

**CLEAN DEVELOPMENT MECHANISM  
PROPOSED NEW METHODOLOGY FOR AFFORESTATION AND REFORESTATION PROJECT  
ACTIVITIES: BASELINE (CDM-AR -NMB)**

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**SECTION A. Identification of methodology**

**A.1. Title of the proposed methodology:**

>> **Restoration of Degraded Lands through Afforestation/Reforestation**

**A.2. List of type(s) of A/R CDM project activity to which the methodology may apply:**

>> The project activity falls in the sector Land Use, Land Use Change and Forestry, and the sub-sector afforestation/reforestation.

**A.3. Conditions under which the methodology is applicable to A/R CDM project activities:**

>> This methodology is applicable if the following conditions are met in the lands to be afforested / reforested under the project activity (degraded lands):

1. Land degradation through, e.g. soil erosion, landslides, and unsustainable land use results in the loss of carbon from the carbon pools of degraded lands and, if left unchecked, will lead to irreversible loss of productivity and adverse impacts on adjoining lands.
2. The lands to be afforested / reforested are at various stages of degradation with less than 10% canopy cover due to natural and/or anthropogenic influences.
3. The low land capability and biophysical limitations permit only the use of less intensive land use options such as afforestation/reforestation to restore the productivity of these lands.
4. The degraded lands with low initial carbon stocks either show a declining trend in the GHG removals or continue to remain in a low steady state.
5. The project entity (public agency, private entity, community council etc.) is sufficiently organized to monitor the carbon pools, collect relevant data at specified intervals, and implement the monitoring plan.

**A.4. Carbon pools covered by the methodology:**

>> The following carbon pools are covered in the methodology.

**Vegetation:** This pool includes the above ground biomass, below ground biomass, deadwood and litter.

**Soil:** This pool includes the soil organic carbon in the degraded lands.

**A.5. What are the potential strengths and weaknesses of this proposed new methodology?**

>> **Strengths**

1. The methodology is applicable to a wide variety of degraded lands that are under the management of public agencies, private entities, and local community councils.
2. The conservative assessment of zero carbon removals in the degraded lands of the baseline scenario (in which carbon is lost) permits a direct estimation of the net anthropogenic GHG removals without the need to monitor baseline removals, thereby saving monitoring costs.
3. The methodology uses location specific research, an internationally recognized CO<sub>2</sub>FIX carbon accounting model, published data, conservative assumptions and the IPCC LULUCF good practice guidelines in assessing the carbon pools of the degraded lands.
4. The sampling framework, precision levels, location specific allometric relationships and the explicit consideration of risks and uncertainties contribute to the conservative estimation of carbon pools.
5. The methodology uses the LULUCF good practice guidelines. It recommends implementation of quality assurance and control measures to ensure that monitoring procedures and results lead to accurate estimations of carbon pools and GHG removals.

>> **Weaknesses**

1. The methodology is limited to degraded lands with continuing loss of carbon or a low steady state of carbon pools.
2. The carbon pools of degraded lands are subject to several uncertainties. The project entity should assess these uncertainties and develop project specific measures to address them.

**SECTION B. Overall summary description:**

>> Under this methodology, degraded lands constitute those lands that have a canopy cover density of less than 10% and are subject to adverse natural and anthropogenic influences such as soil erosion, landslides, and unsustainable land use practices. In official records, these lands are often categorized under the broad categories of degraded lands, barren lands, degraded pastures, glades, abandoned arable lands, and other such categories of land that are characterized by the long-term soil and vegetation loss.

This methodology proposes steps to assess land use and carbon pools of degraded lands and outlines the methods to evaluate alternatives to restore their productivity through cost effective land use options. The methodology takes into account the national policies, regulatory framework and institutional arrangements associated with the management of degraded lands. Considering the existing and historical contexts of the degraded lands, this methodology selects the baseline approach 22(a) to characterize the plausible and most likely future uses of these lands in line with historic and existing land use patterns and to select the relevant baseline scenario for the degraded lands.

Considering the declining or low steady state of the carbon pools in the baseline scenario of degraded lands, this methodology conservatively treats the baseline carbon pools to be unchanging and the net GHG removals of the baseline scenario to be zero.

The methodology stratifies land use, employs sampling methods and outlines the maximum permissible error to achieve the desired accuracy in the estimation of carbon pools. The methodology applies the CDM Executive Board's additionality tool. The methodology monitors carbon pools and compares the GHG removals of the baseline and project scenarios to calculate net removals. It includes an assessment of risks and uncertainties affecting the carbon pools and outlines measures to hedge against these risks.

The methodology used location specific data, an internationally recognized and peer-reviewed carbon accounting model (CO<sub>2</sub>FIX)<sup>1</sup>, published literature, expert inputs from the national forest management agencies and the LULUCF good practice guidelines in assessing the carbon pools and their evolution on the degraded lands. Thus, the methodology leads to a conservative and transparent assessment of the land use and associated carbon pools of the degraded lands.

**SECTION C. Choice of and justification as to why one of the baseline approaches listed in paragraph 22 of CDM A/R modalities and procedures is considered to be the most appropriate:**

**C.1. General baseline approach for A/R project activities:**

X ? Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary;

<sup>1</sup> CO2FIX is a simulation and book keeping model developed as part of the CASFOR II project financed under the European Commission INCO2-Programme. The model simulates the stocks and fluxes of carbon in trees, soil, and wood products on one hectare unit and in time steps of one year. The use of CO2FIX in this methodology is described in Section E5 and F1. Additional information on the model can be found at <http://www2.efi.fi/projects/casfor/>

- ? Changes in carbon stocks in the carbon pools within the project boundary from a land use that represents an economically attractive course of action, taking into account barriers to investment;
- ? Changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts.

**C.2. Justification of why the baseline approach for A/ R project activities chosen in C.1. above is considered the most appropriate:**

>> In this methodology, the baseline approach 22(a) is chosen for the reasons outlined below.

- Degraded lands reflect the long term interaction of physiographic and anthropogenic factors. The existing and historical land use patterns on these lands highlight the demands placed on them and the resulting impact on their productivity over time.
- Degraded lands have historically been used for meeting the demands of local stakeholders. The inability of project entities to generate adequate investment for the restoration of these lands is a major factor for their continued unsustainable use.
- Unregulated use, lack of investment, inadequate institutional arrangements to manage these lands, the common property nature of the degraded lands over a long period have transformed them into an open access resource, leading to further unsustainable use.

The baseline approach 22(b) is not relevant considering the low land capability and few economically attractive alternatives for degraded lands. Moreover, these lands do not have adequate above and below ground biomass and soil carbon pools, which reflects the inability of these lands to support economically viable alternatives.

