01. Forest and Natural Resources Conservation/Afforestation

1. Typical Project Outline

・ Afforestation from non-forest lands such as devastated lands, pasture and agricultural lands.

2. Applicability

(1) Target lands defined as no forests in the target country.

(2) The forests should be sustainably managed.

(3) Not cover wet lands.

3. Methodology of Emission Reduction Calculation

Since trees absorb in and fix carbons from atmosphere for their growth through photosynthesis, they are known as the carbon dioxide (or carbon) reservoirs/pools. Thus, the net anthropogenic GHG absorption through afforestation is calculated as the difference between increase in carbon dioxide sinks in forested lands (or reduction due to thinning and harvesting) (project absorption) and assumed increase (or decrease) in carbon dioxide sinks in the case of without afforestation (baseline absorption) plus GHG emission associated with the afforestation activities in the project (project emission).

$$ER_{AR,y} = \Delta C_{PJ,y} - \Delta C_{BL,y} - PE_y$$

$\mathrm{ER_{AR,y}}$: Net anthropogenic GHG absorption with afforestation project in year y (t-CO_2e/y)

$\mathrm{\Delta C_{PJ,y}}$: Annual GHG absorption with afforestation in year y (t-CO_2e/y)

$\mathrm{\Delta C_{BL,y}}$: Annual GHG absorption without afforestation in year y (t-CO_2e/y)

$\mathrm{PE_y}$: GHG emission associated with afforestation activities in year y (t-CO_2e/y)

Here,

$$\Delta C_{PJ,y} = (C_{PJ,t2} - C_{PJ,t1})/(t2 - t1)$$

$$\Delta C_{BL,y} = (C_{BL,t2} - C_{BL,t1})/(t2 - t1)$$

$\mathrm{C_{PJ,t1}}$: CO_2 stock of the forested land in year t1 (t-CO_2e/y)

$\mathrm{C_{PJ,t2}}$: CO_2 stock of the forested land in year t2 (t-CO_2e/y)

$\mathrm{C_{BL,t1}}$: CO_2 stock of grass and other plants in the absence of the project in year t1 (t-CO_2e/y)

$\mathrm{C_{BL,t2}}$: CO_2 stock of grass and other plants in the absence of the project in year t2 (t-CO_2e/y)

t_1, t_2 : Year of start and end of each CO_2 stock accounting (monitoring) period.

Regarding the difference of CO_2 sink in the forested lands, the difference between year t2 and year t1 is not necessarily one year, but can be obtained as a difference between multiple years (for example, 3 years ago, 5 years ago). In this case, divide by (t2-t1) years to find GHG sink per year.

Then, the cumulative net anthropogenic GHG absorption after the project implementation until year y can be expressed in the following formula.

$$ER_{AR,Y} = \sum_{y}^{Y} ER_{AR,y}$$

Project absorption is obtained as the difference of carbon dioxide stocks in the forested land between the year t1 and the year t2. Baseline absorption is obtained as the difference of carbon dioxide stocks in the project area in the year t1 and the year t2 in the case of without the project. If the vegetation originally grown in the target land is reproduced in the same cycle over years, it becomes $C_{BL,t1} = C_{BL,t2}$ and $\Delta C_{BL,y}$=0.

On the other hand, project emission includes nitrogen monoxide (N_2O) emission due to fertilization (nitrogen fertilizer, caustic lime) and GHG emissions due to clearing grasses, crops and trees originally grown on the project area. The former is usually seen as negligibly small, thus treated as zero here. The latter is limited only to the initial stage of preparation for forestation. However, it is not always negligible.

