomass information);
- but differs from tier 1 by using country specific data (i.e. collected within the national boundary) (e.g. table 11), and
- by resolving forest biomass at finer scales through the delineation of more detailed strata.

Table 11. National information on biomass of various forest types in Ethiopia (Source: WBISPP, 2004)

Forest type	Average biomass (tons/ha)	Remark
Montane conifer	100	(*Podocarpus* & Juniper in central

		Ethiopia
Montane broadleaved forest	89.16	Southwest and southeast forest
Dryland Juniper	69	e.g. Yabello
Woodland	10.19	Dry land forest
Cultivated land (cereals with scattered on-farm trees)	1.71	Cereal
Cultivated land (perennial crops)	9.00	Enset, coffee, etc

Tier 3:
- This uses local level information such as actual inventory with repeated measurements using permanent plots to assess changes in forest carbon ; hence assess GHG emissions, or
- Combination of well parameterized models (allometric equations) in combination with plot data.
- Tier 3 often focuses on measurements of trees only and also mostly above ground biomass only. For other pools it uses region/forest specific default data and modeling.

3.5. Estimations of carbon stock from field measurements (Tier 3)

Two methods exist to estimate carbon stock of a tree and/or a forest area. These are:
1. Biomass Expansion Factors (BEF) or Biomass Conversion and Expansion Factor (BCEF) method, or
2. Allometric equation method.

Both are widely used in forest carbon stock estimation. Both are used to convert data obtained through field inventory on easily measured tree or stand parameters into biomass and carbon stock.

Biomass Expansion Factor (BEF) refers to the ratio of the total aboveground oven-dry biomass density of trees with a minimum DBH of 10 cm or more to the oven-dry biomass density of the merchantable volume. This factor is applied to convert **available forest inventory data**, as long as it is recent, that usually refers to merchantable volume. By applying the BEF on existing volume based data designing and conducting new forest inventory work can be escaped and considerable cost can be saved. The procedure to apply BEF is as follows: first the partial stem wood volume (merchantable volume) is multiplied by wood density (WD, and then by BEF. This converts the data to whole tree biomass. The product is multiplied by **0.5, carbon fraction of a tree,** to convert to carbon stock per tree. The sum of carbon stock of trees in a plot will give carbon stock per plot, which can be multiplied by 10000/plot area fraction to obtain carbon stock per ha. If volume data per hectare exist, then BEF can be applied on this to directly obtain carbon stock per ha.

Biomass (tons) = $V(m^3)$ x WD (tons/m^3) x BEF

Where:
- V is merchantable volume over bark (m^3/ha) (available from previous inventory)
- WD is basic wood density (for species specific WD refer to TABLE 3A.1.9-2 of the IPCC-GPG, page 3.173; otherwise have your own national database or use average conservative value such as 0.65 tons/m3);
- BEF = Biomass Expansion Factor (apply default value as in table 6 or develop value applicable to your forest condition)

Conservative default values exist for BEF for different forest types and regions, and these are provided by IPCC GPG-LULUCF (Table 3A.1.10) (see also table 12 below).

Table 12. Default values of biomass expansion factors (BEF) ((TABLE 3A.1.10, IPCC)

Climate region	Forest type	Minimum DBH (cm)	BEF over bark
Tropical	Pine (conifer)	10.0	1.3 (1.2-4.0)
	Broadleaf	10.0	3.4 (2.0-9.0)

Alternatively biomass and carbon stock can be calculated from Volume Over Bark (VOB) data by multiplying directly with what is called **Biomass Conversion and Expansion Factor (BCEF)**.While BEF is used to 'expand' available partial tree stem volume data to **biomass of whole tree**, perhaps the best way of using BEF is an integration of biomass conversion and expansion components into one factor, as BCEF. Such biomass conversion and expansion factors (BCEF) then convert the most widely available data on stem volume (on per ha basis) directly to whole tree or compartment biomass (above ground, below ground, etc.), and eventually into carbon stock.

The general definition of BCEF provided by IPCC (2006) is a multiplier with dimension (tons/m^3) that transforms growing stock in volume (m^3) directly into aboveground biomass or above-ground biomass growth or biomass removals (tons) (also Table 13):

- B_i = $BCEF_i$ (tons/m3)×V(m3/ha)

BCEFs can be calculated for each stand (sampling plot), as the ratio of the biomass to the volume:

- $BCEF_i = B_i/V_i$

Where:
- V is stand volume (**total volume**) with bark (m^3/ha);
- B is biomass (dry weight) in (tons/ha);

Table 13. Values of BCEF for application to volume data from IPCC GL AFOLU guidelines

Forest type	Growing stock volume – average and range (VOB, m3/ha)						
	<20	21-40	41-60	61-80	80-120	120-200	>200

Natural broadleaved	4.0 2.5-12.0	2.8 1.8-3.4	2.1 1.2-2.5	1.7 1.2-2.2	1.5 1.0-1.8	1.3 0.9-1.6	1.0 0.7-1.1
Conifer	1.8 1.4-2.4	1.3 1.0-1.5	1.0 0.8-1.2	0.8 0.7-1.2	0.8 0.6-1.0	0.7 1.6-0.9	0.7 0.6-0.9

Allometric Equations (AE) are regression models (equations) that express mathematically the relationships between the different components of a tree such as diameter and/or height with volume and/or biomass. They are derived first from samples of trees harvested and their biomass or volume measured precisely. Once developed, allometric equations allow foresters to convert simple measurements of trees such as stem diameter to characteristics which are more difficult to measure such as volume, biomass and carbon stocks, minimizing the need for expensive and time-consuming destructive measurement of trees in the field.

Allometric equations are available for both biomass and volume. Where available, use of biomass allometric equation rather than volume equation is recommended for carbon assessment. This is because if volume equation is used results should be converted to biomass using BEF or BCEF. Biomass equations are generally more straight forward and accurate. However, use of biomass or volume allometric equations is most often not a choice between varying levels of scientific or statistical rigor but rather a decision that tends to be based upon the availability of prior data. Where there exists inventory data on volumes, it is more cost effective to apply BEF and convert the data to carbon values. But where new data has to be collected, inventories for carbon projects will typically follow a direct tree measurement of diameter, height, etc. and apply **appropriately chosen and validated** biomass allometric equations.

The choice between volume and biomass equations is also determined by the specific methodology (standard) a project design decides to follow. BEF is allowed by all CDM methodologies and most VCS methodologies. It is important to note, however, that both the Avoided Deforestation Partners (VM0007) and Wildlife Works Carbon (VM0009) REDD Methodologies omit BEFs, dealing only with allometric equations.

IPCC GPG-LULUCF (4.A.1-4.A.3) provides a list of allometric equations (see annex 1 for exhaustive list of allometric equation) contained in peer-reviewed publications. One can choose from this list appropriate allometric equation(s) fitting the forest condition under consideration and apply these in combination with field measured variables to obtain carbon stock of a forest stand.

Locally developed allometric equations, which may be area-specific or species-specific are much better to use wherever available. Moreover, project developers can construct their own new equations. The process of developing new allometric equations is not particularly complicated as it can be completed with a relatively brief sampling effort of **about 30 trees for a particular species** or grouping of similar species. Nonetheless, for species rich tropical rain forests, still it is not that easy if all the species in a forest are to be represented.

Therefore are some species-specific and general biomass allometric equations for Ethiopia. These are presented in table 8 below. The equation developed by the woody biomass inventory project is developed for application to the forests of the country. Under all circumstances it is worth checking (validating) which equations, whether global or local, yield more accurate and precise estimate before jump start applying a particular equations. It is also essential to calibrate the available equations to best fit local forest conditions. Doing so will improve the accuracy of biomass estimation for the forests in the country.

There are two forms of biomass based allometric models as well:
1) one that models the trunk only (i.e. merchantable biomass), and
2) other that models the entire biomass (total tree biomass).
In the former case, the biomass of the other compartments (foliage, branches, etc). is estimated from **Biomass Expansion Factors**.

Tips on Choosing Appropriate Allometric Equations

Allometric equations are important tools for quantifying forest resources. However, all allometric equations are not the same, and cannot be used without careful evaluation of applicability to the context they are supposed to be used. This is because **errors and uncertainties** in the application of these equations to individual trees often propagate to errors at the forest and country level when estimating forest carbon stock and carbon stock changes. Therefore, before putting into application a given model, it should be validated in order to minimize error (see below for validation).

The most widely used allometric equation today is that of Chave et al (2014). Commonly used global allometric equations for tropical rainforests are also those from Brown (1997), Brown et al (1989), Chave et al. (2005; 2014) and Henry et al. (2010) (Table 8). These are also limited to trees with diameter <148, <156 and 180 cm, respectively. Trees with larger diameters are rare, but do occur. For instance, Chave et al. (2003) reported that trees with DBH > 150 cm represent 9.75% of total biomass in a Brazilian tropical rainforest. So it is generally safe to use these equations where the population of very large trees (with DBH greater than indicated above) are limited.

Various authors have reported that increasing the number of predictors (and particularly incorporating the crown diameter and tree height) improves precision of allomteric models. Chave et al. (2005) reported that for tropical forests, the most important predictors of tree biomass were, in decreasing order of importance, trunk diameter at 1.3m (DBH), wood specific gravity, total height and forest type. Gibbs et al. (2007) reported that DBH alone explains more than 95% of the variation in aboveground tropical forest carbon stocks. While the model developed by Brown (2002) explains 95% of the variability found in less than 150 tree samples. These studies also imply that use of most influential factor although single variable can result in a reasonably accurate and conservative estimate.

Generally considering that constructing allometric models specific to each country is destructive, time-consuming and expensive, for tropical forests, particularly those in Africa, it is suggested to use the Chave et al (2014) models as a first approximation to estimate tree biomass when country-specific allometric models are not available.

Validating allometric equations is essential

When choosing to apply a non-local allometric equation for estimating biomass and carbon stock, this has to be validated independently. This is a mandatory requirement as part of maintaining standard emission reduction or removal accounting to secure carbon finance.

Validation involves a destructive or semi-destructive near accurate assessment of biomass of independent sample trees (observed value), and this will be compared to the estimate obtained by applying the allometric equation (prediction value). The observed and predicted values are compared for under or overestimation. If there is a serious deviation between the two, an alternative allometric equation should be sought or a local allometric equation should be developed.

Several criteria may be used to compare predictions with observations for their deviations. These are:
- Bias: sum of $(Y_{obs} - Y_{pred})$
- sum of squares of the residuals: SSE =Sum of $(Y_{obs}-Y_{pred})^2$
- residual variance: s^2 = SSE/(n'−p), or
- R2 of the regression: R2 = $1−s^2/Var_{(Yobs)}$

P is number of freely estimated parameters in the model

Limitations of allometric equation are that: first existing equations are mostly limited to above ground tree biomass estimation. Second, they can only be used for their domain of validity (i.e. for the range of DBH/Ht used in their development). Therefore, before using a model, we must make sure that the characteristics of the tree whose volume or biomass we wish to predict fall within the valid range of the samples used for the construction of the model. If a volume or biomass model has been fitted for trees of DBH between D_{min} and D_{max}, in principle it cannot be used to predict the volume or biomass of a tree whose dbh is less than D_{min} or more than D_{max}. However, not all models are subject to the same degree of errors when extrapolated outside their valid ranges. Power models can generally be extrapolated outside their valid ranges and still yield reliable. By contrast, polynomial models often behave abnormally outside their valid range (e.g. predicting negative values), particularly when using high-order polynomials. In general, applications of global allometric equation to local forest will always introduce significant error in carbon stock estimation. Despite the cost implication it is therefore recommended either to adapt these global equations to local contexts or good to make efforts to develop equations that are local. Research should help in this regard. Until allometric equations of local application are developed, it is also good to validate possible global equations and recommend which to use based on their applicability.

Module exercises

A. Testing significance assessment of a carbon pool

1. The Bale natural forest is subject to limited selecting logging. Data obtained from Oromia Forest and Wildlife Enterprise on annual volume of selectively removed timber from the forest is indicated in table below. The annual total carbon emission from the forest block for the corresponding years is also included. Assess whether carbon in harvested wood is significant for inclusion or not?

Year	Selective logged volume (m3/ha)*	Average Carbon stock in the forest (ton C/ha)
2010	10	500
2011	9	500
2012	12	500
2013	5	500
2014	10	500
Average		500

*The volume should be converted to biomass using a wood gravity and a default Biomass Expansion Factor (BEF) (IPCC 2003) or a default biomass conversion and expansion factor (IPCC 2006).

The formulas are:
Biomass partial (kg/ha)= V (m3/ha) * WD;
Total Biomass (kg/ha) = Biomass partial * BEF
Carbon stock (kg/ha) = Total biomass * 0.5

Or directly by
Carbon stock (Kg c/ha) = V * BCEF * 0.5

Where;
    Biomass partial is the biomass of the merchantable volume (kg),
    V is the merchantable volume (m3),
    WD is the wood gravity (kg m–3),
    BEF is the biomass expansion factor and
    BCEF is the biomass conversion and expansion factor (which is = WD*BEF).

B. Use of BCEF

1. The Arsi branch of Oromia Forest and Wildlife Enterprise has recently conducted a forest inventory. The data on merchantable volume per hectare of five plots is shown in the table below. Convert the data into biomass and carbon stock per tree applying the BEF (For BEF, check the default table below)

Plot No.	Total Volume over bark (m³/ha)	Biomass (kg/ha)	Carbon stock (kg/ha)
1	250		
2	327		
3	316		
4	289		
5	401		

C. Calculate biomass using BEF

For a tropical broadleaf forest with a VOB of 350 m³/ha and weighted average wood density of 0.65 t/m³, calculate the biomass corresponding to the volume fraction, BEF and above ground biomass. For the same forest calculate above ground biomass using the IPCC default BEF value.

D. Carbon stock estimation

1. Estimate carbon stock (tier1 & 2)
    a) expected in 2500 ha forest in Kaffa zone of SNNPRS;
    b) expected in 3500 ha of Menagesha-suba forest
2. Compare the estimate in tier1 and tier 2
3. Give the below field data on DBH from a dry afromontane forest, calculate the average biomass and carbon in AGB. Choose at least two allometric equations and also compare the difference in estimate between the two (use the woody biomass inventory equation as well).

Plot No								
1	2	3	4	5	6	7	8	9
24.0	60.0	20	27	18	27	30.0	55.0	39
38.0	25.5	21	47	14.5	24.5	25.0	40.0	27.5
23.0	20.0	29	28	14	28.5	22.0	62.0	20
31.0	106.0	24	50	10	29.5	23.0	37.0	21.5
60.0	46.0	40	37	10	33	37.0	22.4	20.5
25.0	20.0	35	28	11	31.5	31.0	30.0	34.5
41.0	98.0	25	24	20	35	32.0	35.0	21.5
28.0	33.5	25	41.5	32	48.5	38.0	21.0	23
30.0	20.0	20	27.1	12	45.5	25.0	21.0	39
31.0	20.5	27	23	19	40	21.0	36.0	22
49.0	20.0	28	40.7	12	20	26.0	36.5	23
42.0	21.5	28	32.3	12	20	45.0	45.0	36.5
24.0	30.0	23	33	17	22	28.0	42.0	24
42.0	32.5	25	44	17	44	54.0	23.0	45

40.0	21.0	26	47.5	21	22	51.0	35.0	42
40.0	61.0	21	29	12	32	65.0	23.0	20
27.0	21.5	25	30.7	21	20	21.0	46.0	26
29.0	32.5	21	31	14	25.5	47.0	49.5	41
39.0	24.5	21	42	14	24	24.0	59.5	21
58.0	27.5	20	33.5	19	20	25.0	26.0	20
48.0	31.0	24	24.2	44	30	21.0	21.0	43
39.0	30.0	26	26	15	20.5	22.0	39.0	25
47.5	47.0	23	39	17	22	25.0	41.0	34
29.0	20.0	23	23.6	34	27	10.0	21.0	21
39.1	24.0	30	47	25	31	10.0	28.0	20
45.0	21.0	34	28	54	20	12.0	41.0	25
29.0	23.0	26	36.7	32	27	13.0	30.0	20.5
22.0	42.0	36	24.8	17	50	11.0	42.0	39
38.0	26.0	37	45	36	28	10.0	24.0	31
51.0	21.5	36	30	14	44	10.0	22.0	23

4. Compare the three results from the three tiers and discuss what the differences would mean in terms of carbon finance;

5. Discuss among yourselves what pros and cons the use of such default values will have on carbon credit.

6. Conduct inventory fieldwork on Menagesha Suba forest and generate own data and calculate carbon stock of the forest using tier 3. Compare estimate from the three tiers and discuss the results.

4. Forest Carbon Inventory design and data acquisition

Module objective: Forest carbon inventory is not a new subject but is simply adaptation of the extensive body of experience with traditional timber/forest inventory methods as well as ecological biomass surveys. Proper inventory is crucial as it forms the basis on which emissions reductions or removals are determined. The primary aim of this module is therefore to outline practical steps and procedures that emphasize field inventory for carbon stock assessment in a forest ecosystem.

Learning outcomes: by the end of the session, participants will be able to
- explain and discuss the steps followed in forest carbon assessment;
- discuss why and how forest boundary is defined, and forest is stratified;
- calculate number of sample plots needed, and apply sampling frames for their forest context;
- explain the value of a quality assessment and control strategy in forest carbon assessment, and
- have identified key strategies on quality assurance and quality control that could be applied in their own situation.

Time Required:
- 2 days (16 hours)

Materials needed:

- Sufficient copies of the technical considerations and protocols; flip charts or whiteboard and markers; laptop computer or exercise book
- Forest map of an example site.

Method of training:

- Combination of PPT presentation by the trainer, group breakout discussion and group exercises;
- Before starting PPT, give participants about 20 minutes to brainstorm and share their experience about what they know of forest inventory including key steps, sampling techniques, plot distribution and measuring of tree variables, and how to ensure quality of data collection, and quality control strategies.

4.1. Key steps in forest carbon assessment

The five main steps to a forest carbon stock assessment comprise those indicated in the figure 15 below:
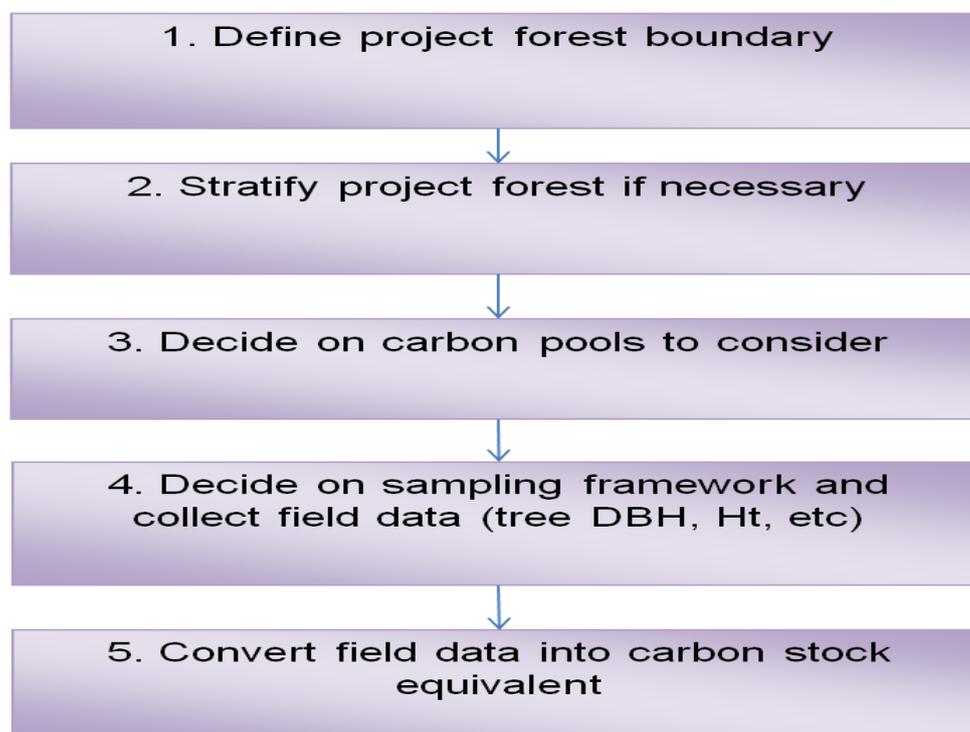
Figure15. Main steps followed for field based forest carbon assessment

4.2. Defining boundary of project forest

Total carbon stock calculation is possible if and only if the project boundary is defined, mapped and its area calculated. Defining the geographic scope of the project forest is therefore a critical first step for forest carbon inventory and emissions reductions or removals. If there is existing prior map of good quality, these can be used. Otherwise, the boundary can be delineated from remote sensing or through GPS based ground surveying. Different carbon standards provide definitions of what qualify as 'project area'[2], and this must be followed if targeting a specific standard. For example, for the VCS, the project area must be 100% forested for at least 10 years prior to the start of the project and minimum crown cover must comply with internationally accepted forest definitions[3], namely the UNFCCC host country forest definition or the FAO forest definition.

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[2] 'Project area' here does not imply the entire project region or project site. Rather it refers to the project forest (which should be 100% forest cover) and designated to be managed under the REDD+ project to yield emission reduction.

[3] Definition of forest in Ethiopian context refers to community of plants with the minimum height of 2m, canopy cover of ≥ 10% and cover an area of 0.01 ha (according to the new revised forest policy)

4.3. Stratifying the forest

Stratification is a process of sub-dividing a project forest area into relatively homogenous sub-categories or sub-classes called strata. If the forest under consideration hosts forest types that differ significant in carbon density, it should be stratified to increase the accuracy of carbon accounting and also increase efficiency of sampling, i.e. lower the costs by reducing the number of sample plots required. The principle behind stratification is to compartmentalize the variability across the forest by grouping stands into units that are relatively homogenous regarding the variable being measured, carbon or biomass in carbon projects. It is a valuable step for generating accurate inventory and monitoring data.

Important attributes commonly applied to stratify the project forest are
- forest type: determined using parameters like elevation/aspect (topographic position), annual average precipitation and temperature;
- species composition;
- stand age, and
- disturbance history.

Stratification can be made using existing maps or using satellite images at large spatial scales. Following stratification, areas of each stratum must be quantified. Sampling and carbon calculations are then applied to each stratum separately and the results are later combined to provide a total estimate of the carbon stock.

4.4. Sampling and sampling technique

Estimates of forest biomass are obtained usually based on values obtained through inventory of a small representative portion of the forest, called samples. The value obtained on these samples will then be extrapolated to the entire forest. This is because in large forest areas it is not practical to measure the biomass of all trees and plants one by one to obtain the biomass or carbon in the entire forest. This procedure is called **sampling**. The purpose of sampling is to achieve a representative data set of the population in as efficient a manner as possible. Data collected through sampling can be used to infer information about the population through a set of descriptive statistics, which typically includes a measure of **central tendency** (mean/mode/ median), and an estimate of the variability of this measure (CI, variance or standard deviations).

Sampling cannot be done haphazardly. Rather to be valid it should follow a standard statistical procedure. In most cases, the most cost-effective design for forest carbon inventory sampling is stratification followed by systematic or random sampling arrangement.
- **Systematic sampling**: plots are placed on the landscape in a regularly-spaced fashion using a grid, such as strip sampling. Different numbers of plots may be placed in each stratum based on stratum size or internal variation (optimal), but the location of these plots is determined by the systematic arrangement. The start location should be randomly generated to avoid bias in the placement of sampling plots.

- **Random sampling**: a pre-determined number of plots are placed randomly within each stratum. Different strata may hold different numbers of plots, with fewer plots in strata with low variability or low size and a greater number of plots in strata with high variability or large size.

In any event, the plot layout should be well-distributed. If the process of randomization leads to poor plot distribution, such as most plots occurring clustered in one area or near roads, the randomization process may have to be repeated or expanded. Random assignment of plots is not a sufficient justification for a plot layout that does not cover most of the project area or is otherwise not representative. Auditors (during validation) will likely challenge results and/or require placement of additional plots to compensate for a perceived lack of representativeness in plot layout. Random assignment of plots is not a sufficient justification for a plot layout that does not cover most of the project area or is otherwise not representative.

4.5. Number of plots

The number of plots required to reach the desired accuracy and precision must be estimated as objectively as possible. To estimate the number of plots, a pilot sampling survey of the forest should be conducted to generate preliminary information on the variance in carbon stock in the forest (or in each stratum). The following steps help to guide estimation of the number of sample plots required for a given forest inventory:

Step 1: Decide the desired precision level for the inventory:
For reasonably accurate estimates of stock and change in forest carbon with a reasonable cost 10% precision level suffices (i.e. estimated value within 10% range of the true value of the mean) at 95% confidence level. Lower precision level would lead to wider confidence interval, and lack precision, while higher precision would demand higher cost to achieve.

Step 2: Conduct few sample assessment to estimating stand variance
The number of sample plots to be surveyed in a particular forest inventory depends on the variability of the parameter to be measured. The higher the variability (variance) in the parameter to be measured the larger the number of samples to be surveyed to achieve the set precision level. To objectively determine the number of sample plots needed an estimate of stand variance is therefore essential. For this conduct inventory of about 15 sample plots in each stratum and establish a rough variance and standard deviation of the forest (Pearson et al., 2005; Verplanke & Zahabu, 2009).

Step 3: Calculate the required number of plots
This formula can be applied to estimate number of samples required:

$$n = (CV^2 * t^2)/E^2$$

Where:
      n = expected number of samples,
      CV = coefficient of variation,

t = student's t value for the specified confidence interval at a specified degree of freedom,

E = acceptable level of error of the true mean.

If n is calculated for the entire forest, the total number of sample will be split between stratum proportional to size of the stratum or equally. Proportional distribution will apply the formula:

$$nhi = n*Nh/N$$

Where:

n = is the expected total sample plot number

nhi = is sample number of a stratum i

Nh = is total sample number expected in a stratum h (area of stratum h/area of plot)

N = is total sample plot number in the entire forest

4.6. Nature of plots: Temporary vs permanent plots

After the sampling frame is decided, the next step is to decide on the nature of plots: temporary and/or permanent plots for the actual inventory. Permanent plots have the advantage to be also used in future monitoring work. They are statistically more efficient in estimating changes in forest carbon stocks than temporary plots because there is high co-variance between observations at successive sampling events. However there are also cases where temporary plots are advantageous over permanent plots (Table 14).

Table 14. Comparison of permanent and temporary plots

Plot type	Advantage	Disadvantage
Permanent	Can be used in future subsequent monitoring	Because of known location project beneficiaries may concentrate efforts on the plots allowing degradation elsewhere.
	Efficient in estimating changes in forest carbon stocks than temporary plots, because there is high co-variance between observations at successive sampling events.	
	Help to easily distinguish actual trends from differences that are only due to changed plot selection (position).	
	Permanent plots are also useful when a third party wishes to verify the measurements.	
Temporary	No need to mark	Result may reflect natural differences between plot locations due to lack of repeated measurement of the same spot.
	No attention by project beneficiaries for differential treatment	
	Efficient in locating as it is determined by the sampling plan	

4.7. Plot size and shape

Decision on plot size and shape is as equally important as determining number of plots to be inventoried. These also affect accuracy of carbon/biomass estimation. The size (area) and shape (circle, square or rectangle) of the sample plot is a trade-off between accuracy, precision, time and cost for measurement.

Sample plots can also be of two types: single plots of a fixed size or nested plots containing smaller sub-units of variable sizes (Figures 16). Nested plots compose several sub-plots (typically two to four, depending upon forest structure), each of which is viewed as separate plots. They are appropriate for forests characterized by trees of wide range sizes (DBH and/or height classes). Under such a condition, smaller sub-units are used to record small size trees that are numerous if large plot sizes are to be used. These are also used to sample litter, herbs (live above ground non-woody plants) and fro collection of soil samples. Single plots may be preferred for stands that are of low variability in terms of size, such as single species plantations. Nested plots are the most cost-efficient in surveying natural forests.
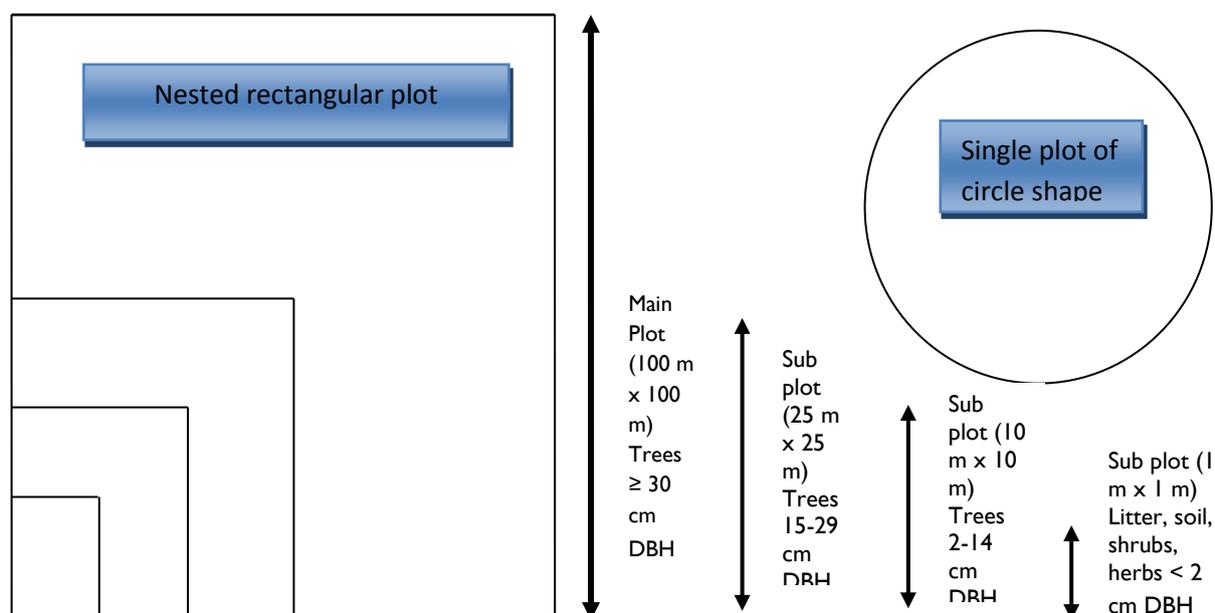
Figure 16. Example of square nested plot and single circle shape plot (For nested circular plot see the below figure 12).

Nested plots can take different forms: nested circles, square or rectangles. Rectangular plots are preferred as they tend to include more of the within-plot heterogeneity, and thus be more representative than circular plots of the same area. The size and number of nested quadrats can vary depending on the homogeneity and heterogeneity of species in the strata (land cover classes).

4.8. Locating sample plot in the field

Precisely locating sample plots in the field is essential. Usually plots are first marked on geo-referenced maps. It is this map location that is transferred to ground by using appropriate navigation system. The most common navigation system is by means of Global Positioning System (GPS). The latitude and longitude of plots' locations is

collected from the map, and uploaded into GPS. The field team then navigates with the help of GPS to locate plots one by one out in the field. Known short comings of use of GPS is the problem of positional accuracy of the receivers. Particularly in dense forests it is not that easy to navigate and locate the exact position of sample plots with GPS in a way that can be replicated (the same spot every time) during validation and/or subsequent monitoring. This is a practical challenge requiring good skill in GPS usage and reading. The inconsistency in point location with GPS calls for the use of supplementary methods that can assist plot re-location. Many inventories use monuments to mark plot centres. The monument must be something that is unlikely to be removed over time. Painted markings on trees toward the plot centre supplemented with good description of the plots using permanent features around it (such as land cover, elevation, roads, rivers and slope) will be located and the order in which plots measurements will take place. Recording the distance and direction from the plot centre to each tree is also useful in later relocating plot centre and facilitating check cruises.

Field layout of plots

After the plot centre is located, the next action of the inventory team is to layout the plot. The following steps are followed for this.

- Navigate to the plot location using GPS;
- Walk an additional 10 steps in the direction of travel. These additional steps reduce bias in choosing the plot centre. The final point will be the plot centre for circular plots. For square/rectangular plots this will be the **first corner of the plot**. For circular plots, this will be the centre of the plot;
- At the plot centre/corner, mark a 'waypoint' on GPS and record GPS coordinates, accuracy, elevation, and waypoint number on data sheet. Before recording the coordinate, wait the GPS for about 5 minutes until it achieves the precision level of close to ±5 meter. Leaving the GPS at one location for several minutes allows the GPS to get a more accurate location by averaging many location acquisitions. The longer the GPS acquires locations the more accurate the final location. The accuracy of the location is estimated and is displayed by the GPS. If there is heavy vegetation cover, it may take a longer time to acquire an accurate location. In some cases, it may be necessary to move slightly or devise a way of getting the GPS higher in the air to acquire satellite signals;
- Measure the slope using a clinometer. If the slope is greater than 10% record the exact **slope for later correction of plot area**.
- Describe land and vegetation conditions of plot and if there is anything unique or unusual in the plot or directly surrounding the plot. This could include things such as small streams, trails, large boulder or termite-mound, and proximity to a paved road;
- For permanent plots additional detail description must be provided on the inventory sheet that can help relocate the plots in the future. Note any hazards encountered in the route to the plot.
- Establish the plot as follows:
    - For circular plot, mark centre of the plot with wooden stake wrapped with flagging tape. This plot centre mark will be used to identify the plot centre during any third-party verification or quality checks.

- In square/rectangular plots, place wooden stakes at each corner of the plot so that verification of plot measurements can be done easily.
- Permanent plots shall be marked using materials that will last longer than the project lifetime.

- For ease of measurement the plot is sub-divided into four (4) quadrats of 50 x 50 m. These quadrats are numbered in sequence, beginning at the **north-west corner** of the plot. The demarcation procedures involved the use of machetes for line cutting, metric tapes for distance measurement and compasses or GPS for direction finding. The layout is shown in Figure 16.

- The external boundaries of the plots should be cleaned to define clearly the extent of the plot. The cleaning involves the removal of small saplings and any other vegetation along the boundary except large trees. For large trees found along external boundaries, clearly marked off-sets should be made around them without causing any injury to the tree. Within the plot, quadrat lines should be cleaned to a lesser degree, with the aim of allowing the measurement team to pass freely from one quadrat to the next.

Measure and record the coordinates of as many trees as possible to assist in future identification of the plot. Also record the position of each measured tree from the centre mark by measuring the distance from the centre and azimuth, this would assist in determining the missed trees during the second inventory or by the validator.

Other information that is included on the demarcation form is the details of site history such as evidence of recent disturbance, including logging or fire damage. The topography of the plot is also recorded at the plot scale. These are usually coded as;
  i.   H = hilly
  ii.   V = valley
  iii. F = flat terrain.
  iv.   Soil type
  v.   Drainage conditions

The corners of the permanent sample plots need to be permanently marked so that after an interval of 5 years or more, they may be precisely and unambiguously relocated. The basic method involves marking the corners of the plot with concrete beacons or durable wooden posts. These beacons or posts can be placed in cairns of heaped soil. However, in such a position the post can be readily pushed over by logging equipment. It is usually better to bury the beacon, so that only a small part protrudes, but to indicate its approximate position through the use of trenches.

The use of trenches is a recommended practice (Figure 17). These are dug along the boundary lines, ending 1 m from each corner, as shown in Figure 17. The trenches should be 30 cm deep, 30 cm wide, and 1.5 m along the quadrat or boundary line. Although such trenches will tend to erode and fill in over a 5-year period, and may be eradicated by logging equipment, in heavier clay soils they are likely to remain clearly visible.
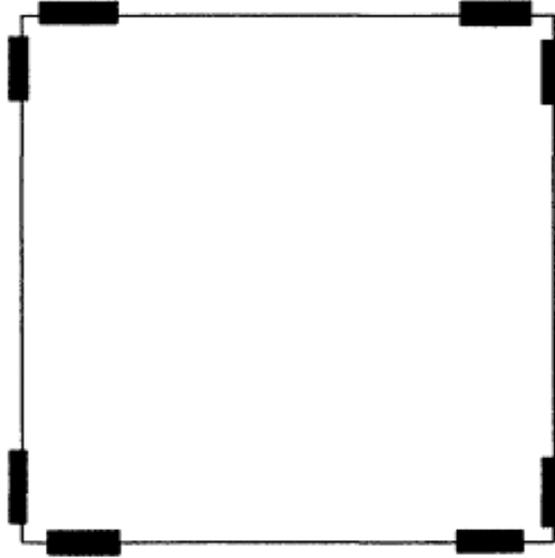
Figure 17. Trenching to mark corners of PSP

4.9. Marking and measuring trees in a plot

The decision on what tree parameters to measure depends on the method of biomass/carbon assessment to be applied. Therefore, decision on what method, and which allomteric equation to apply should be decided ahead of field inventory as these guide which tree parameter to measure. In this manual only diameter measurement is included assuming this is the dominant parameter measured and used in natural forest carbon assessment. DBH alone explains more than 95% of the variation in tree biomass even in highly species rich tropical forests.

Following plot and quadrats establishment (Figures 1; 19), trees in the plot and sub-units should be marked and numbered. Then measurements on the selected tree parameter follows according to the order of number given to the trees. For this the inventory team should have a permanent marking paint. Sequence of movement within a plot is essential to make complete and efficient inventory. In a nested plot structure, enumeration should begin in "quadrat 1" (at the North West corner) and works southwards (Figure 18) following the sequence of quadrats indicated in the layout (Figure 18). Moreover, within each quadrat inventory is conducted in a systematic way to avoid missing of trees and to ensure that the position of each tree is measured accurately.
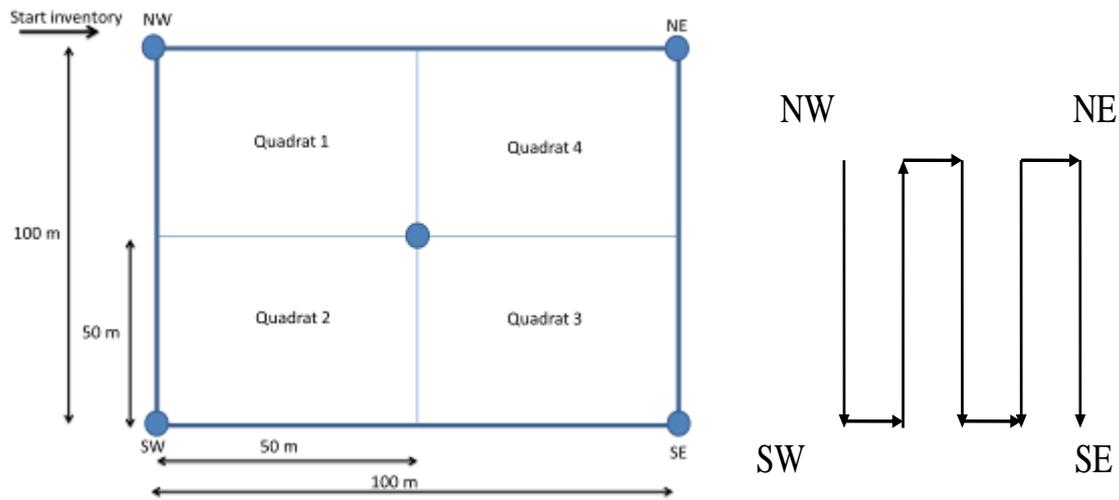
Figure 18. Sequence of enumeration in a sample plot
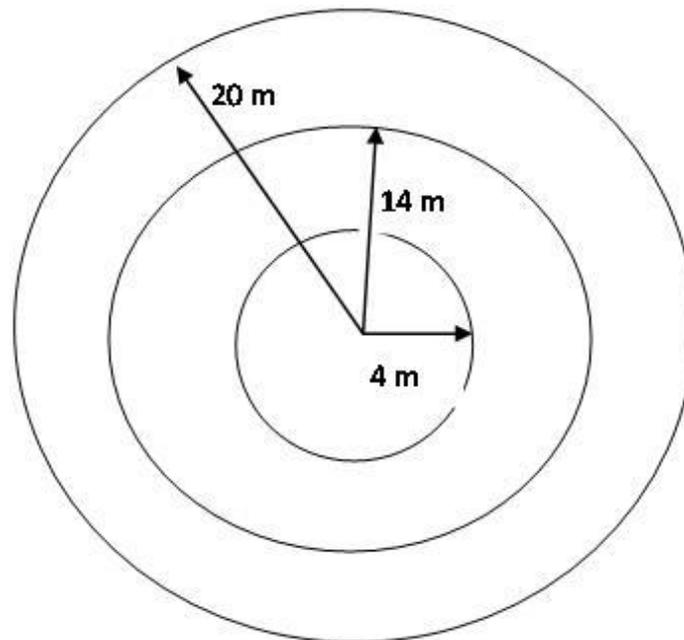
Figure 19. Example of circular nested sample plots (MacDicken, 1997):

In order to include trees with all range of diameter, nested, fixed area circular plots can be used. The example nested plot is with radii of 20 m for large plot for trees > 50 cm DBH, 14 m for intermediate plots for trees with 20-50 cm DBH, and 4 m for small plot for trees with DBH 5-20 cm.

For each tree, data are collected on its local/scientific name, diameter at breast height (DBH), and tree height (if appropriate) of selected trees that is representative of the diameter classes in the 1 ha plot. Also, remarks about the condition of the plot in terms of disturbance etc should be recorded.

4.10. Measuring tree diameter

Tree diameter measurement is the most important measurement for estimating tree biomass, and then tree carbon. This is what will be fed into allomteric equations to estimate tree level biomass and carbon. Therefore, it should be measured carefully and properly. Any error in diameter measurement will propagate to all scale including ecosystem carbon stock estimation.

In a given forest woody plant (live plant) greater than or equal to 2 cm DBH should be treated as above ground woody plant, and its DBH measured. Tree diameter is measured at a point called breast height; hence the name Diameter at Breast Height (DBH). This is the diameter at the height of an average person's breast, or the breast height of the person measuring the diameter. DBH is theoretically diameter at 1.3 metres above the ground from the base of the trees, though the actual height at which the measurement is made varies depending on the breast height of the person. This breast height difference between individuals is generally considered small; and the error generally insignificant.