The baseline approach 22(c) does not lead to different assessments, because the methodology uses the existing or historic changes in carbon stock to determine the most likely land use at the time the project starts.

**SECTION D. Explanation of how, by applying the baseline methodology, baselines are developed in a transparent and conservative manner:**

>> The methods, assumptions, and procedures used in the methodology facilitate the transparent and conservative development of baselines. The following aspects of the methodology highlight the conservativeness and transparency achieved in developing the baseline scenario.

- The methodology takes into account the national and sector policies and socio-economic variables to characterize the land use patterns and selects the baseline approach 22(a), which best reflects the evolution of the baseline scenario.
- The methodology unites several categories of degraded lands under a common baseline scenario, thereby enhancing the cost effectiveness and conservative assessment of the baseline of a wide variety of lands that are spread over different geographic regions and land use regimes.
- Transparent and conservative assumptions with regard to the measurement and monitoring of the above and below ground biomass and soil carbon and the adoption of the LULUCF good practice guidelines help to conservatively assess the baseline.
- The methodology treats the declining or steady state GHG removals of the baseline scenario as unchanging, which provides for a conservative assessment of baseline removals from degraded lands. The assumption of unchanging baseline removals enhances transparency and reduces possible errors, since baseline data need not be collected and processed.
- The sampling framework and the specification of a maximum permissible error improve the precision and accuracy of carbon stock estimates. The combination of field data, peer reviewed literature, LULUCF good practice guidelines and the widely recognized CO2FIX carbon accounting model further increase the quality, accuracy and transparency of the methodology.

**SECTION E. Explanation and justification of the proposed new baseline methodology:**

>> There is no approved methodology for this type of CDM project. The new methodology takes into account the specific characteristics of degraded lands in terms of their status, distribution, common access regime and competing uses. The need for the methodology and an explanation of its application is outlined below.

### **Justification of the methodology**

Degraded lands form a major proportion of land resources that need to be restored for more productive uses. Growing demands on land use calls for a need to enhance their potential. Efforts to improve the productivity of these lands in the past have been constrained by low investment, weak institutional arrangements, and poor market mechanisms to support their restoration and management. The lack of incentives, and often the large investment required in the restoration of these lands have acted as major barriers to their restoration.

The recognition that A/R activity, supported by the CDM incentive, can be used to restore and protect degraded lands and enhance their carbon pools has increased the interest in these activities. We estimate that related project activities will become sufficiently widespread to warrant a methodology that makes use of the specific conditions of degraded lands.

This new baseline methodology is associated with a new monitoring methodology, which helps to assess carbon pools and monitor progress at specified intervals, thus helping to protect and enhance carbon pools in A/R projects. Therefore, this methodology presents a systematic approach to the long-term restoration of degraded lands.

### **Explanation of the methodology**

The methodology uses a step-wise approach outlined below, which confirms with the paragraph 22(a) as the relevant baseline approach:

#### **Step 1: Analysis of land use in a socio-economic and policy context**

1. Assess the existing and historical land use patterns to identify the factors influencing the land use in order to gain an understanding of the anthropogenic influences over time.
2. Using multiple sources of data, e.g. primary data from field studies, socioeconomic surveys, semi-structured interviews, participatory assessments, and secondary data from official records, archived information, aerial photographs and related evidence, to evaluate the biophysical, socioeconomic and policy variables that impact the use of degraded land.
3. Assess the significance of the existing land use for the local economy and evaluate the policy and market mechanisms that influence land use. For example, communities often depend on degraded public lands for subsistence needs such as fuelwood, grazing and non-timber products and services. Markets, in particular returns from alternative uses and proximity to urban centres, also influence land use decisions.
4. Consult with stakeholders to assess the existing land use practices and the role of institutional arrangements in managing the degraded lands.

#### **Step 2: Outline the plausible land use practices and identify the baseline scenario from amongst the plausible alternatives**

5. Outline the plausible uses of degraded land. The plausible land uses provide an overview of carbon pools in the land use categories. Follow the step-wise approach outlined in E.2 below to evaluate the scenarios and to identify the scenario that most likely represents the existing land use in the absence of interventions. This shall include an assessment of any pre-existing A/R programs and activities, which may be part of the baseline scenario.

**Step 3: Assess the variables influencing the carbon pools in the baseline and project scenarios**

6. The assessment undertaken by trained personnel can provide detailed information on the factors influencing the carbon pools by analyzing the following aspects of land use.
  - a) Above and below ground vegetation, including biodiversity.
  - b) Soil, water, air, climate and landscape characteristics.
  - c) Anthropogenic influences.
7. Prepare detailed maps to stratify the project area and characterize soil, vegetation, and carbon pools using field studies, published literature, and the LULUCF good policy guidelines.
8. Use sampling methods to investigate the strata and to specify a tolerable error that improves the precision and decreases the variability in assessing the carbon pools. The sampling methods shall take into account the specific characteristics of the carbon pools such as the direction and magnitude of change. For example, the stratification for vegetation and soil carbon pools may require different sampling frameworks.

**Step 4: Estimate the carbon pools in the baseline and project scenarios and their expected evolution over time.**

9. Estimate the carbon pools in the baseline and project scenarios and their trends using location specific measurements, yield tables, allometric equations, IPCC default parameters, and LULUCF good policy guidelines.
10. Confirm that the condition of degraded lands is met by the lands included in the project activity, in particular declining trends in carbon pools or a low steady state. For such lands, set the net change in GHG removals under the baseline scenario to zero.
11. Estimate the anthropogenic emissions associated with the project scenario.
  - i) Estimate the emissions within the project boundary.
  - ii) Estimate the leakage associated with land use outside the project boundary.
12. Estimate the GHG removals of the project scenario with CO<sub>2</sub>FIX or a similar peer-reviewed model. The carbon balance estimated in each stratum shall be summed up to obtain the carbon balance at the project level. The carbon balance of the project scenario shall take into account the emissions from the project and any leakage, which may include any observed shortfall in pre-existing A/R activity levels in the country during the project implementation (planting) period.

**Step 5: Evaluate the additionality of the project**

13. Compare the removals in the carbon pools of the project scenario with the assumption of zero-removal in the baseline scenario.
14. Apply the additionality tool to test the additionality of the project scenario.

**Step 6: Assess the sources of uncertainties and adequacy of measures implemented.**

15. Assess the risks and uncertainties that influence the baseline and project scenarios. Estimate 95% confidence interval for the measured carbon pools. Perform a sensitivity analysis, evaluate the risks that influence the GHG removals and develop measures to overcome them.