(1) Calculation of Project Absorption

Annual project absorption after project implementation can be obtained as the difference of carbon dioxide stocks in the afforested area between the year t1 and the year t2. Carbon dioxide stocks can be obtained by multiplying per hectare carbon stock of forested land with the forested acreage and CO_2 conversion factor of carbon.

$$\Delta C_{PJ,y} = C_{PJ,t2} - C_{PJ,t1}$$

$$C_{PJ,t2} = \sum_i (N_{t2,i} \times A_{PJ,i} \times 44/12)$$

$$C_{PJ,t1} = \sum_i (N_{t1,i} \times A_{PJ,i} \times 44/12)$$

$N_{t2,i}$: Per hectare carbon stocks in the stratum i in year t1 in the project (t-C/ha)

$A_{PJ,i}$: Acreage of the stratum i in the forested land (ha)

$N_{t1,i}$: Per hectare carbon stocks in the stratum i in year t2 in the project (t-C/ha)

$44/12$: CO_2 conversion factor of carbon

A stratum represents forest growth attributes such as species, density, forested year, degree (grade of land fertility) of the forested land. All attribute data are required per stratum. Since there is no standardized stratification, strata can be specifically defined in each project. In the land with uniform degree, the required stratum may be species only even in a wide area. More numbers of strata are required in lands with diverse species and degrees. The CDM projects typically defined 2 -16 strata. Stratification can be simplified, for example, trees can be roughly classified into 3 strata based on growth rate where diverse species are found. Appendix table A-11 shows the example of stratification for afforestation.

Determination of $N_{y,i}$:

Generally, carbon stocks include aboveground biomass, belowground biomass, dead wood, litter and soil organic carbon. For the methodology carbon stocks acquired through afforestation are mainly calculated based on the aboveground and belowground biomasses for simplicity and conservativeness.

$$N_{y,i} = N_{A,y,i} + N_{B,y,i}$$

$N_{A,y,i}$: Per hectare carbon stock of aboveground biomass in the stratum i (t-C/ha)

$N_{B,y,i}$: Per hectare carbon stock of belowground biomass in the stratum i (t-C/ha)

Carbon stocks of aboveground and belowground biomasses are calculated by multiplying amount of aboveground biomass (dry matter stem, branches, and leaves) and belowground biomass (dry matter roots) with carbon fraction of trees, respectively.

$$N_{A,y,i} = T_{A,y,i} \times CF_i$$

$$N_{B,y,i} = T_{B,y,i} \times CF_i$$

$T_{A,y,i}$: Per hectare aboveground biomass in the stratum i (t-dm/ha: ton dry matter/h*a*)

$T_{B,y,i}$: Per hectare belowground biomass in the stratum i (t-dm/ha)

CF_i : Carbon fraction of trees in the stratum i

The amount of aboveground biomass is calculated by multiplying volume of trees with the biomass expansion factor and bulk density.

$$T_{A,y,i} = SV_{y,i} \times BEF_i \times WD_i$$

$SV_{y,i}$: Per hectare tree volume in the stratum i (m^3/ha)

BEF_i : Biomass expansion factor of the stratum i

WD_i : Bulk density of the stratum i (t-dm/m^3)

On the other hand, the amount of belowground biomass is calculated as follows.

$$T_{B,y,i} = T_{A,y,i} \times R_i$$

R_i : Ratio of belowground biomass to aboveground biomass for stratum i (ratio of belowground vs. aboveground)

(2) Calculation of Baseline Absorption

Baseline absorption would be zero under the assumption that the vegetation grows in the same cycle over years without afforestation project.

(3) Calculation of Project Emission

Project emission may include emission of nitrogen monoxide (N_2O) associated with fertilization and GHG emission associated with clearing grasses and crops to prepare for afforestation.

Emission of nitrogen monoxide (N_2O) associated with fertilization:

N_2O emission associated with fertilization is usually negligibly small compared to CO_2 absorption after project implementation, thus it is negligible. Therefore, $N_2O = 0$.