Diameter at Breast Height measurement with a Caliper

There are obvious exceptions also when DBH will not be at 1.3 m or breast height. Rules are needed to deal with these to ensure consistency in measurement and to ensure tree biomass is not over-estimated. Different inventory manuals may provide slightly different rules for locating the diameter at breast height, but the following rules are fairly standard for all forest biomass assessment.

Rule 1. Tree is straight, single bole and is fund on flat ground. Measure diameter at 1.3 m or breast height (Figure 12)
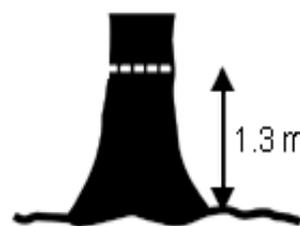
Rule 2: The tree is forked, if the fork starts below 1.3 m, measure DBH as if for two trees.
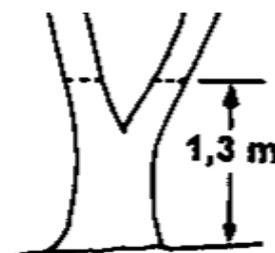
Rule 3. The tree is forked but above 1.3m, measure DBH as a single tree at breast height (1.3 m) (Figure 14)
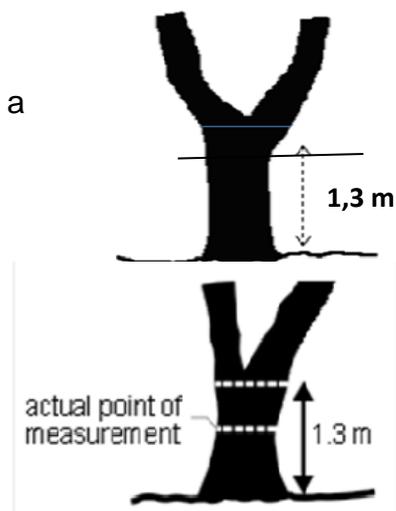
Rule 4. The tree is forked exactly at 1.3m, measure Diameter below 1.3 m (Figure 15)
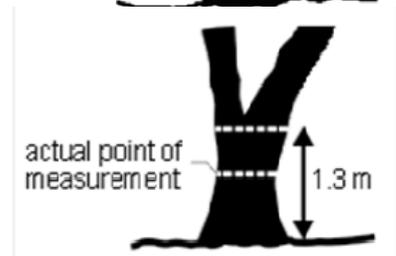
Rule 5. Grooved and buttressed trees (Figure 16)
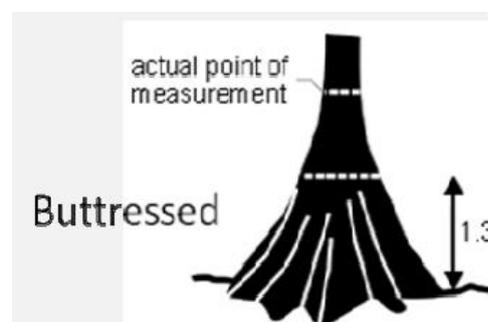
Rule 6. Trees on steep slope, measure the diameter from the upper side of the slope (Figure 17)
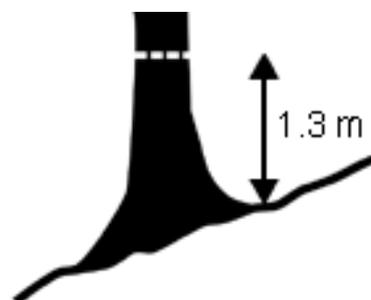
Rule 7. For bulged tree at breast height, measure diameter above and below, at clean sites and take the average of the two measurements (Figure 18)
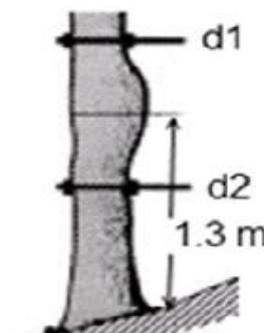
4.11. Field challenges in DBH measurements and suggestions

In natural tropical forests it is not easy to find many trees that are having straight and boles to apply normal DBH measurement at 1.3 m (breast height). Most of the trees are forked or strangled with climbers and other parasitic plants. Many are also buttressed and grooved tall trees that present challenge (Figure 20), for which the application of the above rules may not be simple. Typical species with such characteristic include *Aningeria Adolfi Friederici; Shiffeleria abyssinica, Ficus vasta, Ficus sur,* etc. Under such a condition a simple suggestion is to apply rule 5. Yet, climbing the height where the bole is buttress or groove free and taking measurement may not be easy, particularly given the numerous number of trees with such typical characteristic. Therefore, consistent measurement of the DBH at 1.3 m with all buttresses or grooves and indicating these in the inventory manual of the project for subsequent monitoring measurement to follow the same measurement is the best and practical approach.

Figure 20. Common challenges in DBH measurement in natural forest of Ethiopia

4.12. Tree height measurements

Tree height is the second most used tree variable in volume and/or biomass assessment. Most allometric equations incorporate height and claim that inclusion of height increases accuracy of standing volume or biomass estimate. However, height measurement, relative to diameter measurement, is difficult especially in dense forest. This is because of blocked visibility of tree apexes due to intermingling of branches and sometime dense under canopy. Therefore, as much inclusion of height increases accuracy it also increases cost of forest inventory. The decision to include or exclude need to be decided on the basis of available funding and level of accuracy required.

Tree height refers to the vertical distance between the top (apex - the highest branch on the crown) and base (ground surface) of a tree (Figure 21). Different techniques are available to measure tree heights.

a) Total height = H

b) Merchantable height
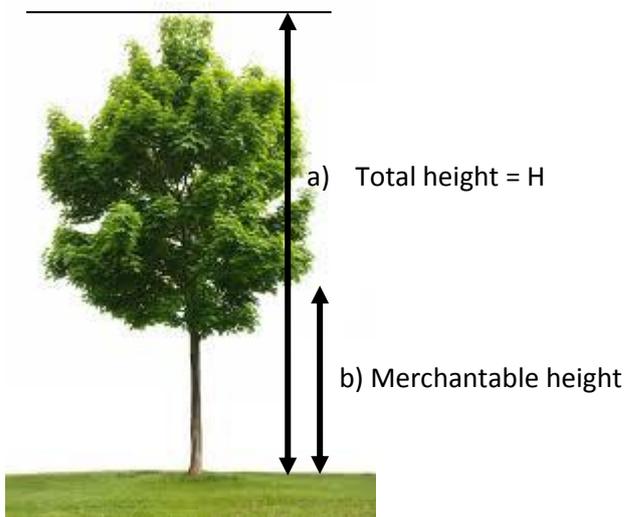
Figure 21. Total tree height (a) -the distance from tree base (ground level) to the apex of a tree, and merchantable height (b) – the length of branch free bole of a tree.

The simplest technique to measure tree height is using a graduated stick or metric tape. In this technique the observer stands and holds the measuring instrument against the tree extending it from the base to the top, and take measurement directly. This technique works well with small trees of up to 10 m. For tall trees other techniques such as hypsometer, described below, is better suited.

Tree height is commonly measured remotely using clinometers (hypsometers) or combination of transit for angles and a measuring tape or infrared laser rangefinder for distance. The principle employed in these techniques is simple trigonometry and laws of similar triangles and right triangles (Figure 22).

Tree on level ground with no lean and top over base

Tip: You can also add the % readings from the clinometer and multiply it by the baseline.

H1

Baseline (B)

A1

A2

H2
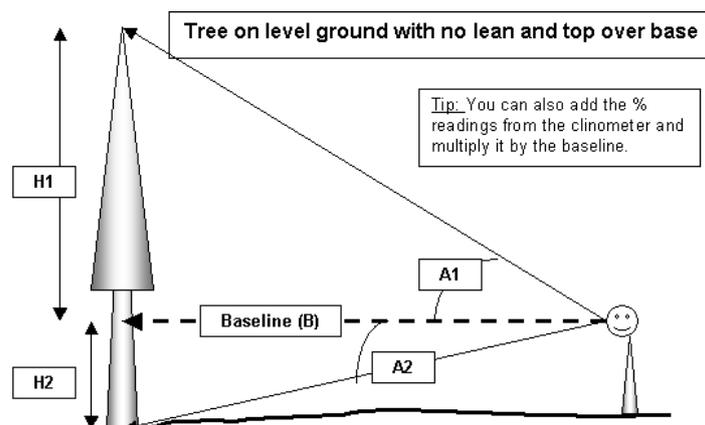
Height= H1+H2, where: H1= B*TAN (A1) and H2= B *TAN (A2). When using clinometer both angles (A1 and A2) need to be read and multiplied with the distance B. IN using hyposmeter the product of angle and base distance for (10,15, 20 and 25m) are already incorporated in the instrument such that base reading (h2) and top reading (h1) are directly obtained and added to provide total tree height.

Figure 22. A simplified technique for tree height measurement (Source: http://www.nativetreesociety.org/measure/tree_measuring_guidelines.htm)

A clinometer or hyposmeter is a hand-held simple instrument used for measuring angles and slopes (in the case of clinometer) or directly a height (in the case of hypsometer). The instrument is held in one hand and viewed through an optical lens fitted with a crosshair, a plus and minus degree scale and a percent scale (clinometer) or just a distance number corresponding to different horizontal distances from the tree (hyposmeter). In reading the instruments, both eyes need to be open with one eye reading the scale on the instrument while the other looks at the target. The following step is followed to measure tree height:

1. Move back 10, 15 or 20 m, a distance that can allow you to see the tree-top comfortably through the crosshair of the clinometers/hypsometer;
2. Take bottom reading by corresponding the cross-hair of the hypsometer to the base of the tree;
3. Take the top reading by corresponding the cross-hair of the hypsometer with the tip on the top of the tree
4. Add the bottom and top readings, which gives the total height

The principle in figure 21 works under the following conditions:

- The highest point of the tree is directly over the base of the tree (i.e., the tree is standing straight, not leaning);
- The highest point of the tree is clearly visible, and
- The tree is growing on level ground.

Often trees do not satisfy all of the above conditions. Older trees and trees in old-growth forests do not typically grow straight (they lean) or may not have a well-defined top when viewed standing on the ground. Trees also grow on sloppy ground, which all make difficult to apply the above technique of height measurement directly. If overlooked, these situation cause considerable error in height measurement; hence standing stock. For measuring height of trees on slopping ground the following procedure will be applied.

Conventional height measurement is based on the horizontal distance between the observer and the tree (10, 15, 20 or 25m) but on sloppy land this distance must be corrected to the horizontal equivalent. After the distance is adjusted, then two readings will need to be taken to find the tree height. One reading is taken to the tree-top (apex) and a second reading is taken to the base of the trunk. When the base of the trunk is below eye level, the reading values are added. If the base reading is above eye level, this reading will be deducted from the top reading to give tree height (Figure 23).
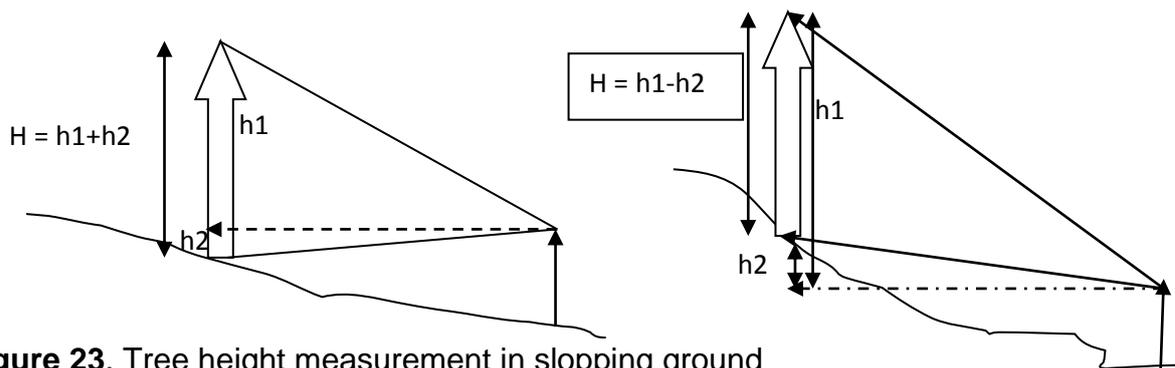
Figure 23. Tree height measurement in slopping ground

4.13. *Wood density*

Wood density is the fraction of mass over volume, and is expressed usually as gm/cm^3 (gm.cm^{-3}). There are different forms of wood density measurement and expression. These include:

- **Air dry density**: is expressed the ratio of oven dry mass to volume (g/cm^3) for wood at specified moisture content by volume, usually 12% or 8% wood moisture content.

  Air dry wood density (g/cm3) = Oven dry mass (g)/air dry volume at specified MC (cm3)

- **Basic density**: is the ratio of oven-dry mass to green wood volume.

  Basic density (g/cm3) = oven dry mass (g)/green volume (cm3)

- **Wood specific gravity**: is the ratio of the mass of a substance to the mass of an equal volume of water. Specific gravity is the same as basic density as long as the metric system is used.

  SG   = (Oven dry mass (g)/green volume (cm3))/density of water
           = Basic wood density/density of water

These diverse expressions provide different values for the same species, and whenever examining wood density values from various sources, it is essential to identify which particular expression is employed. Most wood density reports in the scientific literature are basic density. This is also what is presented in this document, unless and otherwise indicated. However, large number of literature also report air dry density, and options exist to convert between air dry density and basic density. One such option is multiplying basic density by a factor of 1.22 to obtain air-dry density or multiplying air-dry density by a factor of 0.82 to obtain basic density (http://www.worldagroforestry.org/treesandmarkets/wood/).

There are also developed regression equation (e.g. Reyes et al., 1992) to convert wood density based on 12% moisture content to basic wood density. This equation is shown below:

$$Y = 0.0134 + 0.800\ X; \ (r2 = 0.99; \ \text{number of data points } n = 379)$$

Where:

Y = wood density based on oven-dry mass/green volume

X = wood density based on 12% moisture content

Wood density is affected by both tree and environmental factors such as age, sampling position (radially and longitudinally within the tree), and edaphic and climatic factors that affect growth rate. Therefore, results from individual samples, depending on site of sampling, position of sampling from the stem and age of the sampled tree may yield different results for a single tree. This is the reason why different values are often observed for the same species in different documents. Few of such examples are provided in this database as well.

Guidance on measuring and determining wood density

Overall, wood density is little studied in Ethiopia. A lot of research needs to be done in this area to improve information of wood density of indigenous and exotic species growing in the country. Correct procedure must be followed to precisely determine wood density. The following describes three major steps in wood density determination.

1. **Sample size**: the number of sample tree as well as sample per tree is essential for precise estimation of average wood density per species. The number of trees required to sample and the samples per tree depends on the variability within the species and characteristic of the wood in the tree. In general, five trees, healthy and straight individuals, are a minimum (Cornelissen et al., 2003). One or two individuals are inadequate because variability among individuals remains unknown. Furthermore, sample disks should be taken proportionally covering all wood portion (core and outer portion), base, middle and top section of the tree. Due to high radial and vertical variability, there is no way to characterize wood density of the entire stem cross section without a disk of wood or a complete pith to bark core, and representative disk removed from several sections along the stem.

   Samples can be removed using bow or two men cross cutting saw or chain saw. Increment borer can also be applied.

2. **Sample volume measurement**: volume of sample disks can be measured using various techniques. Measurement by water displacement or calculated from the dimensions of a sample block or core measured with callipers are possibilities. Accurate water displacement requires immersion of the wood sample into a beaker of water loaded on a top-loading electronic balance. The wood sample is pressed below the water surface with the aid of a "volume less" needle or insect pin. The volume of the wood is read accurately on the balance as the mass of the displaced water. Older methods of volume displacement in graduated cylinders or beakers where water levels are read by sight are much less accurate and increase variance in volume measurements.

3. **Oven drying**: Oven drying requires putting the sample disks or cores in 101 – 105 °C because wood contains bound water, in addition to free water. All bound water cannot be driven off at less than 100 °C. Plant biologists commonly oven dry leaves or fruits around 60 °C or 70 °C because there is little bound water in fleshy plant parts and higher temperatures result in losses of low molecular weight organic compounds (Westerman, 1990; Pearcy et al., 1989). However, for over drying wood in such low temperature is unacceptable. The wood samples should be kept in over at such temperature for 48 – 72 hours depending on sample dimension, until the sample provides a more or less constant weight. Perhaps one can remove the samples first after 24 hours to record the initial weight, and every 6 to 12 hours until constant weight is achieved. The final weight reading will be the weight of the sample

4. **Calculation wood density**: the over dry weight is divided by the green volume to obtain basic density. If the metric is IS, then this is also equal to the specific gravity.

Wood density for trees grown in Ethiopia

Wood density data of over 400 tree species grown in Ethiopia is collected (**Annex 2**). The wood density data is compiled to assist precise wood biomass and carbon stock assessment; hence to assist accurate emission factor estimation for REDD+ program design. The data included in this document is compiled from various literatures: local (national), regional and global. As far as available, values from local (national) sources are provided. When this is not the case regional database, primarily ICRAF's wood density data base, value is provided. The global database is referred to when both national and regional values were not available. In rare cases, values from neighbouring country (for the same species), specifically from Uganda (https://cdm.unfccc.int/Projects/DB/JACO1309233364.97/view), is referred. In most of the cases, species level value is provided. However, when this was not possible genus level average value is used. In absence of any information, the regional average dry wood density value for tropical Africa (0.580 g/cm3). Due to the paucity of local data, database from ICRAF (2007) was the major source of the data compiled.

4.14. Quality Assurance and Quality Control in data collection

Error associated to field measurement is unavoidable. Measurement error results from a host of issues, including not only mis-measurement of DBH and height (especially the latter in closed canopy broadleaf forests), but also species misidentification, misinterpretation of live versus dead, misinterpretation of border trees and strata boundaries, and mis-implementation of boundary correction methods. At the plot level, with well-trained field crews, measurement error of around 4 % is achievable. Where field measurements include tree heights, measurement error may reach 8 %, particularly in closed canopy forest.

Measurement related error can be a major cause for a significant over or under estimation of forest carbon. Validation of forest carbon projects requires accurate quantification of forest carbon stocks and changes. A strategy to reduce or minimize measurement error is adherence to meticulous field measurement protocols. As

there is no easy way of checking this and that it cannot be readily calculated like sampling error, a protocol called Quality Assurance and Quality Control (QA/QC) is applied to quantify the magnitude of measurement related error. Therefore, forest inventory planners should prepare a suite of QA/QC steps to maintain the quality of data collected. Common QA/QC procedures include repeated measurement of a randomly or systematically selected 10-20% of survey plots by **separate individuals, i.e.** by people other than the original field crews**.** This re-measurement also called blind checks is not to be used for reconciling of measurement error but maintained as separate data for indication of uncertainty in inventory measurements. After re-measurement, data analysis is conducted and biomass estimates are compared with estimates from the original data. Any errors discovered could be expressed as a percentage of all plots that have been rechecked to provide an estimate of the measurement error. This error level will be included in the carbon stock reporting. For all the verified plots:

$$\text{Measurement Error (\%)} = \left| \frac{(\text{t C/ha of measured plot - t C/ha of remeasured plot})}{\text{t C/ha of remeasured plot}} \times 100 \right|$$

Important requirements for the blind check (QA/QC) include:
- R-measurement of all trees in the selected plots.
- Field crews taking the initial measurements should not be aware of which plots will be re-measured.
- Any errors found should be corrected and recorded.

QA/QC also includes the following activities (Pearson et al 2007):
- Hot checks: a supervisor oversees plot measurement of field team on the spot to immediately identify and correct any systematic measurement errors.
- Cold checks: a supervisor re-measures a plot after the departure of the field crew, comparing new measurements to previously collected measurements and reconciling substantial (e.g., >5%) discrepancies.

QA/QC procedures should also be developed for data entry and storage as well as any laboratory analyses and equipment used. For each standard (CDM, VCS, etc) refer to their QA/QC requirements and apply procedures therein accordingly. IPCC Good Practice Guidance also provides good guidance on QA/QC.

Module exercises

1. Bale Eco-Region is an area where there exist big blocks of high forest remnants are observed in the Ethiopia. The eco-region comprises two landscape conditions: the southern and eastern slope and aspect descending to the Borana and Somali lowlands. The second is the western and northern slope/aspect facing the Arsi-Bale plateau. While the eastern and southern aspects received a bio-modal rainfall of average 1400 mm annually, the northern/western is uni-modal rainfall in the range of 1100mm annually. The forests on the eastern/southern aspects are species rich including *Coffea arabic*, and is classified as tropical moist forest by most vegetation ecologists. The forests on the northern/western aspects compose mainly conifers principally *Juniperus procera* and other associated species. Do you think that the Bale eco-region forest can be treated as one continuum forest given the above description? If no, how can you suggest the forest for stratification?

2. Visit a forest area where there are clearly two different types of forest stands (e.g. natural forest and planted forests). Discuss among yourselves the obvious differences between the two forest types in terms of their structure, tree size, species composition, etc.. Then decide on what criteria could be used to stratify the forest.

3. Given the following information, calculate the number of sample plots to be inventoried
   Area = 5,000 ha
   Plot size = 0.08 ha
   Mean stock = 101.6 t C/ha
   Standard deviation = 27.1 t C/ha
   N = 5,000/0.08 = 62,500
   Desired precision = 10%
   E = 101.6 x 0.1 = 10.16
   (answer = 29 plot)

4. If the above forest is sub-divided into two strata of 2000 and 3000 ha, what are the number of sample plots expected for each stratum

5. Discuss among participants why internationally 1.3 m is used as a standard height for diameter measurement. At the same time let them think of what the problem would be to use DBH as a single variable to estimate tree volume/biomass, and how this can be relatively better solved.

6. Discuss again, whether 1.3m and breast height are always synonymous. Let everybody cut a stick 1.3 m long. Compare this with his/her breast height, and calculate the difference. What is the average class deviation of breast height from 1.3m?

Data Entry and Analysis

Field collected data must be entered into a computer and stored in a simple yet safe and retractable way. All the data including the original field sheets are required during validation (audit) by third party and they should be kept safely. Their absence or improper storage will disqualify the project. There must be a person assigned to managing the field sheets and that person should take charge of the sheets as soon as they are filled in or, if this is not possible, at the end of each day. If possible a digital camera can be carried as part of the field equipment and be used to record a digital image of each field sheet before departing each plot. This provides a backup in case the original sheet is lost or damaged. The person responsible for the field sheets should also make sure that both hardy copy files and the digital images are transferred to the office.

In the office, all the field sheets should be filed and properly stored. If digital images were taken in the field, they should be stored electronically in appropriately labelled folders; if not, all the field sheets should be scanned. The original sheets should be photocopied and the two hard copies stored in different secure locations, using an appropriate filing method.

After data entry, the electronic files should be organised appropriately and backed up on a server.

The soft copy files should be converted to biomass and carbon data. Extended excel sheets should be used with interconnected cells. This will minimize computational related error significantly.

Calculating Forest Carbon Stocks from Field Measurements

Forest biomass carbon stock density is calculated by multiplying the estimated forest biomass stock density by a carbon fraction. The default carbon fraction used for calculating forest biomass carbon stock is 0.50 (IPCC 2003). The above- and below-ground carbon are added together to obtain the total biomass carbon estimate per forest type or stratum.

The forest type-specific biomass carbon stock density is multiplied by the total area of the respective forest types to obtain total carbon stock. The total forest biomass carbon stock is estimated by summing together the carbon stock of different forest types or strata.

1. **Calculating Above Ground Biomass/Carbon:** Above ground biomass is calculated for each tree for which diameter and/or height is measured by inserting the measured diameter into the selected or developed allometric equation. The steps are:

2. Select or develop appropriate and validated allometric equation for forest type or group of species or each species or family;

3. Estimate above ground biomass for each tree (kg/tree) using the appropriate allometric equation;

4. Estimate carbon fraction (Kg) by multiplying by 0.5 (1/2[4]), which is a default value

$$Carbon\ stock\ per\ tree = \frac{\text{Biomass of the tree}}{2}$$

1. Calculate the carbon stock (kg) in a **sub-plot (e.g. 25*25 = 625 m^2 or 15*15 = 225m^2)**

$$Carbon\ stock\ in\ sub\ plot = \ Summation\ of\ carbon\ stock\ of\ trees\ in\ the\ subplot$$

2. Estimate carbon stock for the **principal sample plot** (10,000 m^2 or 100*100)

$$Carbon\ stock\ of\ the\ prinicial\ sample\ plot$$
$$= \frac{Summation\ of\ carbon\ stock\ of\ sub\ plots}{areas\ of\ the\ sub\ plots} * 10,000\ m2$$

3. Calculate the carbon stock in ton/ha

$$Carbon\ stock\ of\ the\ smaple\ plot\ (ton/ha) = \frac{Carbon\ stock\ of\ the\ principal\ sample\ plot}{1000}$$

4. Calculate the mean above ground carbon stock of the plot in carbon dioxide equivalent

$$Mean\ carbon\ stock\ (ton/ha) = \sum_{n=1}^{x} Carbon\ stock\ per\ plot)/n$$

5. Calculate and convert to tCO$_2$e value:

CO$_2$e (ton/ha) = (mean biomass (ton/ha) *44/12)

Estimating below ground biomass/carbon: unlike for the aboveground biomass, for below ground biomass there are no allometric equations to apply. However, below ground biomass for forests is highly correlated with estimates of aboveground biomass. A synthesis of global data used in the IPCC 2006 guidelines, provides simple equations that estimate belowground biomass based on aboveground biomass or based on a series of root-to-shoot (R/S) ratios by major forest types. This default value is used to estimate below ground biomass. The default values are as follows (Table 15):

Table 15: Root to shoot ratios

Domain	Ecological zone	AGB (t/ha)	Root to shoot ratio	Range
Tropical	Tropical rain forest	<125	0.20	0.09-0.25
		>125	0.24	0.22-0.33
	Tropical dry forest	<20	0.56	0.28-0.68
		>20	0.28	0.27-0.28

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[4] Default value for carbon fraction used may range form 0.47 – 0.5. It is up to the project developer to justify which fraction to apply.

	Subtropical humid forest	<125	0.20	0.09-0.25
		>125	0.24	0.22-0.33
	Subtropical dry forest	<20	0.56	0.28-0.68
		>20	0.28	0.27-0.28

Above ground non-woody biomass/carbon: Any live vegetation (woody and herbaceous) below 2 cm DBH will be considered as non-woody above ground biomass. The Sampling frame method (i.e. 1 m by 1 m frame) will be deployed to measure these non-woody vegetation. The frame will be laid at the four corners and the center of the sample plot.

Steps
1. Lay a 1 x1m frame at one of the four corners of the sample plot
2. Cut all living vegetation inside the frame at base and record the fresh weight
3. Take adequate sub-sample from the weighted sample and record the fresh mass of the sub sample. Repeat the same in the remaining corners and at the centre
4. Label the sub-sample and take them to laboratory and oven dry them at 70-80 ^{0}c temperature to constant weight
5. Estimate the dry mass of the original sample from the wet to dry ratio of the sub-sample

$$\text{Dry mass of the sample} = \frac{Sub\ sample\ dry\ mass}{Sub\ sample\ fresh\ mass} * Fresh\ Mass\ of\ the\ sample$$

6. Estimate the mean above ground non-woody dry mass for the sample plot

$$\text{Mean above ground non} - woody\ Dry\ mass\ per\ plot \\ = \frac{DM1 + DM2 + DM3 + DM4 + DM5}{5\ (0r\ \#\ of\ sub - samples)} + 10,000m2$$

Where DM1,2,3… are dry mass of samples 1 to 5.

Estimate the mean above ground non-woody carbon stock for the sample plot

Calculating Total Carbon Stocks: To estimate the total amount of carbon stocks within a stratum, simply sum the carbon stocks in all measured pools. To convert tons of carbon to tons of carbon dioxide equivalence, simply multiply by a value of 3.666, which is the atomic weight difference between C and CO_2 (44/12), where the atomic weight of C and O is 12 and 16, respectively.

C_{total} (t C/ha) = $C_{AG-tree}$ + $C_{BG-tree}$ + $C_{Non-tree}$ vegetation + $C_{StandingDead}$ + $C_{Lying\ Dead+Litter)}$

C_{total} (t CO_2/ha) = $C_{total} * 3.666$

4.15. Uncertainty in carbon stock and emission factor calculation

Carbon stock estimation and associated calculation of emission reductions have uncertainties associated with the measures/estimates of: area or other activity data, carbon stocks, and other coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), expert judgment, or estimates based on sound statistical sampling. In fact, during inventory planning a number of measures are taken to reduce uncertainty in final estimates. These measures include taking sufficient sample number, stratification and quality assurance/control. Yet, uncertainties in calculated values still need to be effectively integrated into the final emission reduction estimation. This is because uncertainty calculation is a key metric to portray the confidence in calculations and an uncertainty assessment quantifies the variability of estimates, based on accuracy and/or precision of measurements. Such an assessment is required for REDD+ accounting under IPCC, UNFCCC, and all major greenhouse gas standards and registries. Uncertainty is estimated for individual measurements such as biomass in carbon pools as well as aggregations of measurements such as the sum of carbon across pools and the development of emission factors. According to VCS, if the uncertainty level is greater than 10%, the carbon stock and emission reductions should be re-adjusted by deducting the uncertainty calculated. Steps to calculate uncertainty is as follows:

Uncertainty is expressed as the percentage of mean carbon stock per hectare by taking the ratio of CI/sample mean for any given pool. CI is calculated as the product of sampling error multiplied by the t-value for the degree of freedom for the sample number used.

Uncertainty (%) = (sqrt (α/2*SD/sqrt(n)^2)/mean*100
= sqrt (CI^2)/mean*100

Example of uncertainty calculation

Carbon pool	Average carbon stock (t CO2e/ha)	n	SD	CI (95%) (α/2*SE)	CI (%) of mean	Total uncertainty	Average carbon stock to use in emission reduction calculation (t CO2/ha)
Above-ground biomass	647.33	72	441.32	112.0958	17.31671	24.49	488.80
Below ground	155.36	72	105.92	26.90298	17.31671		117.31

biomass						

Module exercise

1. Given the DBH data of three trees in the table below, calculate above ground biomass and carbon stock (tcarbon/tree) of the trees (use Chave et al. (2005) allometric equation and WD of 0.65).
2. For the data under question number one, assuming the three trees are the only in a plot of 100*100 m dimension, estimate the carbon stock per ha in tCarbon.

DBH (CM)	Biomass (tons/tree)	Biomass per plot (tC/ha)
24.0		
38.0		
23.0		

3. Given the data in the table below calculate AGB and BGB of the individual trees

Plot No	Tree No	DBH (cm)	AGB (kg/tree)	BGB(kg/tree)
1	1	16.3		
1	2	18.7		
1	3	48.1		
1	4	8.9		
1	5	9.2		
1	6	62.8		
1	7	26.4		
1	8	23.0		
1	9	55.0		
1	10	5.3		

4. Following the same procedure calculate the carbon stock and its CO2e for the data you collected during a practical fieldwork

5. Estimating Forest Carbon Stock Changes and net GHG Emissions Reductions

Module objective: the very purpose of forest carbon accounting is to calculate the net change (increase or decrease) in stock of carbon and other GHGs as a result of forest loss or gain. This net change, called net emission reduction or removal, is calculated and estimated into the future called ex-ante calculation or after actions/interventions are implemented called ex-post calculation. These involve:
- knowledge of existing carbon stock in the pre-deforestation land cover (covered in the previous modules),
- projection of areas to be deforested and/or subject to degradation in the future under business as usual (called baseline scenario),

- estimation of what the proposed carbon project can manage to reduce part or all of the projected deforestation and forest degradation including possibilities for enhancing carbon stock (called project scenario), and
- calculation of the net differences in emission between the two scenarios (baseline scenario - project scenario emission) to obtain emission reduction.

The aim of this module is to provide a step-by-step guidance to how these activities can be accomplished.

Learning outcomes: After attending this module participants are expected to:
- Explain what baseline scenario (business as usual) and project scenarios mean;
- Explain and apply the various alternative approaches to project future deforestation and estimate project annual area of deforestation;
- Able to calculate ex-ante quantity of GHG emissions and emission reductions;
- Explain leakage and how it can be minimized or avoided

Time required:
- 1.5 days

Materials:
- Copy of the module
- Hypothetical data (see example in the annex)
- Computers with excel program
- Pens/note books

Training method:
- Group practical exercise on available prior inventory data, presentation and group discussion

5.1. Baseline and Project scenarios

Emission reductions from forest ecosystem are quantified by contrasting **project outcomes** (called project scenario) with a counterfactual **business as usual** (called baseline scenario). Baseline scenario describes future conditions and outcomes that would be expected if no project activity were to take place. In other words, it is what is expected in terms of area of deforestation or GHG emissions under the business-as-usual condition. Projects generate carbon offsets by implementing different activities to the extent that they reduce deforestation and/or sequester more carbon compared to what is expected under the baseline scenario, and these achievements

of the project are called **project scenario**. These two distinct scenarios are portrayed in figure 24.

Emission = AD*EF
Emission reduction = AD*EF(baseline scenario) − AD*EF(project scenario) = $(AD_{bl} - AD_{ps})$-EF
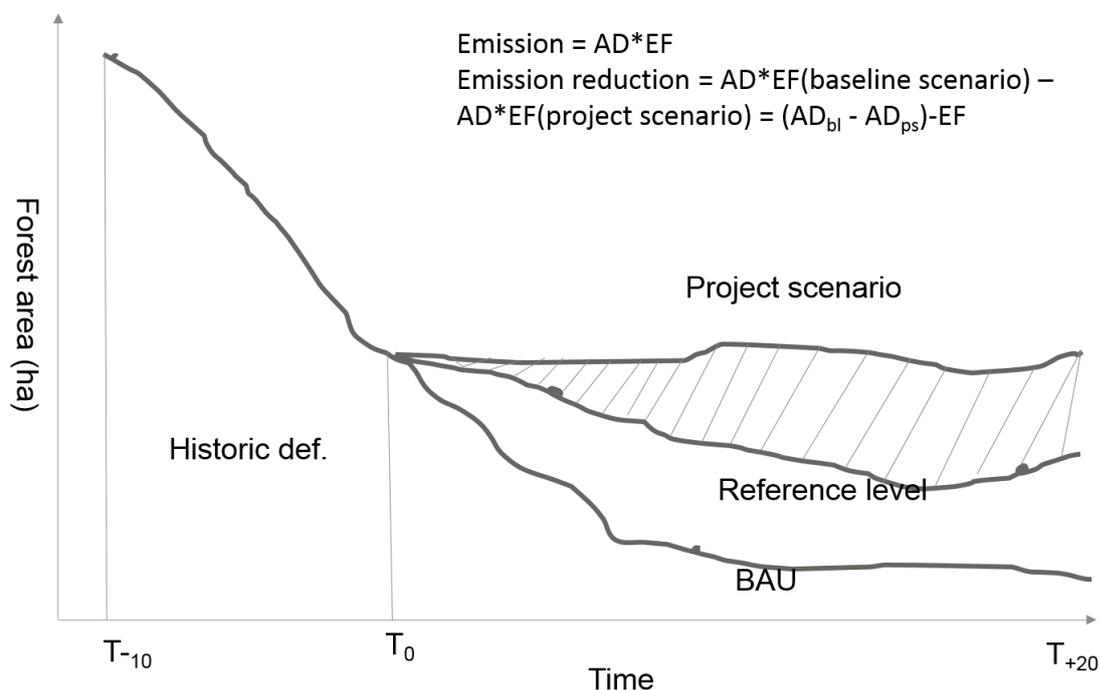
Figure 24. Diagrammatic representation of baseline and project scenarios

While actual carbon credit worth payable is calculated and known only after project is implemented and achievements monitored, called ex-post calculation, it is also possible to make ex-ante calculations to predict possible emission reductions. Ex-ante calculation of emission reductions/removals require two essential inputs:

a. Projection of historical deforestation into the future and estimation of probable area of annual deforestation over the project period under the baseline scenario, and

b. Anticipated project effect in reducing (the whole or part) of the area of the projected deforestation, i.e. proportion of area saved from deforestation as a result of the project under the project scenario.

To predict the future area deforested without and with project scenarios (the broken lines in Figure 24), it is indispensable to understand forest conditions before the project start date (also called historical condition). This historic condition of the forest helps to establish what is called reference level. From this reference level future projections of area of annual deforestation under baseline scenario are estimated. Projection of **probable area of annual deforestation** under baseline scenario is a critical input to make ex-ante and ex-post calculation of emission reductions. Because the basic equation to estimate GHG emission requires this variable as input as shown below:

Emissions = AD*EF

Where:

AD = activity data, which is area of annual deforestation (ha) or an area of afforestation/reforestation;

EF = emission factor (carbon stock per ha in the pre-deforestation class);

In the same way, a simple equation for emission reduction calculation is:

$$\text{Emission reduction} = AD*EF(\text{baseline scenario}) - AD*EF(\text{project scenario})$$
$$= (AD_{bl} - AD_{ps})*EF$$

Besides establishing the reference level, projecting and estimating change in area of forest annually requires decision on the method for **projection** of deforestation into the future under the without project scenario or the baseline scenario. This is also discussed in the following sections.

5.2.   *Reference level/Reference Emission Level*

A reference level is a fundamental concept in REDD+ project design. It refers to a bench mark of area or GHG emission considered without REDD+ project in an area or a region against which achievements of emission reduction are measured. . For a national or sub-national level REDD+ program, the reference region is the whole country or the whole jurisdiction. For a project level REDD+, a reference region is an area larger than the project forest and sharing a similar forest type, and biophysical and socio-economic condition.

RL/REL is not necessarily the same as BAU scenario condition as RL/REL are set based on certain modifications. Reference level provides a quantitative way to measure the performance of a country, programme, or project in reducing emissions or increasing removals. It is usually established based on deforestation rate that forests in the project site have been experiencing during the period before REDD+ project starts. This is also called **historic deforestation, and refers usually to deforestation rates within 10 years before the project start date**. This usually refers to deforestation and forest degradation levels in the area adjacent to the project forest within an area designated as **a reference region**. A reference region is an area of land, could be a country, sub-region or a territory that can be used as a reference for the forest to be brought under REDD+ (Figure 25). This area should share similar forest type(s), similar ecological characteristics, similar drivers and agents of deforestation and forest degradation. The assumption is that the forest in this reference region including its landscape configuration, climate and edaphic factors, and socio-economic contexts are similar to the forest planned to be brought under REDD+ project. Therefore, one can expect the trend of deforestation and degradation taking place in the reference region to continue on to the project forest area (called project area) in the future. The reference region should be big enough, and preferably circumscribes the project area (Figure 25).

REL/RLs are expressed in tonnes of carbon dioxide equivalent per year. REL/RL can be set in a variety of ways: extrapolating historic rate, historic average or modelling approaches. However, the historic average has become the most common method. While, voluntary carbon markets standards and CDM projects tend to favour the

development of "business as usual" reference levels to measure performance, jurisdictional approaches tend to favour a strong reliance on historical data and conservative approaches.

In REDD+ negotiations, REL/RL has been one of the dividing point between project developers and carbon buyers. Baseline methods that rely on extrapolating historic rates of deforestation have been seen as problematic, particularly by "high forest cover, low deforestation" (HFLD) countries that are under increasing pressure from economic growth or agricultural expansion and, absent additional policies or measures, would expect deforestation to increase. High deforestation countries, on the other hand favour, the extrapolation of historic deforestation rate. It is generally agreed that REDD+ REL/RLs should "take into account historic data" but also can "adjust for national circumstances". World Bank group sticks to historic average projection approach, for instance, in the case of the OFLP.

A reference level is set based on historic land cover/land use analysis (deforestation trend) about 10-15 years prior to the project start date in the reference region using multi-temporal satellite imageries.
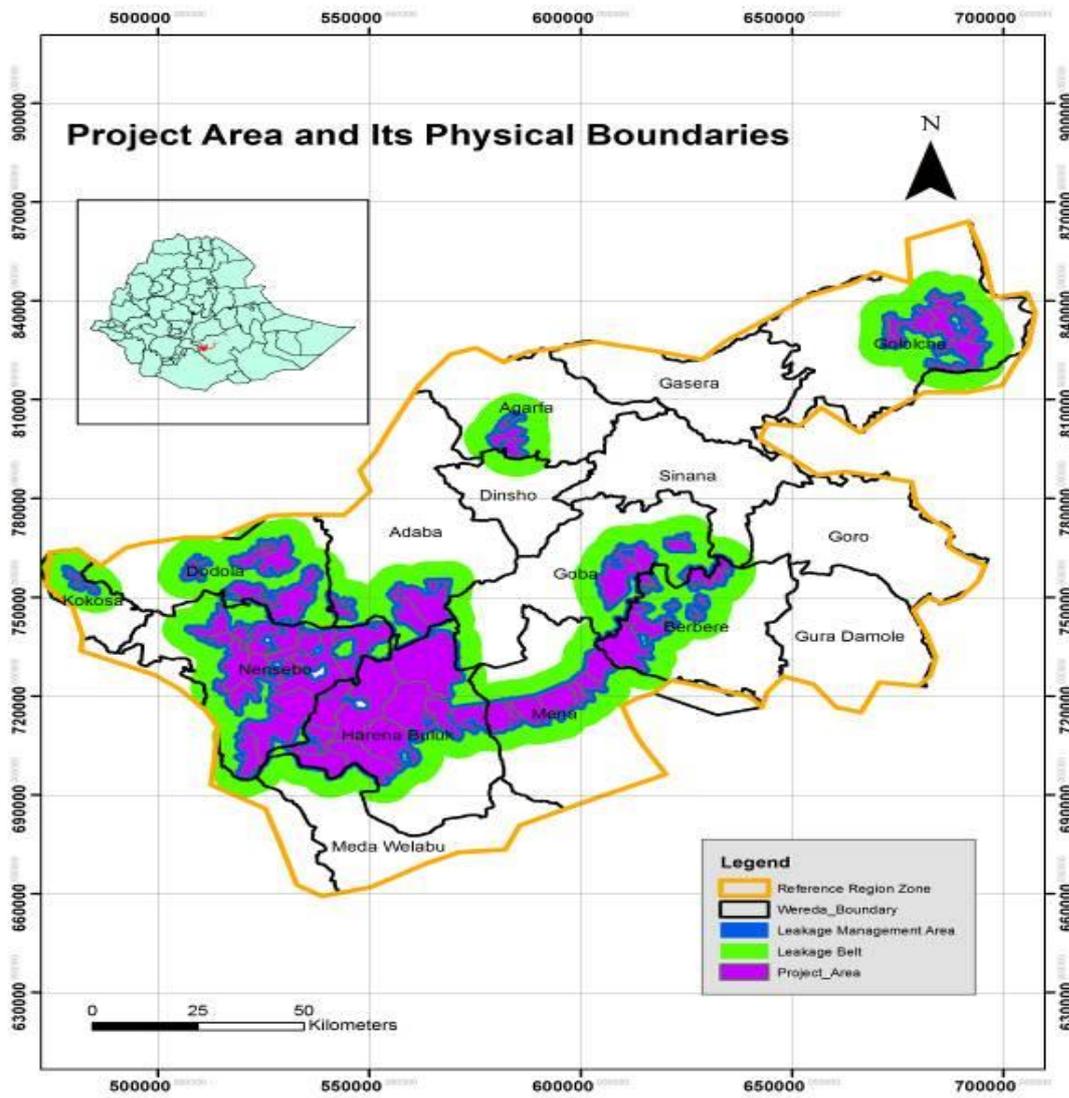
Figure 25. Example of reference region for establishing historical deforestation (taken from Bale REDD+ project).