<p><b>E.1. Explanation of how national and/or sectoral policies and circumstances could be taken into account by the application of the methodology:</b></p>
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>> The policy setting of a country influences the land use decisions of stakeholders, including public agencies, local councils and private landowners. Although the legal basis for the improvement of degraded lands exists in several countries, the implementation is often incomplete due to financial constraints, weak policy regime, inadequate institutions and lack of enforcement.

As outlined in Step 1 above, as well as in E.2 and in the application of the additionality tool in E.3 below, the methodology assesses the impact of national and/or sectoral policies and circumstances on the existing land use and its alternatives.

This analysis carries over to the assessment and design of the project activity, which may have to strike a balance between traditional access rights to degraded lands and the new rights to carbon pools. For example, the local community may have to follow new guidelines on land use. Explicit contractual arrangements may be necessary to guarantee professional management, maintain the integrity of the carbon pools under the project and minimize long term risks.

Market forces also influence land use, which often respond to market and price variables with some delay. Therefore, this methodology highlights the need to consider market impacts on the use of degraded lands

**E.2. Explanation of how the methodology determines the baseline scenario (that is, how it indicates the scenario that reasonably represents the sum of the changes in carbon stocks in the carbon pools within the project boundary that would occur in the absence of the proposed A/R project activity):**

>> The methodology determines the applicable baseline scenario that is in line with approach 22(a). The assessment confirms that the historic and existing land use represent the baselines scenario. The exclusive focus of this methodology on degraded lands enables it to consider the specific circumstances of degraded lands including an analysis of policy, economics and management of these lands. The assessment is summarized in the following steps:

***1. Analysis of the national and sector policies that influence existing or future land use:***

Since degraded lands in most countries are under the control of the government, public agencies, and communities, national and sector polices influence their management. The methodology requires analyzing these policies and especially their influence on the degraded lands.

***2. Identification of plausible scenarios of land use:***

Plausible scenarios shall include the historic and current land use patterns and the A/R activity of the degraded lands under the project. Plausible scenarios may also include alternative future public or private activities on the degraded lands including any A/R activity under existing programs or any other feasible agricultural or land development activities, provided there is some evidence of such activities or plans in comparable regions of the country or region. At least two sources of data such as land records, field studies, still photographs, and aerial photography shall be used to make a realistic assessment of the plausible land use scenarios. Plausible scenarios shall be outlined based on data and feedback from stakeholders. A systematic analysis of plausible scenarios shall be undertaken in order to evaluate the historical influences on land use.

***3. Identification of the baseline scenario from amongst the land use alternatives:***

The above scenarios shall be analyzed with regard to their probability. Unless there is a strong probability of private or public activities on the degraded lands other than a continuation of existing practices and/or any A/R plans, which may contradict the use of the approach in 22(a), the observed historic or current pattern determines the baseline scenario. Current land management practices may include some level of ongoing public or private A/R activity. In such case this activity shall be included in the baseline scenario, provided the activity could be undertaken on the degraded lands included in the project activity, e.g. because some degraded land is under A/R activity every year.

***4. Assessment of land use and carbon pools associated with the baseline scenario:***

If the assessment of alternative scenarios shows that the approach in 22(a), and therefore the proposed methodology, are not applicable, the project activity shall use a different methodology. In all other cases the scenario that reflects historic or current land use practices that are in line with national and sector policies shall be identified as the baseline scenario. The baseline scenario may make provisions for any pre-existing and regularly undertaken level A/R activities, e.g. by a national forest agency, for which no removals can be claimed. The methodology assumes, and monitors, that the pre-existing level of A/R activity is kept up during the implementation of the project activity (i.e. during the planting phase). And if this is not observed, the methodology treats any shortfall as leakage and corrects its own net removals accordingly.

**E.3. Explanation of how, through the methodology, it can be demonstrated that a proposed A/R project activity is additional and therefore not the baseline scenario (section B.3 of the CDM-AR-PDD):**

>> The methodology uses the EB-approved additionality tool in its applicable version and appropriately adapted to A/R projects to determine the additionality of the project activity. Any adaptations of the tool for use with A/R projects are discussed below:

**Step 0: Early start project**

**Step 1: Identification of alternative scenarios consistent with legal and regulatory framework**

**Step 2: Investment analysis** (as alternative to Step 3)

If the project is promoted by a private entity or a small community group, financial analysis is adequate. However, if the project entity is a public entity, in addition to financial analysis, it is recommended to conduct an economic analysis to demonstrate that the project is additional on the basis of an economic rate of return, taking externalities into account. An important externality of degraded lands is the off-site impact of soil erosion. Studies show that unregulated grazing on degraded lands lead to soil erosion and loss of productivity of downhill pastures and agricultural lands, loss of storage capacity in reservoirs and damage to infrastructure. From societal perspective, the benefits from erosion control and other benefits to society favor afforestation, possibly even without considering the potential benefits from forest products. These benefits shall be assessed along with any barriers to investment in A/R projects, which are likely to be significant due to the common property characteristics in combination with a limited and differential use of some of the societal benefits from A/R projects.

**Step 3: Barrier analysis** (as alternative to Step 2)

In the context of degraded lands, barriers illustrated below or other specific barriers relevant to the project context shall be considered.

i) Investment barriers:

- The upfront investment associated with the project activity is high and concentrated in the early phase, whereas benefits from the project start may only after 5 years in the form of thinning or revenue from selected non-timber products.
- The common property characteristics of degraded lands and the uneven distribution of benefits from related A/R activities may make it difficult to obtain sufficient (political) support for undertaking and maintaining the A/R activities at the optimal level.

ii) Barriers due to prevailing practices:

- Most degraded lands are under the control of public agencies or local councils, often as common property resources. Weak institutions and lack of regulation promote unsustainable land use and increase the risk of degradation. Therefore, lack of institutional arrangements and legally enforceable measures are major barriers in restoring the degraded lands.

iii) Technical/operational barriers.

- The afforestation of degraded lands requires sound silvicultural practices and trained personnel to raise successful plantations.
- Since environmental benefits hold key to the success of afforestation projects on degraded lands, lack of awareness on the environmental impact of soil erosion inhibits local communities to actively participate in the management of degraded lands.