GHG emission corresponds to carbon stocks in vegetation originally grown on the afforestation land:

It can be calculated by multiplying per hectare carbon stocks of biomass (dry matter) such as grasses before the project with the acreage of land forested and CO_2 conversion factor of carbon. Note that this emission is calculated for the year of clearance for afforestation only.

$$C_{RMV,py} = \sum_{j} (O_{py,j} \times A_{gr,j} \times 44/12)$$

$O_{py,j}$: Per hectare carbon stocks in the stratum j in the year of clearance for afforestation (t-C/ha)

$A_{gr,j}$: Acreage of the stratum j (ha)

$44/12$: CO_2 conversion factor of carbon

Determination of $O_{py,j}$:

It is determined as follows.

$$O_{py,j} = R_{A,py,j} + R_{B,py,j}$$

$R_{A,py,j}$: Per hectare aboveground carbon stocks in the stratum j in the year of clearance (t-C/ha)

$R_{B,py,j}$: Per hectare belowground carbon stocks in the stratum in the year of clearance (t-C/ha)

Aboveground and belowground carbon stocks are calculated by multiplying amount of aboveground biomass (dry matter stem and leaves) and belowground biomass (dry matter roots) with their carbon fractions, respectively.

$$R_{A,py,j} = V_{A,py,j} \times 0.5$$

$$R_{B,py,j} = V_{B,py,j} \times 0.5$$

$V_{A,py,j}$: Per hectare aboveground biomass in the stratum j in the year of clearance (t-C/ha)

$V_{B,py,j}$: Per hectare belowground biomass in the stratum j in the year of clearance (t-C/ha)

0.5 : Carbon fraction of vegetation biomass

Belowground biomass is calculated in the following formula.

$$V_{B,py,j} = R_j \times V_{A,py,j}$$

R_j : Ratio of belowground biomass to aboveground biomass for the stratum j (ratio of belowground vs. aboveground)

Vegetation in scope of biomass calculation

Among vegetation in pasture or agricultural lands, perennial plants are included in carbon stock calculation. Perennial plants prefer to grow in pasturelands. In addition, shrubs grown on pasturelands are also in scope of calculation. Among crops on agricultural lands, perennial orchards and horticultural trees such as gum trees and date palms are also in scope of calculation. Annual crops (vegetables, corns and cottons) are grown and harvested in a year, thus contribution to carbon stocks would be almost zero.

CO_2 stock calculation per land use

Biomass in pasture and agricultural lands is preferably calculated for aboveground and belowground, respectively. However, biomass per land use issued in the target country can be used to estimate CO_2 stocks per hectare. The tables below show some samples.

< Biomass and CO_2 stocks per land use>

Land use category			Biomass (t-dm/ha)	Carbon fraction (t-C/t-dm)	Conversion factor from carbon to carbon dioxide	CO_2 stock (t-CO_2/ha)
Before conversion	Agricultural land	Paddy	0.00	0.50	44/12	0.00
		Upland	0.00			0.00
		Orchard	IE	0.48		56.16
	Pasture		13.50	0.47		24.75
	Wetland, developed land, others		0.00	0.50		0.00

Land use category			Biomass (t-dm/ha)	Carbon fraction (t-C/t-dm)
After conversion	Agricultural land	Paddy	3.0 (t-C/ha/yr)	0.50
		Upland	0.00	
		Orchard	IE	0.48
	Pasture		2.70 (t-d.m./ha/yr-)	0.47
	Wetland, developed land, others		0.00	0.50
	Conifer		3.0	0.51
	Broadleaf			0.48

※IE＝Included into the biomass of agricultural land which is not diverted.
Extracted from "Report of Greenhouse Gas Inventory of Japan"(2018)

Land use category	Biomass (t-dm/ha)	Carbon fraction (t-C/t-dm)	Conversion factor from carbon to carbon dioxide	CO_2 stock (t-CO_2/ha)
1. Grass land	11	0.5	44/12	20
2. Grass land with shrubs	16			29
3. Annual crops/fallow land (slash and burn)	0			0
4. Perennial crops	24			44

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4. Data and Parameters Estimated and Need Monitoring