5.3. Projection of future deforestation and forest degradation

To obtain the activity data (AD) described above and then to quantify both expected quantity of emission under baseline scenario and emission reductions under project scenario, the reference level deforestation should be projected into the future. This projection is not necessarily about a linear extension of the historical deforestation, but different techniques can be applied. There are three different techniques that can be used to project future deforestation:

a) **Historical average approach**: Under this approach, the rate of baseline deforestation is assumed to be a **continuation of the average annual rate** measured during the historical reference period within the reference region or, where appropriate, within different strata of the reference region.
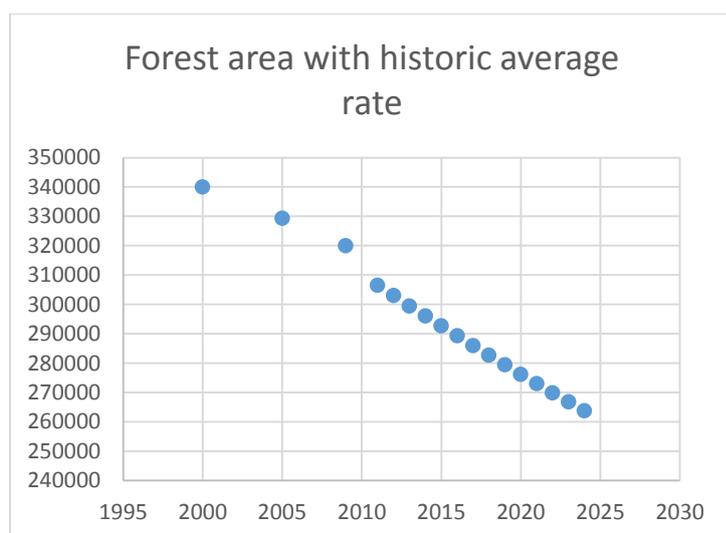
Year	Forest area	Historic Rate	Average
2000	340000		
2005	329310.2	0.628812	
2009	320028.2	0.704655	
2011	306488.7	2.11536	
			1.149609
2012	302965.3		
2013	299482.4		
2014	296039.5		
2015	292636.2		
2016	289272		
2017	285946.5		
2018	282659.3		
2019	279409.8		
2020	276197.7		
2021	273022.5		
2022	269883.8		

Forest area with historic average rate

b) **Time function approach**: With this approach, the rate of baseline deforestation is estimated by extrapolating the historical trend observed within the reference region (or its strata) as a function of time using either **linear regression, logistic regression or any other statistically sound regression technique**. This approach requires multiple deforestation measurements during the 10-15 years prior project start date.

Linear projection

$y = -2837.3x + 6E+06$
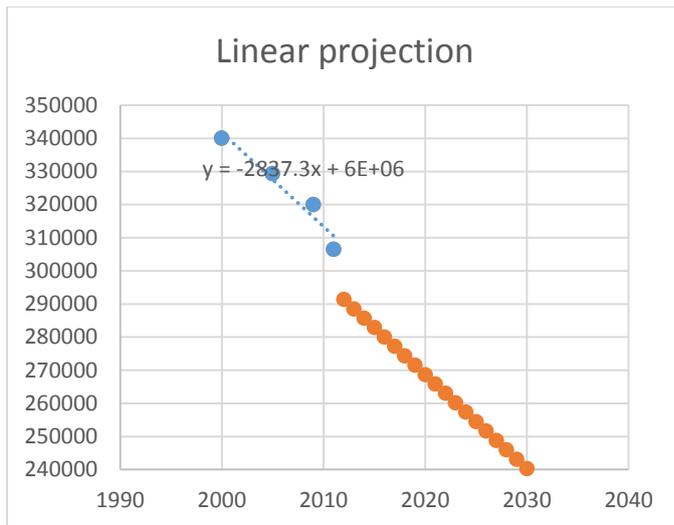
Year	forest area	RL
2000	340000	Historic
2005	329310.2	Historic
2009	320028.2	Historic
2011	306488.7	Historic
2012	291352.4	Projected
2013	288515.1	Projected
2014	285677.8	Projected
2015	282840.5	Projected
2016	280003.2	Projected
2017	277165.9	Projected
2018	274328.6	Projected
2019	271491.3	Projected
2020	268654	Projected
2021	265816.7	Projected
2022	262979.4	Projected

c) **Adjusted country context deforestation rate:** In some cases pure, national or global, historic average deforestation rate application is criticized for use. This is criticized by counties with historically low deforestation but high forest cover. The reason is that past drivers of deforestation and anticipated future drivers tend to differ, given the growing interest by all countries to speed up their national economic growth and rural development, which will increase pressure on forest. This has led to the development of a new approach that "takes into account historic data" but also can "adjust for national circumstances". However, information to substantiate such adjustments must be provided. The guidance provided to date also suggests an approach for REL/RLs that is flexible (allowing for some choice in pools, gases and activities), step-wise (allowing for improvements over time in data and methodologies), and transparent (countries submit information and a rationale). There is no agreement yet, however, on how REDD+ REL/RLs relate to financing.

d) **Modeling approach**: With this approach, the rate of baseline deforestation will be estimated using **a model that expresses deforestation as a function of driver variables** selected by the project proponents.

AD = f(proximity to road and village, population growth, slope, aspect, RF, etc)

The estimate by one of the three methods will then be taken as the projected future area of deforestation under the baseline scenario.

5.4. Baseline emission (REL)

Baseline emission refers to the carbon stock change or CO2 equivalent GHG emission expected between the project start date and end date as a result of the projected BAU deforestation. This is the sum of emissions per year (AD/yr*EF) during the project period under the baseline scenario:

$$\text{Baseline emission} = \sum_{n=1}^{t} AD * EF$$

Where: AD= Activity data (area projected to be deforested under baseline scenario (ha)
$\qquad$ EF = carbon stock (tCO_2e/ha) in the forest
$\qquad$ t = project life time (from t_1 to t_n)

This emission is calculated ex- ante, and is called ex-ante estimation of GHG (carbon) emission under baseline scenario. Once the projection of future deforestation is completed under the BUA, baseline emission calculation of the GHG (CO_2e) follows. This involves a simple multiplication of the average tons of CO_2e per ha obtained from field forest inventory for each strata (EF) by the projected area of deforestation of the same strata (AD).

Actual emission, however, depends on the carbon stock in the **post deforestation** land use type (Figure 26), i.e. stock of carbon remaining in the land use after deforestation (also called post-deforestation land use class). It is obvious that deforestation will not completely (100%) get rid of the original vegetation and carbon stock. Some residual vegetation will remain in the final non-forest class created after deforestation. The carbon stock expected in this non-forest class after deforestation is called **Anthropic vegetation in equilibrium (AVE)**. Global value used for this is 18 tCO_2e /ha. This means the amount of carbon remaining after conversion of a forest to non-forest. The actual ex-ante emission due to deforestation – this time called ex-ante GHG emission in post-deforestation class is the pre-deforestation emission minus AVE:

Ex-ante post deforestation class emission (tCO2e/yr) = $\sum_{t=1}^{n} (AD * EF) - AVE$

Pre-deforestation class (intact forest) that is holding the original total carbon stock

Post deforestation class land use with some remnant carbon stock from the original forest, which is described as Anthropic Vegetation in Equilibrium

Figure 26. Pictorial description of Pre- and Post-deforestation land cover/land use classes

Example:
For the dry forest in Bale, the average emission factor (EF) in tCO_2e/ha was 469.77. Taking the above projected deforestation area using historic average, the expected GHG emission (CO_2e) under the baseline scenario in pre and post deforestation classes are as shown in the table below.

Year	Deforested area (AD) Col A	Pre-deforestation class ex-ante CO2e emission (tons) Col B (Col A *469.77)	Post-deforestation class ex-ante CO2e emission tons (taking AVE of 18 tCO2e/ha) Col C (Col B -18)
2012	3,523	1655198	1655180
2013	3,483	1636169	1636151
2014	3,443	1617360	1617342
2015	3,403	1598767	1598749
2016	3,364	1580387	1580369
2017	3,325	1562219	1562201
2018	3,287	1544259	1544241
2019	3,249	1526506	1526488
2020	3,212	1508958	1508940
2021	3,175	1491610	1491592
2022	3,139	1474463	1474445
2023	3,103	1457512	1457494
2024	3,067	1440757	1440739
2025	3,032		1424175

5.5. *Project activities and project scenario*

The project scenario refers to where the project designs and implements a number of activities that address deforestation and forest degradation as well as enhance forest carbon density. These are called project activities. In the case of Ethiopia, typical project activities involve actions that address common drivers of deforestation and forest degradation (direct and underlying) and interests of agents of deforestation. The activities comprise but not limited to the following:
1) PFM implementation to improve local institutional conditions and enhance sense of ownership;
2) Supporting small holder agriculture intensification;
3) Energy sector innovation such as use of efficient stoves, solar panel, etc;
4) Agroforestry and plantation developments around project areas to create alternative sources of wood and forest products;
5) Improving law enforcement, and
6) Improving livestock productivity.

These project activities are expected to reduce the area of forest expected and projected to be deforested under the baseline scenario. Project developers are expected to anticipate the magnitude of this achievement and be able to estimate ex-ante GHG emission reductions due to the project intervention. In the process of doing this, two issues deserve attention:

1) **Performance Factor (PF):** this is a factor that project developers set to indicate what proportion of deforestation under the baseline scenario they can manage to reduce considering the various challenges, opportunities, strengths and weakness exist around project performance. It is obvious that 100% avoidance of deforestation is impractical, at least during some of the initial project implementation periods, but reduction by some percentage. PF, therefore, sets a practical percentage that project implementation can achieve in reducing deforestation. PF can initially be set low and gradually be increased if there is obvious reason to believe that project performance will improve with more experiences and internalization of it by all stakeholders. For instance, in the case of Bale REDD+ PF was set to 50% during the first five year of the project, and then increased gradually to each 80% during the final five year. The overall PF was about 67%.

2) **Buffer for Risk (Assess Non-Permanence Risks and Develop Mitigation Strategies):** All forest carbon projects face multiple potential risks that may undermine their performance (i.e., achieving carbon benefits) or the permanence of emission reduction and removals. Permanence (or non-permanence) is perceived as a key issue for forest carbon projects since any carbon removed or emissions avoided, could potentially be rereleased into the atmosphere through future clearing, burning or dieback. This marks a fundamental difference between forest carbon projects and activities that achieve emissions reductions by reducing fossil fuels consumption.

5.6. Ex-ante estimation of net GHG Emission Reductions

Under project intervention (i.e. with project scenario) reduction of emission of GHG is expected. The amount of ER expected is simply the difference between baseline emission and project scenario emission. In other words, using the PF set, and project scenario should calculate the emission level expected under project scenario. This will then be deducted from the baseline scenario emission to yield ex-ante ER. See the example below taking again the case of Bale REDD+ project (Table 16). The net ER, however, is estimated when risks are identified, and buffer for this risk (i.e. any risk that could cause non-permanence in the ER) is set aside.

Identifying risks early is a crucial aspect of project development and needs to be reflected in the design of project activities and specific risk mitigation strategies. An evaluation of risks is called for under CCBA (Criterion G3.5) and by VCS, and this is a highly recommended exercise for any project to ensure project performance and to anticipate potential challenges, irrespective of the standard or project type.

The VCS specifically mandates an assessment of risks using the systematic AFOLU Non-Permanence Risk Tool, to be conducted by the project proponent and assessed by an independent auditor. This is used to determine a percentage of a project's carbon credits to be retained in a non-permanence risk buffer which are not available

for trading. This pooled buffer ensures against project failures or future reversals of carbon benefits, and thereby underscores the integrity of issued credits. Risk discounts can be as high as 60% for high-risk projects and are based on **apparent risks** and **project's capacity to manage these risks**. Risks fall into different assessment categories, namely internal risks (e.g., project management capacity or financial viability), natural risks (e.g., occurrence of fires and pests), and external risks (e.g., land tenure conflict) (see Box 2). In severe cases, projects can fail the risk assessment and, consequently, validation.

A project's buffer credits may be released over time based on ongoing project performance and risk assessments, conducted at every verification event. In the case of the CDM, this type of risk assessment is not formally required since permanence risk for AR projects is dealt with through the issuance of temporary CERs.

Box 2

Internal Risks:
- Project Management, including new use of non-native species, need for ongoing enforcement to protect carbon stocks and capacity of management team.
- Financial viability
- Opportunity costs and associated pressures of alternative land uses
- Project longevity based on legal agreements or requirements

External Risks:
- Land tenure, including ownership and resource access/use rights
- Community engagement, consultation of households inside and within 20 Kms of project boundaries
- Political risk, based on World Bank Institute Worldwide Governance Indicators, adjusted if country is engaged in international REDD+ readiness initiatives

Natural risks:
- Significance and likelihood of fire, pest and disease outbreaks, extreme weather events such as hurricanes, and geological risk such as earthquakes and volcanoes.

Table 16. Example of calculating ex-ante net GHG emission reductions

Year	Col1 AD (Deforested area(ha)	Col2 Pre-deforestation (Ex-ante baseline scenario) GHG emission (tCo$_2$e) (Col 1*tCO2e/ha)	Col3 Anthropic vegetation in Equilbrium (tCO$_2$e)	Col4 Post deforestation carbon stock (18*area deforested) Col1*col3	Col5 Net-ex-ante baseline scenario emission (Col2-Col4)	Col6 Performance factor (%)	Col7 Ex-ante project scenario emission (Col5-(Col6*Col5)	Col8 Ex-ante project scenario ER (Col5-Col7	BR (buffer for risk) 15%	Total ex-ante net GHG ER under project scenario
2012	7252.9	3407182	18	130551.7	3276630	50	1638315	1638315	245747.25	1392567.75
2013	6774.2	3182308	18	121935.3	3060372	50	1530186	1530186	229527.9	1300658.1
2014	6327.1	2972275	18	113887.6	2858388	50	1429194	1429194	214379.1	1214814.9
2015	5909.5	2776105	18	106371	2669734	50	1334867	1334867	200230.05	1134636.95
2016	5519.5	2592882	18	99350.49	2493532	60	997412.7	1496119	224417.85	1271701.15
2017	5155.2	2421752	18	92793.36	2328959	60	931583.5	1397375	209606.25	1187768.75
2018	4814.9	2261916	18	86669	2175247	60	870099	1305148	195772.2	1109375.8
2019	4497.2	2112630	18	80948.84	2031681	60	812672.4	1219009	182851.35	1036157.65
2020	4200.3	1973196	18	75606.22	1897590	60	759036	1138554	170783.1	967770.9
2021	3923.1	1842965	18	70616.21	1772349	65	620322.2	1152027	172804.05	979222.95
2022	3664.2	1721330	18	65955.54	1655374	65	579380.9	1075993	161398.95	914594.05
2023	3422.4	1607722	18	61602.47	1546119	65	541141.8	1004978	150746.7	854231.3
2024	3196.5	1501612	18	57536.71	1444076	65	938649.1	505426.9	75814.035	429612.865
2025	2985.5	1402506	18	53739.29	1348767	65	876698.3	472068.	70810.30	401258.395

								7	5	
	Total ex-ante net emission reduction									14194371.51

5.7. Leakage and leakage management

Leakage is an important aspect that should be considered in forestry projects for GHG emission reduction or removals. Leakage refers to the displacement or relocation of deforestation and forest degradation that is usually called 'activity shifting' to other adjacent forests following the protection or improved management of project forests. Any emission to be called leakage it should be attributable to the project, and is usually within the same jurisdictional boundary as the project. International leakage, like increased import of wood product by a given country, will not be considered as leakage. Leakage is very important in any carbon forestry project as it reduces net gains in GHG emission reduction achievable by a given project by causing greater than normal GHG emissions outside project area. Unless managed it will make forest based climate mitigation efforts almost fruitless. Therefore, to make sure that forestry projects yield net positive GHG emission reductions or removals leakage should be monitored and accounted. If leakage emissions are found greater than what can happen under the baseline scenario, it should be deducted from the emission reduction claimed in the project forest.

For monitoring leakage, leakage monitoring boundary should be defined. In the case of VCS methodology, an area called leakage belt is defined and leakage is monitored within this belt (see figure 19). Leakage belt can comprise forest and non-forest areas but should be close to the project area (project forest). The geographic extent of leakage belt is determined based on various factors such as mobility of the agents of deforestation and forest/agricultural product movement.

Projects are expected to calculate the amount of emission to occur under the baseline scenario in what is called the leakage belt. However, if actual leakage in the leakage belt in *ex-post* assessment (monitoring) is found to be greater than what was anticipated under the baseline case, the extra emission need to be considered.

Leakage could also be market based. This refers to increased purchase of forest products or agricultural produces from outside the project area that can be linked to increased deforestation in another area of the same geographic (jurisdictional)[5] boundary. Market leakage also occurs when the project activity reduces the production of a commodity that results in an increase in production elsewhere to meet continuing market demand.

The calculation of GHG emissions due to leakage follows the same procedure as emission accounting in the project forest. It is simply the product of activity data (area deforested or biomass removed in the area defined as leakage belt) and emission factor set for the forest. This is done both under baseline scenario to estimate ex-ante expected leakage, which is normal emission expected, and after project implementation, ex-post leakage. The difference between ex-post and ex-ante GHG emissions is what will indicate whether there is greater or lesser emission in the leakage belt.

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[5] Jurisdiction in the context of REDD+ means the geographical boundaries, defined either on the basis of administrative boundaries or ecological conditions within which carbon accounting is conducted.

Projects are expected to design strategies to reduce leakage, called leakage management. These are various activities to be implemented in the all or part of the leakage belt to address factors that may instigate greater leakage than normally expected. Such efforts like agricultural intensification, provision of alternative energy or improving energy efficiency and afforestation/reforestation or improving forest management are some of the activities for managing leakage.

The net GHG emission reduction credit that considers leakage is calculated as follows:

Net GHG emission reductions credit (Verified Carbon Units) = Baseline emissions (projected ex ante) - Project emissions (monitored ex post) - Leakage (monitored ex post) -Risk Buffer withholding

5.8.   Jurisdictional approach as a solution to leakage management

Leakage is considered as one of the many reasons that delay mainstreaming of project based REDD+ initiatives into compliance market. However, it is clear that the larger REDD+ projects get the lesser leakage will be. Given that leakage is not considered across political boundaries (no international leakage) designing REDD+ projects at national or at least at sub-national scales are one strategy to significantly minimize leakage. This is called jurisdictional approach to REDD+ projects development. "Jurisdiction" is defined as any politically defined region delineated for the purposes of tracking carbon stocks, deforestation rates, and GHG reductions through REDD+ project activities. A jurisdiction may be a national or sub-national political entity (nation, state, province, district, etc.), though other ways of defining jurisdictional boundaries are also possible. One means to accommodate project based initiatives is by means of working in a nested approach, where projects can run their activities, but emission accounting being done across all projects.

An advantage of JR is that they do not need to account for leakage but should identify and mitigate it to the extent possible. Similarly, sub-national jurisdictions do not need to account for it, but must identify the potential of baseline drivers to cause leakage and develop and implement measures to avoid or reduce the risk of leakage.

Module Exercise

I.   Given the data in annex 1 on forest inventory of 120,000 ha of dry forest
     (designated as project area) in Munessa-Shashamane forest, and additional
     information as follows:
     a) Average historical deforestation rate of 0.98%
     b) Carbon fraction of 0.5
     c) WD of 0.65 tons/m3

     Answer the following questions?
     1. Calculate an activity data (area of deforestation) for a project life time of 10
         years;
     2. Calculate the average forest carbon stock (Emission Factor) per ha of the
         forest;
     3. Calculate the ex-ante pre-deforestation GHG emissions and post-
         deforestation GHG emissions under the baseline scenario;
     4. Calculate the ex-ante post-deforestation GHG emissions under the baseline
         scenario from the project area;
     5. Decide on project performance factor, and calculate ex-ante emission under
         project scenario;
     6. Calculate ex-ante project scenario Emission Reductions;
     7. Assuming a buffer for risk of 20%, calculate ex-ante net GHG emission
         reduction under the project scenario.

II. If the same average historical deforestation rate is expected in a leakage belt,
     which is 25,000 ha, calculate the expected GHG emissions under baseline
     scenario in the leakage belt as well.

6. Monitoring, Reporting and Verification

Module objective: Following project development and validation, projects need to
implement activities prescribed in the Project Design Document that addresses
drivers of deforestation and ensure emission reductions. For carbon revenue to be
generated, the impacts of such project activities should be monitored, reported and
third party verified. Third party **verification** is mandatory for generating carbon
revenue. Monitoring, reporting and impartial verification of project impacts is
therefore part of the key components of making REDD+ work in practice. This
module provides detail outline of how these key activities are accomplished.

Learning outcomes: after this module participants, will be able to:
*   Develop simple monitoring plans for REDD project;
*   Justify the need for monitoring, and understand how it is done
*   Understand how to prepare and write monitoring reports
*   Justify the need for third party verification,

Time required:

- 2 days

Materials:
- Copies of the module, note book, pen/pencil, laptop computer

Training method:
- Start the training with brainstorming of the need for monitoring, reporting and verification. What are these three words stand for. Then provide copy of the module for group reading and discussion on each of the three. Conclude the module with exercise at the end.

Implementing planned project activities

REDD+ or AR-CDM projects spell out detail project activities that are expected to deliver the emission reductions or removals anticipated under the project scenario. These project activities are often multi-sector and include agriculture, energy, forest related and institutional/governance aspects. It is essential to bear in mind that implementation is the **phase that will require the vast majority of project effort, resources, and commitment** - and this over many years to ensure the total emission reduction envisaged over the project life time. Implementation must follow exactly what has been laid out in the project design document (PDD).

6.1.   Monitoring

Monitoring, which is one of the most critical steps in any project implementation, is used to check the realization of envisaged climate (carbon) and non-climate benefits of carbon projects. In forest carbon projects, monitoring involves documenting of the actual emission reductions and sequestration of GHGs (i.e. ex post project emission reductions/removals) as a result of implementation of project activities. It is **the instrument** that helps to communicate the successes of a project in realizing the envisaged project benefits (climate and non-climate) to all interested parties, particularly buyers of carbon credits. Without complete and documented monitoring results, there is little verifiable evidence that the project is generating GHG benefits worth paying carbon credit for. Monitoring can, therefore, well be described as a management function that entails reviewing successful implementation of planned project activities and achievements of project objectives and goals. Monitoring of project operation is a precondition for verification of achieved emission reduction, and issuance of sellable carbon units. Monitoring is conducted by project proponent (first party report) that reports on achievements transparently as this will be third party verified.

What is monitored depends on project activities and carbon pools included in the project development. If deforestation is the only variable included, the deforestation area is monitored. If carbon enhancement is also included monitoring will also include this. If planned degradation was also included, this will also be monitored. Whether included or not, degradation is essential to monitor always. This is because, although forest area may remain intact or deforestation is reversed, there could be a significant reduction in carbon stock of the forest due to degradation. Either permanent or temporary sample plots can be used to monitor this.

Monitoring of project activities will follow the monitoring plan contained in the PDD. The monitoring plan should spell out, what to monitor (which carbon pool), when to monitor (date when monitoring data should be collected – monitoring frequency), how to monitor (methodology – data collection procedure), quality control/quality assurance procedures, and who is responsible for the operations (organizational and responsibilities of parties involved). Projects should clearly indicate the frequency over which they monitor performance. These are usually five years cycle, but depending on context the frequency could be lower or higher.

Monitoring protocol should be similar to the protocol used in the project development. Carbon measurement (pools and inventory data collection method), deforestation assessment (like imagery used, image analysis procedure, etc.) including formats and tables should follow the same procedure and process as used in the development of the project document. This will ensure consistency and comparability of the *ex ante* and *ex post* methodologies; hence to clearly quantify real climate and associated benefits of the project. If different methodologies are applied the result may require independent validation of methodological comparability. This is because, what can be claimed achievement may result from methodological deviation rather than actual achievement. During verification auditors will field verify that monitoring was conducted as required by the methodology and planned in the PDD.
Frequent monitoring may be advisable to keep track of project performance, as well as to help decide when renewed verification becomes economically attractive. The interval between full monitoring (and verification) events can often be adjusted to ensure that costs incurred will be justified by a sufficient volume of carbon credits to be generated.

6.2. Reporting

Monitoring data, calculations, and results need to be thoroughly documented and presented to third-party auditors during the verification process. Reporting refers the presentation of measured information from the monitoring in a transparent and standardized manner. Reported information encompasses forest-related data and estimates of ex-post GHGs emissions and emissions reductions, and the methodologies used to derive them, as well as other related issues, such as quality assurance and quality control (QA/QC) activities and uncertainty estimation.

Regular reassessment of the implementation of the monitoring plan on the ground can provide valuable feedback on project performance and help identify problems early on. In addition, having a reasonably good idea of carbon benefits that have

been generated up to a certain point is important when deciding when to invest resources into a costly external verification. Please note that cost of external verification/third party verification is to be covered by project proponent.

6.3. Calculating and reporting ex-post emission reduction

Ex-post net emission reductions should be accounted in order to quantify the actual emission reduction (carbon credit) generated by the project after being operational. This emission reduction when verified by a third party it is called Verified Carbon Units (VCU).

In monitoring carbon stock change (emission reductions or removals), three tasks should be exercised:
- Monitoring of actual AD, i.e. area of deforestation following project implementation (in project area and leakage belt);
- Calculating the actual carbon stock changes (GHG emissions reductions) within the project area and leakage belt, and
- Reporting net ex-post GHG emission reduction achieved.

The following tasks are also expected to be monitored:
- Monitoring of project implementation: what activities, where and how much is implemented
- Monitoring of land-use and land cover change (i.e. deforestation reduced);
- Monitoring of carbon stocks (if necessary) and if degradation of significant scale is expected. Otherwise, the *ex-ante* estimate average carbon stock per LU/LC class can be applied.

Monitoring of leakage is to make sure that there is no significant activity shift because of the project to other areas. If leakage is greater than anticipated under baseline scenario in the leakage belt, then this will be considered as activity displacement leakage, and should be deducted from the carbon credit to be claimed under the project scenario (Table 17).

Table 17. Example of deforestation monitoring and ex-post calculation of ER.

Year	Baseline scenario projected deforestation (ha)	Actual deforestation obtained from monitoring (ha)	Actual PF
2014	6327.1	3532	55.8%
2015	5909.5	2920	49.4%

Calculate the **ex-post quantity** of GHG (carbon) emission reduced from the project

Answer:
ER (2014)   = 469.77*3532 =1659228 tCO$_2$e
ER (2015)   = 469.77*2920 =1371728 tCO$_2$e

Note: 469.77 represents the emission factor for the forest or carbon stock per ha in CO$_2$e per ha.

6.4. Verification and issuance of carbon credit

Verification is the key step preceding actual issuance of carbon credits. It refers to the assessment by a third party of the completeness, consistency and reliability of the reported information on project achievements through an independent process. Verification provides inputs to improve data (including GHG emission reductions/ removals as well as all measured data or derived parameters) and helps to build confidence in, and improve scientific understanding of, estimates and trends. During verification, an external auditor reviews and certifies the volume of GHG benefits that the project has actually achieved. The audit verifies the monitoring procedure as well as report for consistency, verifiability and standard, based on the monitoring plan and procedure described in the PDD.

Under both VCS and CDM, verification involves the following basic steps:
5. Recruitment of a third party verifier through international bid. These are firms recognized by the developers of the methodology used to develop the carbon offset project (e.g. if VCS is used, the verifier should be firms recognized by VCS);
6. Submission of a monitoring report to the third-party auditor. The project developer prepares a monitoring report summarizing the calculation of emission reductions based on the monitored data during the period for which it is intended to claim carbon credits (i.e., the monitoring period);
7. Site visit by auditor. After an initial desk review by the auditor, a site visit is conducted. During this site visit the auditor checks that the data records, monitoring systems and equipment, and organization follow the monitoring plan described in the PDD.
8. Draft verification report. After the site visit the auditor will prepare a draft verification report with their findings, forwarding their **clarification or correction** requests as necessary to the issues identified during the desk review and site visit. The project proponent needs to provide satisfactory responses to the auditor until all the issues raised are cleared.
9. Final verification report and issuance of verification statement. Once all clarification and correction requests raised by the auditor have been addressed and clarified, the auditor will issue the final verification report.

The verification report will indicate the volume of carbon credits generated during the corresponding monitoring period. At this stage, the project will be ready to request issuance of the **carbon credits** to the corresponding issuance body.

Timing of the first verification event is an important decision for project proponents. Each verification event can be costly and will involve additional monitoring effort. However, early verification can help achieve early revenues, with higher prices for issued credits compared to forward sales. On-going monitoring (even if only involving a reduced set of key indicators) can help determine trigger points where the volume of offsets generated is likely to justify the expense of external verification. In addition, a first verification round can serve as an important test for the efficiency of a project's monitoring system. Methodologies may also be quite specific as to how frequently some or all parameters in the PDD need to be monitored, limiting the flexibility of project proponents.

Verification and issuance are somewhat different in nature under VCS and CDM. Verification plays a quite different role for CCB as the standard does not issue any carbon credits.

a. Under the CDM, first verification can be undertaken at any time, with subsequent verifications every 5 years. The verifier reviews emissions reductions and formally "certifies" the GHG benefits of the project by communicating to the CDM Executive Board that the project has resulted in a specific volume of emission removals during a defined period of time. This formal communication is termed the "certification report" and constitutes a request for issuance of carbon credits (UNFCCC, 3/CMP.1, 2005). If the request for issuance is granted by the Executive Board, it then instructs the CDM Registry administrator to issue the CERs.

b. Under the VCS, the request for issuance is made by the project proponent to an approved VCS Registry, where they must have opened an account (see Section 6.3). Upon successful verification, the verifier will issue a verification report and verification statement (a legal document certifying that the project has resulted in emissions reductions or removals under VCS rules)[6].The project proponent then presents a request for registration and issuance including the verification statement and other project documentation to VCS registry administrator. The VCS Registry Administrator will review documentation and then issue Verified Carbon Units (VCUs) into the account of the project proponent. Please note updates to this procedure as part of the 2011 update to VCS Version 3.

c. Under CCB, a verification audit of the project must be conducted at least every 5 years. The audit verifies that net positive climate community and biodiversity impacts have been achieved according to the project design and monitoring plans. Please note again that CCB does not issue credits, so for CCB verification only results in the continued certification of the project as a "CCB project" adhering to this social and biodiversity focused standard.

Similar to registration, issuance is a more substantial hurdle under the CDM than it is under the VCS. The CDM Executive Board quite frequently issues review requests, which take time to resolve, and may even reduce the actually-issued volume from what has been documented in the verification report. Issuance requests are much more of a formality under VCS once all the required documentation has been assembled. The VCS Association does not itself receive issuance requests; rather, these are simply instructions to allow registries to perform the necessary steps to issue credits.

The VCS stipulates no mandatory minimum or maximum interval for verifications. However, the buffer pool creates an incentive for renewed verification because this can lead to the release of a part of the credits held back in the buffer pool. If subsequent verification demonstrates that risks have been reduced through successful project implementation, the risk buffer discount may be reduced. If the assessed risk level remains constant, or if it is lower than at the previous verification,

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[6] Validation and verification reports and statements may be combined under the VCS in cases where validation and verification are conducted in a single event.

15% of all buffer reserve credits (including newly verified credits) are released every 5 years, upon verification.

Conversely, not seeking renewed verification under the VCS within a maximum of 5 years leads to automatic cancellation of 50% of the project's buffer reserve credits. After 15 years of not submitting a verification report, buffer credits equal to the total number of credits issued to the project are cancelled from the pooled buffer account (on the assumption that there may have been a reversal due to failure or abandonment of the project). See REDD Guidance for more on calculating the risk buffer.

Module exercise
1. For the project under module 5 exercise, a post project monitoring during the first five years after project start date was conducted, and the following data was obtained:
   a. Deforestation rate in the project area was 0.56%
   b. Deforestation rate in the leakage belt was 1.05%

If the leakage belt of the project is 25,000 ha, calculate the net GHG emission reductions (carbon credits) achieved under the project during this monitoring period.

2. Discuss the results of question number 1, and check the differences in performance factor envisaged and performance factor actually achieved?

3. Based on the PF achieved, re-adjust and re-calculate the ex-ante GHG emission reductions for the project

Training Manual on REDD+ Safeguards

Compiled By

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Module 1. An Overview of Environmental Management Tools

Module 2 Origin and Development of REDD+ Safeguards

Module 3. Legal and Policy Framework Related to Safeguards

Module 4. Safeguard Instruments for REDD+

7.1. An Overview of Environmental Management Tools

This Module is designed to provide a general background of environmental management tools to the trainers.

The Module covers short description on:

- Environmental Impact Assessment (EIA)
- Strategic Environmental Assessment (SEA)
- Social Impact Assessment (SIA)
- Biodiversity Impact Assessment (BIA)
- Environmental Management Systems (EMS)
- Environmental Auditing (EA)
- Life Cycle Assessment (LCA)

Definition of Environmental Management

Environmental management (EM) is a subject that combines policy, science, and socioeconomic applications. It primarily stresses on finding solution to practical problems that people face in cohabitation with nature, resource exploitation, and waste production.

It is a response to human actions considering the increasing seriousness and significance of today's disastrous human impact on natural ecosystems. It is comforting to know that with a smaller global population base and a less pervasive use of technology, the environment might be able to recuperate on its own from human misuse and abuse, but it is now widely recognized fact that in many cases positive intervention is necessary if the environment is to recover in view of the fact that people have bestowed more importance on economic growth than preservation of the natural ecosystems.

Thus, Environmental management is closely linked with issues regarding sustainable economic growth, ensuring fair and equitable distribution of resources, and conserving natural resources for future generations.

Why Environmental Management

Advantages of undertaking environmental management these include:

- Reduced environmental risk
- Reduced social risk
- Ensuring legislative compliance
- Anticipating future legislation
- Meeting supply chain requirements
- Improved relations with regulators
- Improved public image
- Increased market opportunities
- Employee enthusiasm

Guiding Principles for Environmental Management

The following are a lists of international principles apply for EM:

Precautionary Principle : In order to protect the environment, a concept which includes peoples' ways of life and the integrity of their communities, the precautionary approach shall be applied.

Uncertainty Principle: It must be recognized that our knowledge of the social world and of social processes is incomplete and that social knowledge can never be fully complete because the social environment and the processes affecting it are changing constantly, and vary from place to place and over time.

Intra-Generational Equity: the benefits from the range of planned interventions should address the needs of all, and the social impacts should not fall disproportionately on certain groups of the population, in particular children and women, the disabled and the socially excluded, certain generations or certain regions.

Inter-Generational Equity: Development activities or planned interventions should be managed so that the needs of the present generation are met without compromising the ability of future generations to meet their own needs.

Recognition and Preservation Of Diversity: Communities and societies are not homogenous. They are demographically structured, and they comprise different groups with various value systems and different skills. Special attention is needed to appreciate the existence of the social diversity that exists within communities and to understand what the unique requirements of special groups may be. Care must be taken to ensure that planned interventions do not lead to a loss of social diversity in a community or a diminishing of social cohesion.

Internalization of Costs: The full social and ecological costs of a planned intervention should be internalized through the use of economic and other instruments, that is, these costs should be considered as part of the costs of the intervention, and no intervention should be approved or regarded as cost effective if it achieves this by the creation of hidden costs to current or future generations or the environment.

The Polluter Pays Principle: The full cost of avoiding or compensating for social impacts should be borne by the proponent of the planned intervention.

The Prevention Principle: It is generally preferable and cheaper in the long run to prevent negative social impacts and ecological damage from happening than having to restore or rectify damage after the event.

Environmental Management Tools

Considering the significance of sound environmental management it is agreed that environmental management is worth investing. To undertake any task one needs to have appropriate tools. This material describes a range of environmental management tools that an organization can use to effectively manage its environmental and social affairs. Some of these tools are still under development, and their use and even terminology varies. However, the following are the prominent tool to manage the environmental and social aspects.

a) Environmental Impact Assessment (EIA)

b) Strategic Environmental Assessment (SEA)

c) Social Impact Assessment (SIA)

d) Biodiversity Impact Assessment (BIA)

e) Environmental Management Systems (EMS)

f) Environmental Auditing (EA)

g) Life Cycle Assessment (LCA)

Environmental Impact Assessment (EIA)

Environmental Impact Assessment (EIA) as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and regulations.

Origin and Development of EIA

EIA as a systematic process started with the passage of the National Environmental Policy Act 1969 (NEPA) in the United States of America (Peckham, 1997; Wood, 2003). It developed slowly in the beginning with developed countries.

There after a major expansion took place during the mid-1980s in almost all the developed countries where each had their own mandatory EIA procedures. However, the EIA process in developing countries commenced much later and at a slower pace, but extended substantially after the Rio Earth Summit in 1992 (Lee, 2000; Wood, 2003). In most of the African countries, EIAs were mainly required or conducted by donor, multilateral agencies, non-governmental organizations and private institutions until the adoption of EIA legislation in the mid-1980s.

In Ethiopian the foundation for establishment of EIA system was laid by Rio Principle 17 in 1992 which endorses the institutionalization of EIA at national level. This was

affirmed by the high level meeting of the African Ministerial Conference on the Environment (AMCEN) in 1995.

Components of an EIA Process

Although legislation and practice vary around the world, the fundamental components of an EIA would necessarily involve the following stages:

Screening: to determine whether or not a proposal should be subject to EIA and, if so, at what level of detail.

Scoping: to identify the issues and impacts that are likely to be important and to establish terms of reference (TOR) for EIA.

Examination of alternatives: to establish the preferred or most environmentally sound and benign option for achieving proposal objectives.

Impact analysis: to identify and predict the likely environmental, social and other related effects of the proposal.

Mitigation and impact management: to establish the measures that are necessary to avoid, minimize or offset predicted adverse impacts and, where appropriate, to incorporate these into an environmental management plan or system.

Evaluation of significance: to determine the relative importance and acceptability of residual impacts (i.e., impacts that cannot be mitigated).

Preparation of environmental impact statement (EIS) or report: to document clearly and impartially impacts of the proposal, the proposed measures for mitigation, the significance of effects, and the concerns of the interested public and the communities affected by the proposal.

Review of the EIS: to determine whether the report meets its terms of reference, provides a satisfactory assessment of the proposal(s) and contains the information required for decision making.

Decision making: to approve or reject the proposal and to establish the terms and conditions for its implementation.

Follow up: to ensure that the terms and condition of approval are met; to monitor the impacts of development and the effectiveness of mitigation measures; to strengthen future EIA applications and mitigation measures; and, where required, to undertake environmental audit and process evaluation to optimize environmental management.

It is desirable, whenever possible, if monitoring, evaluation and management plan indicators are designed so they also contribute to local, national and global monitoring of the state of the environment and sustainable development.

Strategic Environmental Assessment (SEA)

Strategic Environmental Assessment (SEA) as, 'the formalized, systematic and comprehensive process of identifying and evaluating the environmental consequences of proposed policies, plans or programmes to ensure that they are fully included and appropriately addressed at the earliest possible stage of decision-making on a par with economic and social considerations'.

Since this early definition the field of SEA has rapidly developed and expanded, and the number of definitions of SEA has multiplied accordingly. SEA, by its nature, covers a wider range of activities or a wider area and often over a longer time span than the environmental impact assessment of projects.

SEA might be applied to an entire sector (such as a national policy on energy for example) or to a geographical area (for example, in the context of a regional development scheme). SEA does not replace or reduce the need for project-level EIA (although in some cases it can), but it can help to streamline and focus the incorporation of environmental concerns (including biodiversity) into the decision-making process, often making project-level EIA a more effective process.

SEA is commonly described as being proactive and 'sustainability driven', whilst EIA is often described as being largely reactive.

Origin, benefits and rationale for SEA

The National Environmental Policy Act (NEPA) is the reference back to which we can find the first requirements for what became known as SEA. In fact, the action-forcing mechanism, shaped as a requirement and subsequently nominated EIA, to bring about substantive environmental reform through the US federal bureaucracy, imposed upon federal agencies to prepare an environmental impact statement for "legislation and other major federal actions significantly affecting the quality of the human environment" (Section 102(2)(c), National Environmental Policy Act of 1969). Since then several international initiatives subscribe the need for SEA.