**Step 4: common practice test**

**Step 5: Registration of the project as CDM activity**

**E.4. Explain and justify formulae/algorithms and/or models used to determine the baseline scenario. Variables, fixed parameters, values and different strata identified have to be reported (e.g. species, growth rates):**

>> Degraded lands include several categories of lands that may occur within the project boundary. For the purpose of this methodology, the different categories all degraded lands can be united under a single baseline condition, namely that of a continuing carbon loss or low steady state carbon pools. Under this condition, the present methodology sets the removals of GHGs in the baseline scenario conservatively to zero for the first crediting period and subsequent crediting periods are subject to the renewal conditions for crediting periods.

$$BR(t)_{CO_2e} = 0 \quad (1)$$

$BR(t)_{CO_2e}$  = CO<sub>2e</sub> GHG removals in the baseline scenario before project start and throughout the first and possibly subsequent crediting periods

**Justification:**

(a) The continuing loss of carbon from degraded lands is confirmed in the literature.

In two extensive reviews of the studies conducted throughout the world, Mann (1986)<sup>2</sup> and Davidson and Ackerman (1993)<sup>3</sup> assessed the mean carbon losses as 20 % and 24 % of the soil carbon inventory expressed as mass C per unit area in the top 30 cm following conversion or unsustainable use of uncultivated lands. The two studies show that most losses are reported to occur over twenty years or more. Since degraded lands are either barren or have scant above ground vegetation, the proportion of above ground biomass to total biomass is often very low. The only major carbon pools in such lands are likely to be soil carbon and litter. The near absence of above ground biomass is also reflected in the low litter mass.

If necessary, the loss of carbon from the carbon pools in the degraded lands within the project boundaries can be confirmed using the sampling techniques and modelling tools explained in Section E.5 for the project activity.

(b) This methodology proposes to support the re-evaluation of the baseline scenario for the purpose of renewal of the crediting period by identifying a control group of statistically relevant baseline sample plots that are not affected by the project activity. The sample plots shall serve as proxy and accurately reflect the development of the degraded lands in the absence of the project activity. If the baseline samples confirm continued land degradation, equation (1) shall be applied for the renewed crediting period. If an increase in the carbon pools in the baseline plots are detected, it is proposed that the crediting period be renewed subject to measuring the increase in the baseline carbon pools, using a methodology as outlined in E.5 below.

**E.5. Explain and justify formulae/algorithms and/or models used to determine the actual net GHG removals by sinks from the proposed A/R CDM project activity. Variables, fixed parameters, values and different strata identified have to be reported (e.g. fuel(s) used, fuel consumption rates):**

>> The following steps shall be followed for the estimation of carbon pools under the project scenario.

<sup>2</sup> Mann, L.K. 1986. Changes in soil carbon storage after cultivation. *Soil Science* 142(5): 279-288.

<sup>3</sup> Davidson, E. A. and I. Ackerman. 1993. Changes in soil carbon inventories following cultivation of previously untilled soils. *Biogeochemistry* 20: 161-193.

**Project boundary and stratification**

Within the project boundary, the area shall be stratified into homogenous units. The stratification shall be carried out using criteria that are directly related to variables measured. In the context of A/R activity in degraded lands, criteria such as soil type, vegetation, diversity of carbon pools, degree of erosion, and anthropogenic influences shall be taken into account. To provide clarity on the project boundaries, maps, records, physical identifiers, aerial photo and other evidence as applicable can be used.

**Sampling**

The large proportion of carbon pools under the project scenario fall under the category of changing pools. The number of plots needed for sampling is dependent on the maximum target error. A precision level of 10% in the mean with a 95% confidence interval is considered adequate in the measurement of carbon pools. The total error comprises sampling, measurement, model and other errors. Sampling errors account for more than 3/4<sup>th</sup> of the total error. Therefore, in order to achieve a 10% precision level, a 7% sampling error needs to be targeted and the remaining 3% error can account other types of errors. By increasing the sample size and plot size, it is possible to increase the precision and decrease the variability of the estimate.

**Carbon pools of the project scenario**

Above ground biomass is a significant part of A/R projects. It includes the biomass in tree and non-tree components. The dead wood component is not likely to be significant in the early stages of A/R projects, but is expected to increase as stands age. The below ground biomass of A/R projects are expected to be significant and should be monitored and accounted. Soil carbon is likely to increase under the afforestation activities that support long-rotation species. Therefore it should be included in the measurement of project pools. **Table 2** below presents the carbon pools of the project scenario.

**Table 2: Assessment of carbon pools in the project scenario of degraded lands**

Degraded land	AGB-tree,	AGB- non-tree	Below ground	Dead wood	Litter	Soil
Size of the pool	Significant	Herb – insignificant Shrub – significant / insignificant	Significant	Early period - insignificant Later period - significant	Significant	Significant over 20 years and beyond
Direction of change	Increasing	Increasing / unchanging	Increasing	Increasing	Increasing	Increasing
Expected net change in GHG removals	Positive	Positive / unchanging	Positive	Positive	Positive	Positive
Carbon pool to measure	Yes	Yes/No	Yes	Yes	Yes	Yes

**Note:** AGB – Above ground biomass

1. The biomass removals through non-tree components, which comprise an herb layer, shall be assumed to be zero, if it is negligible or the same as that of the baseline scenario.
2. The deadwood biomass is likely to be non-existent or negligible during early years of the project scenario and the biomass from deadwood components can be assumed to be zero. If the deadwood proportion increases at the later years of the project scenario, it shall be monitored, measured and accounted.
3. The soil carbon in the project scenario is expected to increase as a result of organic matter accumulation under the afforestation activity; it shall be monitored at 20 years intervals and accounted.
4. Additional information on the measurement of carbon pools may be obtained from Section 4.3.3.5 of the LULUCF good practice guidelines.

**Measurement of carbon pools in project scenario**

The changes in the carbon pools under the project scenario are represented as

$$C_{PB} = \left\{ \sum_1^m [B_T + B_{NT} + B_{BB} + B_{DW} + B_L] * 0.5 \right\} \quad (2)$$

Where,

- $C_{PB}$  = Carbon removals through the sinks in the project scenario (in Mg/ha)
- $B_T$  = Biomass removals in the above ground tree biomass
- $B_{NT}$  = Biomass removals in the above ground non-tree biomass
- $B_{BB}$  = Biomass removals in the below ground biomass
- $B_{DW}$  = Biomass removals in the deadwood (set to zero if no deadwood is observed, especially in the early years of the project)
- $B_L$  = Biomass removals in the litter
- 0.5 = Factor to convert biomass into carbon
- 1...,  $m$  = Number of carbon pools in a stratum

$$C_{PR} = C_{PB} + C_{PS} \quad (3)$$

$C_{PR}$  = Carbon removals in the project scenario in (Mg/ha)