	Description	Data Sources

Data		For baseline emission calculation		For project emission calculation	
		Ex-ante	Ex-post	Ex-ante[1]	Ex-ante
$A_{PJ,i}$	Acreage of the strata i in the forested land (ha)	N/A		A planned value	A monitored value
$T_{A,y,i}$	Per hectare aboveground biomass in the stratum i (t dm/ha)	N/A		A IPCC default value (Table A-5,7 and 8, Appendix) However, if there is no default value applied or if there is another appropriate value, that value may be used.	
$SV_{y,i}$	Volume of trees per hectare in the stratum i （m^3/ha）	N/A		A planned value	A monitored value
BEF_i	Biomass expansion factor of the stratum i	N/A		A IPCC default value (Table A-1, Appendix) However, if there is no default value applied or if there is another appropriate value, that value may be used.	
WD_i	Bulk density in the stratum i (t-dm/m^3)	N/A		A IPCC default value (Table A-2, Appendix) However, if there is no default value applied or if there is another appropriate value, that value may be used.	
CF_i	Carbon fraction of trees in the stratum i (t-C/t-dm)	N/A		A IPCC default value (Table A-3, Appendix) However, if there is no default value applied or if there is another appropriate value, that value may be used.	
R_i	Ratio of belowground biomass to aboveground biomass (ratio of belowground vs. aboveground) for the stratum i	N/A		A IPCC default value (Table A-9, Appendix) However, if there is no default value applied or if there is another appropriate value, that value may be used.	
$A_{gr,j}$	Acreage of the stratum j (ha)	N/A		A monitored value	
$V_{A,py,j}$	Per hectare aboveground biomass in the stratum j in the year of clearance (t-C/ha)	N/A		A IPCC default value (Table A-4, Appendix) However, if there is no default value applied or if there is another appropriate value, that value may be used.	
R_j	Ratio of belowground biomass to aboveground biomass for the stratum j	N/A		A IPCC default value (Table A-9, Appendix) However, if there is no default value applied or if there is another appropriate value, that value may be used.	

5. Others

[1] It refers to a value for ex-ante calculation of project emissions.

(1) Project Boundary

The project boundary is the afforestation lands in the project areas.

(2) Leakage

If residents and/or farming activities (cultivation, animal husbandry) need to be migrated in the course of project implementation, loss of carbon stocks (leakage) might be a concern in relation to deforestation out of the project boundary. Although pasture and agricultural lands are in scope of afforestation in this estimation formula, migration of many farmers and farming activities out of the project boundary is not assumed in the course of the project implementation. Therefore, leakage is deemed as zero. However, migration of residents and farming activities (cultivation, animal husbandry) needs to be counted as a concern, leakage should be calculated in consideration of cultivated acreage and number of livestock migrated out of the project boundary. For example, in CDM methodology, 15% of anthropogenic GHG reduction is calculated as leakage for cases where 10-50% of cultivated lands are migrated out of the project boundary.

(3) Monitoring

JICA's ODA loan projects usually require post-project evaluation only once after project completion. Baseline absorption monitoring is not required in afforestation projects. Other items (project absorption and project emission) need monitoring when the afforestation outcomes can be confirmed for the purpose of post-project estimation. Challenges inherent to afforestation projects include difficulties to know the timing to implement post-project evaluation as well as the wide extent of the project area. To cope with such challenges, satellite images may provide useful means.

For the long-term monitoring for 10-30 years throughout the forest growth period, it needs to set up permanent sampling plots and temporary sampling plots (for soil plots) to monitor states after afforestation (2-3 years) and even after 5, 10 years through several times.

(4) Comparison with existing CDM methodologies

The logic of emission reduction calculation in the methodology is almost the same as that of the AR-ACM0003 (Afforestation and reforestation of lands except wetlands, Version 02) and AR-AMS0007 (Afforestation and reforestation project activities implemented on lands other than wetlands, Version 03).

The methodology conducts estimations based on the aboveground and belowground biomass only while J-VER methodology has also neglected biomasses of dead wood, litter and soil organic. On the other hand, CDM methodologies put these carbon pools as optional. Moreover, neglecting of the above biomass pools in the case of afforestation is considered as a conservative way while these carbon pools will be increased by the project activities.