Guidelines for Stratification for REDD+

Using a National Inventory

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Lowering Emissions in Asia's Forests (LEAF)

GUIDELINES FOR STRATIFICATION FOR REDD+ USING A NATIONAL INVENTORY

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1 Introduction

1.1 Background

Engaging in REDD+ and seeking to take part in the opportunities and benefits of REDD+ requires credible scientifically-based estimates of emissions and removals of greenhouse gases from human-induced activities that change the cover and use of forest lands. This means data have to be collected on the extent of areas affected by human-induced activities that promote land cover change. The focus of this report is to provide step-by-step guidance on stratifying the forested landscape to facilitate the design of cost effective field sampling plans for measuring forest carbon stocks. .

To measure forest carbon stocks, the forestland undergoing human-induced changes need to be sampled[1]. Because not all forests are equal in composition, structure and carbon stocks, the focal forest lands, hereinafter referred to as the population of interest, must be stratified into sub-populations, or strata, that form relatively homogenous classes with similar carbon stocks. Stratification increases the precision of carbon stock estimates as it diminishes the sampling effort necessary, while maintaining the same level of confidence, because of smaller variation in carbon stocks in each stratum than in the whole area.

In the situation where a national inventory already exists, the purpose of stratification is to optimally divide forest areas between areas with carbon stock similarity. The divided areas will incorporate inventory plots, and with a good stratification high precision will result and consistent pairing will be possible with respective activity data.

1.2 Goal of this document

The purpose of this report is to provide a user-friendly sequence of steps guiding the stratification process for the development of accurate and statistically rigorous estimates of forest carbon stocks.

The set of steps depend on availability of data and encourages the use of existing national forest inventory data. The stratification process starts at a coarse global level classification, and through a series of steps, it narrows down to local expert knowledge of the forested landscape. The ultimate goal is to develop forest strata with little variability in carbon stocks.

[1] It is not possible to get credit for natural/non-anthropogenic changes in carbon stocks

2 National Inventories and Carbon Stratification

National inventories exist throughout the world and are designed for multiple purposes, including timber management, biodiversity monitoring, or resource inventory, and are increasingly proposed to support greenhouse gas inventories. But inventories in developing countries are typically implemented based on lessons learned in developed countries that were not designed for tracking changes in carbon stocks due to anthropogenic impacts on forests.

These inventories, such as the United States, cannot easily separate out natural versus anthropogenic impacts on the forest, thus they cannot readily identify changes caused by human activities that result in deforestation, forest degradation nor enhancement of carbon stocks—the design just gives the net change in carbon stocks across all forests.

Instead, the most effective use of the inventory is to develop emission factors[2] that can be paired with the activity data specific to human-induced deforestation, degradation or carbon stock enhancement. As such, carbon stocks and emission factors need only be determined for areas where there is a likelihood of deforestation, degradation or enhancement being recorded, because systematically installed plots in distant and hard to access areas are of little value in the short to medium term.

Under national inventories, plots are usually permanently installed. This is similar to the approach in the US where plots are revisited and the increment of growth represents the changes in stock. However, for the purpose of estimating emissions, the data needed are the emission factors appropriate to the given stratum rather than any increment of change in the specific location of the plot. This is more appropriate for a temporary plot approach whereby total stocks are assessed at new locations (relative to human-induced changes) with each inventory. Where the approach is to determine emission factors across strata there is no weakness in using permanent plots as a means of setting emission factors that will remain constant until the next inventory.

National inventories usually have significant costs associated and so may not be the most efficient means of developing emission factors. However, an inventory gives ancillary benefits in terms of information on biodiversity and timber and can be a consistent, systematic means of collecting the relevant data.

[2] An emission factor is a coefficient that quantifies the emission or removal per unit of human activity. This is not just the carbon stock for deforestation as the emission will be dependent on the post deforestation carbon stock and the fate of the removed trees. For degradation the emission factor will equally represent the stock before and after degradation but with consideration of fate of removed biomass and potential regrowth after initial degrading human activity.

National forest inventory data presents a significant data richness opportunity in developing a REDD+ program but also some challenges for optimal use. The purpose of these guidelines is to present a simple methodical approach to stratification of national forest inventory data to facilitate use for REDD+ implementation.

3 Steps for Stratification

3.1 Key considerations

Ecological factors (e.g. soil, climate, species composition) affect the amount and rate at which forests sequester carbon, but *anthropogenic factors* such as human disturbance, management practices and land use history affect forest carbon stocks as well.

Stratification has the purpose of dividing the forest population of interest into groups with similar carbon stocks. Variation in carbon stocks can be divided between natural and anthropogenic variation, caused by either current and/or historic human influence.

The stratification ultimately improves the efficiency of sampling and ensures representativeness of sampled population.