$C_{PS}$  = Carbon removals in soil in the project scenario in (Mg/ha)

$$PR_{CO2e} = \sum_1^n [(C_{PR} * (44/12)) - PE_{CO2e}] * A_n \quad (4)$$

$PR_{CO2e}$  = CO<sub>2</sub>e GHG removals in the project scenario

$PE_{CO2e}$  = CO<sub>2</sub>e Carbon emitted by project activities

44/12 = Factor to convert C to CO<sub>2</sub>e

$A_n$  = Number of hectares of area

1...,  $n$  = Number of strata 1...,  $n$

### **Tree ( $B_T$ )**

Permanent sample plots shall be used for estimating the tree biomass (see LULUCF good practice guidelines for projects, Chapter 4.3.3.5.1) Biomass in the tree carbon stock shall be estimated using the diameter at breast height (dbh) or dbh and height. When using the direct method, nested permanent sample plots shall be used. All dbh of trees above the minimum diameter defined (5 cm or 10cm) shall be measured and biomass stocks are estimated using the allometric equations. If local allometric equations are not available, they can be constructed by relating the biomass to the easily measured values such as dbh and height. Regression equations for each site class and species group can be developed to relate the diameter at breast height (or basal diameter) to aboveground biomass. The stem volume is calculated from dbh and the mean tree height using allometric relationships and dry biomass is calculated using mean wood densities.

It is possible that the project scenario may have several species mixed in the afforestation/reforestation of degraded lands with some species accounting for a large proportion of the planting stock. The predominant species that cover more than 50% in the species mix shall be categorized as species types for the purposes of estimating the carbon pools. Associated species that have similar growth behaviour and form small proportions shall be grouped under the major species groups. The grouping of species helps to overcome a lack of yield tables for some species and permits to categorize the species by growth behavior and management requirements and allows cost effective estimation of biomass.

The tree biomass removals for the project scenario in the CO<sub>2</sub>FIX model can be represented as follows.

$$B_T = B_S + B_F + B_B \quad (5)$$

Where

$B_T$  = Growth of tree biomass (based on yield tables and allometric equations) (Mg/ha)

$B_S$  = Growth of stem biomass (Mg/ha)

$B_F$  = Growth of foliage biomass =  $B_S * F_f$

$B_B$  = Growth of branch biomass =  $B_S * F_b$

The growth of stem biomass ( $B_S$ ) and the biomass allocation coefficients (F) for foliage and branches are expressed as a function of age. The initial values can be derived from the yield tables and further refined based on monitoring data.

#### **Non-tree biomass ( $B_{NT}$ )**

The biomass of sample plots is harvested and oven dried. Herbaceous vegetation represents a small proportion (1 to 3 %) of biomass and will likely be comparable among with- and without-project sites. Therefore, measurement of herb layers may not be required considering the costs and effort involved.

For large shrub species destructive harvesting methods may be used. If shrubs fall in the range of tree height, they shall be treated as trees in minimum diameter class. The shrub and herb biomass is often low in the afforestation projects. If shrubs are introduced as part of the restoration of degraded lands, shrub biomass may be accounted in the project carbon pools. However, shrub growth is suppressed once canopy closes, i.e. the area reaches normal stocking density per the yield tables. Shrubs may form significant component of the project if planted in significant proportion. The biomass regressions, for shrubs and small diameter stems, shall be developed during thinning after 5 years, before the first monitoring period. A subset of stems harvested in the course of the first thinning shall be measured to develop the allometric relation between basal diameter and dry biomass and dbh and total dry biomass.

#### **Below ground biomass ( $B_{BG}$ )**

For below ground biomass, it is recommended that the literature be searched and functions based on age, site class, and aboveground biomass be developed. In the CO2FIX Model, the relation between below ground biomass and above ground biomass is expressed as follows.

$$B_{BG} = [B_T * B_{Fr}] \quad (6)$$

Where

$B_{BG}$  = Below ground biomass growth (Mg/ha)

$B_T$  = Stem biomass growth (Mg/ha)

$B_{Fr}$  = Fraction of root biomass

The below ground biomass estimate of the CO2FIX can be checked against the values estimated from the literature such as the relationship between below ground biomass to above ground biomass (root-shoot ratio of ~ 0.2) (Cairns et al. 1997)<sup>4</sup> as outlined below.

$$B_{BG} = \exp[-0.7747 + 0.8836 * \ln AB] \quad (7)$$

Where,

$B_{BG}$  = Below ground biomass (Mg/ha)

AB = Above ground biomass (Mg/ha)

#### **Litter ( $B_L$ )**

Litter includes all dead biomass of less than 10cm diameter such as dead leaves, twigs, dry grass, and small branches. Litter is measured by placing a circular frame of 30cm radius to collect the litter biomass. Depending on the number of strata, up to 3 samples for each plot can be laid to collect litter, including small

<sup>4</sup> Cairns, M.A.; Brown, S. et al. (1997) : Root biomass allocation in the world's upland forests. *Oecologia* (1):1-11.

woody material. Litter samples should be collected at the same time of year in order to account for seasonal influences. The collected litter is oven dried and weighed to estimate the biomass.

**Deadwood ( $B_{DW}$ )**

The deadwood is small or non-existent at the early stages of the project scenario, but it may increase as the A/R areas age. In the CO<sub>2</sub>FIX model, deadwood is included in coarse woody litter (stems and stumps) and, to a lesser extent in the form of short fine woody litter (fine and coarse branches, coarse roots). Its two components - standing or lying dead wood shall be considered for measurement.

$$B_{DW} = B_{SDW} + B_{LDW} \tag{8}$$

Where,

$B_{PDW}$  = Biomass of deadwood (Mg/ha)

$B_{PSDW}$  = Standing deadwood (Mg/ha)

$B_{PLDW}$  = Lying deadwood (Mg/ha)

*Standing dead wood*

Standing dead trees shall be measured with the same criteria and monitoring frequency as that of live trees. The relative state of decomposition corresponds to a percent of original living biomass. The decomposition classes for standing dead wood include: (i) tree with branches and twigs that resembles a live tree (except for leaves), (ii) tree with no twigs but with persistent small and large branches; (iii) tree with large branches only; and (iv) bole only, no branches

*Lying dead wood*

The lying dead wood is highly variable in the early stages of an afforestation activity. In the first few decades, this pool is small and has little value for measuring. However, as the stands age, the lying dead wood pool will increase. In the event that substantial accumulation of lying dead wood is observed over time, measurements can be instituted to quantify the decrease in biomass.