To date, only a relatively small number of countries and international organisations have made formal provision for SEA. These frameworks vary, sometimes substantially, and indicate the flexible adaptation of SEA to different levels and types of decision-making. As presently institutionalized, SEA is a multi-stage process that encompasses a spectrum of approaches and diverse arrangements, procedures and methods.

Despite taking different forms, SEA systems have a common purpose: to take account of environmental concerns in policy and planning decision-making, thereby contributing to sustainable development. However, there are varying interpretations of the role, scope and process of SEA.

Aims and objectives of SEA

To help achieve environmental protection and sustainable development by:
• Consideration of environmental effects of proposed strategic actions
• Identification of the best practicable environmental option
• Early warning of cumulative effects and large-scale changes

To strengthen and streamline project EIA by:
• Prior identification of scope of potential impacts and information needs
• Clearance of strategic issues and concerns related to justification of proposals
• Reducing the time and effort necessary to conduct individual reviews

To integrate the environment into sector-specific decision-making by:
• Promoting environmentally sound and sustainable proposals
• Changing the way decisions are made

Environmental Audit

An environmental audit is a tool that is used to check whether a company is doing what it should be doing.

Environmental auditing originated in North America in the 1970's as a management tool to determine whether or not companies, organizations, projects and programs were complying with the increasingly numerous and complex laws and regulations that were coming into force at that time. Checking whether the activities of a company/organization that are covered by environmental legislation (i.e. what the company/ organization is doing) actually comply with that legislation (i.e. what is should be doing) is called a legislative compliance audit.

Auditing is an important part of an environmental management system. ISO 14001 requires that an audit to be undertaken to check whether a firm's EMS meets its requirements.

Social Impact Assessment (SIA)

Social impacts are impacts of developmental interventions on human life, livelihoods and human settlements. Such impacts not only need to be identified and measured but also need to be managed in such a way that the positive externalities are magnified and the negative ones minimized.

Social Impact Assessment can be defined in terms of efforts to assess or estimate, in advance, the social consequences that are likely to follow specific policy actions (including programs and the adoption of new policies), and specific government actions. It is a process that provides a framework for prioritizing, gathering, analyzing, and incorporating social information and participation into the design and delivery of developmental interventions. It ensures that development interventions are:

- Informed and take into account the key relevant social issues; and
- Incorporate a participation strategy for involving a wide range of stakeholders.

The nature of SIA in an international context

The objective of SIA is to ensure that development maximizes its benefits and minimizes its costs, especially those costs borne by people (including those in other places and in the future). Costs and benefits may not be measurable or quantifiable and are often not adequately taken into account by decision-makers, regulatory authorities and developers. By identifying impacts in advance: (1) better decisions can be made about which interventions should proceed and how they should proceed; and (2) mitigation measures can be implemented to minimize the harm and maximize the benefits from a specific planned intervention or related activity.

Biodiversity Impact Assessment

Biodiversity matters to all. Its loss impoverishes the environment and reduces its capacity to support people now and in the future. Impact assessment can help to ensure development is compatible with the conservation and sustainable use of biodiversity. The first World Summit on Environment and Development in Rio de Janeiro (1992) emphasized the importance of biodiversity as the basis of our very existence, to be used

wisely and sustainably and conserve for current and future generations. The main threats to global biodiversity are associated with human activities causing habitat loss or damage.

The Convention on Biological Diversity (CBD), the Ramsar Convention, and the Convention on Migratory Species (CMS) recognize Environmental Management tool such as Biodiversity Impact Assessment (BIA) as an important decision support tool to help plan and implement development with biodiversity "in mind."

The Conventions require Signatories ("Parties") to apply EIA and SEA to proposals with potential negative impacts on biodiversity to help meet their objectives, so that development proposals respect mechanisms for the conservation of biodiversity, result in sustainable use of biodiversity resources, and ensure fair and equitable sharing of the benefits arising from use of biodiversity.

Life Cycle Assessment

Life Cycle Assessment (LCA) is a tool for identifying and assessing the various environmental impacts associated with a particular product. LCA takes a "*cradle to*

grave" approach looking at the impacts of the product *throughout its life cycle* i.e. from the raw materials acquisition (the "*cradle*") through its production and use to its final disposal (the "*grave*"). LCA allows manufacturers to find ways of cost-effectively reducing the environmental impact of a product over its life-cycle and to support their claims about the environmental impact of their products.

7.2. Origin and Development of REDD+ Safeguards

This Module is designed to provide a critical overview of REDD+ Safeguards to the trainers.

The Module covers:

- Historical background of REDD+ Safeguards
- Definitions and Concepts of REDD+ Safeguards
- purpose and objective of REDD+ Safeguards
- REDD+ Safeguard Principles
- Social and environmental safeguards in REDD+

Historical Background for REDD+ Safeguards

Forest carbon projects have existed since the mid-1990s with the majority situated in Latin America. The primary focus of these projects was reducing deforestation and estimate net impacts on greenhouse gas emissions. Similarly, in recent years initiatives to reduce emissions from deforestation, degradation and enhance forest carbon stocks in developing countries (REDD+) have played a prominent role in international forest conservation finance, implementation, and policy discourse.

REDD+ Projects and programs have emerged in multiple countries, national programs are under development in all regions of the world, and negotiations regarding REDD+ have progressed much faster than in other areas of international climate talks. REDD+ was originally conceived as a market-based carbon-offsetting scheme, where emitters in developed countries pay entities in developing countries to reduce deforestation below a projected counterfactual scenario in order to offset the carbon emissions in developed countries.

As incentive-based, results-driven environmental policy, many believe REDD+ holds promise to bring about transformational change and deliver "triple wins" for climate, forests, and poverty reduction. To others the potential for governments, and conservation organizations to make forest conservation a profitable endeavour via carbon markets has sparked concerns that REDD+ would harm local populations by ignoring customary tenure rights and restricting land use and access to forests without sufficient compensation or alternatives. In response to such concerns, the governance and social dimensions of REDD+ have received increasing attention amongst stakeholders as programs and projects develop, with many adopting policies designed to "safeguard" vulnerable populations from harm. Some have gone a step further to insist that REDD+ must also benefit local populations.

In 2007, at the 13th UNFCCC COP, the parties adopted the "Bali Action Plan", which paved the way for REDD+. The focus of early dialogues on REDD+ revolved around MRV of reduced deforestation and degradation. The Bali Action Plan included only minimal language regarding the needs of local communities, which stood to be significantly affected through changes in access to forests. Following adoption of the Bali Action Plan, advocates pressed the Parties to include and recognizing peoples' rights and safeguarding the welfare of local communities. These calls were initially met with resistance by those worried that REDD+ would become overburdened with social objectives, distracting from its purpose as a tool for protecting forests for the purpose of mitigating climate change. However, by 2010, as evidenced by the language of the Cancun Agreement reached at the UNFCCC COP 16, Parties are called upon to promote, support and report on the implementation of social and environmental safeguards for REDD+.

Since COP 16, Parties' support for both safeguards and non-carbon "co-benefits" appears to have strengthened. At COP 17 in Durban, South Africa, parties committed to developing guidance on how countries could address and report on safeguards (known as "Safeguard Information Systems" (SIS). To advance and guide negotiations at Doha's COP 18, Parties met in Bangkok in September 2012 and forged an informal draft REDD+ text that puts forward multiple options for each aspect of the REDD+ architecture. Included in these options is the suggestion that carbon and non-carbon benefits are inextricably linked, as well as a request that

results-based payments be contingent on the provision of both carbon and non-carbon benefits. Non-carbon benefits of REDD+ are the suite of ecosystem services provided by forests (in addition to carbon storage) as well as social and development benefits. In the work plan agreed to by the parties at COP 18 in Doha, investigating options for incentivizing non-carbon benefits is given a prominent place on the agenda. The Warsaw Agreement, established at COP 19, requires that countries establish SIS to be eligible for results-based payments.

Multilateral and bilateral donors have also developed safeguard policies of their own. The World Bank Group's (WBG) Forest Carbon Partnership Facility (FCPF), which works with countries to build their institutional capacity for the design and implementation of REDD+, is now applying the institution's environmental and social risk management framework and Safeguard Policies to REDD+. Meanwhile, the UN REDD Programme has developed social and environmental principles and criteria that are congruent with the Cancun Agreement's safeguards. Bilateral donors, such as the United States Agency for International Development (USAID), the Norwegian Agency for development (NORAD), and Australian Aid, are crafting safeguard policies for their REDD+ programs.

Definitions and Concepts of Safeguards

There is no universally agreed upon definition of 'safeguards'. However, 'safeguards' have been traditionally used by financial institutions such as the World Bank as measures to prevent and mitigate undue harm from investment or development activities. In this case, safeguards are most commonly associated with a 'risk-based approach', which involves pricing and prioritizing risks according to a logic of economically efficient 'risk management'. A risk management process aims to insure against the risk of a certain type of activity triggering an initiative's safeguard accountability mechanisms.

REDD+ safeguards (safeguard systems) are broadly defined as a set of principles, rules and procedures put in place to achieve social and environmental goals. These principles and rules outline safeguards' (e.g., protection of local community rights and biodiversity), procedures delineate the task of implementing, monitoring and

enforcing safeguards (e.g., safeguard information systems or compliance assessments).

Safeguards are formulated by different entities and serve different purposes. Government, Public or private investors and project developers use safeguards to prevent risks or undesirable outcomes of a particular project, program or policy. Public entities normally develop their own safeguard policies, whereas private investors rely on public legislation or private standard systems.

In foreign assistance and investment, the notion of formulating 'safeguards' is most commonly associated with planning and implementing investment projects by multilateral development banks (MDBs). The World Bank's safeguard policies "…require that potentially adverse environmental impacts and selected social impacts of Bank investment projects should be identified, minimized, and mitigated." Beyond the avoidance of adverse impacts, safeguards provide a mechanism for integrating environmental and social concerns into decision-making. World Bank's safeguard policies provide that:

a) Potentially adverse environmental impacts affecting the physical environment, ecosystem functions and human health, and physical cultural resources, as well as specific social impacts, should be identified and assessed early in the project cycle;

b) Unavoidable adverse impacts should be minimized or mitigated to the extent feasible;

c) Timely information should be provided to stakeholders, who should have the opportunity to comment on both the nature and significance of impacts and the proposed mitigation measures.

In addition to the public sector and multilateral organizations, the private sector also has an interest in safeguards where standards mitigate investment risks and improve project quality. Safeguards can mitigate both project failure and reputational risks, therefore the private sector has increasingly invested in forest carbon projects that address social and environmental issues. Aside from safeguards supporting particular investments or projects, there are also safeguard systems developed to inform policy formulation. Such systems are composed of guidelines built around

principles, rather than binding obligations and mandated results. These standards, whether formulated by private or public bodies, target public agencies and support public policy making.

Purpose and objective of Safeguards

Forest carbon projects and REDD+ safeguards were established to ensure a given project or program does not contravene its own long-term climate and forest goals in addition to maximizing wider sustainable development and social and environmental protection benefits. As forest carbon/REDD+ sector safeguards have evolved, their purpose and objective have grown from minimal criteria of 'do no harm' underlying much of the environmental impact assessment requirements from public and private financiers as well as national legislation, to more proactive 'do good' principles to promote the long-term environmental and social co-benefits of REDD+.

However, opinions still differ about the appropriate emphasis of REDD+ safeguards. 'Do no harm' proponents argue that the main goal of REDD+ is climate change mitigation, therefore safeguards should serve to mitigate risks – be they social risks to populations living in affected areas, environmental risks to the forest areas and related ecosystems and biodiversity, legal risks to the state or responsible project developers and certifiers, or financial risks to funders and investors.

Such an approach allows countries the flexibility to manage decisions related to positive social and environmental co-benefits rather than to mandate them. On the other hand, 'do good' proponents expect REDD+ to not only reduce net greenhouse gas emissions, but also to improve the welfare of forest communities and biodiversity, pointing out that REDD+ will not succeed or gain legitimacy otherwise.

They propose directly targeting poor forest communities and biodiversity forests for REDD+ activities, rather than just areas with high emission mitigation or carbon enhancement potential. While these objectives seem divergent, country-level studies (spatial and socioeconomic) have shown synergies and significant overlaps between climate change mitigation and other social and environmental benefits. Additionally, both types of proponents tend to support 'no regrets' measures, or activities relevant to REDD+ such as improved forest governance and land tenure reforms that will be beneficial regardless of the outcomes in UNFCCC negotiations, REDD+ financing

and carbon markets. Ultimately, the REDD+ country, often in cooperation with its donor or investor partners, will determine the primary and secondary policy goals of REDD+ and integrate those within safeguard systems and national strategies (prioritization of activities and locations).

Generally the safeguards ensure that REDD+ will be implemented in an inclusive, transparent manner, with respect for the rights of indigenous peoples and local communities and with consideration for the protection of biodiversity. It's also about how it would change the lives of those whose culture, survival and heritage depend o**n** the forests themselves.

Safeguard Principles

According to the decision of the 16th conference of United Nation Framework Convention on Climate Change (UNFCCC) in Cancun, the following principles applied to safeguarding rights under REDD+:

Principle 1   Actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements: This principle requires countries to ensure that their REDD+ actions are consistent with their national forest programmes, as well as relevant international conventions and agreements. UNFCCC REDD+ Safeguard (a) does not imply any new commitments. On the contrary, it merely reaffirms already existing international obligations. By ensuring that REDD+ actions complement or are consistent with these relevant international instruments, REDD+ countries have the opportunity to implement the UNFCCC REDD+ Safeguards by building upon their existing domestic systems developed to comply with those international conventions and agreements. REDD+ countries will need to reassess and potentially strengthen their domestic systems by enacting and/or strengthening laws, policies and institutions to ensure that the UNFCCC REDD+ Safeguards are being addressed and respected.

Principle 2 Transparent and effective national forest governance structures, taking into account national legislation and sovereignty: This principle focuses on national forest governance structures, particularly with regards to transparency and effectiveness. 'Transparent' governance structures should:

1) Provide a right of access to information, especially to vulnerable groups such as local peoples and forest dependent communities;

2) Ensure that institutions are capable of maintaining accountability and preventing corruption, and can guarantee access and distribution of information to members of the public on pertinent matters; and

3) Provide information to promote public awareness of the right of access to information, and the publics' ability to exercise that right.

Characteristics of 'effective' governance structures generally include:

1) enhancement of laws and regulations relating to governance and sustainable use of forests;

2) public participation in forestrelated decision-making;

3) clear rights of ownership and possession (land tenure);

4) equitable benefit sharing; and

5) enforcement of those laws.

It also means having adequate institutions and administrative frameworks, including judicial or administrative procedures providing for an effective remedy for infringement of rights, especially for indigenous peoples. Effective forest governance also requires preventing corruption, and providing adequate funds for forest protection and conservation. Furthermore, coordination is needed between sectors affecting forests, as well as integration of social and environmental considerations into decision-making processes.

Principle 3 Respect for the knowledge and rights of members of local communities, by taking into account relevant international obligations, national circumstances and laws: This principle clearly focuses on the importance of recognizing and respecting the rights of local peoples and forest dependent communities. In this way, REDD+ actions and activities must be implemented in accordance with international law regarding local peoples and forest dependent communities, and international human rights law. These rights apply both to the individual and the group as a whole, and include:

1) The right to equal enjoyment of internationally-recognized human rights;

2) Respect and protection of rights regarding land tenure—including statutory, customary and traditional—and use of natural resources;

3) Self-determination;

4) Nondiscrimination;

5) Benefit-sharing;

6) Consultation and Participation, or free, prior and informed consent (fpic); and

7) Respect for traditional knowledge.

Principle 4 The full and effective participation of relevant stakeholders, in particular local people and forest dependent communities: While developing national policies, implementing programs, developing monitoring mechanisms, and determining forest baseline for REDD+, it requires the full and effective participation of relevant stakeholders. In international legal instruments, full and effective participation is generally associated with the recognition and implementation of procedural rights (also known as access rights) such as access to information, participation and justice. In order to implement this safeguard, it will be necessary to create an enabling environment for individuals to practice their procedural rights. This includes:

1) Identifying and notifying potentially affected persons, individuals and groups as early as possible;

2) Active dissemination of pertinent information at all levels in a timely, culturally appropriate and accessible manner;

3) Promotion, awareness-raising and capacity building for participation;

4) Existence of mechanisms to ensure that views are taking into consideration in the decision making process; and

5) Mechanisms to ensure access to justice for instances where participation is not enabled. In this context, the term 'relevant stakeholder' is understood to include all members of the public potentially affected by a specific decision. Additionally,

This principle specifically recognizes indigenous local peoples and forest dependent communities, and the need to deal with them as a separate relevant stakeholder, because they are more vulnerable to being left out of decision-making processes.

Principle 5 Actions are consistent with the conservation of natural forest and biological diversity: This principle aims to ensure environmental integrity throughout REDD+ implementation. According to this safeguard, REDD+ actions should be consistent with the conservation of natural forests and biological diversity. Specifically, REDD+ actions must not be used for the conversion of natural forests. Furthermore, protection of natural forests and their ecosystem services should be incentivised. Actions that contribute to the conservation of natural forest and biological diversity include: 1) identification, mapping and monitoring of natural forests and biodiversity; 2) regulation of biodiversity; 3) support for conservation research; 4) awareness-raising; and 5) integration of biodiversity concerns into other national sectors. REDD+ actions should also promote the enhancement of environmental and social benefits, such as environmental or ecosystem services and livelihoods.

Principle 6 & 7 Actions to address the risks of reversals; and Actions to reduce displacement of emissions: These principle require REDD+ countries to take actions to address the risks of reversals, and to take actions to reduce displacement of emissions. Much of what makes up these safeguards is technical and REDD+ specific, and therefore they are not directly reflected in existing international obligations. However, there are many social and environmental measures that can assist in ensuring that leakage does not occur, and that reductions are long-lasting. Examples include:

- promotion of sustainable use and management of forests;

- responsible planning;

- building awareness;

- strengthening institutional governance and regulatory frameworks; and

- ensuring participation and equitable sharing of sustainable benefits of REDD+.

International cooperation in the implementation of these measures is also very important, since reductions in one country bordering another may result in transboundary leakage.

Social and environmental safeguards in REDD+

Reducing deforestation and forest degradation is a requirement for all countries implementing REDD+. While addressing the causes of deforestation and forest degradation, positive or negative impacts might occur on the social and environmental aspects. It is equally important to reduce the adverse impact of REDD+, while promoting the positive impacts of REDD+. Therefore, social and economic security has to be addressed carefully during the implementation of REDD+. In this chapter, how to develop a scenario with and without REDD+, the positive and negative impacts of REDD+ on social and economic conditions, the method to measure impacts, the impact of REDD+ in reducing poverty and livelihoods, the challenges in REDD+ implementation and benefit sharing, and the involvement of forest-dependent people on benefit sharing will be discussed.

Situation with and without REDD+

To assess the impacts of REDD+, the situation before implementing REDD+ should be analyzed. The forest management without REDD+ refers to the continuation of an existing management system. The negative and positive effect of forest management without REDD+ on society and environment can be understood from the baseline situation assessment and Initial Environmental Examination (IEE) and an Environmental Impact Assessment (ESIA). The assessment shows how the community is using the forest.

Analysis is needed on how forests can be managed through REDD+ implementation and how forest conservation and management can be done to enhance carbon stock. While assessing, it is necessary to assess the social and environmental impact of forest management according to the REDD+ process. In this way, the analysis of impact with and without REDD+ on society and environment can be done.

Impact assessment technique

REDD+ has stated social and environmental impacts which have to be assessed through different methods. The impact assessment techniques that can be used includes:

- Review of relevant document

- Expert observation and judgment

- Check lists

- Matrix

- GIS analysis

Potential Positive and Negative Impacts of REDD+

REDD+ program can have both positive and negative social, economic and environmental impacts. To understand these impacts, a detailed study is required.

The potential Positive Impacts of REDD+

Due to the implementation of REDD+ program there may be a decrease in the collection of firewood and fodder as well as grazing, since without proper protection of forests, forest carbon stock cannot be increased. For this, protection of plants and grazing control will be necessary. This may increase the availability of Non-Timber Forest Products. Due to an increase in production of timber, the income of a community may increase. Similarly, other positive impacts include enhancement of aesthetic value of forests; an increase in agriculture production due to an increase in the availability of water and compost; improved biodiversity; enhanced forest carbon stock; and increased soil productivity due to improved fertility. Similarly, there will be a decrease in the use of forest products by applying alternative energy. The indirect positive impacts include watershed conservation, which increases water storage and the retaining period; and the practice of stall feeding improves the productivity of land.

In the social sector, poverty alleviation is indirectly supported through REDD+ implementation. Furthermore, this creates an environment for sensitization of local communities to the process of REDD+ implementation.

The other benefit that REDD+ implementation promotes is forest conservation and increased forest stocks, it will also support poverty alleviation. The income received from the carbon trade can be used in activities related to poverty alleviation, such as alternative energy promotion and rural micro-enterprise related skill development. Similarly, REDD+ improves forest conditions, which results in increased availability of forest products and improved biodiversity. Furthermore, improving access rights

for local communities and indigenous peoples can support expanded NTFP collection, bolstering local livelihoods.

The potential Positive and Negative Impacts of REDD+

The direct negative impacts as a result of REDD+ Implementation may include a decrease in the fallow period by shifting cultivation practice. The indirect negative impacts of REDD+ include migration of people due to limited availability for grazing, fodder, and access control, while illegal collection of forest products may also increase negative impacts.

While implementing REDD+, the existing use of forest resources by forest-dependent people may be restricted. However, situations should be created to secure the traditional use rights of forest-dependent groups.

Possible challenges in REDD+ implementation and benefit sharing

The main objective of REDD+ implementation is forest conservation and enhanced forest carbon stocks, often necessitating changes in existing forest use practices. This is one of the key challenges, as changing existing use practices needs the consent from all users.

The speed and process of REDD+ implementation could be a challenge. Reliable forest stock measurement methods, verifying such a report and the issue of making REDD+ implementation cheaper, simpler and more reliable are some of the challenges facing REDD+. Similarly, there will be a challenge on what benefit sharing mechanism to use in different forest management regimes. The major issue could be the allocation of revenue from REDD+ to different levels (National to community level).

Participation opportunity of Forest-Dependent Group

During the implementation of REDD+, communities should be able to manage and use forest resources as they have been using them traditionally. Sustainable forest management, forest carbon stock enhancements, and forest protection depends on a reduction in deforestation and forest degradation. The forest-dependent local communities should have rights in forest management related decisions, including implementation and benefit sharing at the local level. The REDD+ program should

create opportunities to implement various livelihood and poverty alleviation related programs.

7.3. Legal and Policy Framework Related to Safeguards

This Module is designed to provide a an overview of International, National and multilateral Legal and policy framework related to REDD+ Safeguards.

The Module covers the:

✓ International Convention and Multilateral agreements such as:-

United Nations Framework Conventions for Climate Change (UNFCCC)

United Nations Convention to Combat Desertification (UNCCD)

United Nations Convention on Biological Diversity (CBD)

CITES (the Convention on International Trade in Endangered Species)

Convention for the Safeguards of Intangible Heritage

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity

Pan African Agency for the Great Green Wall (PAGWW)

World Bank Safeguard Policies

- National policy and legal frameworks such as:
- The Rural Development Policy and Strategy, 2001
- Forest Conservation and Utilization Policy and Strategy, 2007
- Forest Development, Conservation and Utilization Proclamation 2007
- Environmental Policy of Ethiopia (EPE), 1997
- Environmental Impact Assessment Proclamation (EIA) No. 299/2002
- Climate Resilience Strategy for Agriculture and Forestry 2015
- Climate Resilience Strategy for Water and Energy
- National Energy Policy -1994
- Ethiopian Water Resources Management Policy-1999
- Access to Genetic Resources and Community Knowledge, and Community Rights Proclamation No. 482 /2006
- Expropriation of Landholdings for Public Purposes and Payment of Compensation
- Rural Land Administration and Land use Proclamation pro No 456/2005)
- Social protection policy of Ethiopia

Legal and Policy Framework Related to Safeguards

International Convention

The 1995 Ethiopian constitution is the supreme law of the land that has laid out the foundations for Ethiopia's commitment to ensure sustainable development, environmental and social safety. As a result, Ethiopia has given due attention to protect the environment and natural resources by ratifying international agreements and preparing national legal frameworks pertinent to environment and natural resources protection.

Ethiopia is either a party or signatory of many international forestry and environment related agreements. The country ratified a range of conventions that demonstrate the country's commitment to global climate change, biodiversity and desertification problems. The country is also an active participant in the global climate change initiatives. Selected relevant international conventions, protocols, and initiatives are summarized as follows:

United Nations Framework Conventions for Climate Change (UNFCCC)

UNFCCC is an international environmental convention negotiated at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held in Rio de Janeiro from 3 to 14 June 1992. The objective of the treaty is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The UNFCCC was opened for signature on 9 May 1992, after an Intergovernmental Negotiating Committee produced the text of the Framework Convention as a report following its meeting in New York from 30 April to 9 May 1992. It entered into force on 21 March 1994. As of March 2014, UNFCCC has 196 parties. Ethiopia ratified the convention in 1994.

The topic of reducing emissions from deforestation in developing countries was first introduced at the eleventh session of the Conference of the Parties (COP) to the

United Nations Framework Convention on Climate Change (UNFCCC) in Montreal (December 2005). The Climate Change Conference in Bali, in December 2007, opened the possibility of developing an incentive mechanism for "reducing emissions from deforestation and forest degradation; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" (REDD+). Subsequently some REDD+ projects have been developed, which already feature in the voluntary carbon markets.

United Nations Convention to Combat Desertification (UNCCD)

UNCCD is established in 1994 with an aim of linking development and environment to ensure sustainable management. The fact that the Convention specifically targets arid and semi-arid areas makes it pertinent to the national goals set to the pastoral and semi-pastoral communities. In the 10-Year Strategy of the UNCCD (2008-2018) that was adopted in 2007, Parties to the Convention further specified their goals: "to forge a global partnership to reverse and prevent desertification/land degradation and to mitigate the effects of drought in affected areas in order to support poverty reduction and environmental sustainability". The Convention's 195 parties work together to improve the living conditions for people in dry lands, to maintain and restore land and soil productivity, and to mitigate the effects of drought. The UNCCD is particularly committed to a bottom-up approach, encouraging the participation of local people in combating desertification and land degradation. Ethiopia ratified the convention in 1997.

The UNCCD invites all Parties to adopt and scale up sustainable forest management policies and practices to prevent soil erosion and flooding, to increase carbon sinks, and to conserve and sustainably use biodiversity (decision4/COP.8). The UNCCD, being the sole legally-binding instrument on land and soil, recognizes the importance and potential for REDD+ in drylands to contribute to land degradation neutrality, sustainable economic growth, poverty eradication and other urgent goals pledged at the Rio+20conference .Moreover, the UNCCD is one of the founding institutions of the Collaborative Partnership on Forests (CPF), a policy forum and partnership on all types of forests, including dry forests. In collaboration with other

organizations of the CPF, the UNCCD facilitates the UNFCCC, UNFF and other processes related to REDD+.

United Nations Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD) entered into force on 29 December 1993. It has 3 main objectives. The Convention is aimed at the conservation of biological diversity, the sustainable use of the components of biological diversity and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. The CBD provides a global legal framework for action on biodiversity. It brings together the Parties in the Conference of the Parties (COP) which is the Convention's governing body. Ethiopia ratified the convention in 1994

The COP for the CBD (COP 10) in its Decision X/33 recognized the importance of REDD+ activities in developing countries in collaboration with various stakeholders, including the UN organs and the national focal points for the CBD with the participation of underserved and local communities, so that actions are consistent with the objectives of the CBD and avoid negative impacts. (Paragraph 9 (g)) It also deals with the assessment of the contribution of REDD+ in achieving the objectives the CBD (Paragraph 13).

COP 11 which took place from 8 to 19 October 2012 in Hyderabad, India conducted important negotiations on REDD+. These include:
- Keeping the Convention's implementation under review; adopting indicators on the Aichi targets; allocating financial resources for the forest biodiversity work program, rather than focusing on non-binding guidelines for reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+);
- Strengthening REDD+ initiatives, geo-engineering and knowledge on linkages between biodiversity and climate change;
- Focusing on safeguards, considering means of monitoring and assessing the impacts of REDD+ on biodiversity;
- Understanding that the issue of forests is not reduced to REDD+;
- Develop indicators to monitor compliance by developing countries with REDD+ safeguards aimed to prevent negative impacts on biodiversity and underserved and local communities;

- Outlining a "roadmap" authorizing the next CBD COP to consider a progress report on REDD+ safeguards that can hopefully feed into the subsequent climate COP and allow for further review at CBD COP 13;

From these COP decisions and discussions it can be discerned that the relevance of REDD+ activities in developing countries to achieve the objectives of the CBD has been given due attention. Moreover, the issue of impacts on the biodiversity and the human society, particularly on underserved peoples and local communities has been repeatedly emphasized.

CITES (the Convention on International Trade in Endangered Species)

CITES is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. CITES is initiated because of the crosses borders nature of the trade in wild animals and plants which necessitates international cooperation to safeguard certain species from over-exploitation. CITES provides a framework to be respected by each Party, which has to adopt its own domestic legislation to ensure that CITES is implemented at the national level. It has about 180 parties. Ethiopia ratified the convention in 1989.

Convention for the Safeguards of Intangible Heritage

Intangible cultural heritage refers to traditions and living expressions that passed from one generation to the other that includes oral traditions, performing arts, social practices, rituals and other traditional knowledge and practices concerning nature and the environment. The major purposes of the convention are to safeguard the intangible cultural heritage, to ensure respect for the tangible cultural heritage of the communities, groups and individuals concerned, to raise awareness at the local, national and international levels of the importance of the intangible cultural heritage, and of ensuring mutual appreciation thereof to provide for international cooperation and assistance.

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity is an international treaty governing the movements of living modified organisms (LMOs) resulting from modern biotechnology from one country to another. It was adopted on 29 January 2000 as a supplementary agreement to the Convention on Biological Diversity and entered into force on 11 September 2003. The Protocol seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology. It establishes an advance informed agreement procedure for ensuring that countries are provided with the information necessary to make informed decisions before agreeing to the import of such organisms into their territory. Ethiopia ratified the convention in 2000.

Pan African Agency for the Great Green Wall (PAGWW)

The Great Green Wall Initiative of the Sahara and the Sahel was conceived as a sound initiative towards ensuring sustainable environmental management to African countries. It is anticipated that it could help in strengthening efforts made to arrest loss of biodiversity, control desert encroachment, and improve resilience of the local community to climate change impacts. The GGWSSI is an initiative with a broader target of increasing food security; reduce poverty by diversifying livelihood opportunities through climate resilient development approaches. This initiative was emerged to protect the expansion of the Sahara desert via planting a wall of trees which stretches from Dakar to Djibouti with a width of 15 kilometers and a length of up to 7000 kilometers. The wall envisioned by 11 African countries (Burkina Faso, Djibouti, Eretria, Ethiopia, Mali, Mauritania, Niger, Nigeria, Senegal, Sudan and Chad) on the southern border of the Sahara, and their international partners, is aimed at preventing the expansion of the Sahara desert into the Sahel. Ethiopia ratified the "Convention related to the Creation of The Pan African Agency of the Great Green Wall Ratification Proclamation No. 842/2014" in July 2014.

National Policies, Strategies, Proclamations and Programs

Forest sector of Ethiopia has been paid considerable national policy and strategy emphasis over the last two decades. There is a national policy and strategy document specifically formulated to this sector. There are also policies and strategy measures relevant to the forestry sectors which are amalgamated into the broader

rural development policy frameworks. Some policies and strategies of other sectors have also significant link to the forest sector. These policies and strategies play crucial roles that determine the extent at which the sector addresses the social, economic and ecological needs of the community to forest goods and services. Although these policy, legal and strategy documents do not directly refer to the issues of REDD+, they have provisions which are relevant for its implementation.

It is important to analyze such legal frameworks in the context of understanding the existing policies, strategies and action programs in view of social and environmental safeguards emanating from the application of REDD+ programs. Among others, the major policy and strategy provisions that are directly and indirectly related to the forest sector include Rural Development Policy and Strategies (RDPS), Forest Conservation and Utilization Policy and Strategy and the Forest Proclamation, the Environmental Policy of Ethiopia, Productive Safety Net Program and Sustainable Land Management, the GTP and CRGE Strategy of Ethiopia. An overview of these legal frameworks and programs are provided below.

The Rural Development Policy and Strategy, 2001

The Federal Democratic Republic of Ethiopia issued a national rural development policy and strategy in November 2001 which is an overarching policy and strategy document that comprised statements in relation to rural development, agriculture and natural resource interventions. The policy underscores agriculture-led economic development as a pathway feasible to Ethiopia in order to ensure rapid economic growth, optimize public benefits, reduce poverty and promote market economy. The major policy directions include efficient use of land resources and formulation of area-specific development packages. Under the pillar stating the need to formulate area-specific development packages, the document underscores the need to rehabilitating degraded lands and forests. The policy suggests that natural resource development and conservation interventions should also serve as source of income to the local community. Especially it underlines on the income which should be accrued from forest development and management activities. REDD+ projects are relevant with this policy statement in that one of the objectives of REDD+ is fetching additional income for the local people. It also stresses on the need to promote target

oriented tree planting programs. Specifically, the policy addresses that afforestation interventions should be focused on agroforestry, which allows farmers harvest wood products and fruits that can be sold in the local market and satisfy household demands. The document further deals with increasing agricultural productivity to reduce pressure as output per landholding increases, farmers will be less likely to expand into forests.

Forest Conservation and Utilization Policy and Strategy, 2007

The adoption of this policy by the council of ministers, which is the first in the history of the country, reflects the government's commitment to improve the economic, social and ecological contributions of the forest resource base. The main objective the policy and strategy is improving the economic contribution of the forest sector and meeting the communities' demands for forest products. Moreover, the policy envisages enhancing the forest sector economic contribution by promoting the engagement of the private sector and farmers. The policy substantiates the need to certifying forest use right which is an important provision to enhance the engagement of farmers, communities and the private sector. The policy also provides statements on the support that should be provided to create market opportunities for forest products. The policy statements provided in this policy document are comprehensive enough to promote sustainable forest management and enhance the social and economic contributions of the sector.This policy and strategy document can be utilized for the implementation of REDD+ as it provides for: possibilities of income generation from forests for the communities; the establishment of participatory forest management schemes by engaging the local people; issuance of forest ownership certificates for individuals, associations (e.g. forest use groups) and private investors.

Forest Development, Conservation and Utilization Proclamation 2007

The Forest Development Conservation and Utilization Proclamation No.542/2007 is the latest forest law presently under implementation. This proclamation attempts to provide legal grounds to the Forest Development, Conservation and Utilization Policy and Strategy of 2007. The proclamation recognizes two types of forest ownerships, state and private forest ownership. The proclamation puts communal forest

ownership under the category of private forest ownership. The proclamation is criticized for consisting of penalty articles that lack clarity to lawyers' interpretation. The lack of act and concrete implementation directives have been mentioned as a bottleneck hindering the effective implementation of this proclamation. Though communal ownership right is integrated in private ownership it provides strong accounts to community participation in the development and management of forests.

Environmental Policy of Ethiopia (EPE), 1997

Currently, MEFCC is preparing a revised version of this policy, though a draft document is not ready yet. This is one of the policies developed in the country that has direct relation to forest development and conservation. The environmental policy of Ethiopia was approved in 1997. The policy aims at improving the quality of life of the people through sustainable development and utilization of natural resources. It also aspires to conserve traditional resource management practices. The policy included soil management and sustainable agriculture, forest and tree resource management, genetic, species and ecosystem biodiversity conservation and management. The EPE has a strong element of encouraging peoples' participation in forest management. The policy addresses the complementary of the roles of communities, private investors and the state in forestry development. The policy emphasizes to the need to restricting forest resources utilization to the regeneration capacity. Thus, the policy attempts to ensure sustainable supply of forest products without disrupting the social, economic and ecological services.

This policy document also provides for, tenure security on land, investing in SLM technologies and conducting intensive agriculture. Moreover, the Policy stresses the uninterrupted and continuing access to the same land and natural resources (e.g. trees, water, wildlife and grazing) on the part of farmers and pastoralists. It also recognizes the customary rights of access to and use of land and natural resource which are constitutionally acceptable, socially equitable and are preferred by local communities. These provisions of the Policy have shown their relevance for REDD+ as they underline on the security of land tenure; agricultural intensification; sustainable utilization of natural resources; traditional resource management by using local knowledge; communities' participation in forest management; and access rights of local people to natural resources such as forests. From these policy

statements it can be understood the rights of local people are not limited to only the landholdings to which they have been provided with the title deeds but could be extended to the forests.

Environmental Impact Assessment Proclamation (EIA) No. 299/2002

The proclamation prohibits implementation of any project that requires environmental impact assessment without authorization from the federal or regional environmental agency. The provisions of this proclamation emphasize on the importance of conducting environmental impact assessment for all development projects and programs which fall in any category listed in any directive issued pursuant to the EIA proclamation. The proclamation indicates that environmental assessment is essential to predict and manage the environmental effects of proposed developmental activities; to harmonize environmental, economic, cultural and social considerations into a decision making process; to implement environmental rights and objectives enshrined in the Constitution; and to bring about administrative transparency and accountability. The definition of EIA in the proclamation includes both project and strategic level assessments and there is no separate law for strategic environmental assessment in Ethiopia. These features of the proclamation make it relevant for the implementation of REDD+. EIA is the most significant law as far as SESA is concerned. Protecting the environment and society from the negative impacts of a proposed project or program by devising safeguard mechanisms (e.g. mitigation measures) is a major purpose of the EIA law. EIA processes hence result in environmental and social safeguards.

Climate Resilience Strategy for Agriculture and Forestry 2015

The Climate reslience strategy for agriculture and forestry is designed to address the impacts of weather variablity and future climate change in crop, livestock and forestry sectors. It has three main objectives: to identify the impacts of current weather variability and projected future climate change on Ethiopia; to identify best scenarios or options to build resilience and reduce the impacts at the same time quantifying the cost; and to map the steps needed to finance and implement efforts to build climate reslience. The strategy supplements the green economy strategy by enhancing the recommendations for resilience. The first phase of the strategy

focuses on the agriculture sector, i.e., agricultural crops, livestock, forestry and disaster prevetion. The strategy is also aligned with the existing strategy of the Ministry of Agriculture and the governance structure. REDD+ will be a vehicle for building resilience through improving the forest cover and maximizing ecosystem services in agricultural landscapes.

Climate Resilience Strategy for Water and Energy

The water and energy sectors have key role in meeting the GTP2 goals. Given their importance, the Climate Resilience Strategy for Water and Energy has three main objectives: to identify the economic and social impacts of current climate variability and future climate change on water and energy in Ethiopia; to identify priority ways that the water and energy sectors can build climate resilience and reduce the impact of climate variability and climate change; and to map the necessary steps to finance and implement measures in the water and energy sectors to build climate resilience in Ethiopia and deliver an integrated Climate Resilient Green Economy.

National Energy Policy -1994

This policy targets at ensuring energy self-sufficiency or meet national energy security. The policy underlines that all energy development activities should be environmentally friendly. It recognizes the promotion of alternative energy sources in order to increase energy supply that has to meet the country's growing demand. It also accounts to the pressure on the biomass energy source and states on the need to increase the biomass energy source through afforestation, re-forestation and agroforestry schemes.

The policy indicates that Ethiopia's energy consumption predominantly based on biomass energy sources, which led to massive deforestation and the resultant land degradation in the country. To overcome these problems, the policy provides for the importance of devising mechanisms to arrest deforestation to increase the reliability of energy supply and to control environmental pollution resulting from energy use. It also emphasizes on the participation of the private sector and communities, particularly women in the development of energy and payment of due and close attention to ecological and environmental issues during the development of energy projects. Alternative energy development from solar, geothermal, wind energy

sources are among the renewable energy sources with the view to relieving pressure on wood resources.

The National Energy Policy is a relevant policy instrument for the application of REDD+ in that it focuses on the renewable energy sources and in energy efficiency approaches. The materialization of the policy will have a positive contribution in reducing emissions from deforestation and forest degradation. It will also contribute in the enhancement of forest development.

Ethiopian Water Resources Management Policy-1999

The policy states the need to ensure sustainable supply of water which necessitates natural resources development interventions in the upper catchments. In line with ensuring the sustainability of water supply the policy clearly states that "Ensure that water resources management is compatible and integrated with other natural resources as well as river basin development plans and with the goals of other sectoral developments in health, mines, energy, agriculture, etc." In its section of the provision on cross cutting policy issues the document addresses environmental issues with two statements. Section 2.2.2-A states that:

- Incorporate environment conservation and protection requirements as integral parts of water resources management.
- Encourage that Environment Impact Assessment and protection requirements serve as part of the major criteria in all water resources projects.

Moreover, section 2.2.2-B which deals about watershed management states that:

- Promote practices of efficient and appropriate watershed management to maximize water yields and quality.
- Ensure that watershed management practices constitute an integral part of the overall water resources management.

Thus the water policy can be understood as well aligned with the natural resource management activities including the present massive public mobilization schemes of the government targeted to implement integrated watershed management development initiative.

Access to Genetic Resources and Community Knowledge, and Community Rights Proclamation No. 482 /2006

This proclamation deals with access to genetic resources (by communities), community knowledge and protection of these rights with the objectives to ensure the communities right to the benefits accrued from genetic resources and community knowledge. It provides communities with the right to regulate access to their community knowledge; an inalienable right to use their genetic resources from their surroundings. The proclamation addresses key issues such as access rights, obligations, and types of benefit and benefit sharing principles.