Lying dead wood shall be sampled using the line intersect method (Harmon and Sexton, 1996)<sup>5</sup>. Two 50-meter length lines are established bisecting each plot and the diameters of lying dead wood ( $\geq 5$  cm diameter) intersecting the lines are measured at the point of intersection. Each dead wood piece is assigned to one of three density states – sound, intermediate, and rotten – and the volume per unit area is calculated using the following equation (Warren and Olsen, 1964)<sup>6</sup>.

$$V_{LDW} = 9.869 * (D^2 / 8) * T \tag{9}$$

Where,

$V_{LDW}$  = Volume of lying deadwood m<sup>3</sup> per sq.meter

D = Diameter of pieces of dead wood square in meters

T = Transect length in meters

To convert volume to mass per unit area, the mean density of lying dead wood is calculated from a representative sub-sample.

$$B_{LDW} = V_{LDW} * MD \tag{10}$$

<sup>5</sup> Harmon, M. E. and J. Sexton. 1996. Guidelines for Measurements of Woody Detritus in Forest Ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

<sup>6</sup> Warren, W.G. and Olsen, P.F. 1964. A line transect technique for assessing logging waste. *Forest Science* 10: 267-276.

Where

$B_{LDW}$  = Biomass in lying deadwood

MD = Mean density of wood

### Soil

The major variables that influence soil carbon include soil depth, bulk density, and concentration of organic carbon in the sample. Soil samples shall be stratified taking into account the soil type and depth. The sample size depends on the accuracy and precision desired, which in turn influences the costs. Soil samples collected shall be aggregated to reduce the variability, sieved through a 2 mm sieve, mixed and analyzed in the laboratory. For bulk density determination, soil samples are oven dried and weighed.

The soil organic matter may change in the afforested areas if the area is likely to be under vegetation for a long period. To reduce costs, the monitoring plan should limit the soil carbon measurements to 20 year intervals.

$$C_{PS} = C_{SOC} * BD * D * CF * M \quad (11)$$

$C_{PS}$  = Soil organic carbon in the project scenario (Mg C/ha)

$C_{SOC}$  = Soil organic carbon from in soil mass from laboratory analysis (g C)

BD = Bulk density (soil mass/volume of sample) (Mg/m<sup>3</sup>)

CF = 1 – (% volume of coarse fragments/100) to adjust the proportion of volume of sample occupied by coarse fragment of > 2mm.

M = Multiplier to convert units into (Mg C/ha)

### Project emissions

The project emissions include the emissions that result from the project implementation. The project emissions in the context of an afforestation activity include the use of fuel in carrying out the afforestation activities.

$$PE_{CO2e} = A * D * ED * + A * G * EG * 0.001 \quad (12)$$

Where

A = project area

D = Quantity of diesel

ED = Emission factor for diesel (2.63 kg CO<sub>2</sub>/l)

G = Quality of gasoline

EG = Emission factor for gasoline (2.40 kg CO<sub>2</sub>/l)

0.001 = Factor to convert kg to Mg

### Estimation of carbon pools using the CO<sub>2</sub>FIX model

The GHG removals can be modelled conservatively using simulation models such as CO<sub>2</sub>FIX, a bookkeeping model that simulates the carbon stocks and fluxes of carbon in the forest ecosystem and soils. The simulation model can project the changes in carbon stocks under the baseline and project scenarios.

### Parameterisation of the CO<sub>2</sub>FIX model

Parameterization is an important step in estimating the carbon stocks. The species models defined should correspond to the growth characteristics (yield classes) of species used in the afforestation. The yield tables, wood density, volume, and parameters relating to the project can be used in CO<sub>2</sub>FIX. The results of the CO<sub>2</sub>FIX model should be compared with the field data and further refinement of parameters during the course of the project. The CO<sub>2</sub>FIX model makes conservative estimation of the carbon stocks in the aboveground biomass and litter.

The growth of stem biomass (Bs) is expressed as a function of age. The values are initially derived from yield tables and refined with the data from inventories. The biomass allocation coefficient (F) for foliage,

branches and roots are expressed as a function of tree age. Like the stem growth rates, the F-parameters have to be refined through limited destructive sampling.

**E.6. Explain how the baseline methodology addresses any potential leakage of the proposed A/R project activity:**

>>

Leakage is the increase of emissions or the loss of carbon pool outside of the project area as a consequence of the project activity. The methodology considers two forms of leakage:

**(1) Staff travel associated with the project activity, calculated as follows:**

$$P_{LK} = D * N * FC * EF * 0.001 \quad (13)$$

Where

- P<sub>LK</sub> = Leakage from transportation under the project scenario
- D = Distance travelled in kilometres
- N = Number of vehicles travelled
- FC = Fuel consumption of vehicle (l/km)
- EF = Emission factor (kg CO<sub>2</sub>e/l)
- 0.001 = Factor to convert kg to Mg

**(2) Diversion of pre-existing A/R activities:**

As noted in Section E.2, pre-existing A/R programs may in implementation in the country and be diverted or scaled down as a consequence of the project, in which case removals in the baseline scenario would be higher than without such diversion or program reduction. The methodology accounts for this possibility through:

- (a) Monitoring and recording of the actual level of A/R activities by relevant entities during the implementation period of the project activity.
- (b) Calculating any shortfall in the annually a/reforested areas in comparison to the average annual normal A/R levels over the previous 10 years.
- (c) Subtracting the shortfall from the A/R area under the project activity, thus reducing the land that can effectively be used to claim GHG removals by the project activity.

**E.7. Explain and justify formulae/algorithms and/or models used to determine the net anthropogenic GHG removals by sinks from the proposed A/R CDM project activity:**

>> Considering that the methodology sets the GHG removals in the baseline scenario to zero for the first and all subsequent monitoring periods, the methodology proposes to calculate the net anthropogenic GHG removals for all monitoring periods as the net GHG removals in the project scenario in that monitoring period:

$$NR(t)_{CO_2e} = PR(t)_{CO_2e} \quad (14a)$$

with:  $BR(t)_{CO_2e} = 0$

Where:

- NR(t)<sub>CO<sub>2</sub>e</sub> = Net anthropogenic GHG removals in the monitoring period t (CO<sub>2</sub>e)
- PR(t)<sub>CO<sub>2</sub>e</sub> = GHG removals in the project scenario in the monitoring period t (CO<sub>2</sub>e)
- BR(t)<sub>CO<sub>2</sub>e</sub> = GHG removals in the baseline scenario in the monitoring period t (CO<sub>2</sub>e)
- t = Indicator for the monitoring period

Note that the equivalent formula reads as follows, if baseline removals are assessed to be positive for subsequent crediting periods:

$$NR(t)_{CO_2e} = PR(t)_{CO_2e} - BR(t)_{CO_2e} \quad (14b)$$

With  $BR(t)_{CO_2e} \geq 0$

**SECTION F. Data sources and assumptions:**

**F.1. Describe all parameters and assumptions (e.g. regarding biomass expansion factors and activity levels): :**

>>

*Assumptions*

- The allometric equations and yield tables may be obtained from local research institutions or from published sources.
- The relationship between above ground biomass and below ground biomass holds in most circumstances.
- The exclusion of one or more carbon pools from the estimation, for example the exclusion of herbaceous biomass, is reasonable and supports the conservativeness in the assessment of carbon pools.
- In situations of declining carbon pool, the assumption of unchanging baseline or net zero GHG removals in the baseline scenario is conservative.