The proclamation recognizes that ownership of community knowledge is vested in the concerned local community. The recognition of the right of knowledge of communities on genetic resources can also be applicable in the forest management. As at is been indicated in a number of studies, the full and effective engagement of local communities and the incorporation of their traditional forest knowledge in forest management strategies are crucial for REDD+ success in curbing climate change. It is widely accepted that local communities have developed significant bodies of knowledge on how to cope with local climatic shifts including agricultural techniques for managing and conserving forests, water, and soil resources. These practices can guide the REDD+ projects and programs.

Expropriation of Landholdings for Public Purposes and Payment of Compensation

The Federal Rural Land Administration and Utilization Proclamation No. 456/2005 recognizes the land use rights of private persons, communities, governmental and nongovernmental organizations. These organs can be issued landholding certificates for definite or indefinite period of time.

Expropriation of landholdings for public purposes and payment of compensation law no. 455/2005 gives power to lower level administrative institutions such as Woredas to seize rural or urban holdings for public purposes. The law includes statements on how land can be leased to investors. The law issues compensation mechanisms not for the land as such, as the land belongs to the state, but for property situated on the land and for permanent improvements made to the land.

The Compensation Proclamation is issued with the view to defining the basic principles that have to be taken into consideration in determining compensation to a person whose landholding is going to be expropriated. The Proclamation is applicable on both rural and urban lands. The general condition for which land and property can be expropriated is for public purpose defined as use of land by the appropriate body or development plan to ensure the interest of citizens to acquire direct or indirect benefits from the use of the land and to consolidate sustainable socio-economic development.

According to the Compensation Proclamation, a landholder is an individual, government or private organization or any other organ that has legal personality and in lawful possession over the land to be expropriated and owns property situated thereon. (Article 2 (3)) Compensation is paid to those who have legally occupied the land and those who have property on such land developed through their labor and capital. Lawful occupants are expected to produce evidence for their legal landholding. The most important evidence for this could be the landholding certificate. However, all rural landholders may not produce landholding certificates as the issuance of such certificate has not yet covered all rural landholders in the country. In the regional states where landholding certificates have not been issued for all of the rural landholders, those who occupied land customarily or other legal means are eligible to compensation payments.

A rural landholder whose landholding has been permanently expropriated (where substitute land is not available) shall be paid displacement compensation, in addition to compensation payable for property situated on the land and for permanent improvements made to such land, which shall be equivalent to ten times the average annual income s/he secured during the five years preceding expropriation of the land.

On the basis of Proclamation No. 455/2005 Article 7 for expropriation of landholdings for public purposes, compensation will be made at replacement cost. With this method of valuation, depreciation of structures and assets will not be taken into consideration. Compensation rates and valuation of properties are based on a nationally set formula based on data collected from local market assessments.

Valuation of property is done by certified institutions or individual consultants on basis of a valuation formula determined at the national level or, where such capacity does not exist, by a committee composed of five persons (in rural areas) designated by the Woreda or city administration. Procedures for valuation are to be determined by specific regulations or directives. To this end, the Council of Ministers issued a Regulation No. 135/2007 Payment of Compensation for Property Situated on Landholding Expropriated for Public purposes. Some regional states also issued further details through directives.

Regarding procedures for expropriation, the law requires that the expropriation order has to be given prior to relocation. Such order shall not be less than 90 days before relocation; however, if there is no crop or perennial plant, farm land could be expropriated within 30 days of receipt of the expropriation order. The law regulates that compensation has to be paid before relocation. With respect to grievance redress, complaints are addressed by a grievance committee established by a Woreda or city administration. The second level of grievance is a Woreda or municipal appellate court and the decision of the court will be final. According to the law, execution of an expropriation order will not be delayed due to complaint regarding compensation payments.

Both the proclamation and the regulation can serve as safeguard systems as determined by the Cancun Agreement. (Decision 1/CP.16, Appendix 1)The Cancun safeguard principles include, addressing transparency, participation of stakeholders, protection of biodiversity and ecosystem services, and respect for rights of underserved and local communities. The expropriation and compensation proclamation and regulation can be applied by implementing these safeguard principles, especially in the respect and protection of the rights of underserved and/or local communities during the implementation of REDD+.

Rural Land Administration and Land use Proclamation pro No 456/2005)

The Government of Ethiopia has issued proclamation on rural land administration and land use. The proclamation mainly states about the right to hold and use of rural land, and rural land use restrictions. As per to the proclamation; farmers and pastoralists engaged in agriculture for living shall be given land free of charge.

Young people above the age of 18 who want to engage in agriculture also have the right to use rural land. It also recognizes that women have the right to get and use rural land.

The legislation also recognizes that citizens who have the right to use rural land may get rural land from his family by donation, inheritance or from competent authorities. It also brings new initiatives which were not there in the past, such as, certificate of holding to be prepared by competent authority. It also recognizes transfer of land through lease to farmers or investors.

In relation to compensation payment to be made for a holder the proclamation in section two, article 7, no. 3 states that:

"Holder of rural land who is evicted for purpose of public use shall be given compensation proportional to the development he has made on the land and the property acquired or shall be given substitute land thereon. Where the rural land holder is evicted by the federal government, the rate of compensation would be determined based on the federal land administration law. Where the rural land holder is evicted by their regional governments, the rate of compensation would be determined based on the rural land administration laws of regions".

Social protection policy of Ethiopia

The social protection policy of Ethiopia was developed by the Ministry of Labour and Social Affairs in March 26, 2012. It includes issues of pension, aging, support to vulnerable children, nutrition, etc., along with food security. The policy states that focus must be given to vulnerable groups of the society with the notion of including the disabled and the aged. It focuses on households and individuals who should receive social assistance in order to function properly, and achieve quality of living within the society (MoLSA, 2014). The main objective of the policy is described as follows:

- Protect poor and vulnerable individuals, households, and communities from the adverse effects of shocks and destitution;
- Increase the scope of social insurance;

- Increase access to equitable and quality health, education and social welfare services to build human capital thus breaking the intergenerational transmission of poverty;
- Guarantee a minimum level of employment for the long term unemployed and under-employed;
- Enhance the social status and progressively realize the social and economic rights of the excluded and marginalized;
- Ensure the different levels of society are taking appropriate responsibility for the implementation of social protection policy.

World Bank Safeguard Policies

The World Bank safeguard policies are designed to help ensure that programs proposed for financing are environmentally and socially sustainable, and thus improve decision-making. The Bank's Operational Policies (OP) are meant to ensure that the Bank does not finance projects that will have irreversible major adverse impacts or cause significant harm to the people and their environment. The Safeguard Policies are lumped into Environment, Social and legal. These operational policies include:

- Environmental Assessment OP/ BP 4.01. In World Bank operations, the purpose of Environmental Assessment is to improve decision making, to ensure that project options under consideration are sound and sustainable, and that potentially affected people have been properly consulted.

- Natural Habitats OP/BP 4.04. To promote environmentally sustainable development by supporting the protection, conservation, maintenance, and rehabilitation of natural habitats and their functions. Use a precautionary approach to natural resources management to ensure opportunities for environmentally sustainable development. Determine if project benefits substantially outweigh potential environmental costs.

- Op 4.36: Forest The objective is to realize the potential of forests to reduce poverty in a sustainable manner, integrate forests effectively into sustainable

economic development, and protect the vital local and global environmental services and values of forests. Ensure that forest restoration projects maintain or enhance biodiversity and ecosystem functionality and that all plantation projects are environmentally appropriate, socially beneficial and economically viable.

➤ OP/BP 4.37 Safety of Dams: The REDD+ strategic options includes establishment of small dams for improving agricultural production and reducing extensive agriculture, which increases deforestation. Thus, OP 4.37 is triggered. Under the Bank's definition, small dams constitute those dams having a height of less than 15 meters. Thus, the safe operation of such dams has significant social, economic, and environmental relevance. Safety on Dams requires that experienced and competent professionals design and supervise construction, and that dam safety measures are adopted and implemented through the project cycle.

➤ OP 4.09: Pest Management Support integrated approaches to pest management. Identify pesticides that may be financed under the project and develop appropriate pest management plan to address risks. If pesticides have to be used in crop protection or in the fight against vector-borne disease, the Bank-funded project should include a Pest Management Plan (PMP), prepared by the borrower, either as a stand-alone document or as part of an Environmental Assessment.

➤ OP 4.10: Indigenous People "underserved peoples": the Ethiopian government recognizes that all people in Ethiopia are indigenou and there are only underserved communities. The World Bank ensures that any project financed by it is not against the underserved peoples' dignity, rights, economic benefit and cultural practices. The Bank further wants to ensure that there is free, prior and informed consultation with the underserved people before endorsing the project. There is a complex relation between local underserved people and natural resources, which they depend on for their livelihoods, spiritual and cultural practices and hence the Bank recognizes this relationship with due regards.

- OP 4.11: Physical Cultural Resources Investigate and inventories cultural resources potentially affected. Include mitigation measures when there are adverse impacts on physical cultural resources or avoid if possible.

- OP 4.12: Involuntary Resettlement Assist displaced persons in their effort to improve or at least restore their standards of living. Avoid resettlement where feasible or minimize. Displaced persons should share in project benefits. The policy aims to avoid involuntary resettlement to the extent feasible, or to minimize and mitigate its adverse social and economic impacts. The policy prescribes compensation and other resettlement measures to achieve its objectives and requires that borrowers prepare adequate resettlement planning instruments prior to Bank appraisal of proposed projects.

- BP 17.50 Consultations and Disclosure requirements: Whenever the Bank requires an environmental assessment (EA) and/or a Resettlement Instrument (RI), the proposed borrower prepares an EA report and/or a RI report as a separate, freestanding document, publicly available to project-affected groups and local NGOs. In the REDD+ project activities, as one of the seven safeguard principles of the Cancun agreement, disclosing information for the public is a requirement.

- BP 4.03 Performance Standards for Private Sector Activities: The Bank screens the Private Sector Activity in order to determine the nature and extent of the environmental and social assessment needed, based on the type, location, sensitivity, and scale of the activity, as well as the nature and magnitude of its potential impacts. This screening also identifies any additional information required to complete the Bank's environmental and social review and determine whether to support the activity.

7.4. Safeguard Instruments for REDD+

This Module is designed to provide a critical overview of Safeguard Instruments for REDD+ Implementation In Ethiopia

The Module covers the:

- Strategic Environmental and Social Assessment (SESA)
- Environmental and Social Management Framework (ESMF) for REDD+ Implementation
- Resettlement Policy Framework (RPF) for REDD+ Implementation

Safeguard Instruments for REDD+ Implementation In Ethiopia

Strategic Environmental and Social Assessment (SESA)

Ethiopia has been implementing the R-PP in the last few years and one of the expectations during the readiness process is to ensure proposed strategic programs and activities "do no harm" society and the environment while trying to "do good" and enhance benefits to local communities and forest ecosystems. Thus, the FCPF requires countries participating in the Readiness and the REDD+ activities implementation to undertake a Strategic Environmental and Social Assessment (SESA) to identify and compile the potential impacts from national REDD+ programs and policies, and to formulate alternatives and to develop mitigation strategies.

SESA is a tool that uses a range of analytical and participatory approaches aiming at integrating environmental and social considerations into policies, plans and programs and evaluates the inter-linkages with economic and institutional considerations. SESA supports the design of the national REDD+ policy framework, including the National REDD+ Strategy. SESA offers a platform for consultations with stakeholders from the higher to the micro-levels. SESA is complemented by an Environmental and Social Management Framework (ESMF), which establishes the principles, guidelines, and procedures for reducing, mitigating, and/or off-setting potential adverse environmental and social impacts, enhancing positive impacts and

opportunities, and otherwise guiding potential investments towards compliance with relevant safeguards.

In the preparation of SESA, preliminary results from the national study on the drivers of deforestation and forest degradation has been used in assessing the impacts of the REDD+ strategic options. Besides, relevant inputs were taken from the strategic options proposed in the national R-PP document, the draft national REDD+ strategy, strategic options proposed in the study of the drivers of deforestation and forest degradation for the Oromia Forested Landscape Program, and the study for deforestation and forest degradation for the Bale REDD+.

Objectives of the SESA

The general objective of SESA aims to ensure that strategic environmental and social assessment principles are applied to integrate environmental and social considerations into Ethiopia's REDD+ readiness process in a manner consistent with Ethiopia's environmental laws and regulations and the World Bank's environmental and social safeguard policies, and that associated risks are addressed from an early stage in the process of formulating REDD Policy and programs, and incorporated throughout the process.

The specific objectives of the SESA are to identify opportunities that:

- Facilitate an understanding of the operating environment for REDD+ programs, including stakeholder analysis and the socio-environmental dimensions of the forestry sector in Ethiopia;
- Identify potential environmental and social impacts related to REDD+ programs in Ethiopia; (the SESA process should ensure full coherence and coordination with the ongoing institutional and legal assessment, including benefit sharing for REDD+ in Ethiopia, led by the Government of Ethiopia);
- Design enhanced stakeholder's consultation and participation approach to mitigate and/or enhance the identified impacts;
- Suggest methods and measures to mitigate environmental and socioeconomic risks during REDD+ strategy implementation.

The SESA is being carried out to ensure that the implementation of the REDD+ mechanism contributes positively to sustainable forest management in line with the objectives of Ethiopia's 2012 Forest Policy (MoARD, 2012). In addition, the SESA would contribute towards Ethiopia's overarching goal of environmental sustainability, climate change, economic growth, job creation and poverty alleviation programmes. With this in mind, the purpose of the SESA is to ensure operational integration of environmental quality objectives, economic efficiency principles, and social and gender equity goals into the REDD+ strategy options.

Summary of the findings of the SESA study

Based on the identified strategic options (in the R-PP, draft national REDD+ Strategy and study on the drivers of deforestation and forest degradation) to reduce deforestation and forest degradation the SESA-ESMF consulting firm assess and identify environmental and social risks and benefits of the proposed strategic options.

The proposed strategic options have multiple environmental and social benefits that can bring significant improvement in local livelihoods and ecosystem are identified and listed.

The potential environmental and social risks of the proposed strategic options and the mitigation measures are also provided in the SESA document.

Environmental and Social Management Framework (ESMF) for REDD+ Implementation

Environmental and Social Management Framework (ESMF) is a tool used by a project proponent to identify and address the potential environmental and social concerns or impacts of a project right from the planning stage to its implementation and post-implementation operations. The objective of developing ESMF is to mainstream it with other project documents in the planning, execution and post-execution stages in order to ensure that environmental and social concerns are adequately taken care of in all these stages. This ESMF has been developed to be used by the Ministry of Environment, Forest and Climate Change, and other Governmental and non-governmental organizations who participated or may

participate in REDD+ program or projects in Ethiopia in order to incorporate the environmental and social safeguards in the planning, execution and operation stages of each project activity. A step-by-step methodology has been provided that can be followed along with institutional interventions required.

The ESMF can be used by the project authorities for incorporation of environmental and social safeguards in the planning, execution and operation stages of each project /sub-project activity/ies.

Steps of the ESMF

The national REDD+ Secretariat is preparing a standalone consultation and participation plan document in order to engage all stockholders throughout the REDD+ readiness process. Public consultations, as part and parcel of the ESMF and environmental assessment process, is also critical in preparing an effective and sustainable REDD+ program and project. The first step in this regard is to hold public consultations with local communities and all other stakeholders during the screening process and in the course of conducting ESIA of the REDD+ project. These consultations should identify key issues and determine how the concerns of all parties will be addressed. To facilitate meaningful consultations, the project planners will provide all relevant material and information concerning the projects in a timely manner prior to the consultation, in a form and language that are understandable and accessible to the groups being consulted.

Environmental and Social Screening Process

Screening is the process of determining whether or not a project requires ESIA and the level at which the assessment should occur. The Woreda /zone/regional safeguard officers will be responsible for the project initiation process by properly preparing and submitting the screening report or form to their respective responsible officers or Departments for review and approval. To be qualified for this task, the safeguard specialists of the Woreda/zone/region will receive relevant environmental and social assessment training.

This ESIA Screening Report will describe the:

a)   proposed activities and their potential impacts
b)   characteristics of the location (sensitivity of the area)
c)   size (small, medium and large scale)
d)   degree of public interest
e)   institutional requirement, environmental enhancement and monitoring considerations

The outcome of screening will result that each REDD+ project is categorized as being a Category A, B or C project.

a) Category A   projects are fed into the standard ESIA process determined by MEFCC/BEF;

b) Category B   projects may not require ESIA, but will necessitate the inclusion of environmental and social mitigation and enhancement measures in the design and implementation of the projects through the use of standard environmental and social management plan; and

c) Category C projects are not subject to environmental assessment as little or no potential adverse impacts are anticipated.

The screening report will be submitted to the relevant department of the regional / zonal bureau of environment and forest with a request for approval. The Regional / Zonal Bureau of Environment and Forest will review the screening report and will:

(a)   Accept the document - with conditions relating to implementation;
(b)   Accept the document with required and/or recommended amendments; or
(c)   Reject the document with comments as to what is required to submit as an acceptable screening report.

Scoping and ToR Preparation

The objective of the scoping activity is to identify the requirements needed in the preparation of the terms of reference (ToR) that can be used to secure and guide a consultant or expert group who has the required expertise and who will carry out the preparation of the required safeguards instruments (such as ESIA/ESMP)for the REDD+ projects(s). The scoping stage will be carried out by an independent consultant or Woreda REDD+ Safeguard Officers in collaboration with Zonal or Regional REDD+ Safeguard Officers. The ToR identifies the objectives, scope, tasks

to be undertaken, the issues or concerns to be assessed, and the significant effects and factors to be considered, outputs and estimated costs of the ESIA.

The ToR for the ESIA will be submitted to the RBEF with a request for approval. The RBEF will review ESIA ToR and accept the document (with conditions relating to implementation), accept the documents with required and/or recommended amendments or reject the document with comments indicating what is required to submit an acceptable ESIA ToR.

Conducting ESIA

Environmental permits are needed for projects for which ESIAs may be required as per the ESIA guidelines. The ESIA will identify and evaluate potential environmental and social impacts for the proposed activities, evaluate alternatives, and design mitigation measures. The preparation of the ESIA will be done in consultation with stakeholders, including people who may be affected. Public consultations are critical in preparing a proposal for the activities of the REDD+ projects likely to have impacts on the environment and communities. The public consultations should identify key issues and determine how the concerns of all parties will be addressed in the ESIA.

According to the guideline series documents of environmental and social impact study reports (2003), the first step to prepare ESIA report is the preparation of the ESIA ToR either by an independent consultant or team of experts at Woreda level such as the Woreda REDD+ Safeguard officers and then hire an independent consultant to execute the job.

The structure and content of the report of ESIA will follow the following format:
- Executive Summary
- Introduction
- Approach to the study
- Assumptions and/or Gap in knowledge
- Administrative, Legal and Policy requirements
- Identifying potential impacts of proposed projects
- Process of public consultations

- Development of mitigation measures and a monitoring plan, including estimates of costs and responsibility for implementation of surveillance and monitoring
- Conclusions and Recommendations
- Appendices

Review and Approval

The purpose of review is to examine and determine whether the ESIA and the environmental and social management plan (ESMP) provide adequate assessments of the environmental and social effects and of sufficient relevance and quality for decision-making.

The Screening Report, ESIA and ESMP, will be presented by the Woreda REDD+ safeguard officer who is responsible for the implementation of the project and will also submit the documents to the Zonal or Regional BEF for review and approval.

The review will be conducted by the Zonal or Regional BEF, and will include review of: a) Screening Report including the ESIA/ESMP ToR; b) ESIA report and ESMP; and c) Performance monitoring or audit reports at different stages in the project cycle.

The review by Zonal or Regional BEF may include considerations of the adequacy of:
- compliance with the environmental requirements (legal and procedural)
- information with regard to :
  - Compliance with the "approved ToR"
  - The examination of alternatives, assessment of impacts, appropriateness of mitigation measures and monitoring schemes as well as implementation arrangements
  - the use of scientific and appropriate methodologies
  - The extent of public involvement and reflection of PAPs concerns and
  - Presentation of the information to decision makers

Public Consultation and Disclosure

In compliance with Government of Ethiopia EIA proclamation no. 299/2002, guidelines and World Bank safeguard policies (OP/BP 4.01) before the approval of a project, the applicable documents (ESIA, ESMP) must be made available for public review at a place accessible to local people (e.g. at a local government office (i.e. Kebele or Woreda council, Zonal and Regional bureaus, at the BEF), and in a form, manner, and language they can understand.

Monitoring and Follow-up

The purpose of monitoring is to check the effectiveness and relevance of the implementation of the proposed mitigation measures for the adverse social and environmental impacts. Monitoring will be done by Woreda BEF. It will be carried out in accordance with the procedures and at the intervals prescribed in the ESMP. When approval has been given to the ESIA/ESMP, a systemic follow-up is needed to:

- ensure that the anticipated impacts are maintained within the levels predicted
- see that the unanticipated impacts are managed and or mitigated before they become problematic
- realize and optimize the benefits expected, and
- provide information for a periodic review and alteration of the environmental management plan and enhance environmental protection through good practice at all stages of the project

Monitoring Plan (MP)

The Monitoring plan sets out the requirements for the monitoring of the environmental and social impacts of the REDD+ projects. Monitoring of environmental and social indicators will be mainstreamed into the overall monitoring and evaluation system for all projects. In addition, monitoring of the implementation of the ESIA will be carried out by RBEF and the key implementing institutions of REDD+.

Resettlement Policy Framework (RPF) for REDD+ Implementation

In general the Resettlement Process includes different activities and steps related to the involuntary resettlement where it is unavoidable, i.e. from policy decision to preparation of RAP. The Figure below presents an overview of the identification/ review process proposed under this RPF to address specifically land impacts and displacement/resettlement needs at program or sub program level.

In the diagram below, in cases where more than 200 people are affected, but none of them are physically displaced and none of them lost 10 percent or more of their productive assets, then an ARAP is acceptable. The steps to be undertaken for each resettlement process include a screening process, a socioeconomic census and land asset inventory of the area and identification of REDD+ program/ Project Affected Parties (PAPs). This is followed by the development of a Resettlement Action Plan, abbreviated as RAP, RAP review and approval, implementation of the RAP and monitoring of RAP implementation and success.

The use of this Resettlement Policy Framework will be triggered when a proposed REDD+ program/ project needs to acquire land and/or impose restriction of access and people or property is disturbed. For example, when land is needed and people are affected because they have houses or other permanent or temporary houses on that land; they use the land for water and grazing of animals; or otherwise they have access to the land for economic, religious, residential or other purposes which will not be possible during and after the implementation of the REDD+ program/ project.

Main Principles and objectives of the RPF

Involuntary resettlement may affect a large number of people unless serious attention is given to the resettlement processes. The resettlement processes need to be conducted in a way that protects the rights of the displaced persons. The following will be the major guiding principles in the process of involuntary resettlement.

1. As far as possible ensure that involuntary resettlement, land acquisition and access restriction is avoided or, where it is necessary, is minimized, by exploring all viable alternatives.

2. Any persons adversely affected by REDD+ program implementation will be compensated and supported by enabling them to get jobs and other assistance.

3. Where involuntary resettlement, land acquisition and access restriction is unavoidable, resettlement and compensation activities are prepared and implemented by providing sufficient investment resources, according to the following Government of Ethiopia's directives:

   ➢ Proclamation No. 455/2005 Expropriation of Landholdings for Public Purposes and Payment of Compensation; and
   ➢ Council of Ministers Regulations No. 135/2007, on the Payment of Compensation for Property Situated on Landholdings Expropriated for Public Purposes and when such compensations are in lower order, then the world bank involuntary resettlement policy, which is the higher order will apply for the benefit of the PAPs.

4. Decisions on resettlement will be based on the informed participation of all affected people, in the form of consultations and agreements reached between the affected people and the respective local and project authorities.

This RPF is developed to achieve the following objectives:

- To provide full consultation with, and informed participation of affected people;
- To avoid, minimize or mitigate potentially adverse effects of new restrictions, and increased enforcement of existing as well as new restrictions, of access to natural resources.
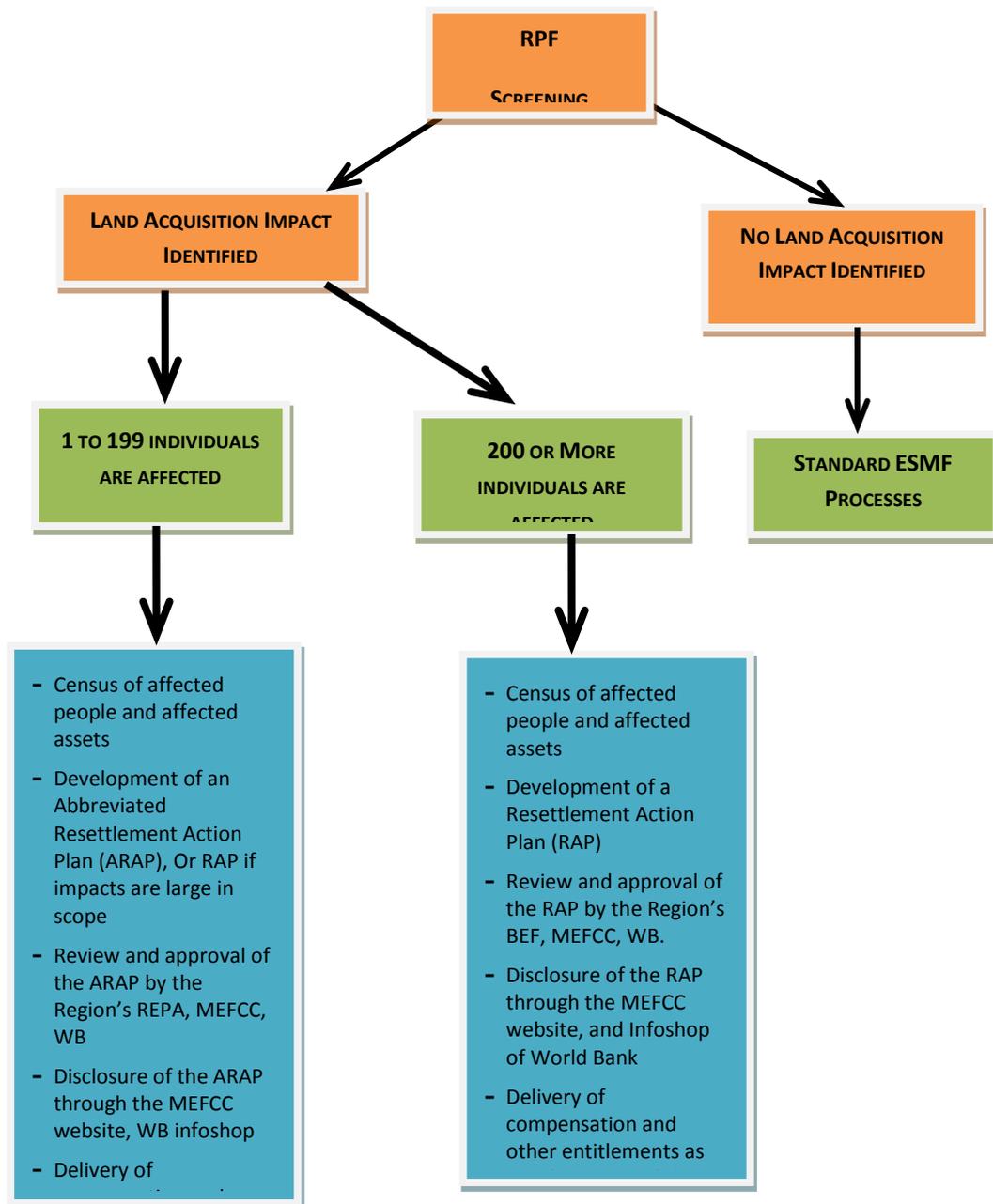
Resettlement Policy Framework

Screening for Involuntary Resettlement

It is a process that would guide to form a list of types and number of infrastructure, including buildings or other structures and assets which the interventions of REDD+ project may have a potentially impact through the acquisition of land, resettlement and/or denying access to natural resources such as forests. Therefore, the list will be

presented to the communities affected through a sensitization and consultation arrangements.

The first step in the process of preparing resettlement and compensation plans is the screening process to identify land or areas that may result in environmental and social impacts, including resettlement. REDD+ project/program screening will be used to identify the types and nature of potential impacts related to the activities proposed under REDD+ program, and provide adequate measures to address the impacts.

Screening will be undertaken by the relevant office that proposes the REDD+ program/ project, with the use of the screening tool, as attached to this RPF. It will take place as early as possible during the REDD+ program/ project process to identify land that is to be taken for the project and PAPs who will need to be resettled and/or compensated. This will be done in consultation with the affected parties to ensure that all considerations are taken into account and all potential impacts are identified.

The Screening Report will be submitted by the Woreda Office of Environment and Forest/ Woreda Coordination Unit to the Regional Bureau of Land Administration and Environment Protection (BLAEP) for review. If the Screening Report shows that no resettlement is required, the development of an abbreviated or full resettlement action plan is not necessary.

The screening report will show resettlement action plan that resettlement will be required :

a. The type of instrument to be used will be determined based on the scope of impact. However, tentatively 200 or more persons are affected, a RAP will be developed; but if more than 200 people are affected, and if none of them are physically displaced and none of them lost 10 percent or more of their productive assets, then ARAP will be prepared.

b. If 1 to 199 persons are affected, an ARAP will be prepared; Or if the scope of the ipact is large, a RAP will be prepared

In both of the above cases, the next step will be to complete Step 2, i.e., to conduct a socio-economic survey and land asset inventory to determine the extent of resettlement required. This will be followed by the preparation of a RAP, ARAP for the REDD+ program /project, or no further documentation is required.

Baseline socio-economic data

The REDD+ project location census will be combined with the collection of relevant demographic data such as age, sex, family size, births, and deaths and associated social and economic data on ethnicity, health, education, occupation, income sources from among the people who are affected. The data will provide resettlement planners a general understanding about the communities that are affected by the project, comprising the host communities, and the limit of compensation and resettlement assistance necessary to alleviate the adverse effects. Hence, the census ought to provide resettlement planners the quantitative data that allows them to work out budgets to resources and services, follow the delivery of the resources and services to the population affected, and solve the problems encountered during the delivery of resources and services throughout implementation of the RAP.

Furthermore, the data collected during the census can produce important base line data at the household and community levels, and will be used to create indicators for resettlement implementation, monitoring and evaluation of income refurbishment and sustainable development initiatives related to a RAP. In essence, the baseline census will achieve the following:

1) offers initial information on the extent of resettlement to be commenced;
2) it provides an indication if further socioeconomic research needed to measure losses to be remunerated and, required, to work out appropriate development interventions;
3) establishes indicators that can be measured at a later date during monitoring and evaluation.

The socio-economic survey could be undertaken by a consultant contracted by MEFCC or BLAEP or the regional coordination unit. When this is not possible, and where the resettlement is minimal - e.g. when a very small percentage of a person's land and livelihood is affected, - the relevant Woreda office, that is proposing the

REDD+ program /project, will carry out the socio-economic survey and a land asset inventory.

Preparation of a subproject RAP/ARAP

Any kind of project that causes either the physical or the economic dislocation of people needs a RAP. However, the range and level of specifics of resettlement planning will differ with conditions, based on the project's density and the degree of its effects. A RAP must prove that the livelihoods of people affected by the project are reestablished to levels prevalent before the initiation of the project. Nevertheless, a simple restoration of livelihood would not be sufficient to safeguard affected populations from adverse project induced impacts, such as competition for resources and employment, and the disruption of social support networks. The implementation of the REDD+ project would cause the displacement and other economic and social risks on the affected people.

Thus, as described earlier, after the socio-economic survey and identification of affected parties, a RAP or ARAP will be developed according to the structure as set out in Box1 and Box 2 below.

Preparation of a Resettlement Action Plan/RAP

The preparation of a RAP will be done by the relevant government office with the support of a consultant and in consultation with the affected parties, particularly in relation to the cut-off date for eligibility, disturbances to livelihoods and income-earning activities, methods of valuation, compensation payments, potential assistance and time frames.

The basic elements of a RAP and ARAP are listed in Boxes 1 and 2. In order that this is not an unnecessarily difficult process, the level of detail and extent of the RAP must be related to the extent of the resettlement impact. Should the resettlement activities be minor (e.g. a very small percentage of a person's land and livelihood is affected), a relatively simple abbreviated RAP will be required. Where the resettlement impact is more major (e.g. the physical displacement of 200 or more individuals), a more extensive and detailed RAP will be required.

The crucial aspect of a RAP process is that it is specific and auditable, which is appropriate to the resettlement impacts, allowing for consultation throughout the process. It must also ensure that those affected by resettlement, whether economic or physical, are no worse off, and preferably better off, than before their displacement.

Box1 Required Elements of an RAP

> ➢ Identification of project impacts and affected populations;
> ➢ Legal framework for land acquisition and compensation;
> ➢ Compensation framework;
> ➢ Description of resettlement assistance and restoration of livelihood activities;
> ➢ Detailed budget and implementation schedule;
> ➢ Description of organizational responsibilities;
> ➢ Framework for public consultation, participation, and development planning;
> ➢ Description of provisions for complaints and appeals; and
> ➢ Framework for monitoring, evaluation, and reporting.

Preparation of an Abbreviated Resettlement Action Plan/ARAP

An abbreviated RAP must be developed if the loss is a small percentage of the affected party's livelihood, such as the loss of part of a fence surrounding a property, – where between 1 and 199 individuals are affected.

Box 2. Required Elements of an Abbreviated RAP

> ➢ A census survey of displaced persons and valuation of assets;
> ➢ Description of compensation and other resettlement assistance to be provided;
> ➢ Consultations with displaced people about acceptable alternatives;
> ➢ Institutional responsibility for implementation and procedures for complaints and appeals;
> ➢ Arrangements for monitoring and implementation; and
> ➢ A timetable and budget.

The relevant government office to prepare a RAP could be the *Woreda* coordination unit at the Woreda Agriculture office. The RAP will then be succumbed to the Regional REDD+ management arrangement.

Review of subproject RAPs

The review of the RAPs will be a stepwise process starting from the submission of the sub-project RAPs by the Woreda team to the Regional REDD+ management body. Then, the RAP with a review report and recommendations will be forwarded to the respective REDD+ task force for further review and scrutiny on the compliance to the RPF. The task force will forward recommendations for approval, modification/revision or rejection to the secretariat at MEFCC.

RAP Implementation Procedures and Schedule

Compensation payments will be made to displaced persons before physical works commence and displaced persons' property is affected, i.e., during the early stages of the implementation of the RAP or ARAP.

RAP Procedures

Following the approval of the REDD+ program/project, RAP or ARAP, the process of implementation must start and take place as per the following procedures:

- Consultation (a continuation of the process entered into during the site selection, screening and RAP development process);
- Notification to affected parties;
- Documentation of assets;
- Agreement on compensation;
- Preparation of contracts; and
- Compensation payments and provision of assistance in resettlement.
- The detail of these steps will depend on the nature and extent of resettlement required.

Consultation

An essential element in the RAP implementation process is consultation and public participation. This will be a continuation of the process entered into during the site visit for screening, census and RAP development process, and will depend on the extent of the resettlement impact. The community and landholders would be informed of the approval of the RAP and implications for all PAPs, as well as the likely implications in terms of resettlement, expropriation and compensation.

Importantly, this would need to be part of an ongoing process, to ensure that no affected individual/household is just simply "notified" only one day and no more. Instead, this process seeks the involvement of all the people affected by the resettlement in a participatory approach from the beginning.

Notification

At the earliest possible opportunity, the Woreda office of Land Administration Environment/Agriculture/ REDD+ project office will provide notification regarding land acquisition to landholders and users. The land holders and/ or users will be informed through both formal notification in writing and by verbal notifications should be delivered in the presence of a Woreda and Kebele representatives and community leader/elders.

Documentation

The relevant Woreda office Environment/Agriculture/REDD+ project office will arrange meetings with the affected individuals and/or households to discuss the compensation process. For each individual or household affected, the Woreda office will complete a compensation record/file containing necessary personal information about the affected party and those that he/she claims to be his/her household members, total landholdings, inventory of assets affected, and information for monitoring their future situation. Records/files will be kept and will include documentation of expropriated land. Each individual will be provided a copy of the record/file at the time of negotiations. This is necessary so that the resettlement process for each individual PAP can be monitored over time. All claims and assets will be documented in writing.

Agreement on Compensation and Preparation of Contracts

All compensation options and types must be clearly explained to the affected individual or household. The Woreda office of Land Administration /Environment/Agriculture/REDD+ project office draws up a contract, listing all expropriated property and land being succumbed, and the types of compensation selected (cash and/or in kind). A person who prefers in kind compensation will have an order form, which is duly signed in the presence of witnesses. The compensation

contract is read aloud in the presence of the affected party and other relevant community leaders prior to signing.

Compensation Payments

All handing over of property, such as land and buildings, and compensation payments, will be made in the presence of the affected party (in the presence of a husband and wife when this applies), woreda and a kebele representative.

RAP Implementation Schedule

It is essential that the time-frames and action plans associated with the RAPs are linked to the REDD+ project implementation schedule. Provisions for compensation and assistance must be made prior to displacement in accordance with proclamation no 455/2005. The assistance includes provision and preparation of resettlement sites with adequate facilities. In particular, land and related assets may be taken away only after compensation has been paid and resettlement sites and moving allowances have been provided to the affected people. For project activities requiring relocation or resulting in loss of shelter, the RPF further requires that measures to assist the project affected persons are implemented in accordance with the individual RAPs.

When approving recommendations for resettlement during screening, PAPs must confirm that the resettlement plans contain acceptable measures that link resettlement activity to civil works, in compliance with this policy. Proper timing and coordination of the civil works shall ensure that no affected persons will be displaced (economically or physically) due to civil works activity before compensation is paid and before any project activity begins.

Complaints and Appeals in Relation to Compensation

At the time that the individual RAPs or ARAPs are approved and individual compensation contracts are signed, affected individuals and households will have been informed of the process of expressing complaints and making appeals in relation to compensation. The relevant law is found in Article 11, Part Three, of

Proclamation No. 455/2005: Expropriation of Landholdings for Public Purposes and Payment of Compensation.

The relevant Sub-Articles are:

- In rural areas and in an urban centre where an administrative organ to hear grievances related to urban landholding is not yet established, a complaint relating to the amount of compensation shall be submitted to the regular court having jurisdiction.

- Where the holder of an expropriated urban landholding is dissatisfied with the amount of compensation, he/she may lodge his/her complaint to the administrative organ established by the urban administration to hear grievances related to urban landholdings.

- The organ referred to in Sub-Article 2 above shall examine the complaint and give its decision within such a short period as specified by the directives issued by the region and communicate its decision to the parties in writing.

A party dissatisfied with a decision rendered in accordance with Sub-Articles 1 and 3 above may appeal, as may be appropriate, to the regular appellate court or municipal appellate court within 30 days from the date of the decision. The decision of the court shall be final.

- **Glossary**

Activity Data: is the annual area (ha/yr) lost or acquired by a Land Use /Land Cover class at a given year 't' or the annual area of a category of LU/LC change for a given year t.

Allometry. Statistical relation on a population scale between two size characteristics of the individuals in this population. This relation in most cases has a power form. Example: there is allometry in vertebrates between adult body mass and brain size.

Baseline carbon is the sum of carbon stock changes and GHG emissions that would occur in the absence of the proposed REDD project activity.

Baseline Scenario: is the expected change in land use and land cover (LU/LC) if business as usual continues or in the absence of any project intervention designed to reduce emissions from deforestation, forest degradation, or enhance carbon stocks.

Carbon flux is the transfer of carbon from one carbon pool to another in units of measurement of mass per unit area and time (e.g., t C ha^{-1} yr^{-1})

Carbon pool is a reservoir of carbon. A system which has the capacity to accumulate or release carbon. A system which has the capacity to accumulate or release carbon. Examples of carbon pools are forest biomass, wood products, soils and atmosphere.

Carbon Stock is the carbon density of an area times the number of hectares in the area.

Carbon trading is a transaction of verified or certified carbon credits generated from REDD in monetary terms.

Deforestation is the direct, human-induced and long-term (or permanent) conversion of forest land to non-forest land50. It occurs when at least one of the parameter values used to define "forest land" is reduced from above the threshold for defining "forest" to below this threshold for a period of time that is longer than the period of time used to define "temporarily un-stocked"51. For example, if a country defines a forest as having a crown cover greater than 30% and "temporarily unstocked" as a maximum period of 3 years, then deforestation would not be recorded until the crown cover is reduced below 30% for at least three consecutive years52. Country should develop and report criteria by which temporary removal or loss of tree cover can be distinguished from deforestation.

Emission Factor (or Carbon Stock Change Factor) is the difference between the carbon density of the two LU/LC classes describing a category of LU/LC change.

Forest degradation is "forest land remaining forest land" but gradually losing carbon stocks as a consequence of direct-human intervention (e.g. logging, fuel-wood collection, fire, grazing, etc.). According to IPCC GPG LLUCF "forest degradation" is "a direct, human-induced, long-term (persisting for X years or more) or at least Y% of

forest carbon stock [and forest values] since time T and not qualifying as deforestation". Note that X, Y% and T are not quantified.

GHG (Carbon) benefits – Any emissions reductions from reducing carbon losses or emission removals from enhanced carbon sequestration due to the forest carbon project activities.

Historical Reference Period is a time period preceding (10-15 years) the starting date of the proposed REDD+ project activity. It is analyzed to determine the magnitude of deforestation and forest degradation in the reference region and to identify agents and drivers of DD and the chain of events leading to land use / land-cover change. In order to be useful for understanding recent and likely future DD trends, the starting date of the historical reference period should be selected between 10 and 15 years in the past, and the end date as close as possible to present.

Leakage is the decrease in carbon stocks and the increase in GHG emissions attributable to the implementation of the REDD project activity that occurs outside the boundary of the Project area.