The parameters and conversion factors are from recognized sources such as the IPCC good practice guidelines for LULUCF and other published research.

*Simulation model – Parameterization of the CO<sub>2</sub>FIX model*

CO<sub>2</sub>FIX is a software program developed by the CASFOR project team of G.J. Nabuurs, J.F. Garza-Caligaris, M. Kanninen, T. Karjalainen, T. Lapvetelainen, J. Liski, O. Masera, G.M.J. Mohren, A. Pussinen, and M.J. Schelhaas of ALTERRA, UNAM, CATIE and European Forest Institute (EFI). CO<sub>2</sub>FIX V2.0 simulates carbon stocks and fluxes on a per hectare basis and at one-year intervals. The software integrates five modules: general parameters, biomass, soil, wood products, and outputs. Initial parameters need to be specified for modules except for output module.

**Table 1: Variables used to parameterize the CO<sub>2</sub>FIX 2 model in baseline and project scenarios**

<b>SPECIES:</b>		
<b>SITE CLASS</b>		
<b>ROTATION LENGTH IN YEARS</b>		
<b>GENERAL PARAMETERS</b>		
Simulation lengths (yr)		
Maximum stand biomass (Mg/ha)		
Growth as a function of:		Age
Completion relative to:		Total stand biomass
Management mortality:		Depends only on the total volume harvested
Cohorts		Species cohorts
Start age (yr)		0
<b>SOIL PARAMETERS</b>		<b>CLIMATE PARAMETERS</b>
Initial Soil Carbon Stock based on annual inputs of:		Annual mean temperature (°C)
- Foliage (Mg C/ha/yr)		Precipitation in growing season (mm)
- Branches (Mg C/ha/yr)		
- Roots (Mg C/ha/yr)		Potential evapo-transpiration in growing season (mm)
- Stems (Mg C/ha/yr)		

SOIL COHORT PARAMETERS		YASSO MODEL PARAMETERS				
Cohort	Quercus	Temperature sensitivity humus decomposition				
Type	Broadleaf / conifer	Initial decomposition rate for soluble compounds				
Estimated Initial Carbon (MgC/ha)						
- Non woody litter		Proportion (MgC/ha)	Soluble compounds	Holo-cellulose	Lignin-like compounds	
- Fine woody litter						
- Coarse woody litter		Non wood litter				
- Soluble compounds		Fine wood litter				
- Holocellulose		Coarse litter				
- Lignin-like compounds						
- Humus stock 1						
- Humus stock 2						
<b>BIOMASS PARAMETERS</b>	<b>STEM</b>	<b>FOLIAGE</b>	<b>BRANCH</b>	<b>ROOT</b>		
Wood Density (Mg DM/m <sup>3</sup> )						
Carbon Content (Mg C/Mg DM)						
Initial Carbon (Mg C/ha)						
Growth Correlation Factor						
Turnover Rate (1/yr)						
<b>BIOMASS DYNAMICS</b>						
<b>Age at 5 year intervals</b>	<b>0</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>	
Stem growth (m <sup>3</sup> /ha/yr)						
Proportion of growth relative to stem growth						
Proportion of branch growth relative to stem growth						
Proportion of roots growth relative to stem growth						
Proportion of Mortality						
Competition (multiplier of standing biomass/max. stand biomass)						
Mortality induced by logging (proportion of standing biomass)						
<b>THINNING &amp; HARVEST</b>						
<b>Age at 5 year intervals</b>	<b>0</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>	
Proportion of biomass removed						
Proportion of stems for log wood						
Proportion of stems for pulp & paper						
Proportion of stems for slash						
Proportion of branches for log Wood						
Proportion of branches for pulp & paper						
Proportion of branches for slash						
Proportion of foliage for slash						
Proportion of slash for firewood						
Proportion of slash to soil						

**F.2. List of data used and their sources:**

>>

**Land use data**

Project area, boundary, and maps: Project entity  
 Silvicultural and management data: Project entity

**Example of yield table data and allometric equations**

**Table: Use of local allometric equations**

Forest Type	Based on Country	Species	Data	Reference
Robinia III Robinia IV	Romania	Robinia pseudoacacia	CAI of stem wood	Romanian yield tables (Giurgiu et al. 1973), p. 273 and p. 720
Populus III	Ukraine	Populus nigra, Populus alba	CAI of stem wood	Ukrainian yield tables (1987), p. 259
Quercus III Quercus IV	Ukraine	Quercus robur, Quercus rubra	CAI of stem wood	Ukrainian yield tables (1987), p. 225

1. Normativno-spravocinîe materialî dlea taxatii lesov Ucrainî i Moldavii – Kiev, “Urajai”, 1987;
2. V. Giurgiu, I. Decei, S. Armasescu. Biometria arborilor si arboretelor din România – Bucuresti, “Ceres”, 1972;
3. Osadciov V.G., Ivankov P.T., Sergovschi P.S. et. Al: Spravocinik po derevoobrabotke (dlea tzehev sirpotreba leshozov), Moskova, 1955;
4. A. Utkin, D. Zamolodcikov i dr. – Opredelenie zapasov ugleroda nasajdenii na probnih ploscedeah: sravnenie allometricescogo i conversionno-obiemnogo metodov, Lesovedenie, nr. 5, Moskova, 1997.
5. CO<sub>2</sub>FIX2.0 parameters are based on the data from species groups and sites classes (Quercus III and IV, Populus III and Robinia III and IV).

**Wood density data**

The wood density values derived from various sources indicate a range of wood density values for different species.

Osadciov<sup>7</sup> (1955) presents the following wood density values that are applicable to Moldova: *Robinia sp* - 780kg/m<sup>3</sup>, *Quercus sp* - 675 kg/m<sup>3</sup>, *Populus sp* - 420 kg/m<sup>3</sup>, *Pinus sp* - 503 kg/m<sup>3</sup>;

The values from literature for *Populus alba*<sup>8</sup> = 410 kg/m<sup>3</sup>, *Robinia*<sup>9</sup> = 730 kg/m<sup>3</sup>, *Robinia*<sup>10</sup> = 730 kg/m<sup>3</sup>, *Quercus robur*<sup>9</sup> = 640 kg/m<sup>3</sup>, *Quercus robur*<sup>10</sup> = 650 kg/m<sup>3</sup>.