Mitigation is actions to reduce greenhouse gas emissions and to enhance carbon sink to curb climate change.

Monitoring – A continuing process that uses systematic collection of data on specified indicators to provide indications of the extent to which objectives are being achieved.

Monitoring period is the period of time (in years) between two monitoring and verification events. Typically it is a fraction of the fixed baseline period. The minimum duration is one year and the maximum is the duration of the fixed baseline period.

Net Emission Reduction: Indicates the expected amount of emissions reductions that will be generated by the project activities on a certain period of time. It's necessary to stress that, in many projects that are still in design phase, these numbers can be very preliminary and may change in the future.

Project Activity is the series of planned steps and activities by which the proponent intends to reduce deforestation and forest degradation and/or enhance forest regeneration.

Project area is the area or areas of land on which the proponent will undertake the project activities. No lands on which the project activity will not be undertaken can be included in the project area.

Project Scenario is the expected change in land use and land cover within the boundary of the project area resulting from the undertaking of the project activity.

Reference region is the spatial delimitation of the analytic domain from which information about deforestation and degradation agents, drivers and LU/LC-change

is obtained, projected into the future and monitored. The reference region includes the Project area57 and is defined by the project proponent using transparent criteria. It must contain LU/LC classes and deforestation agents and drivers similar to those found in the project area under the baseline and project scenarios.

Sequestration (uptake): The process of increasing the carbon content of a carbon pool other than the atmosphere.

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Annex 1. Global and local allometric equations to be used in processing data collected through the NFI

i) Global allometric equations

Trees

Sr. No	Forest/vegetation type	Ethiopian equivalent vegetation type	Reference	Equation (per tree unless and otherwise stated)	Variable	r2	No. sample	DBH range	Quality
1	Global (all forest type)	All forest types	[chave et al 2014.pdf](#)	AGB (kg) =0.0673*(WD*DBH^2*Ht)^0.976	WD(g/cm3); DBH (cm); Ht (m)	**nd**	4004	5-158	**H**
2	Global (all forest type)	All forest types	[chave et al 2014.pdf](#)	AGB(kg) = 0.0559*(WD*DBH^2*Ht)	WD(g/cm3); BH(cm); Ht(m)	**nd**	4004	5-158	**H**
3	Tropical dry forest	Dry afromontane forest	[Chave_et_al-2005.pdf](#)	AGB(kg) =WD*exp(-0.667+1.784*ln(DBH)+0.207*(ln(DBH))^2-0.0281*(ln(DBH))^3)	WD(g.cm-3) & DBH(cm)	0.996	2,410	5-156	M
4	Tropical dry forest	Dry afromontane forest	>>	AGB (kg) =exp(-2.187+0.916*ln(WD*DBH^2*Ht))	WD(g.cm-3); DBH(cm) and Ht(m)	0.969	2,410	5-157	M
5	Tropical moist deciduous forest	Humid/transition afromontane forest	>>	AGB (kg) =exp (-2:977+ln(WD*DBH^2*H) =0509*WD*DBH^2*H	WD(g.cm-3), DBH(cm)ad Ht(m)	0.996	2,410	5-160	M
6	Tropical moist deciduous forest	Humid/transition afromontane forest	>>	AGB (kg) =1.499+(2.148*ln(DBH))+(0.207*(ln(DBH))^2)-(0.0281*(ln(DBH))^3))	DBH(cm)	0.969	2,410	5-161	M
7	Tropical wet forest	none	>>	AGB(kg) =exp(-2.977+ln(WD*DBH^2*Ht)) = 0.0776*(WD*DBH^2*Ht)^0.940	WD(g.cm-3); DBH(cm); Ht(m)	0.996	2,410	5-165	M
8	Tropical wet rainforest	none	>>	AGB (kg) = WD* exp(-1.239 + 1.980*ln(DBH)+0.207 (ln(DBH))^2 - 0.0281(ln(DBH))^3)	WD(g.cm-3); DBH (cm)	0.969	2,410	5-168	M
9	Tropical wet rainforest	none	>>	AGB (kg) =1.349+(1.980*ln(DBH))+(0.207*(ln(DBH))^2)-(0.0281*(ln(DBH))^3))	DBH(cm)	0.996	2,410	5-169	M
10	Tropical rainforest (wet)	Humid/transition afromontane forest	[Brown (1997).Estimating Biomass and Biomass Change of Tropical Forests.pdf](#)	AGB (kg) =21.297-6.953*DBH+0.740*(DBH)^2	DBH(cm)	0.920	169	4-112	M
11	Tropical moist	Humid/transition	>>	ABG (kg) =42.69-12.800*(DBH)+1.242*(DBH)^2	DBH(cm)	0.840	170	5-148	M

#	Forest type	Vegetation	Reference	Equation	Variables	R²	n	Range	Quality
	forest	afromontane forest							
12	Tropical dry forest	Dry afromontane forest	>>	AGB (kg) =exp(-1.996+2.32*ln(DBH))	DBH(cm)	0.890	28	(5-40)	L
13	Tropical dry forest	Dry afromontane forest	>>	AGB (kg) =10^(-0.535+ln(DBH))	DBH(cm)	0.940	191	(3-30)	M
14	Tropical moist forest	Humid/transition afromontane forest	>>	AGB (kg) = exp{-2.134+2.530*ln(DBH)}	DBH(cm)	0.970	ND	ND	L
15	Tropical dry forest	Dry afromontane forest	Brown et al (1989). Biomass Estimation Methods for Tropical Forests with Applications to Forest Inventory Data.html	AGB(kg) =34.4703-8.0671*DBH+0.6589*(DBH^2)	DBH(cm)	0.670	ND	>5	M
16	Tropical shrubland	acacia-commiphora woodland	>>	AGB (kg) =34.4703-8.0671*DBH+0.6589*(DBH^2)	DBH(cm)	nd	nd	nd	M
17	Tropical moist rainforest	Humid/transition afromontane forest	>>	AGB(kg) =exp(-3.1141+(0.9719*ln(((DBH^2)*Ht)))	DBH(cm); Ht(m)	0.970	ND	>5	M
19	Tropical moist	Humid/transition afromontane forest	>>	AGB (kg) =exp(-2.4090+(0.9522*ln((BA^(2))*DBH*Ht*WD)));	DBH(cm); Ht (m); WD (g/cm3)	0.99	ND	>5	M
20	Tropical moist deciduous forest	Humid/transition afromontane forest	>>	AGB (kg) =exp(-2.4090+(0.9522*ln((BA^(2))*DBH*Ht)))	DBH(cm); Ht (m) and BA (m2)	0.990	ND	>5	M
21	Tropical moist	Humid/transition afromontane forest	>>	AGB (kg) = exp{-2.4090+ 0.9522 x ln[(DBH^2)*Ht*WD]}		0.990	ND	>5	M
22	Tropical rainforest	Humid/transition afromontane forest	Ponce-Hernandez, R. 2004.pdf	AGB (kg) =exp(2.134+(2.530*ln(DBH)))	DBH(cm)	ND	ND	ND	L
23	Tropical moist deciduous forest	Humid/transition afromontane forest	>>	AGB (kg) =exp(2.134+(2.530*ln(DBH)))	DBH(cm)	ND	ND	ND	L
24	Agroforestry trees and shrubs	Agroforestry	Kuyah et al. (2012)	AGB (kg)= 0.091 × DBH^2.472	DBH (cm)	0.980	72	ND	M
25	Dry-moist transition	none	FAO (nd)	AGB (kg)= exp{-1.996 + 2.32 x ln(DBH)}	DBH (cm)	0.890	ND	5-40 cm	L

	Dry-moist transition (Rainfacll < 900 mm)	none	FAO (nd)	AGB(kg) = 10 ^ (-0.535 + log10(π x r2))	r (cm)	0.940	ND	3-30 cm	L
26									
27	Moist forest	Humid/transition afromontane forest	FAO (nd)	AGB(kg) = exp{-2.134 + 2.530 x ln(DBH)}		0.970	ND	<80 cm	L
28	not specified	All forest types	Luckman (no date)	AGB(kg)= (0.0899 ((DBH2)0.9522) x (H0.9522) x (S0.9522))	ND	ND	ND	ND	L
Non-tree equations									
1	Liana	liana	Putz, 1983	AGB (kg) = exp (0.12+0.91log(BA-cm2)	ND	ND	ND	ND	L
2	Banana	Banana	Hairiah et al., 2011	AGB (Kg) = 0.03*DBH^2.13	ND	ND	ND	ND	L

ND = no data

ii)   Woody Biomass Strategic Planning Project designed local/national allometric equations

Sr. No.	Agro-ecology	Species	AGB (Oven dry mass = kg)	R^2	Number of samples	Max. DSH
1	Moist kolla	Acacia brevispica	('0.2265 *DSH) + (0.0769 * (DSH exp 2.4))	0.88	24	15
2	Moist kolla	Acacia bussei	(0.1006 * DSH) + (0.2207 * (DSH exp 2.2))	0.89	48	36
3	Moist kolla	Acacia abyssinica	('0.0497 * DSH)+(0.0300 *(DSH exp 2.8))	0.9	29	54
4	Dry Kolla	Acacia dolichocephala	('0.9304 * DSH)+(0.0571 *(DSHexp 2.6))	0.95	17	29
5	Moist kolla	Acacia dolichocephala	(0.9304 * DSH) + (0.0571 * (DSH exp 2.6))	0.95	27	29
6	Dry Kolla	Acacia drepanolobium	('0.0819 *DSH) + (0.3601 * (DSH exp 1.9))	0.84	24	16
7	Wet kolla	Acacia drepanolobium	(0.1280 * DSH)+(0.0037 *(DSH exp 3.8))	0.98	14	9
8	Dry Kolla	Acacia etbaica	(-0.1024 * DSH) + (0.1502 * (DSH exp 2.3))	0.88	39	37
9	Wet kolla	Acacia lahai	(-0.0565 *DSH) + (0.0912 * (DSH exp 2.3))	0.73	20	19
10	Moist kolla	Acacia macrothyrsa	(0.3771 * DSH) + (0.0212 * (DSH exp 2.8))	0.99	11	42
11	Dry Kolla	Acacia mellifera	(0.0627 * DSH) + (0.3091 * (DSH exp 1.9))	0.91	49	27
12	Dry Kolla	Acacia nilotica	(2.3624 * DSH) + (0.0035 * (DSH exp 3.4))	0.96	17	27
13	Moist kolla	Acacia nilotica	(2.3624 * DSH) + (0.0035 * (DSH exp 3.4))	0.96	17	35
14	Moist kolla	Acacia polyacantha	(0.0191 * DSH) + (0.7448 * (DSH exp 1.8))	0.96	18	35
15	Wet kolla	Acacia polyacantha	(0.0577 * DSH) + (0.1573 * (DSH exp 2.3))	0.98	10	15
16	Moist weyna Dega	Acacia polyacantha	(0.3251* DSH) + (0.3517 * (DSH exp 1.9))	0.98	14	50

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17	Moist kolla	Acacia reficiens	(0.0573 * DSH) + (0.0643 * (DSH exp 2.9))	0.97	12	9
18	Dry Kolla	Acacia robusta	(0.0573 * DSH) + (0.0643 * (DSH exp 3.6))	0.95	16	36
19	Moist kolla	Acacia sieberiana	(0.0417 * DSH)+(0.0485 *(DSH exp 2.6))	0.98	19	17
20	Moist weyna Dega	Acacia sieberiana	(0.4250* DSH) + (0.0528 * (DSH exp 2.5))	0.98	10	25
21	Moist kolla	Acacia senegal	(2.2819 *DSH) + (0.0696 * (DSH exp 2.5))	0.93	53	34
22	Dry Kolla	Acacia seyal	(0.1124 * DSH) + (0.1238 * (DSH exp 2.4))	0.97	40	34
23	Moist kolla	Acacia seyal	(0.1124 * DSH) + (0.1238 * (DSH exp 2.4))	0.95	12	36
24	Moist weyna Dega	Acacia seyal	(0.9103* DSH) + (0.6782 * (DSH exp 1.7))	0.9	19	48
25	Dry Kolla	Acacia tortilis	(1.1725 * DSH) + (0.0106 * (DSH exp 3.0))	0.97	40	30
26	Moist kolla	Acacia tortilis	(0.1725 * DSH) + (0.0106 * (DSH exp 3.0))	0.97	13	50
27	Dry Kolla	Acacia Zanzibarica	(0.4021 * DSH)+(0.5212 *(DSH exp 1.8))	0.76	59	35
28	Moist kolla	Acokanthera schimperi	(0.2383* DSH) + (0.2211 * (DSH exp 1.9))	0.98	16	24
29	Moist weyna Dega	Acokanthera schimperi	(0.1788 *DSH) + (0.0319 * (DSH exp 2.6))	0.96	25	29
30	Moist weyna Dega	Albizia gummifera	(0.0517* DSH) + (0.0236 * (DSH exp 2.8))	0.99	42	46
31	wet weyna Dega	Albizia gummifera	(0.1200 * DSH) + (0.0701 * (DSH exp 2.3))	0.97	12	18
32	Moist weyna Dega	Albizia schimperiana	(1.2910* DSH) + (0.0124 * (DSH exp 2.9))	0.99	16	33
33	Dry Kolla	All species	(0.4861 * DSH) + (0.1659* (DSH exp 2.2))	0.78	654	47
34	Moist kolla	All species	(1.4277 * DSH) + (0.0088 * (DSH exp 3.0))	0.75	2040	55
35	Wet lower Dega	All species	(0.2313 * DSH)+(0.1073 *(DSH exp 2.0))	0.98	8	37
36	Dry weyna Dega	All Species	(0.3197 * DSH) + (0.0383 * (DSH exp 2.6))	0.93	118	39
37	Moist weyna Dega	All Species	(0.3658* DSH) + (0.1144 * (DSH exp 2.2))	0.86	798	54
38	wet weyna Dega	All Species	(0.0633* DSH) + (0.0104 * (DSH exp 2.9))	0.84	68	31
39	Wet kolla	All specious	(0.3989* DSH) + (0.0126 * (DSH exp 2.9))	0.82	557	50
40	Moist kolla	Balanites aegyptiaca	(0.0982 * DSH) + (0.0643 * (DSH exp 2.4))	0.95	31	53
41	Moist weyna Dega	Balanites aegyptiaca	(0.4743* DSH) + (0.0693 * (DSH exp 2.3))	0.98	14	54
42	Dry Kolla	Balanites glabra	(0.1980 * DSH) + (0.2496 * (DSH exp 2.0))	0.98	6	33
43	Dry Kolla	Barbeya oleoides	(-0.2370* DSH) + (0.2727 * (DSH exp 2.1))	0.92	47	37
44	Moist kolla	Barbeya oleoides	('0.1980 *DSH) + (0.2496 * (DSH exp 2.0))	0.97	28	43

45	Moist kolla	Berchemia discolor	(0.8007 * DSH) + (0.6036 * (DSH exp 1.8))	0.93	15	31
46	Moist weyna Dega	Bersama abyssinica	(0.1189* DSH) + (0.0011 * (DSH exp 4.0))	0.98	39	17
47	Moist kolla	Boswellia hildebrandtii	(0.0424 * DSH) + (0.1717 * (DSH exp 1.9))	0.81	21	23
48	Wet kolla	Bridelia micrantha	(-0.0007 * DSH) + (0.0648 * (DSH exp 2.5))	0.85	11	16
49	Moist kolla	Carissa edulis	(0.0345 * DSH) + (0.0377 * (DSH exp 3.3))	0.91	13	7
50	Moist kolla	Canthium euryoides	(0.0312 * DSH) + (0.0554 * (DSH exp 2.6))	0.98	12	25
51	Wet kolla	Canthium euryoides	(0.0312 * DSH) + (0.0554 * (DSH exp 2.6))	0.98	5	21
52	Wet kolla	Canthium giordanii	(0.3845 * DSH)+(0.0870 *(DSH exp 2.4))	0.86	19	48
53	Moist kolla	Calpurnia subdcandra	(-0.5385 * DSH)+(0.5341 *(DSH exp 1.6))	0.98	9	23
54	Moist weyna Dega	Calpurnia subdcandra	(0.9511 * DSH) + (0.0295 * (DSH exp 2.4))	0.98	12	14
55	Dry Kolla	Cassia singueana	(0.3845 * DSH) + (0.0870 * (DSH exp 2.9))	0.82	6	8
56	Moist kolla	Cassia singueana	(0.3845 *DSH) + (0.0870 * (DSH exp 2.9))	0.82	13	9
57	Wet kolla	Combretum aculeatum	(0.1135 * DSH) + (0.1140 * (DSH exp 2.3))	0.94	27	29
58	Moist kolla	Combretum colinum	(0.2130 * DSH) + (0.0055 * (DSH exp 3.2))	0.91	47	36
59	Moist kolla	Combretum molle	(0.0922 * DSH) + (0.1540 * (DSH exp 2.2))	0.86	38	49
60	Wet kolla	Combretum molle	(0.0922 * DSH) + (0.1540 * (DSH exp 2.2))	0.87	13	29
61	Dry weyna Dega	Combretum molle	(0.0922 * DSH) + (0.1540 * (DSH exp 2.2))	0.86	6	30
62	Dry Kolla	Commiphora african	(1.0800 * DSH) + (0.0939 * (DSH exp 2.3))	0.84	33	27
63	Moist kolla	Commiphora bruceau	(0.0581 * DSH) + (0.0703 * (DSH exp 2.3))	0.87	16	18
64	Wet kolla	Commiphora bruceau	(0.1408* DSH) + (0.0481 * (DSH exp 2.4))	0.72	25	33
65	Moist kolla	Commiphora erythraea	(0.3004 * DSH) + (0.0781 * (DSH exp 2.4))	0.93	47	44
66	Moist kolla	Commiphora ogadensis	(0.0365 * DSH) + (0.0232 * (DSH exp 2.6))+(-0.0106 * (DSH exp 3.5))	0.96	17	14
67	Wet kolla	Commiphora ogadensis	(0.0365 * DSH) + (0.0232 * (DSH exp 3.3))+(-0.0106 * (DSH exp 3.5))	0.96	25	48
68	Dry Kolla	Commiphora tenuis	('0.0046 *DSH) + (0.0604 * (DSH exp 2.4))	0.87	16	28
69	Moist kolla	Commiphora tenuis	(0.0046* DSH) + (0.0604 * (DSH exp 2.4))	0.87	33	28
70	Wet kolla	Cordia ovalis	(0.0175 *DSH) + (0.2220 * (DSH exp 2.2))	0.98	18	12
71	Moist kolla	Croton dichogamus	(0.2938 * DSH) + (0.0562* (DSH exp 2.6))	0.98	19	19
72	Moist kolla	Croton macrostachyus	(0.2972* DSH) + (0.1588 * (DSH exp 2.2))	0.88	30	37

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73	Moist weyna Dega	Croton macrostachyus	(0.3679 *DSH) + (0.0459 * (DSH exp 2.5))	0.99	22	47
74	Moist weyna Dega	Cussonia holstii	(0.3681* DSH) + (0.2063 * (DSH exp 1.6))	0.97	12	18
75	Dry Kolla	Delonix elata	(0.9054 * DSH) + (0.0805 * (DSH exp 2.5))	0.89	20	34
76	Moist kolla	Delonix elata	('0.9054 *DSH) + (0.0805 * (DSH exp 2.5))	0.89	6	44
77	Moist kolla	Diochrostachys cinerea	(0.4012 * DSH) + (0.0251 * (DSH exp 2.7))	0.96	49	33
78	Moist weyna Dega	Diphasia dainellii	(0.0285* DSH) + (0.1386 * (DSH exp 2.0))	0.97	12	18
79	Moist kolla	Dodoaea angustifolia	(0.1505 * DSH) + (0.0122 * (DSH exp 2.0))	0.99	11	13
80	Moist weyna Dega	Dombeya torrida	(0.8630* DSH) + (0.0744 * (DSH exp 1.2))	0.93	15	13
81	Moist kolla	Ehretia cymosa	(0.0197 * DSH) + (0.2344 * (DSH exp 1.8))	0.58	11	17
82	Moist weyna Dega	Ehretia cymosa	(0.8808* DSH) + (0.0348 * (DSH exp 2.5))	0.98	13	40
83	Moist kolla	Entada abyssinica	(-0.7586* DSH) + (0.3910 * (DSH exp 1.9))	0.99	21	47
84	wet weyna Dega	Erythrina abyssinica	(0.1228* DSH) + (0.0330 * (DSH exp 2.4))	0.96	17	30
85	Moist kolla	Euclea schimperi	(0.0397 * DSH) + (0.2144 * (DSH exp 1.9))	0.94	23	14
86	Moist weyna Dega	Euclea schimperi	(0.0935 * DSH) + (0.0140 * (DSH exp 3.6))+(-0.0035 * (DSH exp 4.0))	0.96	19	26
87	Moist kolla	Faurea saligna	(0.1381 * DSH) + (0.0535 * (DSH exp 2.4))	0.87	16	23
88	Moist kolla	Flacourtia indica	(0.0891 * DSH)+(0.1115 *(DSH exp 2.4))	0.97	8	13
89	Moist kolla	Galiniera saxifraga	(0.0388 * DSH) + (0.0557 * (DSH exp 3.1))+(-0.0140 * (DSH exp 3.5))	0.97	15	23
90	Dry Kolla	Grewia bicolor	(0.2483 * DSH) + (0.2214 * (DSH exp 2.1))	0.84		12
91	Moist kolla	Grewia bicolor	(0.2483 * DSH) + (0.2214 * (DSH exp 2.1))	0.84		36
92	Moist kolla	Grewia ferruginea	(0.5983* DSH) + (0.0017 * (DSH exp 3.7))	0.96	29	17
93	Dry Kolla	Grewia mollis	(0.1963 * DSH) + (0.3438 * (DSH exp 1.8))	0.88	7	30
94	Moist kolla	Grewia mollis	(0.1963* DSH) + (0.3438 * (DSH exp 1.8))	0.88	11	22
95	Moist weyna Dega	Grewia villosa	(1.1346 * DSH) + (0.0149 * (DSH exp 1.5))	0.88	6	7
96	Moist weyna Dega	Hypericum revolutum	(0.0164 * DSH) + (0.1514 * (DSH exp 1.9))	0.96	6	8
97	Moist kolla	Ilex mitis	(0.0576 * DSH) + (0.1243* (DSH exp 2.3))	0.93	24	16
98	Moist weyna Dega	Ilex mitis	(0.0576* DSH) + (0.1243 * (DSH exp 2.3))	0.93	7	17
99	Moist kolla	Kirkia burgeri	('0.0045 *DSH) + (0.5661 * (DSH exp 1.8))	0.84	32	54
100	Wet kolla	Lannea fruticosa	(0.0410 * DSH) + (0.0078 * (DSH exp 2.9))	0.98	10	18

101	Dry Kolla	Lannea schimperi	(1.1750 * DSH) + (0.0444 * (DSH exp 2.5))	0.95	58	42
102	Moist kolla	Lannea stuhlmannii	(0.0913 * DSH) + (0.0745 * (DSH exp 2.2))	0.99	12	33
103	Moist kolla	Lannea triphylla	(0.1675 * DSH) + (0.0173 * (DSH exp 2.7))	0.89	54	40
104	Moist kolla	Maerua angolensis	(0.4312 * DSH) + (0.1848 * (DSH exp 20.))	0.79	13	33
105	Wet kolla	Maerua angolensis	(0.4312 * DSH) + (0.1848 * (DSH exp 2.0))	0.79	6	29
106	Moist weyna Dega	Maerua calophylla	0.1373* DSH) + (0.5803 * (DSH exp 1.3))	0.96	32	17
107	Dry Kolla	Maerua crassifolia	('0.4960 *DSH) + (0.7262 * (DSH exp 1.8))	0.99	6	47
108	Moist kolla	Maerua crassifolia	(0.1229 * DSH) + (0.2550 * (DSH exp 2.0))	0.95	40	45
109	Wet kolla	Maesa lanceolata	(0.0229 * DSH) + (0.0525 * (DSH exp 2.3))	0.98	6	14
110	Dry weyna Dega	Maesa lanceolata	(0.1751 * DSH) + (0.2044 * (DSH exp 2.0))	0.93	3	19
111	Moist weyna Dega	Maesa lanceolata	(0.1751 * DSH) + (0.2044 * (DSH exp 2.0))	0.93	26	18
112	Moist kolla	Maytenus addat	(0.1317 * DSH)+(0.1075 *(DSH exp 2.4))	0.93	17	14
113	Dry Kolla	Maytenus senegalensis	(0.2685 * DSH) + (0.0492 * (DSH exp 2.3))	0.88	22	31
114	Dry weyna Dega	Maytenus senegalensis	(0.0587 * DSH) + (0.0509 * (DSH exp 2.4))	0.93	25	17
115	Moist weyna Dega	Millettia ferruginea	(0.3494 * DSH) + (0.3687 * (DSH exp 2.0))+(-0.0780 * (DSH exp 2.4))	0.96	15	26
116	Moist weyna Dega	Mimusops Kummel	(0.6143 * DSH) + (0.0014 * (DSH exp 3.3))	0.98	15	26
117	Moist kolla	Mystroxylon aethiopicum	(0.1472 * DSH) + (0.0029 * (DSH exp 3.3))	0.94	9	18
118	Wet kolla	Mystroxylon aethiopicum	(0.1472 * DSH)+(0.0029 *(DSH exp 3.3))	0.94	32	18
119	Moist weyna Dega	Nuxia congesta	(0.6804 * DSH) + (0.0020 * (DSH exp 4.0))+(-0.0005 * (DSH exp 4.4))	0.98	30	31
120	Moist kolla	Ocotea viridis	(0.0238 * DSH) + (0.0786 * (DSH exp 2.0))	0.85	50	47
121	Moist weyna Dega	Olea africana	(0.6806* DSH) + (0.0422 * (DSH exp 2.7))	0.91	16	23
122	Moist kolla	Olea capensis sub. Hochstetteri	(0.0117 * DSH) + (0.4742 * (DSH exp 2.6))+(-0.1859 * (DSH exp 2.9))	0.96	25	17
123	Dry weyna Dega	Olea capensis sub. Hochstetteri	(0.0358 * DSH) + (0.0389 * (DSH exp 2.4))	0.98	9	13
124	Moist weyna Dega	Opilia campestris	(0.3061 * DSH) + (0.3635 * (DSH exp 1.4))	0.96	15	25
125	Moist kolla	Ozoroa insignis	(0.0015 * DSH) + (0.0690 * (DSH exp 3.1))+(-0.0316 * (DSH exp 3.3))	0.94	25	37
126	Wet kolla	Ozoroa insignis	(0.0015 * DSH) + (0.0690 * (DSH exp 3.1))+(-0.0316 * (DSH exp 3.3))	0.94	10	12
127	Moist weyna Dega	Ozoroa insignis	(0.1362 *DSH) + (0.1759 * (DSH exp 2.0))	0.98	13	52
128	Wet kolla	Ozoroa pulcherrima	(0.0670 * DSH) + (0.0413 * (DSH exp 2.4))	0.78	23	21

129	Dry Kolla	Pappea capensis	(0.2445 * DSH) + (0.2451 * (DSH exp 2.6))+(-0.1022 * (DSH exp 2.8))	0.92	17	43
130	Moist kolla	Pappea capensis	(0.2445 * DSH) + (0.2451 * (DSH exp 2.6))+(-0.1022 * (DSH exp 2.8))	0.92	5	48
131	Moist kolla	Pilidiostigma thonningii	(0.1423 * DSH) + (0.0127 * (DSH exp 2.9))	0.95	25	27
132	Wet kolla	Pilidiostigma thonningii	(0.1423 * DSH) + (0.0127 * (DSH exp 2.9))	0.9	17	17
133	Moist kolla	Pistacia lentiscus	(0.0318 * DSH) + (0.2136 * (DSH exp 1.8))	0.97	13	11
134	Wet kolla	Pistacia lentiscus	(0.0184 * DSH) + (0.1301 * (DSH exp 2.1))	0.81	9	7
135	Moist weyna Dega	Pittosporum viridiflorum	(0.0051* DSH) + (0.6359 * (DSH exp 1.2))	0.99	21	17
136	Moist weyna Dega	Podocarpus falcatus	(0.0475 * DSH) + (0.4485 * (DSH exp 2.3))+(-0.2394 * (DSH exp 2.5))	0.97	9	14
137	Wet kolla	Premna schimperi	(0.1423 * DSH) + (0.0065 * (DSH exp 3.2))	0.99	9	15
138	Moist weyna Dega	Protea gaguedi	(0.8716 * DSH) + (0.0108 * (DSH exp 2.5))	0.99	9	13
139	Moist kolla	Rhus natalensis	(0.0281* DSH) + (0.1505 * (DSH exp 2.3))	0.96	20	13
140	Dry weyna Dega	Rhus natalensis	(2.0281 *DSH) + (0.1505 * (DSH exp 2.3))	0.97	8	18
141	Moist weyna Dega	Rhus natalensis	(0.0281 * DSH) + (0.1505 * (DSH exp 2.3))	0.97	10	17
142	Moist kolla	Rhus vulgaris	('0.0038 * DSH)+(0.6092 *(DSH exp 1.5))	0.84	21	14
143	Moist kolla	Sclerocarya birrea	(0.4000 * DSH) + (0.5142 * (DSH exp 1.6))	0.94	15	25
144	Wet kolla	Sclerocarya birrea	(0.4000 * DSH) + (0.5142 * (DSH exp 1.6))	0.94	6	4
145	Moist weyna Dega	Sclerocarya birrea	(0.4000* DSH) + (0.5142 * (DSH exp 1.6))	0.94	3	18
146	Moist weyna Dega	Scherebera alata	(-0.0111* DSH) + (0.1014 * (DSH exp 1.3))	0.94	14	26
147	Dry Kolla	Sterculia setigera	(0.1638 * DSH) + (0.0216 * (DSH exp 2.4))	0.89	19	38
148	Moist kolla	Steganotaenia araliacea	(0.0176 * DSH) + (0.0261 * (DSH exp 2.6))	0.94	12	18
149	Wet kolla	strychnos innocua	(0.3515 * DSH) + (0.0643 * (DSH exp 2.3))	0.95	23	35
150	Moist kolla	Stereospermum kunthianum	(0.3513 * DSH) + (0.0032 * (DSH exp 3.1))	0.95	12	18
151	Moist kolla	Tamarindus indica	(0.5031 * DSH) + (0.2536 * (DSH exp 2.1))	0.88	23	36
152	Wet kolla	Tamarindus indica	(0.5031 * DSH) + (0.2536* (DSH exp 2.1))	0.89	10	40
153	Moist kolla	Teclea nobilis	(0.0648 * DSH) + (0.1561 * (DSH exp 2.2))	0.98	18	18
154	Moist weyna Dega	Teclea nobilis	(0.2619 * DSH) + (0.3880 * (DSH exp 2.3))+(-0.0667 * (DSH exp 2.7))	0.99	19	46
155	Moist weyna Dega	Teclea simplicifolia	(0.2896* DSH) + (0.6451 * (DSH exp 1.1))	0.96	18	30
156	Dry Kolla	Terminalia brownii	(0.4040 * DSH) + (0.0766 * (DSH exp 2.4))	0.96	42	28

157	Moist kolla	Terminalia brownii	(0.4040 * DSH) + (0.0766 * (DSH exp 2.4))	0.96	4	43
158	Moist kolla	Teerminanlia laxiflora	(0.0110 * DSH)+(0.0771 *(DSH exp 2.4))	0.82	28	30
159	Dry Kolla	Terminalia mollis	(0.4253* DSH) + (0.0056 * (DSH exp 3.4))	0.98	10	24
160	Moist kolla	Terminalia mollis	(0.3682 *DSH) + (0.0944 * (DSH exp 2.3))	0.97	26	38
161	Wet kolla	Terminalia mollis	(0.1527* DSH) + (0.1614 * (DSH exp 2.1))	0.72	11	15
162	Moist kolla	Terminalia prundioides	(0.0240 * DSH) + (0.2974 * (DSH exp 2.2))	0.94	48	42
163	Moist kolla	Terminalia schimperiana	(0.1603 * DSH) + (0.0320 * (DSH exp 2.6))	0.93	18	33
164	Moist kolla	Terminalia sopinos	(0.2934* DSH) + (0.1109 * (DSH exp 2.4))	0.89	38	29
165	Moist kolla	Ximenia caffra	(0.7883 * DSH) + (0.0111* (DSH exp 2.9))	0.91	22	14
166	Moist kolla	Zanthoxylum chalybeum	(0.0101 * DSH) + (0.0115 * (DSH exp 3.1))	0.83	14	28
167	Moist kolla	Ziziphus mauritania	(0.1067 * DSH) + (0.0131 * (DSH exp 3.0))	0.94	38	24
168	Moist kolla	Ziziphus mucronata	(0.0443 * DSH) + (0.0021 * (DSH exp 3.5))	0.71	12	24
169	Moist weyna Dega	Ziziphus mucronata	(0.2359* DSH) + (0.1457 * (DSH exp 2.2))	0.99	30	18
170	Wet kolla	Ziziphus spina-christi	(0.0340 * DSH) + (0.0431 * (DSH exp 2.6))	0.97	9	12

iii)   Other local and national allometric equations developed by research, project and others

Sr. No	Agroecology (geography)	Species/Forest type	Reference	Equation	Variable	r2	No. sample	DBH range	Remark
1	Dry afromonaten (Gedio-southern Agroforestry	*Coffea arabica* (agroforestry)	Mesele Negash (2014)	$AGB(kg) = 0.147 *(D_{40})^2$	D40 = diameter at 40 cm above ground	0.800	31	2.5-25	
2	>>	*Enseta ventricosa (*Enset*)*	Mesele Negash (2014)	$\ln(AGB(kg)) = -6.57+2.316\ln(D_{10})+0.124\ln(Ht)$	D10 = diameter at 10 cm and h = is height	0.910	40	15-55	
3	Northern Highland	*Eucalyptus camadulensis (Amahar region)*	Zerfu Hailu (2002)	$AGB(kg)= 0.0155×(DHB^{2.5823})$	DBH(cm)	0.990	9	1-200	
4	Northern Highland	*Eucalyptus camadulensis (Amahar region)*	Zerfu Hailu (2002)	$AGB (Kg) =0.0129*(DBH^{2.588})$	DBH(cm)	0.970	9	(1-200)	
5	South central	*Eucalyptus*	Pukkala & Pohjonen	$AGB(kg) =$	DBH(cm) & Ht(m)	0.79	983	(1,33)	

No.	Region	Species	Source	Equation	Variable	R²		Range	Notes
	highland	*globulus* (Munessa-shashamane)	(1993)-Cupressus lusitanica.pdf	((0.08283×(DBH^1.873))×(Ht^0.8242))×10^(−3)		0			
6	Central highland	Eucalyptus globulus (Intoto)	Mulugeta Zewdie et al., (2009)	AGB (kg)= 1.92–1.48×Ht+0.22×(Ht^2)	Ht(m)	0.700	79	1--16	
7	>>	Eucalyptus globulus (Intoto)	Mulugeta Zewdie et al., (2009)	AGB (kg) = 0.09×(DBH^1.9)	DBH(cm)	0.790	83	1--16	
8	>>	Eucalyprus globulus (Intoto)	Mulugeta Zewdie et al., (2009)	AGB (kg)= 0.59+0.03×DBH×(Ht^2)	DBH(cm) and Ht(m)	0.860	83	1--20	
9	>>	*Eucalyptus globulus* (coppice-Intoto))	Mulugeta Zewdie (2008)	AGB(t/ha)= −33.6+19.4×yr	Year (yr)	0.860	83	nd	On hectare base
10	>>	*Eucalyptus globulu*s (Intoto)	Mulugeta Zewdie (2009)	AGB(kg)= 1.92–1.48*Ht+0.22*(Ht^2)	Ht(m)	0.950	88	(5-16)	
11	>>	Eucalyptus globulus (Intoto)	Mulugeta Zewdie (2009)	AGB(kg)= 0.27+0.1*(DBH^2.39))	DBH(cm) and Ht (m)	0.800	76	(0-20)	
12	>>	*Eucalyptus globulus* (Intoto)	Mulugeta Zewdie (2009)	AGB(kg)= 0.45×(DBH^(−2.01))×(Ht^(3.41))	DBH (cm) and Ht (m)	0.910	83	(0-20)	
13	Dry afromonaten (central highland)	Juniperous procera	Eyosias Work and Teshome Soromessa (2015).pdf	Ln(ABG(kg)=ln(-2.3072)+2.32ln(DBH)	DBH	0.860	24	30-100	
14	>>	Podocarpus falcatus	>>	Ln(ABG)=ln(-0,125)+1.785ln(DBH)	DBH	0.840	24	30-100	
	Acacia-Commiphora semi-arid	*Acacia bussei (Borana)*	Hasen-Yusuf et al. (2012) - Predicting aboveground biomass of woody encroacher species in semi-arid rangelands, Ethiopia.pdf	ln(AGB) = -5.6308+ 2.5838ln(SB)	SB = stem circumfrence at base (cm)	0.960	ND	ND	
	>>	Acacia mellifera (Borana)	>>	ln (AGB) = -2.7777+0.963ln(SB)+0.7503ln(CV)	CV = Cofficient of Variation	0.960	ND	ND	
	>>	Acacia etabaica (Borana)	>>	ln(AGB) = 7.0822+2.877ln(SB)	SB = stem circumfrence at base (cm)	0.960	ND	ND	
	>>	Acacia senegal (Borana)	>>	ln(AGB) = 1.5515+ 0.5579ln(SB)+0.5922ln(CV)	CV = Cofficient of Variation	0.820	ND	SB= 11-100	
	>>	Acacia drepanolobium (Borana)	>>	ln(AGB) = 3.3387+1.1296ln(SB)+1.7012ln(Ht)	SB = stem circumfrence at base (cm) & Ht (m)	0.840	ND	SB = 11-85;	

								CV = 1.8-1409	
>>	Acacia oerfota (Borana)	>>	ln(AGB) =1.32+1.1084ln(CV)	CV = Cofficient of Variation	0.850	ND	CV = 6-256	
>>	Acacia reficiens (Borana)	>>	ln(AGB) = 0.1774+0.872ln(CV)	CV = Cofficient of Variation	0.880	ND	CV = 1.2-440	
>>	Commiphora africana (Borana)	>>	ln(AGB) =2.7882+1.1324ln(SB)+0.3163ln(CV)	CV = Cofficient of Variation	0.930	ND	SB = 11-40	
Dry highland (North)	Euclea shimperi (Tigray)	Cleemput et al., 2004.pdf	AGB (g)= 63.07*(DSH^(1.78))	DSH = diamter at 30 cm above the ground	0.950	7		
>>	Grewia bicolor (Tigray)	>>	AGB (g) = 52.97*DSH^(1.91))	DSH = diamter at 30 cm above the ground	0.960	8		
>>	Otostegia integrifolia (Tigray)	>>	AGB(g) = 45.80×(DSH^(2.26))	DSH = diamter at 30 cm above the ground	0.990	7		
>>	Dichrostachys cinerea (Tigray)	>>	AGB(g)= 230.98*(DSH^(1.47))	DSH = diamter at 30 cm above the ground	0.870	5	nd	
>>	*Ficus thonningii* (Tigray)	Mulubrhan Balehegn et al., 2010	AGB (kg) = 0.8470*CV - 0.2202*DSH - 1.5315	CV = Crown volume; DSH= diameter at stamp ht	0.990			
South central highland	Croton macrostachys (Munessa)	Asferachew Abate (2004)	AGB (kg) = 22.601DBH - 242.74	DBH	0.930	10-50 cm		
>>	Cupresus lusitanica (Munessa)	Aferachew Abate (2004)	AGB (Kg) = 27.293DBH-380.14	DBH	0.960	10-35 CM		
>>	Eucalyptus globulus (munessa)	Asferachew Abate (2004)	AGB (kg) = 29.517DBH - 294.8	DBH	0.980	10-45 CM		

Volume equations									
1		*Podocarpus species*	Chaffy (1978)	Ln(V) = 2.08ln(DBH)-7.72	X = DBH (cm)	nd	nd		
2		*Juniper procera*	>>	Ln (V) = 2.19ln(DBH)-8.45	X = DBH (cm)	nd	nd		
3		*Ekebergia capensis*	>>	Ln(V) =2.24ln(DBH) -9.0	X = DBH (cm)	nd	nd		

4		Hagenia, Olea, Maytenus, Schefflera, and all other indigenous species	>>	$Ln(V) = 1.7ln(DBH)-6.54$	X = DBH (cm)		nd	nd		
5		*Cupressus lusitanica*	Orlander (1986)	$Ln(v) = -3.2161+1.8096*ln(d)+1.1491*ln(ht)$	DBH & Ht		nd	nd		This is volume equation

Annex 2. Basic wood density of indigenous and exotic tree species in Ethiopia

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
1	*Acacia abyssinica*	0.826	average of genus (ICRAF database)	M	
2	*Acacia albida*	0.562	http://www.worldagroforestry.org/regions/southeast_asia/resources/db/wd	M	
3	*Acacia asak*	0.769	average of genus (ICRAF database)	M	
4	*Acacia brevispica*	0.769	>>	M	
5	*Acacia bussei*	0.769	>>	M	
6	*Acacia decurrens*	0.816	Getachew Desalegn et al., 2012	H	Air dry density
7	*Acacia dolichocephala*	0.769	average of genus	M	
8	*Acacia drepanolobium*	0.769	>>	M	
9	*Acacia etbaica*	0.590	Vreugdenhil et al., 2012	H	
10	*Acacia gerrardii*	0.775	Tropical Africa: global database (Zanne et al., 2009)	M	
11	*Acacia goetzei*	0.883	>>	M	
12	*Acacia hokii*	0.769	average of genus (ICRAF database)	M	
13	*Acacia lahai*	0.769	>>	M	
14	*Acacia macrothyrsa*	0.769	>>	M	
15	*Acacia mellifera*	0.482	Vreugdenhil et al., 2012	H	
16	*Acacia mollis*	0.482	Vreugdenhil et al., 2012	H	
17	*Acacia nilotica*	0.723	Vreugdenhil et al., 2012	H	
18	*Acacia oerofota*	0.769	average of genus	M	
19	*Acacia pentagon*	0.826	average of genus (ICRAF database)	M	
20	*Acacia polyacantha*	0.769	average of genus	M	
21	*Acacia reficiens*	0.769	>>	M	
22	*Acacia robusta*	0.769	>>	M	
23	*Acacia senegal*	0.741	Vreugdenhil et al., 2012	H	
24	*Acacia seyal*	0.497	Vreugdenhil et al., 2012	H	
25	*Acacia sieberiana*	0.769	average of genus	M	
26	*Acacia tortilis*	0.590	Vreugdenhil et al., 2012	H	
27	*Acacia xiphocarpa*	0.769	average of genus	M	
28	*Acacia Zanzibarica*	0.769	average of genus	M	
29	*Acallypha acrogyna*	0.300	A. Cauturus (Zanne et al.; global database),	L	
30	*Acanthus sp.*	0.592	Global database (Zanne et al., 2009)	M	
31	*Acokanthera schimperi*	0.784	*Acokanthera oppositifolia (from Global database)*	L	
32	*Acrocarpus fraxinifolius*	0.610	Getachew Desalegn et al., 2012	H	air dry density
33	*Adansonia digitata*	0.590	Vreugdenhil et al., 2012	H	
34	*Adathada schimperiana*	0.640	same species from wood density for trees of Uganda	L	

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35	*Alangium chinense*	0.420	http://db.worldagroforestry.org//wd/species/Alangium_chinense	M	
36	*Alangium Chinese*	0.408	>>	M	
37	*Albizia aylemeri*	0.579	Genus average	M	
38	*Albizia glaberiima*	0.555	http://db.worldagroforestry.org//wd/species/Alangium_chinense	M	
39	*Albizia grandibracteata*	0.534	Albizia gummifera	L	
40	*Albizia gummifera*	0.580	Getachew Desalegn et al., 2012	H	air dry density
41	*Albizia lebbeck*	0.596	http://db.worldagroforestry.org//wd/species/Alangium_chinense	M	
42	*Albizia lophantha*	0.579	Genus average	M	
43	*Albizia malacophylla*	0.579	Genus average	M	
44	*Albizia schimperiana*	0.530	Getachew Desalegn et al., 2012	H	air dry density
45	*Alchernea laxiflora*	0.525	*A. hirtella;* Zanne et al.*; global database*	L	
46	*Alchornea euphorbiacae*	0.525	>>	L	
47	*Alihornea euphorbiscara*	0.525	>>	L	
48	*Allophylus abyssinicus*	0.580	Getachew Desalegn et al., 2012	H	air dry density
49	*Allophylus abyssinicus*	0.491	Vreugdenhil et al., 2012	H	
50	*Allophylus rubifolius*	0.494	Genus average	M	
51	*Alstonia boonei*	0.387	http://db.worldagroforestry.org//wd/species/Alstonia_boonei	L	
52	*Annona crassiflora*	0.400	http://db.worldagroforestry.org//wd/species/Alstonia_boonei	L	
53	*Anogeissus leiocarpa*	0.880	>>	L	
54	*Antialis toxicalia*	0.432	*Antiaris africana*;	L	
55	*Antiaris toxicaria*	0.470	Getachew Desalegn et al., 2012	H	air dry density
56	*Apodytes dimidiata*	0.610	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
57	*Apodytes dimidiata*	0.710	Getachew Desalegn et al., 2012	H	air dry density
58	*Argomaellera maerophylla*	0.640	Wood density of trees of Uganda	L	
59	*Arundinaria alpine*	0.630	Getachew Desalegn et al., 2067	H	air dry density
60	*Azadirachta indica*	0.728	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
61	*Balanites aegyptiaca*	0.542	Vreugdenhil et al., 2012	H	
62	*Balanites glabra*	0.684	Genus average	M	
63	*Baphia abyssinica*	0.559	*B. Nitida (global database: Zanne et al., 2009)*	L	
64	*Berberis holstii*	0.641	Genus average	M	
65	*Berchemia discolor*	0.895	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
66	*Bersama abyssinica*	0.671	http://db.worldagroforestry.org//wd/genus/Bersama_&_also_global database	H	
67	*Blighia unijugata*	0.700	Getachew Desalegn et al., 2012	H	air dry density
68	*Blighia unijugata*	0.564	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
69	*Boswellia hildebrandtii*	0.500	Boswellia sp	L	
70	*Boswellia microphylla*	0.500	>>	L	

71	*Boswellia neglecta*	0.500	>>	L	
72	*Boswellia papyrifera*	0.500	>>	L	
73	*Boswellia rivae*	0.500	>>	L	
74	*Boswellia sp*	0.500	*Boswellia serrata (FAO data)*	L	
75	*Bridelia cathartica*	0.587	Genus average	M	
76	*Bridelia micrantha*	0.540	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
77	*Brucea antidysenterica*	0.640	Wood density of Trees of Uganda	L	
78	*Buddleia polystachya*	0.400	Vreugdenhil et al., 2012	H	
79	*Caesalpinia trothae*	0.951	Genus average	M	
80	*Caesalpinia volkensii*	0.951	http://db.worldagroforestry.org//wd/genus/Caesalpinia) Genus average	M	
81	*Callistemon citrinus*	0.951	>>	M	
82	*Calotropis procera*	0.794	Genus average	M	
83	*Canthium euryoides*	0.643	Genus average	M	
84	*Canthium giordanii*	0.643	Genus average	M	
85	*Canthium oligocarpum*	0.643	*Genus average*	M	
86	*Canthium setiglarum*	0.643	Genus average	M	
87	*Capparis cartilagenia*	0.691	Genus average	M	
88	*Capparis micrantha*	0.691	Genus average	M	
89	*Capsicum conicum*	0.482	Vreugdenhil et al., 2012	H	
90	*Carissa edulis*	0.650	*Carissa spinarium* http://www.hindawi.com/journals/tswj/2012/790219/tab1/	L	
91	*Cassia didymobotrya*	0.745	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
92	*Cassia sinqueana*	0.706	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
93	*Cassipourea malosana*	0.673	Genus average	M	
94	*Casuarina equisetifolia*	0.766	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
95	*Catha edulis*	0.658	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
96	*Celtis africana*	0.745	http://db.worldagroforestry.org//wd/species/Celtis_africana	M	
97	*Celtis africana*	0.760	Getachew Desalegn et al., 2012	H	air dry density
98	*Celtis kranssiana*	0.604	Genus average	M	
99	*Celtis philippinensis*	0.611	http://db.worldagroforestry.org//wd	M	
100	*Celtis zenkeri*	0.59	FAO database	M	
101	*Chaionanthus mildbraedii*	0.705	Average Chionanthus	L	
102	*Citrus aurantifolia*	0.699	Genus average	M	
103	*Citrus aurantium*	0.699	Genus average	M	
104	*Citrus grandis*	0.590	http://db.worldagroforestry.org//wd	M	
105	*Citrus medica*	0.770	http://db.worldagroforestry.org//wd	M	
106	*Citrus meolica*	0.699	Genus average	M	
107	*Citrus reticulata*	0.699	Genus average	M	
108	*Citrus sinensis*	0.699	Genus average	M	

109	*Clausena anisata*	0.482	http://db.worldagroforestry.org//wd/species/Clausena_anisata	M	
110	*Clematis hirsuta*	0.526	Genus average	M	
111	*Coffea arabica*	0.620	http://db.worldagroforestry.org//wd/species/Coffea_arabica	M	
112	*Combretum aculeatum*	0.474	Vreugdenhil et al., 2012	H	
113	*Combretum binderianum*	0.880	http://db.worldagroforestry.org//wd/species	M	
114	*Combretum colinum*	0.590	Vreugdenhil et al., 2012	H	
115	*Combretum ghasalense*	0.845	http://db.worldagroforestry.org//wd/species	M	
116	*Combretum molle*	0.482	Vreugdenhil et al., 2012	H	
117	*Combretum voldensii*	0.845	http://db.worldagroforestry.org//wd/species	M	
118	*Commiphora africana*	0.276	http://db.worldagroforestry.org//wd/species	M	
119	*Commiphora africana*	0.482	Vreugdenhil et al., 2012	H	
120	*Commiphora alaticaulis*	0.389	http://db.worldagroforestry.org//wd/species	M	
121	*Commiphora billia*	0.389	http://db.worldagroforestry.org//wd/species	M	
122	*Commiphora bioviniana*	0.646	http://db.worldagroforestry.org//wd/species	M	
123	*Commiphora boranensis*	0.389	Genus average	M	
124	*Commiphora bruceau*	0.389	Genus average	M	
125	*Commiphora confusa*	0.389	Genus average	M	
126	*Commiphora ellenbeckii*	0.389	Genus average	M	
127	*Commiphora erlangeriana*	0.389	Genus average	M	
128	*Commiphora erythraea*	0.389	Genus average	M	
129	*Commiphora habessinica*	0.389	Genus average	M	
130	*Commiphora ogadensis*	0.389	Genus average	M	
131	*Commiphora schimperi*	0.389	Genus average	M	
132	*Commiphora sphaerophylla*	0.389	Genus average	M	
133	*Commiphora tenuis*	0.389	Genus average	M	
134	*Cordia africana*	0.482	http://db.worldagroforestry.org//wd/species/Cordia_africana	M	
135	*Cordia africana*	0.410	Getachew Desalegn et al., 2012	H	air dry density
136	*Cordia allliodora*	0.390	Getachew Desalegn et al., 2012	H	air dry density
137	*Cordia monoica*	0.482	Vreugdenhil et al., 2012	H	
138	*Cordia ovalis*	0.544	Genus average	M	
139	*Crasocephalum montuosum*	0.331	*C. Manii*	M	
140	*Crassocephalus montus*	0.331	*C. Manii*	M	
141	*Croton dichogamus*	0.525	Genus average	M	
142	*Croton macrostachyus*	0.518	http://db.worldagroforestry.org//wd/species/Croton_macrostachyus	M	
143	*Croton macrostachyus*	0.560	Getachew Desalegn et al., 2012	H	air dry density
144	*Cupressus lusitanica*	0.430	Getachew Desalegn et al., 2012	H	air dry density
145	*Cussonia holstii*	0.409	Genus average	M	
146	*Cussonia ostinii*	0.409	Genus average	M	

147	*Dalbergia boehmii*	0.821	Genus average	M	
148	Dalbergia melanoxylon	0.728	Vreugdenhil et al., 2012	H	
149	*Dichrostachys cinerea*	*0.482*	*Vreugdenhil et al., 2012*	H	
150	*Diospyros abyssinica*	*0.790*	*Getachew Desalegn et al., 2012*	H	*air dry density*
151	*Diospyros mespiliformis*	*0.758*	*Genus average*	M	
152	*Discopodium penninervium*	*0.482*	*Vreugdenhil et al., 2012*	H	
153	Dodonaea angustifolia	1.040	*http://db.worldagroforestry.org//wd/species*	M	
154	Dombeya bruceana	0.580	Genus average	M	
155	Dombeya quenguesta	0.580	Genus average	M	
156	Dombeya torrida	0.451	Vreugdenhil et al., 2012	H	
157	Dombeya torrida	0.588	*http://db.worldagroforestry.org//wd/species*	M	
158	Dovyalis abyssinica	0.579	*http://db.worldagroforestry.org//wd/species*	M	
159	Dracaena afromontane	0.418	Genus average	M	
160	Dracaena fragrans	0.418	genus average *(http://db.worldagroforestry.org//wd/genus/Dracaena)*	M	
161	Dracaena steudneri	0.418	>>	M	
162	Ehretia cymosa	0.560	http://globalspecies.org/ntaxa/2529407	L	
163	Ehretia cymosa	0.484	*http://db.worldagroforestry.org//wd/species*	M	
164	Ekebergia capensis	0.580	Getachew Desalegn et al., 2012	H	air dry density
165	Embelia schimperi	0.775	Embelia oleifera	L	
166	Erica arborea	0.357	Vreugdenhil et al., 2012	H	
167	Erythrina abyssinica	0.426	http://db.worldagroforestry.org//wd/species/Erythrina_abyssinica	M	
168	Erythrina brucei	0.314	Genus average *http://db.worldagroforestry.org//wd/genus/Erythrina*	M	
169	Erythrococca abyssinica	0.58	Average of tropical Africa	L	
170	Erythrococca Kirkii	0.58	Average of tropical Africa	L	
171	Erythrococca trichogynol	0.58	Average of tropical Africa	L	
172	Erythroxylum fisherriii	0.802	Average Genus *(http://db.worldagroforestry.org//wd/genus/Erythroxylum)*	M	
173	Eucalyptus camaldulensis	0.853	Getachew Desalegn et al., 2012	H	air dry density
174	Eucalyptus citriodora	0.830	*http://db.worldagroforestry.org//wd/species*	M	
175	Eucalyptus deanei	0.570	Getachew Desalegn et al., 2012	H	air dry density
176	Eucalyptus deglupta	0.410	Getachew Desalegn et al., 2012	H	air dry density
177	Eucalyptus delegatensis	0.530	Getachew Desalegn et al., 2012	H	air dry density
178	Eucalyptus dunii	0.610	Getachew Desalegn et al., 2012	H	air dry density
179	Eucalyptus fastigata	0.650	Getachew Desalegn et al., 2012	H	air dry density
180	Eucalyptus globulus	0.780	Getachew Desalegn et al., 2012	H	air dry density
181	Eucalyptus grandis	0.560	Getachew Desalegn et al., 2012	H	air dry density

182	Eucalyptus grandis	0.665	http://db.worldagroforestry.org//wd/species	M	
183	Eucalyptus microcorys	0.860	Getachew Desalegn et al., 2012	H	air dry density
184	Eucalyptus nitens	0.760	Getachew Desalegn et al., 2012	H	air dry density
185	Eucalyptus obliqua	0.670	Getachew Desalegn et al., 2012	H	air dry density
186	Eucalyptus paniculata	0.830	Getachew Desalegn et al., 2012	H	air dry density
187	Eucalyptus pilularis	0.948	Getachew Desalegn et al., 2012	H	air dry density
188	Eucalyptus regnans	0.480	Getachew Desalegn et al., 2012	H	air dry density
189	Eucalyptus saligna	0.680	Getachew Desalegn et al., 2012	H	air dry density
190	Eucalyptus viminalis	0.670	Getachew Desalegn et al., 2012	H	air dry density
191	Euclea schimperi	0.741	http://db.worldagroforestry.org//wd/species/Erythrina_abyssinica	M	
192	Euphorbia abyssinica	0.471	http://db.worldagroforestry.org//wd/species	M	
193	Euphorbia candelabrum	0.471	genus average	M	
194	Euphorbia sp.	0.314	Vreugdenhil et al., 2012	H	
195	Euphorbia tirucallii	0.471	genus average	M	
196	Fagaropsis angolensis	0.700	Getachew Desalegn et al., 2012	H	air dry density
197	Faurea saligna	0.704	http://db.worldagroforestry.org//wd/species	M	
198	Ficus brachypoda	0.441	http://db.worldagroforestry.org//wd/species	M	
199	Ficus elastica	0.607	http://db.worldagroforestry.org//wd/species	M	
200	Ficus exasperata	0.377	http://db.worldagroforestry.org//wd/species	M	
201	Ficus gnaphalocarpa	0.441	Genus average	M	
202	Ficus mucuso	0.441	Average Ficus (http://db.worldagroforestry.org//wd/genus/Ficus)	M	
203	Ficus oxata	0.441	>>	M	
204	Ficus sp.	0.482	Vreugdenhil et al., 2012	H	
205	Ficus sur	0.441	http://globalspecies.org/ntaxa/869708	L	
206	Ficus sycomorus	0.422	http://globalspecies.org/ntaxa/869708	L	
207	Ficus sycomorus	0.482	Vreugdenhil et al., 2012	H	
208	Ficus thonningii	0.432	http://globalspecies.org/ntaxa/911819	M	
209	Ficus vasta	0.441	Average Ficus (http://db.worldagroforestry.org//wd/genus/Ficus)	M	
210	Filicium decipiens	0.960	http://db.worldagroforestry.org//wd/species	M	
211	Flacourtia indica	0.778	http://db.worldagroforestry.org//wd/species	M	
212	Flueggea virosa	0.770	Genus average	M	
213	Foeniculum vulgare	0.58	Average of tropical Africa	L	
214	Galiniera saxifraga	0.399	Vreugdenhil et al., 2012	H	
215	Gardenia ternifolia	0.672	Genus average	M	
216	Gardenia volkensii	0.571	Vreugdenhil et al., 2012	H	
217	Grevillea robusta	0.530	Getachew Desalegn et al., 2012	H	air dry density
218	Grewia auriculifera	0.583	http://db.worldagroforestry.org//wd/species	M	
219	Grewia bicolor	0.456	Vreugdenhil et al., 2012	H	

220	*Grewia ferruginea*	0.583	Genus average	M	
221	*Grewia flavescens*	0.583	Genus average	M	
222	*Grewia mollis*	0.583	Genus average	M	
223	*Grewia tembensis*	0.583	Genus average	M	
224	*Grewia tenax*	0.583	Genus average	M	
225	*Grewia trichocarpa*	0.583	Genus average	M	
226	*Grewia villosa*	0.482	Vreugdenhil et al., 2012	H	
227	*Hagenia abyssinica*	0.591	http://db.worldagroforestry.org//wd/species/Hagenia_abyssinica	M	
228	*Hagenia abyssinica*	0.560	Getachew Desalegn et al., 2012	H	air dry density]
229	*Halleria lucida*	0.715	http://db.worldagroforestry.org//wd/species	M	
230	*Haplocoelum foliolosum*	0.788	http://db.worldagroforestry.org//wd/species	M	
231	*Heteromorpha trifoliata*	0.58	Average of tropical Africa	L	
232	*Hildebrandtia africana*	0.58	Average of tropical Africa	L	
233	*Hippocratae africana*	0.876	H. maingayi	L	
234	*Hippocratea macrophylla*	0.876	H. maingayi	L	
235	*Hippocratea pallens*	0.876	H. maingayi	L	
236	*Hypericum revolutum*	0.726	Genus average	M	
237	*Ilex mitis*	0.466	Vreugdenhil et al., 2012	H	
238	*Indigofera garekeana*	0.580	Average of tropical Africa	L	
239	*Jasminum abyssinicum*	0.580	Average of tropical Africa	L	
240	*Juniperus procera*	0.628	http://db.worldagroforestry.org//wd/genus/Juniperus	M	
241	*Juniperus procera*	0.540	Getachew Desalegn et al., 2012	H	air dry density]
242	*Justicia schimperiana*	0.580	Average of tropical Africa	L	
243	*Kigelia eethopun*	0.661	http://db.worldagroforestry.org//wd/genus	M	
244	*Kirkia burgeri*	0.661	>>	M	
245	*Lannea fruticosa*	0.515	http://db.worldagroforestry.org//wd/genus	M	
246	*Lannea schimperi*	0.515	Genus average	M	
247	*Lannea stuhlmannii*	0.515	>>	M	
248	*Lannea welwitschii*	0.405	http://db.worldagroforestry.org//wd/species/Lannea_welwitschii	M	
249	*Lantana trifolia*	0.58	Average of tropical Africa	L	
250	*Lecaniodiscus fraxinifolius*	0.405	>>	L	
251	*Lecaniodiscus laxiflorus*	0.405	>>	L	
252	*Lepidotrichilia volkensii*	0.58	Average of tropical Africa	L	
253	*Lippia citriodora*	0.700	*Lippia mcvaughii*	L	
254	*Lippia javanica*	0.700	>>	L	
255	*Lippia spp.*	0.700	>>	L	
256	*Lonchocarpus laxiflorus*	0.761	genus average	M	
257	*Lonicera johnstonii*	0.58	Average of tropical Africa	L	

258	*Lycium europaeum*	0.58	Average of tropical Africa	L	
259	*Macaranga capenesis*	0.416	global database	M	
260	*Macaranga kilimandscharica*	0.404	Genus average (http://db.worldagroforestry.org//wd/genus/Macaranga)	M	
261	*Maerua angolensis*	0.58	Average of tropical Africa	L	
262	*Maerua calophylla*	0.58	Average of tropical Africa	L	
263	*Maerua crassifolia*	0.58	Average of tropical Africa	L	
264	*Maesa lanceolata*	0.676	Genus average (http://db.worldagroforestry.org//wd/genus	M	
265	*Magnifera indica*	0.630	Wood density of trees of Uganda	L	
266	*Malacantha alnifolia*	0.450	http://db.worldagroforestry.org//wd/genus/Malacantha	M	
267	*Manilkara butugi*	0.880	Getachew Desalegn et al., 2012	H	air dry density]
268	*Manilkora butugi*	0.953	Average Genus, Africa	M	
269	*Maytenus addat*	0.713	Genus average(http://db.worldagroforestry.org//wd/genus/Maytenus)	M	
270	*Maytenus arbutifolia*	0.713	Genus average(http://db.worldagroforestry.org//wd/genus/Maytenus)	M	
271	*Maytenus auriculifera*	0.713	Genus average(http://db.worldagroforestry.org//wd/genus/Maytenus)	M	
272	*Maytenus gracilipes*	0.713	Average Genus, Africa	M	
273	*Maytenus heterophylla*	0.495	http://db.worldagroforestry.org//wd/genus	M	
274	*Maytenus ovatus*	0.403	Vreugdenhil et al., 2012	H	
275	*Maytenus senegalensis*	0.713	http://db.worldagroforestry.org//wd/genus	M	
276	*Maytenus undatus*	0.732	http://db.worldagroforestry.org//wd/genus	M	
277	*Melacantha alnifolia*	0.620	Average Genus, Africa	M	
278	*Melia azedarach*	0.463	http://db.worldagroforestry.org//wd/genus	M	
279	*Milicia excelsa*	0.570	Getachew Desalegn et al., 2012	H	air dry density]
280	*Millettia ferruginea*	0.738	Average Millettia, Africa	M	
281	*Mimusops kummel*	0.856	Average, Africa (http://db.worldagroforestry.org//wd/genus/Mimusops)	M	
282	*Mimusops kummel*	0.880	Getachew Desalegn et al., 2012	H	air dry density]
283	*Mimusops kummel*	0.482	Vreugdenhil et al., 2012	H	
284	*Moringa oleifera*	0.262	http://db.worldagroforestry.org//wd/genus	M	
285	*Moringa stenopetala*	0.262	http://db.worldagroforestry.org//wd/genus	M	
286	*Morus alba*	0.622	http://db.worldagroforestry.org//wd/genus	M	

287	*Morus mesozygia*	0.722	http://db.worldagroforestry.org//wd/species/Morus_mesozygia	M	
288	*Morus mesozygia*	0.690	Getachew Desalegn et al., 2012	H	air dry density]
289	*Myenus reticulata*	0.58	Average of tropical Africa	L	
290	*Myrica salicifolia*	0.618	http://db.worldagroforestry.org//wd/species	M	
291	*Myrsine africana*	0.721	http://db.worldagroforestry.org//wd/species	M	
292	*Myrsine melanophloeos*	0.732	http://db.worldagroforestry.org//wd/species	M	
293	*Mystroxylon aethiopicum*	0.58	Average of tropical Africa	L	
294	*Nuxia congesta*	0.512	Vreugdenhil et al., 2012	H	
295	*Ocotea kenyensis*	0.545	Genus average	M	
296	*Ocotea kenyensis*	0.560	Getachew Desalegn et al., 2012	H	air dry desnity
297	*Ocotea viridis*	0.545	Genus average	M	
298	*Olea africana*	0.590	Vreugdenhil et al., 2012	H	
299	*Olea capensis*	0.805	http://db.worldagroforestry.org//wd/species/Olea_capensis	M	
300	*Olea capensis*	0.990	Getachew Desalegn et al., 2012	H	air dry density]
301	*Olea europaea*	0.807	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
302	*Olea hochstetteri*	0.800	Genus average	M	
303	*Olea welwitschii*	0.814	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
304	*Olea welwitschii*	0.820	Getachew Desalegn et al., 2012	H	air dry density]
305	*Olinia rochetiana*	0.768	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
306	*Olinia Usamberansis*	0.825	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
307	*Oncoba spinosa*	0.647	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
308	*Opilia campestris*	0.58	Average of tropical Africa	L	
309	*Ormocarpum mimosoides*	0.742	*Ormocarpum kirkii*	L	
310	*Osryia lanceolata*	0.854	*Osyris arborea*	L	
311	*Osyris compressa*	0.854	*Osyris arborea*	L	
312	*Osyris wightiana*	0.854	>>	L	
313	*Otestegia steudneri*	0.58	Average of tropical Africa	L	
314	*Oxyanthus sp.*	0.525	Genus value	M	

315	*Oxyanthus speciosus*	0.525	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
316	*Oxytenanthera abyssinica*	0.608	Getachew Desalegn et al., 2012	H	air dry density]
317	*Ozoroa insignis*	0.715	*Ozoroa longipetiolata*	L	
318	*Ozoroa pulcherrima*	0.715	>>	L	
319	*Pappea capensis*	0.883	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
320	*Persea americana*	0.561	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
321	*Peterocarpus lucens*	0.58	Average of tropical Africa	L	
322	*Piliostigma thonningii*	0.371	Vreugdenhil et al., 2012	H	
323	*Pinus patula*	0.450	Getachew Desalegn et al., 2012	H	air dry density]
324	*Pinus radiata*	0.450	Getachew Desalegn et al., 2012	H	air dry density]
325	*Pistacia falcata*	0.720	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
326	*Pistacia lentiscus*	0.720	Genus average	M	
327	*Pittosporum abyssinicum*	0.645	Genus average (http://db.worldagroforestry.org//wd/species/Pittosporum_abyssinicum)	M	
328	*Pittosporum viridiflorum*	0.633	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	air dry density]
329	*Podocarpus falcatus*	0.523	Genus average (http://db.worldagroforestry.org//wd/genus/Podocarpus)	M	
330	*Podocarpus falcatus*	0.520	Getachew Desalegn et al., 2012	H	air dry density]
331	*Polyscias ferruginea*	0.286	http://db.worldagroforestry.org//wd/species/Polyscias_ferruginea	M	
332	*Polyscias fulva*	0.440	Getachew Desalegn et al., 2012	H	air dry density]
333	*Polyscious ferrogenia*	0.38	*Polyscias nodosa*	L	
334	*Pouteria adolfi-friederici*	0.600	Getachew Desalegn et al., 2012	H	air dry density]
335	*Pouteria abyssinica*	0.711	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
336	*Pouteria altissima*	0.442	http://db.worldagroforestry.org//wd/species/Pouteria_altissima	M	
337	*Premna schimperi*	0.658	Average Genus (http://db.worldagroforestry.org//wd/genus/Premna)	M	
338	*Prosopis juliflora*	0.827	Getachew Desalegn et al., 2012	H	air dry density]
339	*Protea gaguedi*	0.663	*Protea angolensis*	L	
340	*Prunus africana*	0.850	Getachew Desalegn et al., 2012	H	air dry density]

341	*Prunus persica*	0.588	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
342	*Pseudocedrela kotschyi*	0.621	http://db.worldagroforestry.org//wd/species/Pouteria_altissima	M	
343	*Psidium guajava*	0.859	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
344	*Psydrax schimperiana*	0.743	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
345	*Pterolobium stellatum*	0.58	Average of tropical Africa	L	
346	*Rabus steudneri*	0.58	Average of tropical Africa	L	
347	*Rapanea melanophixas*	0.732	http://db.worldagroforestry.org//wd/species/Pouteria_altissima	M	
348	*Rapanea simensis*	0.722	genus average	L	
349	*Rhamnus prinoides*	0.579	genus average	L	
350	*Rhamnus sp.*	0.579	Genus average	L	
351	*Rhinorea friisii*	0.689	*R. ferruginea*	L	
352	*Rhinorea laxiflora*	0.689	*R. ferruginea*	L	
353	*Rhoicissus tridentala*	0.538	*R. revoilii*	L	
354	*Rhus glutinosa*	0.620	genus average	M	
355	*Rhus natalensis*	0.620	genus average	M	
356	*Rhus retinorrhoea*	0.620	genus average	M	
357	*Rhus vulgaris*	0.620	genus average	M	
358	*Rothmania urcelliformis*	0.642	Africa (extratropical): global database	L	
359	*Rothmannia whitfieldii*	0.745	*R. Fischeri: global database*	L	
360	*Rubus steudneri*	0.350	*Rubus alceifolius: global database*	L	
361	*Rumex nervousus*	0.58	Average of tropical Africa	M	
362	*Salix subserata*	0.525	http://db.worldagroforestry.org//wd/species/Sapium_ellipticum	M	
363	*Sapium ellipticum*	0.576	http://db.worldagroforestry.org//wd/species/Sapium_ellipticum	M	
364	*Schefflera abyssinica*	0.405	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
365	*Schefflera abyssinica*	0.491	Vreugdenhil et al., 2012	H	
366	*Schefflera volkensii*	0.405	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
367	*Scherebera alata*	0.790	Uganda data	M	

368	*Sclerocarya birrea*	0.515	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
369	*Securidaca longepedunculata*	0.880	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
370	*Securindaca virosa*	0.880	*Securidaca longepedunculata*	L	
371	*Senna singueana*	0.706	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
372	*Sideroxylon oxyacantha*	0.715	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
373	*Sideroxylon sp.*	0.715	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
374	*Solanum incanum*	0.428	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
375	*Spathodea nilotica*	0.504	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
376	*Steganotaenia araliacea*	0.370	Uganda data	M	
377	*Sterculia africana*	0.482	Vreugdenhil et al., 2012	H	
378	*Sterculia setigera*	0.320	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
379	*Stereospermum kunthianum*	0.741	Vreugdenhil et al., 2012	H	
380	*Strychnos innocua*	0.870	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
381	*Strychnos mitis*	0.733	http://db.worldagroforestry.org//wd/genus/Strychnos	M	
382	*Strychnos spinosa*	0.733	genus average	M	
383	*Syzygium guineense*	0.712	http://db.worldagroforestry.org//wd/genus/Syzygium	M	
384	*Syzygium guineense*	0.740	Getachew Desalegn et al., 2012	H	air dry density]
385	*Tamarindus indica*	0.624	Vreugdenhil et al., 2012	H	
386	*Tapura fisherii*	0.660	Genus average: global database	M	
387	*Teclea nobilis*	0.798	http://db.worldagroforestry.org//wd/genus/Teclea	M	
388	*Teclea simplicifolia*	0.798	*Teclea nobilis*	L	
389	*Terminalia laxiflora*	0.654	genus average	M	
390	*Terminalia brownii*	0.654	Average of genus (http://db.worldagroforestry.org//wd/genus/Terminalia)	M	
391	*Terminalia brownii*	0.495	Vreugdenhil et al., 2012	H	
392	*Terminalia laxiflora*	0.574	Vreugdenhil et al., 2012	H	
393	*Terminalia macroptera*	0.819	http://db.worldagroforestry.org//wd/genus/Teclea	M	
394	*Terminalia mollis*	0.654	genus average	M	

395	*Terminalia prundioides*	0.654	genus average	M	
396	*Terminalia schimperiana*	0.654	genus average	M	
397	*Terminalia sopinos*	0.654	genus average	M	
398	*Thunbergia alata*	0.640	Uganda data	M	
399	*Toddalia asiatica*	0.798	*Toddalia nobilis*	L	
400	*Trema guineensis*	0.366	genus average	M	
401	*Trema orientalis*	0.366	genus average	M	
402	*Trichilea prieuriana*	0.647	http://db.worldagroforestry.org//wd/species/Trichilia_prieuriana	M	
403	*Trichilia dregeana*	0.482	http://db.worldagroforestry.org//wd/species/Trichilia_prieuriana	M	
404	*Trichilia madagascariense*	0.622	http://db.worldagroforestry.org//wd/species/Trichilia	M	
405	*Trichilia pouerianu*	0.622	http://db.worldagroforestry.org//wd/species/Trichilia	M	
406	*Trichocladus ellipticus*	0.640	Uganda data	M	
407	*Trilepisium madagariense*	0.499	http://db.worldagroforestry.org//wd/species/Trilepisium_madagariense	M	
408	*Trilepisium madagascariense*	0.560	Getachew Desalegn et al., 2012	H	
409	*Urera hypselodendron*	0.324	average of genus (http://db.worldagroforestry.org//wd/genus/Urera)	M	air dry density
410	*Vepris dainellii*	0.700	*Vepris undulate*	L	
411	*Vernonia amygdalina*	0.413	average (http://db.worldagroforestry.org//wd/genus/Vernonia)	M	
412	*Vernonia auriclifera*	0.413	average (http://db.worldagroforestry.org//wd/genus/Vernonia)	M	
413	*Warburgia ugandensis*	0.865	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
414	*Warburgia ugandensis*	0.770	Getachew Desalegn et al., 2012	H	air dry density]
415	*Ximenia americana*	0.867	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
416	*Ximenia caffra*	0.812	genus average	M	
417	*Zanthoxylum chalybeum*	0.629	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
418	*Ziziphus mauritania*	0.711	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
419	*Ziziphus mucronata*	0.758	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	

| 420 | *Ziziphus spina-christi* | 0.482 | Vreugdenhil et al., 2012 | H | |

* data quality refers to author's personal judgement of the goodness of the woo density value depending on whether they are locally relevant or not. L = low; M = medium and H = high quality.

Annex 3. Global and Tropical Africa average wood density values

Wood basic density (g/cm3)	SD	Sample size	Applicable	Source
0.613		2482	Global	Chave et al., 2014
0.598	0.16	2482	Tropical Africa	Chave et al., 2009
0.580		282	Africa	(http://www.fao.org/docrep/w4095e/w4095e06.htm)
0.580		ND	Africa - broadleaves	Brown and Lugo (1984)
0.450		ND	Africa-coniferous species	Brown and Lugo (1984)
0.620		ND	Global	IPPCC, 2006

Annex 4. DBH measurement of trees in the dry afromontane forest of Munessa Shashamane (plot size was 1.0 ha)

							Plot no								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
x	685987	686000	685000	686946	684996	683000	684867	684924	687019	524020	518934	829145	687135	689345	582396
y	833049	832000	830990	533272	829984	830000	825006	822497	825963	766784	760944	685062	833423	836365	801871
1	24.0	60.0	20	27	18	27	30.0	55.0	39	136	95.0	22.0	21.0	27.0	38.0
2	38.0	25.5	21	47	14.5	24.5	25.0	40.0	27.5	32.0	21.0	22.0	20.0	19.0	55.0
3	23.0	20.0	29	28	14	28.5	22.0	62.0	20	19.0	91.0	37.0	34.0	34.0	19.0
4	31.0	106.0	24	50	10	29.5	23.0	37.0	21.5	25.0	96.0	56.0	43.0	22.0	29.0
5	60.0	46.0	40	37	10	33	37.0	22.4	20.5	37.0	39.0	33.0	22.0	29.0	53.0
6	25.0	20.0	35	28	11	31.5	31.0	30.0	34.5	26.0	57.0	25.0	51.0	28.0	26.0
7	41.0	98.0	25	24	20	35	32.0	35.0	21.5	111.0	97.0	23.0	26.0	31.0	33.0
8	28.0	33.5	25	41.5	32	48.5	38.0	21.0	23	19.0	88.0	25.0	28.0	50.0	46.0
9	30.0	20.0	20	27.1	12	45.5	25.0	21.0	39	83.0	79.0	27.0	16.0	39.0	31.0

10	31.0	20.5	27	23	19	40	21.0	36.0	22	55.0	32.0	20.0	38.0	15.0	23.0
11	49.0	20.0	28	40.7	12	20	26.0	36.5	23	72.0	87.0	26.0	18.0	50.0	57.0
12	42.0	21.5	28	32.3	12	20	45.0	45.0	36.5	132.0	89.0	43.0	19.0	43.0	28.0
13	24.0	30.0	23	33	17	22	28.0	42.0	24	77.0	15.0	23.0	20.0	21.0	40.0
14	42.0	32.5	25	44	17	44	54.0	23.0	45	21.0	15.0	44.0	36.0	50.0	23.0
15	40.0	21.0	26	47.5	21	22	51.0	35.0	42	45.0	83.0	55.0	47.0	18.0	26.0
16	40.0	61.0	21	29	12	32	65.0	23.0	20	32.0	63.0	28.0	21.0	67.0	25.0
17	27.0	21.5	25	30.7	21	20	21.0	46.0	26	55.0	32.0	21.0	15.0	33.0	52.0
18	29.0	32.5	21	31	14	25.5	47.0	49.5	41	35.0	49.0	22.0	25.0	41.0	33.0
19	39.0	24.5	21	42	14	24	24.0	59.5	21	97.0	67.0	37.0	18.0	27.0	55.0
20	58.0	27.5	20	33.5	19	20	25.0	26.0	20	102.0	71.0	32.0	41.0	50.0	17.0
21	48.0	31.0	24	24.2	44	30	21.0	21.0	43	72.0	43.0	40.0	15.0	22.0	24.0
22	39.0	30.0	26	26	15	20.5	22.0	39.0	25	21.0	19.0	46.0	40.0	25.0	22.0
23	47.5	47.0	23	39	17	22	25.0	41.0	34	94.0	46.0	52.0	48.0	83.0	19.0
24	29.0	20.0	23	23.6	34	27	10.0	21.0	21	84.0	33.0	42.0	27.0	30.0	36.0
25	39.1	24.0	30	47	25	31	10.0	28.0	20	125.0	39.0	33.0	18.0	38.0	39.0
26	45.0	21.0	34	28	54	20	12.0	41.0	25	103.0	20.0	22.0	37.0	91.0	42.0
27	29.0	23.0	26	36.7	32	27	13.0	30.0	20.5	54.0	56.5	25.0	47.0	15.0	42.0
28	22.0	42.0	36	24.8	17	50	11.0	42.0	39	107.0	21.0	21.0	41.0	17.0	18.0
29	38.0	26.0	37	45	36	28	10.0	24.0	31	28.0	34.0	41.0	26.0	49.0	17.0
30	51.0	21.5	36	30	14	44	10.0	22.0	23	24.0	86.0	37.0	17.0	50.0	65.0
31	23.0	33.0	42	38.6	11	20	15.0	40.0	29	11.0	44.0	33.0	33.0	25.0	48.0
32	47.0	56.0	37	49	13	35	22.0	22.0	45.5	27.0	62.7	20.0	21.0	29.0	22.0
33	38.8	21.0	29	46	14	22	15.0	25.0	29	31.0	41.0	25.5	15.0	41.0	25.0
34	20.0	79.6	34	33	20	24	18.0	24.0	25	200.0	36.0	43.0	29.0	33.0	16.0
35	21.0	32.5	23	47.4	11	22	14.0	42.0	23	28.0	26.0	20.0	19.0	50.0	15.0

36	25.0	37.0	39	30	45	20	12.0	42.0	20.5	21.0	30.0	26.0	24.0	42.0	20.0
37	30.0	30.0	31	21.4	16	25	11.0	28.5	23	77.0	93.0	34.0	34.0	41.0	20.0
38	47.0	28.0	38	36	51	22	17.0	21.0	32	26.0	47.0	40.0	42.0	36.0	22.0
39	27.0	26.5	31	27.2	42	20	10.0	38.0	42	50.0	80.4	33.0	27.0	38.0	111.0
40	29.0	26.0	22	43.4	14	22.5	10.0	42.0	33	23.0	106.0	39.0	47.0	36.0	49.0
41	43.0	27.0	23	22	12	28.5	10.0	32.0	40	110.0	27.0	39.0	15.0	50.0	92.0
42	32.0	33.0	20	30	14	31	15.0	21.0	38.5	91.0	50.0	42.0	17.0	18.0	15.0
43	23.0	40.0	31	25	14	20	16.0	20.0	28.5	60.0	82.0	28.0	49.0	26.0	17.0
44	33.0	43.0	32	44.4	14	36	11.0	22.0	27	90.0	36.0	29.0	78.0	21.0	17.0
45	30.0	24.5	24	50	18	20	18.0	33.0	20	70.0	43.0	20.0	23.0	34.0	24.0
46	20.0	50.0	33	44	14	50	15.0	35.0	50	26.0	39.0	21.0	24.0	65.0	33.0
47	30.0	29.0	33	20	14	50	12.0	25.0	30	18.0	34.0	22.0	25.0	49.0	49.0
48	28.0	20.0	38	36.4	35	28	12.0	22.0	33	25.0	78.0	24.5	20.0	25.0	19.0
49	34.0	34.5	40	32	20	20	13.0	37.0	20	128.0	39.0	28.0	26.0	18.0	45.0
50	21.0	31.0	42	23.5	16	44	15.0	14.5	47	32.0	22.0	27.0	21.0	50.0	15.0
51	39.0	30.0	36	40	12	20	10.0	11.0	44	24.0	50.0	48.0	15.0	15.0	29.0
52	34.0	46.0	29	34	27	20	12.0	15.0	37	26.0	65.0	38.0	16.0	76.0	30.0
53	65.0	47.0	36	48	13	21	11.0	10.0	26	24.0	130.0	45.5	40.0	15.0	85.0
54	31.0	20.0	34	24.3	12	20	2.0	10.5	43	118.0	114.0	28.0	33.0	50.0	15.0
55	30.0	37.5	28	27.8	16	49	2.5	10.2	22.5	19.0	117.0	31.5	26.0	16.0	19.0
56	23.0	23.0	26	29.3	23	32	2.0	10.0	24	22.0	104.0	38.0	17.0	82.0	23.0
57	25.0	34.0	36	22	15	21	2.5	10.5	35.5	44.0	34.0	26.0	28.0	15.0	23.0
58	25.0	35.0	36	26	24	22.5	3.5	11.0	22	38.0	30.0	28.5	15.0	66.0	135.0
59	32.0	35.0	36	36	11	30.5	4.0	10.0	33	109.0	32.0	40.0	16.0	54.0	15.0
60	34.0	33.0	39	21	14	21	3.0	16.0	31	27.0	44.0	20.0	15.0	15.0	26.0
61	37.0	24.0	41	26	20	26	2.0	16.0	27	20.0	67.0	21.1	33.0	22.0	90.0