Wood samples analyzed by using MOBILA-TEST (Test and Certify Centre for Furniture and Wood Manufactured Goods) gave the following values).

*Robinia sp* - 695kg/m<sup>3</sup>, *Quercus sp* - 835 kg/m<sup>3</sup>, *Populus sp* - 510 kg/m<sup>3</sup>, *Pinus sp* - 535 kg/m<sup>3</sup>;

The following wood densities were used to conservatively estimate the carbon pools:

*Quercus* - 675 kg/m<sup>3</sup>, *Populus* - 420 kg/m<sup>3</sup>, *Robinia* - 700 kg/m<sup>3</sup> and *Shrubs*<sup>11</sup> - 620 kg/m<sup>3</sup>.

<sup>7</sup> Osadciov V.G., Ivankov P.T., Sergovschi P.S. et. Al: Spravocinik po derevoobrabotke (dlea tzehev sirpotreba leshozov), 1955

<sup>8</sup> Bressneck, Bosa, Viviani in Zycha, H. et al. (1959): Die Pappel. Paul Paray, Hamburg and Berlin, 121 pp

<sup>9</sup> Knigge, W; Schulz, H. (1966): Grundriss der Forstbenutzung. Paul Paray, Hamburg and Berlin, 583 pp

<sup>10</sup> Sachsse, H. (1984): Einheimische Nutzhölzer. Paul Paray, Hamburg and Berlin, 159 pp

<sup>11</sup> Estimated from local forest expert experience.

***Below ground biomass:***

Cairns, M.A, S. Brown, E.H. Helmer, and GA Baumgardner (1997): Root biomass allocation in the World's Upland Forests, *Oecologia* 111: 1: 11.

***Data on carbon fraction of dry matter***

IPCC good practice guidelines for LULUCF

***GHG emissions from fuel use***

Revised IPCC 1996 guidelines

**F.3. Vintage of data (e.g. relative to starting date of the proposed A/R CDM project activity):**

>>

- Baseline carbon pools: data based on field studies on above ground biomass, litter, and soil. data should not be older than 5 years.
- Socioeconomic data: data on land use and socio-economic characteristics from socio-economic study, not older than 5 years.
- Default factors: from most recent IPCC reports.
- Biomass of stratum from field studies: not older than 5 years
- Data on the carbon pools, e.g. below ground biomass: Current version of the “Good practiced guidelines for LULUCF” activities (2004)

**F.4. Spatial resolution of data (e.g. local, regional, national):**

>>

**National:** maps showing project area and project boundary.

**Regional:** data on land use, policies, socioeconomic variables, biodiversity.

**Local:** plot level data on carbon pools in the above ground vegetation and soil.

**SECTION G. Assessment of uncertainties:**

>>

Several risks may affect the carbon pools of the A/R activity. The sum of these multiple risks translates into a non-permanence risk. Therefore, this methodology recommends to evaluate the potential risks and to assess the adequacy of measures implemented to insure the carbon pools against risks.

- The reliability of data used to determines the *present carbon stocks* in the project sites. This includes the quality of information, land-use, soil types and plot sizes, yield tables, and sampling.
- The *development of baseline carbon stocks*. The scenario of continuing land use on degraded and pasturelands need to be checked and the data on soil erosion processes should be considered.

The overall risk of the baseline and project scenario shall be estimated using the error margins for the field data<sup>12</sup>, and a realistic assessment of risks shall be undertaken by partitioning the risk into various categories depending upon the availability of the data for the baseline and project scenarios.

***Sources of uncertainty***

The major sources of risk that affect carbon pools and introduce uncertainty in the estimates of GHG removals include:

*Natural:* Damage from multi-period drought, fire, disease, and wind

*Anthropogenic:* Unregulated grazing; illegal felling, technical and management capacity

*Measurement:* Uncertain in model parameters, yield table estimates, and site productivity

<sup>12</sup> For example, under the assumptions of a normal distribution, the soil carbon for degraded lands and pastures will be of the order of 78.6 t/ha +/- 15.0 t/ha, with a probability of 95%.

*Natural influences*

The natural influences on the project are mostly in the form of natural hazards such as droughts, fire, and pests and diseases. Drought during the first five years of the project results in increased mortality and the fire risk also significantly increases during dry period and in areas with high fuel load.

*Anthropogenic influences*

Grazing practiced on the project area and on adjoining lands may reduce litter and result in smaller gains in carbon in the absence of mitigating measures. The illegal felling for firewood is a major risk, which requires careful monitoring of above ground carbon biomass.

*Measurement error*

The errors in the measurement of carbon pools may be due to sampling errors, measurement errors, and model errors. The sampling error from each stratum may result in the large spatial variability. Thus by adopting an appropriate sampling framework, it is possible to reduce the sampling error in the above and below ground biomass and soil carbon. Since the time and periodicity of measurement influences the measurement error in carbon pools, quality assurance becomes critical in minimizing the variability of estimates.

With reference to model errors, the CO<sub>2</sub>FIX predictions are based on a general model for carbon sequestration. The yield models assume full stocking and a set sequence of thinnings over the life of the crop. The model may either over- or underestimates carbon. An overestimate of the site class may also result in the overestimation of carbon flows.

***Measures to reduce uncertainty***

Several actions can be implemented to reduce the risks to the project. The project entity shall ensure adequate technical and financial resources to hedge against the risk.

The project entity can retain a proportion of carbon benefits generated to self-insure. The simulations of the CO<sub>2</sub>FIX model account for the self-insurance possibilities since a carbon reduction factor can be built into the estimates to account for possible losses from grazing, drought, illegal felling, and disease. If the area under afforestation is net of roads and other construction (e.g. high-voltage power lines), a reduction of 5% carbon in the pool is conservative to cover the losses from unforeseen factors.

The monitoring data can be used to update the risk profiles of carbon pools at each monitoring interval. Based on the expected risks, a sensitivity analysis shall be carried out to assess the impact of risks on the carbon pools. The sensitivity analysis presents the impact of likely risks and helps to initiate mitigation measures.

Other mitigation measures include:

- Fencing of sites: recommended in areas where this is worthwhile to reduce the impact of grazing on the project activity.
- Strengthening relations with the local communities to reduce the levels of illegal felling for firewood.
- The CO<sub>2</sub>FIX parameters can be reviewed in the light of project monitoring and independent third party validation and periodically corrected to improve the reliability of the estimates.
- The project entity shall make conservative assumptions in assessing the site productivity class.