62	40.5	52.0	43	43.2	16	26	3.0	13.0	26.1	20.0	42.0	47.0	21.0	56.0	59.0
63	25.0	42.0	35	32	25	50	3.5	11.0	41	16.0	132.0	51.0	19.0	43.0	107.0
64	28.0	26.0	22	43.6	11	21	3.0	12.0	23	15.0	81.0	49.0	43.0	18.0	15.0
65	46.0	22.0	40	33.3	25	20	3.5	12.0	20	39.0	72.0	45.0	45.0	63.0	22.0
66	35.0	21.0	44	30.3	12	37	3.5	11.0	21	60.0	32.0	27.0	32.0	15.0	24.0
67	60.0	21.0	28	33.8	11	50	3.0	10.5	31	16.0	65.0	43.0	15.0	26.0	15.0
68	28.0	44.0	34	22	13	45	4.0	10.0	40	18.0	119.0	44.5	36.0	25.0	19.0
69	28.0	50.0	27	47.4	15	27	2.5	12.0	36	34.5	76.0	37.0	26.0	15.0	17.0
70	28.0	29.0	39	25.8	12	22	3.0	14.0	33	16.5	20.0	32.0	26.0	36.0	16.0
71	28.0	24.5	35	26	20	22	2.0	11.9	36	32.0	71.1	38.5	22.0	59.0	25.0
72	23.0	32.0	21	33	13	50	2.0	15.0	31	42.0	90.0	39.5	26.0	15.0	20.0
73	47.0	36.0	27	45	33	26.5	2.5	13.0	20	29.0	73.0	22.0	22.0	46.0	18.0
74	58.0	33.0	24	50	59	25	6.0	13.0	31	47.0	42.0	50.0	17.0	50.0	21.0
75	34.0	24.0	27	49	15	20	5.5	17.0	20	125.5	64.0	20.0	16.0	26.0	17.0
76	41.0	57.0	35	22.3	24	25.5	2.5	17.0	32	30.0	72.0	38.0	30.0	37.0	31.0
77	29.0	49.0	27	27	12	22	3.0	11.6	43	55.0	67.0	31.0	50.0	21.0	17.0
78	42.0	31.0	45	20.3	20	50	5.5	12.0	34	32.0	38.0	32.5	20.0	22.0	15.0
79	29.0	28.0	41	50	15	50.5	2.5	10.0	28	55.0	29.0	45.0	47.0	47.0	19.0
80	21.0	34.0	45	43	16	47.5	2.0	14.6	36	31.0	59.0	22.0	50.0	53.0	15.0
81	45.0	20.0	40	24	13	23.5	2.5	12.0	20	19.0	22.0	25.5	40.0	50.0	24.0
82	32.2	30.5	25	38	10	36.5	2.5	10.2	21	18.0	50.0	44.0	22.0	45.0	17.0
83	42.0	46.0	26	41.8	38	63.7	2.0	10.3	39	19.0	26.0	29.9	23.0	16.0	32.0
84	36.0	54.0	36	22.3	22	24	3.5	14.2	35.5	95.5	49.0	26.0	20.0	23.0	35.0
85	45.0	48.0	27	35.6	19	52.5	2.0	16.3	25	21.0	35.0	45.0	23.0	15.0	24.0
86	31.0	35.0	37	25.6	11	28	2.5	11.1	39	31.0	29.0	33.0	18.0	18.0	30.0
87	24.0	32.5	22	50	13	36.5	2.0	10.0	25.9	159.0	84.4	44.0	19.0	17.0	91.0

88	36.0	24.0	27	32.2	28	39	3.0	17.9	40	27.0	44.0	58.5	30.0	67.0	29.0
89	34.0	20.0	35	34	14	35	2.0	16.2	40	99.0	72.0	22.0	29.0	15.0	69.0
90	25.0	31.0	37	23.3	11	39.5	2.0	12.0	22	95.0	84.1	24.0	50.0	17.0	20.0
91	56.0	24.0	35	22	18	38	2.5	12.0	21	26.0	19.0	23.0	33.0	44.0	19.0
92	43.0	30.0	27	26.3	35	20	2.0	12.0	20	16.0	35.0	31.0	24.0	40.0	44.0
93	38.0	41.0	36	22	26	27	2.5	16.0	26	61.0	47.0	29.5	45.0	27.0	19.0
94	34.0	50.0	25	23	18	35.5	4.0	18.0	20	123.0	31.0	22.0	20.0	37.0	20.0
95	26.0	20.0	25	22	16	30	2.5	11.7	38	31.0	29.0	21.5	47.0	33.0	57.0
96	37.0	43.0	24	50	12	40	2.5	12.0	21	51.5	50.0	23.5	28.0	33.0	78.0
97	21.0	28.0	22	24	32	20	2.0	16.3	21	125.0	16.0	30.5	26.0	38.0	19.0
98	20.0	53.0	35	44	16	27.5	2.0	16.5	26	96.0	15.0	36.5	22.0	44.0	21.0
99	53.0	38.0	40	20	14	50	4.0	12.0	21	114.0	27.0	54.5	20.0	20.0	65.0
100	43.0	29.0	20	40.3	12	23	3.0	11.9	50	34.0	60.0	34.5	23.0	36.0	19.0
101	25.0	30.5	24	44.7	21	42	3.0	14.5	45	28.0	114.0	41.0	17.0	42.0	87.0
102	27.0	20.0	29	22	11	20	2.0	12.5	26	18.0	108.0	35.5	16.0	65.0	16.0
103	37.0	33.0	25	21.2	17	33	2.5	12.0	30	36.0	56.0	36.0	20.0	72.0	19.0
104	28.0	30.5	25	45	17	20	2.0	18.9	20	148.0	32.0	30.0	49.0	17.0	15.0
105	25.0	23.0	31	24.2	39	39	5.5	12.2	28	150.0	26.0	40.0	21.0	44.0	28.0
106	21.0	34.0	40	29	20	20	2.0	10.0	21	16.0	56.0	29.5	16.0	16.0	58.0
107	26.0	22.0	28	28	11	21	4.5	12.0	31	26.0	42.0	30.5	29.0	50.0	22.0
108	22.0	26.0	41	32	30	50	3.0	11.0	28	72.0	16.0	41.2	27.0	42.0	15.0
109	24.0	26.0	26	20.9	13	40	3.0	11.0	40	122.0	33.0	43.0	19.0	95.0	50.0
110	43.0	30.0	35	4	19	31	2.0	12.0	32	29.0	16.0	26.2	21.0	50.0	19.0
111	21.0	29.0	34	4.5	14	33	2.0	11.0	36	29.0	45.0	29.0	15.0	40.0	15.0
112	22.0	38.0	42	2	14	47.5	8.0	14.0	41	60.0	23.0	26.3	37.0	22.0	15.0
113	23.0	20.0	46	2.5	11	25	7.5	2.2	20.5	118.0	46.0	40.0	22.0	24.0	25.0

114	23.0	24.0	37	3	12	24	2.0	2.0	41	16.0	64.0	60.2	50.0	37.0	16.0
115	22.0	27.0	36	4	11	22.5	3.0	2.3	20	26.0	36.0	26.5	16.0	17.0	16.0
116	21.0	46.0	34	5	13	21	4.5	2.0	20	33.0	32.0	20.0	15.0	50.0	28.0
117	34.0	36.0	22	6.5	37	34	3.0	2.5	30	29.0	61.1	21.0	35.0	44.0	18.0
118	26.0	34.0	48	2.5	105	24	3.0	3.0	35	127.0	45.0	30.5	44.0	42.0	19.0
119	55.0	28.0	35	2	11	11	2.5	2.9	26	200.0	23.0	39.5	15.0	35.0	15.0
120	31.0	22.0	47	2	32	12	2.5	2.0	30	66.0	46.0	23.5	20.0	24.0	15.0
121	22.0	29.0	24	2.5	10	12	2.5	2.3	23	31.0	36.0	22.0	43.0	47.0	16.0
122	48.0	39.0	25	4.5	13	14	3.0	2.2	20	39.0	38.0	63.0	19.0	18.0	80.0
123	28.0	41.0	24	7	10	12	2.0	2.0	38	73.0	42.0	24.5	40.0	16.0	24.0
124	20.0	44.0	24	5	16	15	3.0	9.7	35	114.0	31.0	28.5	22.0	69.0	40.0
125	23.0	23.0	45	2	13	15.5	4.0	8.0	20	25.0	18.0	20.5	40.0	36.0	24.0
126	34.0	31.0	45	2	12	11	2.5	2.5	30	66.0	39.0	23.0	18.0	15.0	16.0
127	38.0	38.0	31	2	11	15.5	4.5	7.0	20	156.0	41.0	24.0	22.0	73.0	33.0
128	28.0	32.0	31	6	20	16.5	4.0	5.0	22	70.0	63.3	20.0	19.0	22.0	27.0
129	27.0	27.0	43	6	27	15	4.0	4.0	36	31.0	29.0	39.0	16.0	52.0	24.0
130	34.0	37.0	47	10.5	56	10	8.0	4.0	26	141.0	42.0	22.0	26.0	50.0	30.0
131	35.0	39.0	27	8.5	14	17.5	6.0	4.0	40	39.0	20.0	50.5	20.0	20.0	21.0
132	33.0	22.0	45	3	15	14.5	3.0	3.0	41	49.0	48.0	35.0	50.0	41.0	100.0
133	24.0	37.0	28	6.5	16	10.5	2.5	4.0	3.5	32.0	48.0	54.0	15.0	21.0	16.0
134	24.0	22.0	21	6.5	20	18	9.0	5.0	13.6	65.0	18.0	24.0	15.0	43.0	21.0
135	48.0	37.0	20	2.5	11	10	2.5	3.0	11.7	42.0	36.0	20.5	30.0	18.0	26.0
136	28.0	37.0	40	3	16	10	5.2	4.0	4.8	25.0	81.0	24.5	19.0	74.0	34.0
137	29.0	34.0	41	3.5	13	11	2.0	3.0	4	26.0	48.0	48.5	32.0	19.0	18.0
138	23.0	39.0	42	2	12	10	2.5	2.1	3.8	21.0	44.0	54.5	44.0	68.0	63.0
139	38.0	41.0	20	2.5	40	15.5	8.0	5.0	11	23.0	18.0	26.0	27.0	15.0	19.0

140	28.0	28.0	21	4.5	29	15	4.0	4.0	4	28.0	44.0	40.5	25.0	20.0	50.0
141	27.0	41.0	20	3.5	10	11.5	2.5	4.0	6	25.0	52.0	36.5	35.0	43.0	17.0
142	22.0	22.0	37	4	11	14.5	2.0	4.0	6.5	115.0	40.0	24.0	21.0	63.0	24.0
143	26.0	23.0	31	14	14	11	2.5	4.0	18	20.0	50.0	22.0	60.0	20.0	29.0
144	26.0	33.5	41	3	27	10	2.0	6.0	4	36.0	50.0	24.5	34.0	23.0	19.0
145	33.0	20.0	27	2.5	19	14	3.0	2.3	38	30.0	50.0	44.0	46.0	23.0	18.0
146	28.0	32.0	27	3	39	12.5	2.0	2.4	4	86.0	29.0	22.0	37.0	20.0	19.0
147	23.0	20.0	26	2.5	19	13.5	2.5	4.5	4	170.0	18.0	24.0	45.0	56.0	18.0
148	24.0	28.0	34	6.5	10	19.5	3.0	4.5	6	55.0	33.0	54.5	16.0	64.0	38.0
149	23.5	42.0	34	12	17	2	3.0	6.0	6	85.0	33.0	60.0	29.0	54.0	40.0
150	50.0	33.0	10	9.1	15	2	2.5	8.0	5	69.0	30.0	36.0	30.0	15.0	21.0
151	34.5	12.0	15	4.8	76	2	2.5	4.0	10	81.0	64.0	20.0	29.0	19.0	40.0
152	27.2	30.5	12	6.2	54	2	5.0	5.0	7.3	78.0	47.0	24.0	28.0	53.0	23.0
153	35.0	42.5	15	6.1	15	2	7.0	2.4	4.3	24.0	22.0	24.5	44.0	15.0	33.0
154	23.0	50.0	14	4	50	2	5.0	7.0	4	42.0	31.0	32.0	18.0	64.0	15.0
155	27.2	48.0	12	5.2	28	4	5.5	7.0	3.4	50.0	33.0	46.0	45.0	40.0	18.0
156	43.0	31.0	10	4.1	24	4	6.0	5.0	6.2	31.0	33.0	20.0	26.0	23.0	37.0
157	34.0	25.0	12	7	17	2	4.5	5.0	3.3	37.0	43.0	22.5	22.0	44.0	17.0
158	32.0	44.5	19.5	4	25	4	4.0	3.0	3	22.0	24.0	26.5	19.0	15.0	17.0
159	36.0	28.0	17	7	26	2.5	2.5	5.0	4	19.0	49.0	20.0	55.0	69.0	16.0
160	43.0	49.0	10	11.3	10	2	2.5	8.0	7.1	18.0	50.0	21.0	18.0	48.0	20.0
161	32.0	21.0	10.5	2.6	15	4	2.0	2.5	11.2	146.0	19.0	20.0	21.0	15.0	25.0
162	34.0	20.5	11.5	8.8	26	2.5	4.0	2.3	4.4	23.0	46.0	4.0	56.0	74.0	25.0
163	40.4	38.0	11.5	7.3	19	3	2.0	2.1	3.9	25.0	42.0	3.5	50.0	66.0	17.0
164	38.0	24.0	15	2.2	28	2	4.0	2.1	11.7	20.0	40.0	4.5	30.0	73.0	25.0
165	45.0	24.0	10.5	2.3	18	3.5	5.5	3.5	5.8	25.0	46.0	4.0	54.0	16.0	15.0

166	38.0	54.0	11	11.3	21	3	4.0	4.0	6.4	74.0	33.0	4.5	17.0	31.0	19.0
167	39.0	24.0	11	2	10	3.5	3.5	5.0	5	102.0	48.0	3.0	21.0	111.0	33.0
168	24.0	45.0	17.5	2.4	47.5	3.5	9.0	3.0	10.7	138.0	49.0	2.5	38.0	22.0	15.0
169	38.0	21.0	10	4.4	32	2.5	7.5	3.5	4.5	140.0	50.0	3.5	22.0	19.0	19.0
170	24.0	24.0	10	10.3	10	3	2.0	4.0	3	117.0	56.0	5.0	34.0	63.0	21.0
171	36.0	23.0	15	8	16	4	2.5	3.0	5	60.0	27.0	8.5	23.0	54.0	17.0
172	36.0	43.0	12	4.4	16	2	3.0	6.0	8.4	34.0	18.0	2.0	20.0	17.0	36.0
173	28.0	23.0	14	3.1	50	4.5	3.5	2.4	11	130.0	20.0	3.0	27.0	15.0	15.0
174	22.0	52.5	17	10.4	28	3	6.5	8.0	3	18.0	83.0	3.5	32.0	50.0	35.0
175	41.0	22.0	13	10.6	40	2.3	3.0	2.3	6.5	22.0	23.0	5.0	16.0	63.0	49.0
176	54.0	20.0	10	8.8	41	2	4.5	3.0	4	125.0	50.0	6.5	43.0	16.0	18.0
177	52.0	49.0	11	9	26	3	2.5	4.0	5.6	40.0	24.0	6.0	25.0	17.0	28.0
178	25.0	25.0	10	8.6	11	3.5	2.0	3.0	7.5	7.0	79.0	2.0	16.0	83.0	27.0
179	27.0	24.0	13	4	10	2	2.0	6.0	7.1	6.0	73.0	2.0	23.0	65.0	28.0
180	44.0	23.0	13	3	19	4	3.0	9.0	5	5.0	41.0	7.0	27.0	19.0	15.0
181	56.0	24.0	10	4	17.5	4.5	2.0	5.0	5.5	6.0	28.0	4.0	16.0	28.0	31.0
182	25.0	20.0	11.5	2.8	26	2	3.0	8.0	6	4.5	36.0	2.0	16.0	15.0	18.0
183	34.0	38.0	11	8	19	2	2.0	9.4	2	5.5	28.0	3.0	18.0	54.0	35.0
184	44.0	51.0	11	3.5	18	3.5	2.5	3.1	6.3	4.0	36.0	7.0	60.0	50.0	17.0
185	43.0	36.0	11.5	2	11	2	3.0	7.0	5.3	4.0	59.0	2.0	17.0	15.0	46.0
186	31.0	40.0	2.5	3	14	2	3.0	4.2	6.1	3.0	18.0	9.0	30.0	21.0	15.0
187	48.0	29.0	2	2.5	10	3	2.0	2.7	7	4.0	25.0	6.0	23.0	43.0	15.0
188	45.0	20.5	3	2	58	3.5	6.0	6.8	11	8.0	19.0	5.0	16.0	15.0	21.0
189	35.0	27.0	4.5	3.5	22	2	6.0	5.0	7.1	4.0	22.0	9.5	15.0	42.0	16.0
190	24.0	24.0	3	4	11	2.5	3.0	8.0	7.5	7.0	54.0	9.0	30.0	21.0	18.0
191	26.0	45.0	5	3.6	11	2	2.0	5.0	15.8	7.0	50.0	8.0	15.0	71.0	20.0

192	49.0	53.2	2	4.6	16	3	5.0	4.0	3	9.0	36.0	3.0	20.0	15.0	29.0
193	34.0	24.0	5	5	14	2	4.0	4.1	15.5	7.0	37.0	2.5	16.0	15.0	29.0
194	26.0	24.0	3.5	2.3	14	2	4.0	4.0	3	3.0	39.0	2.5	16.0	32.0	94.0
195	12.0	27.0	2	4	17	4.5	3.0	4.0	10.1	2.9	17.0	4.0	16.0	17.0	28.0
196	11.5	44.5	4.5	12.8	11	3	3.0	2.3	4	8.0	16.0	2.5	22.0	61.0	25.0
197	12.5	25.0	4	2	16	2.2	2.0	3.0	7	3.5	50.0	5.0	21.0	49.0	47.0
198	11.2	21.0	2.5	7.8	15	3		6.0	3.7	6.0	32.0	2.0	23.0	23.0	16.0
199	16.0	25.0	4	2.6	28	2.3		2.2	3.5	9.0	16.0	4.0	20.0	16.0	18.0
200	10.1	45.0	3	4.5	12	2		3.0	8.2	5.0	22.0	3.0	47.0	56.0	35.0
201	11.5	40.0	5	16	22	3		4.0	3.2	12.0	50.0	4.5	15.0	22.0	15.0
202	18.0	53.0	2	13.8	14	2		5.3	4	10.0	34.0	3.5	30.0	55.0	19.0
203	15.6	30.0	4.5	3.2	11	2		4.0	6.2	12.0	28.0	3.5	50.0	84.0	17.0
204	12.0	15.0	3	3	18	3		3.0	5.7	3.0	21.0	3.0	24.0	25.0	38.0
205	19.3	11.0	3.5	3.8	18	2		2.3	7	3.0	25.0	5.0	17.0	16.0	19.0
206	11.0	10.0	2.5	3.6	38	3		3.0	3.4	6.0	50.0	3.0	26.0	18.0	23.0
207	14.0	13.0	3	3	13	3		7.0	4.6	12.0	35.0	5.5	40.0	76.0	26.0
208	10.5	10.0	2	7.5	12	2.5		3.0	7.1	3.0	36.0	7.0	15.0	28.0	15.0
209	11.5	11.3	4.5	9	37	3.5		4.0	7.4	5.0	16.0	3.0	19.0	16.0	44.0
210	11.3	10.5	3.5	11.7	12	3		11.0	3.7	6.0	47.0	6.0	17.0	29.0	15.0
211	11.1	13.5	4	11.6	16	3		8.0	4.2	6.0	46.0	2.5	21.0	37.0	34.0
212	16.0	11.0	3	6	22.5	3.5		3.0	3.5		50.0	8.0	18.0	19.0	19.0
213	13.0	10.0	3.5	3.5	33	2		3.0	4		17.0	8.0	18.0	34.0	22.0
214	13.0	11.0	2	3	28	3		2.2	4.6		30.0	7.0	16.0	21.0	20.0
215	15.0	18.0	2	5	54	2		5.0	7.8		83.0	7.0	26.0	15.0	15.0
216	2.5	10.0	9	9	50	4		4.0	6.1		42.0	4.5	15.0	31.0	15.0
217	2.0	12.0	3	10	11	3.5		2.3	12.2		17.0	4.0	16.0	21.0	21.0

218	8.0	10.0	4	4.3	13	5		5.0	2.4		17.0	3.0	21.0	31.0	38.0
219	3.2	11.0	4.5	3	13	3		4.0	3.2		21.0	6.0	17.0	19.0	20.0
220	4.2	11.0	3	3.3	20	6.5		6.0	3.5		15.0	6.0	37.0	39.0	15.0
221	5.0	17.0	4	8	43	4.5		3.0	4.8		18.0	6.0	20.0	30.0	21.0
222	5.4	12.0	4	5.7	13	3		3.0	3.2		20.0	5.5	36.0	22.0	17.0
223	4.0	12.5	2.5	3	26	4			2		21.0	5.5	15.0	26.0	15.0
224	8.2	18.0	3	2	12	2			3.5		40.0	3.0	40.0	36.0	20.0
225	6.0	10.0	2.5	9	28	3			2.4		43.0	3.3	20.0	20.0	21.0
226	7.0	11.0	2	2	16	2			4.2		62.0	3.0	32.0	22.0	20.0
227	7.1	10.0	3.5	10.4	23	4			11		56.0	6.0	19.0	55.0	16.0
228	5.0	14.0	9	4.7	13	4			10.3		36.0	8.5	18.0	46.0	21.0
229	6.0	13.0	6	4.8	13	3			5		31.0	9.0	17.0	52.0	23.0
230	4.2	13.0	2	2.5	17	3			4.6		15.0	5.0	18.0	22.0	41.0
231	4.5	13.0	5	4	17.5	3			2		49.0	6.5	20.0	17.0	20.0
232	3.0	15.0	5	2	13	4			4		58.0	4.0	17.0	23.0	41.0
233	4.8	18.0	9	2.3	24	4.5			4		40.0	4.0	37.0	66.0	42.0
234	3.0	10.0	4	4	12	2			2		34.0	7.0	18.0	41.0	43.0
235	5.0	14.0	7	2.4	55	4			9.3		16.0	8.0	43.0	57.0	15.0
236	9.5	18.0	2	8	21.2	2.5			12.1		46.0	8.5	42.0	35.0	17.0
237	5.2	14.0	2.5	5	39	2			9.5		69.6	4.5	18.0	16.0	15.0
238	4.0	12.0	5	10.2	28	3			6		29.0	2.0	32.0	34.0	18.0
239	9.2	12.0	4	3	13	3			4		80.0	8.0	15.0	57.0	15.0
240	3.5	10.0	2	6	11	2.5			3.1		67.0	5.0	20.0	15.0	28.0
241	10.0	15.0	2	5.2	12	2.5			4.5		23.0	10.0	20.0	24.0	15.0
242	11.0	11.0	2.5	6	15	3			3.6		102.0	11.0	27.0	45.0	27.0
243	15.0	14.0	3	6.5	22	3			4.2		30.0	11.0	22.0	24.0	19.0

244	11.0	18.0	3	4.5	49	2			3		110.0	15.0	24.0	18.0	23.0
245	11.0	10.5	3.5	13	13	2.5			2.5		20.0	14.9	37.0	17.0	15.0
246	23.0	15.0	3	3.1	18	2			2.5		21.0	10.0	19.0	59.0	54.0
247	13.0	13.0	3	3	43	2			5.2		16.0	18.5	38.0	26.0	22.0
248	13.0	11.0	3	4	29	2			7.5		32.0	14.9	29.0	20.0	19.0
249	13.0	10.0	3.5	4.3	11	3			4		48.0	13.0	22.0	51.0	19.0
250	13.0	11.0	5	7	25	5			3.5		21.0	17.0	31.0	53.0	41.0
251	11.3	15.0	2.5	3.1	16	3.2			8.5		3.0	11.0	65.0	25.0	17.0
252	13.1	10.0	3	8.9	17	2.5			5.6		2.0	10.0	35.0	42.0	43.0
253	14.0	10.0	4	5.8	37	3.5			5.3		2.0	12.0	16.0	26.0	18.0
254	13.0	12.0	4	10	48	6.5			3.4		2.0	12.0	23.0	56.0	43.0
255	14.0	11.0	2.5	8.9	19	5			10.3		2.0	14.0	30.0	22.0	27.0
256	10.0	15.0	3	4.3	13	3			5.6		3.0	11.0	17.0	19.0	23.0
257	16.0	4.5	3	7	16	4.5			4.4		2.0	10.0	17.0	82.0	21.0
258	16.0	2.5	2.5	8	11	3.5			4		6.0	13.0	43.0	20.0	44.0
259	12.0	5.0	3	9	22	2.5			7.2		2.0	10.5	18.0	45.0	19.0
260	14.0	6.5	3	7	40	5			8		5.0	12.0	35.0	21.0	26.0
261	11.0	2.5	2.5	5.5	11	3			6.1		6.0	10.5	16.0	31.0	25.0
262	14.0	5.5	3.5	3.1	12	2			8		7.0	10.0	18.0	17.0	20.0
263	14.0	2.5	6.5	3	11	2			3.6		9.0	10.0	18.0	27.0	21.0

Annex 5. Field guidelines for carbon pools measurement

Objective

- To determine and compare biomass and soil carbon stocks

Preparation for Fieldwork

Materials for inventory and soil sampling

– Compass	for measuring bearings
– Fibreglass metre tapes (100m and 30m)	for measuring distances
– Global Positioning System (GPS)	for locating plots
– Plot centre marker (rebar/PVC tubing)	for marking plots
– Metal detector	for locating belowground plot markers
– Aluminium nail and number tags	for marking trees
– Tree diameter at breast height (dbh) tape	for measuring trees
– Clinometers (percent scale)	for measuring tree height and slope
– Coloured rope and pegs or a digital measuring device (DME)	for marking plot boundaries
– 100m line or two 50m lines	for measuring dead wood
– Calipers	for measuring dead wood
– Hand saw	for collecting dead wood samples and cutting destructive samples
– Spring scales (1kg and 300g)	for weighing destructive samples
– Large plastic sheets	for mixing forest floor/understory sample
– Soil sampling probes	for sampling soil
– Rubber mallet	for inserting soil probes
– Cloth (for example, Tyrek) or paper bags	for collecting soil and understory samples

Number of sample plots: two approaches
1) Calculate the sample size (number of plots) based on pre-sampling (5-10 plots)
   Where
   - n = number of plots to be measured
   - Syx = estimation error
   - t = Studet t value
   - S = variance
   - X = mean value

$$n = \left[\frac{t \times s}{\left(\frac{S_{yx} \times \chi}{100} \right)} \right]^2$$

2) Pragmatic approach: the number of sample plots should be decided based on resources (budget, time, etc.), ≥ 15 plots per stratum

Type of plot (Temporary or permeant plots)

- It can be square, rectangle or circle
- The size of the plot various depend on the nature of ecosystem being studied, in this practical, we use nested square plot size 10 m x 10m
- Sample 2-3 plots from each ecosystem

Example   Even-aged stand

10 m

10 m
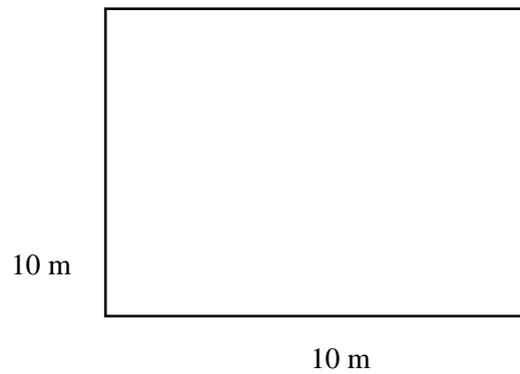
Uneven-aged stand (nested plot)

Large plot:
radius 20m
trees > 50cm dbh

Intermediate plot:
radius 14m
trees 20–50cm dbh

Small plot:
radius 4m
trees 5–20cm dbh

Large plot:
20m x 50m
trees > 50cm dbh

Intermediate plot:
17m x 35m
trees 20–50cm dbh

Small plot:
5m x 10m
trees 5–20cm dbh
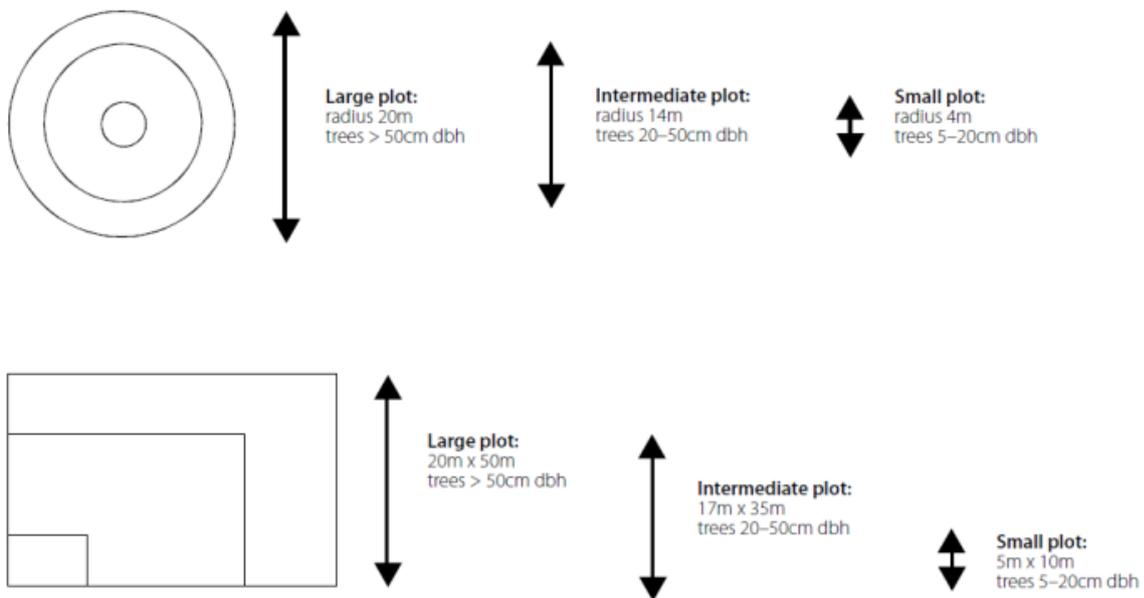
Plot location

Step 1 Delineate the boundary of the study area
Step 2 Decide whether plots will be distributed systematically or randomly.
Step 3 The random location of plots can be achieved using random number tables
Step 4 The systematic location of plots within each stratum can be achieved by overlaying a grid on the project map and allocating plots in a regular pattern across the strata.

- a systematic sample with a random starting location will provide a more accurate estimate of population parameters than a stratified random sample of the same size
- when establishing plots, it is important to be aware of edge and other effects on tree growth when they are located near population boundaries

Measuring biomass and soil carbon pools
a) Aboveground biomass measurement
Measuring trees/shrubs
- Accurately locate the plot centre
- If the plot is permanent, mark the centre (if plot is circular) or the boundaries (if plot is square)
- Starting at the north of the plot, begin measuring trees
- Flag the first tree to mark the start/end point.
- Measure trees at dbh (at 1.3m) using the guidance below. However, measurement at a height of 10cm (d10) or 30 cm (d30) is also common, especially on small trees and shrubs or trees prone to forking below 1.3 m diameter.
- Where there are multistems , the diameter equivalent (de) of all stems may be calculated as the diameter of a circle of area equal to the sum of cross-section areas of all stems at that height

$$d_e = \sqrt{\sum_i^n d_i}2$$

where di = diameter of the ith stem at the measurement height

- Then, measure tree height using hypsometer, clinometer.
- After measuring a tree, move clockwise to the next tree
- Occasionally trees will be close to the boundary of a plot.
    - If more than 50% of the trunk is within the plot boundary, the tree is in.
    - If more than 50% of the trunk is outside of the boundary, it is out and should not be measured.
    - If the tree is exactly on the border of the plot, flip a coin to determine if it is in or out.

DBH measurements
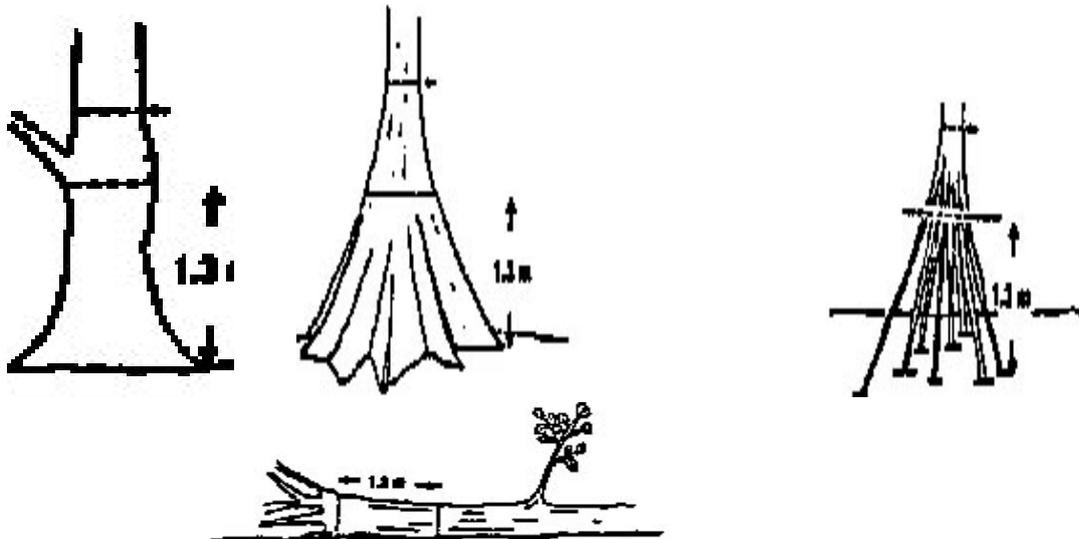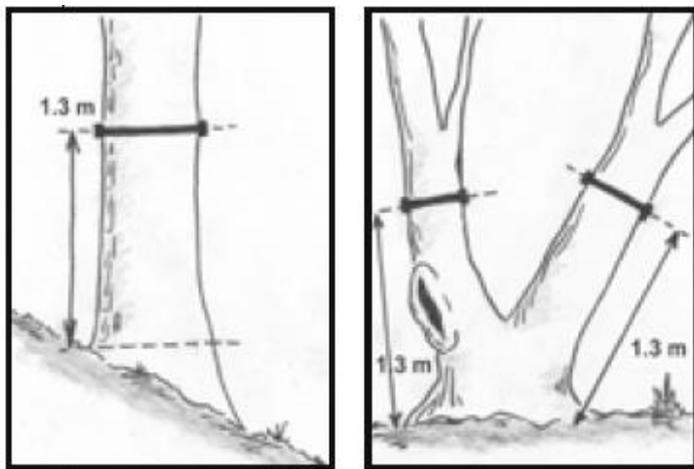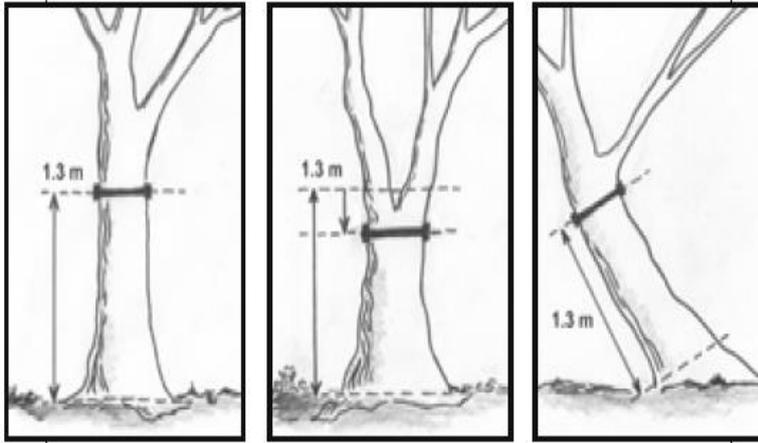
- Height measurement with hypsometer should account ground distance of measurement from the tree
- Insert your data in excel sheet
- Calculate the aboveground biomass using already developed allometric equations (e.g. species specific equation, or generic equation – e.g. Chave et al., 2014) or you can develop site-species specific allometric equation.
- Calculate the aboveground biomass carbon, multiplying by 50% carbon content (Aboveground biomass carbon = Aboveground biomass x 0.5)
- Determine the aboveground biomass carbon stocks per plot, and extrapolate for hectare (Mg ha-1 or tonnes ha-1)

b) Belowground biomass measurement

- Apply a regression equation to stem diameter or some other measure of tree size in order to estimate root biomass. But, measurement of root biomass is time consuming and expensive.
- Thus, a simple root:shoot ratio is used. This ratio ranges from 20 to 45 % and the global average of 26% is commonly used; i.e. Belowground biomass = Aboveground biomass x 0.26; the product is multiplied by 50% to calculate belowground biomass stock.

c) Dead organic matter measurement

Litter
- Litter sample would be taken from the nested plot of 1 m x 1m with 3-5 replications per plot (see the figure below)
- Measure total fresh weight on the site , and take 100g sample to determine dry weight to fresh weight
- Samples should be oven-dried to constant weight at 70°C for 24 hours.
- Dry mass = (subsample dry mass/subsample fresh mass) x fresh mass of whole sample
- Determine the dry biomass and carbon stocks per plot and extrapolate on hectare basis (tonnes ha -1) (Expansion factor = 10,000 m2 /Area of plot (m2))

d) Soil organic matter measurement

- Collect soil samples from nested plots (3-5 replications per plot, see figure below)
- Steadily insert the soil augur to 0-10 and 10-20cm depths
- Carefully extract the augur and place the soil sample into a plastic bag. Give maximum cares not include organic matter, which will overestimation of soil carbon stocks.
- At each sampling point, take the same number of samples for determination of bulk density using soil core samplers.

- Take to the laboratory and oven-dry at 1050c for 48 hours. These apply to both soil carbon and bulk density samples.
- The soil samples for carbon analysis will be sieved 2mm sieve
- Carbon content will be determined using Walkey-Black method
- For soil samples > 2mm, extract the fine roots to oven-dry and estimate the dry biomass of fine roots.
- Calculate the bulk density of the mineral soil core

    Bulk density, g/m3 = Oven dry mass (g)/Core volume (m3),
- If there is stone content, Bulk density (g/m3)=: Oven dry mass (g)/(Core volume (m3)- Mass of coarse fragments (g)/Density of rock fragments (g/m3))

    Where: The bulk density is for the < 2mm fraction, coarse fragments are > 2 mm. The density of rock fragments is often given as 2.65 g/cm3.
- The soil C stocks (Mg C ha-1) will be calculated as

    C (t/ha) = [(soil bulk density (gcm-3) x soil depth (cm) x C content (%)] x 100

Soil sample plots
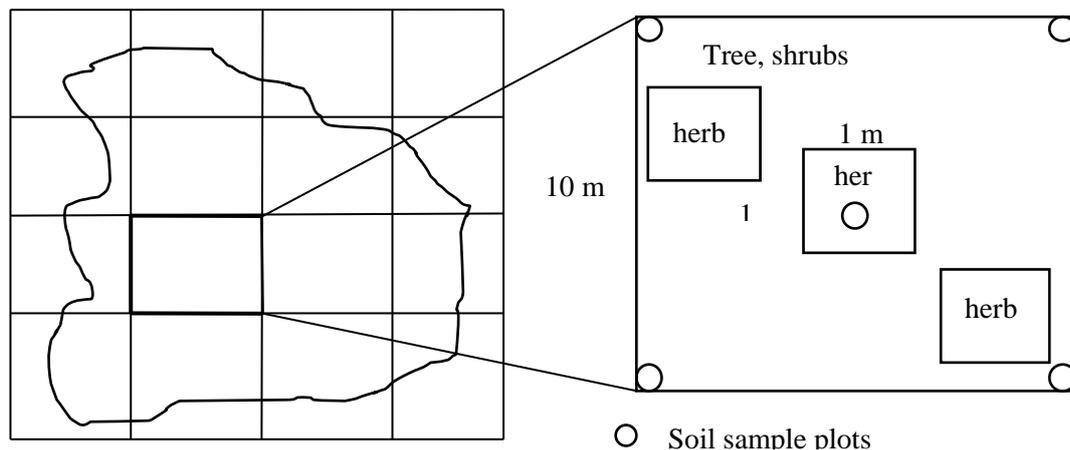
For further information on the methodology, please look into the following Manuals and guidebooks
- IPCC, 2006. IPCC Guidelines for National Greenhouse gas inventories for Agriculture, Forestry and Other Land Use
- Pearson, T., Walker, S., Brown, S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects
- Snowdon et al., 2002. Protocol for Sampling Tree and Stand Biomass. National Carbon Accounting System. Technical Report No. 31
- MacDicken, K.G. 1997. A guide to monitoring carbon storage in forestry and agroforestry project. Winrock International Institute of Agricultural Development.
- Picard N., Saint-André L., Henry M. 2012. Manual for building tree volume and biomass allometric equations: from field measurement to prediction. Food and Agricultural Organization of the United Nations, Rome, and Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Montpellier, 215 pp.

Woody species inventory format

Code	Ecosystem	Plot no.	Species	DBH, cm			Total height, m
				D1	D2	D_{mean}	

Date: _____ data collector : _____

Soil data to determine carbon pools

Code	Ecosystem	Plot no.	Replication no.	Soil depth	BD, g/cm3	C, %

Date: _____ data collector : _____