3.1.1 Natural variation in stocks

Natural variation will be the result of different growth conditions (climate, soil, topography) interacting with species and/or species group distributions.

3.1.2 Anthropogenic variation

Forests disturbed by humans are not only variable due to natural causes but also due to a variety of human activities that can reduce or enhance the carbon stocks. The effect of the human-caused variation depends on the intensity of the activities and the duration. Thus the variation brought about by human activities generally increases the variation in forest carbon stocks.

3.2 The steps

The steps for developing a forest stratification map based on a national inventory here are designed to go from simple to complex. The initial simple starting point allows countries to consider the most economical approach to stratification before introducing additional layers of complexity.

Precision and Stratification

Indicative confidence intervals[3] are given for acceptable levels of precision under stratification plans. It should be noted that these confidence intervals are given for guidance on selecting appropriate stratification, NOT for the purpose of crediting. Confidence intervals for crediting will typically be considered across strata not within individual strata.

Typical acceptable levels of uncertainty for crediting would be 10 or 15% of the mean at the 95% confidence level, or 10% of the mean at the 90% confidence level. This would be across all strata rather than within individual strata. Thus here we suggest a slightly lower level as an indication for individual strata with the reality that across strata a higher confidence level will be achieved.

3.2.1 IPCC categories

The IPCC in its Guidelines for National Greenhouse Gas Inventories gives the following forest type classifications for tropical and subtropical regions (a digital map for this product is available at http://www.fao.org/geonetwork/srv/en/main.home - search Global Ecological Zones).

- For Tropical regions:
    - Tropical rain forest
    - Tropical moist deciduous forest
    - Tropical dry forest
    - Tropical shrubland
    - Tropical mountain systems

- For Subtropical regions:
    - Subtropical humid forest
    - Subtropical dry forest
    - Subtropical steppe
    - Subtropical mountain systems

[3] "Confidence Interval: The true value of the quantity for which the interval is to be estimated is a fixed but unknown constant, such as the annual total emissions in a given year for a given country. The confidence interval is a range that encloses the true value of this unknown fixed quantity with a specified confidence (probability). Typically, a 95 percent confidence interval is used in greenhouse gas inventories. From a traditional statistical perspective, the 95 percent confidence interval has a 95 percent probability of enclosing the true but unknown value of the quantity. An alternative interpretation is that the confidence interval is a range that may safely be declared to be consistent with observed data or information. The 95 percent confidence interval is enclosed by the 2.5th and 97.5th percentiles of the PDF."
IPCC Guidelines for National Greenhouse Gas Inventories 2006, Volume 1, Section 3.1.3.

Analysis steps:

STEP 1: Where a national forest map exists overlay on the inventory plots;

STEP 2: Overlay the IPCC forest type data layer on the inventory plots (and if relevant the national forest map);

STEP 3: Within each of the IPCC forest type categories take the mean of measured carbon stocks (usually measured in tons of carbon per hectare) and 90% confidence interval of all inventory plots;

STEP 4: Where the half width of the 90% confidence interval is less than 20% of the mean for each stratum examined then the precision is sufficient and no further stratification is necessary;

STEP 5: Where the precision test is not met for one or more of the IPCC forest categories examine national forest maps (see 3.2.2).

3.2.2 National forest maps

STEP 1: For all IPCC categories for which the precision test failed, overlay with a national forest map (if one exists, if not see next section) and determine the mean of measured carbon stocks and 90% confidence interval of all plots by each forest class within the national map;

STEP 2: Where the half width of the 90% confidence interval is less than 20% of the mean for each stratum examined then the precision is sufficient and no further stratification is necessary;

STEP 3: Where the precision test is not met for one or more of the national forest classes within the IPCC categories then proceed to the case-specific expert assessment.

3.2.3 Expert opinion

STEP 1: For all forest areas where no preceding analysis has met the precision test, consult national and if necessary international experts to determine appropriate stratification. The following represent potential means of stratification:

- Accessibility (e.g. buffer around roads to have more and less accessible strata – likely to have more and less existing degradation);
- Management (e.g. where significant in area, plantations can and should be separated from natural forest);
- Splitting or lumping existing national forest map classes

STEP 2: For each of the expert-derived strata take the mean and 90% confidence interval of all plots;

STEP 3: Continue reassessing until all strata meet the test of the half width of the confidence interval being less than 20% of the mean at the 90% confidence level;

STEP 4: For specific areas and scenarios where precision cannot be met consider collection of additional targeted data.

3.3 Hypothetical example application of guidelines

A country "X" is wishing to conduct a stratification of the carbon data in its National Forest Inventory. According to the IPCC classes, country "X" has three different forest types: A, B, and C as well as non-forested areas as shown in Figure 1 below.

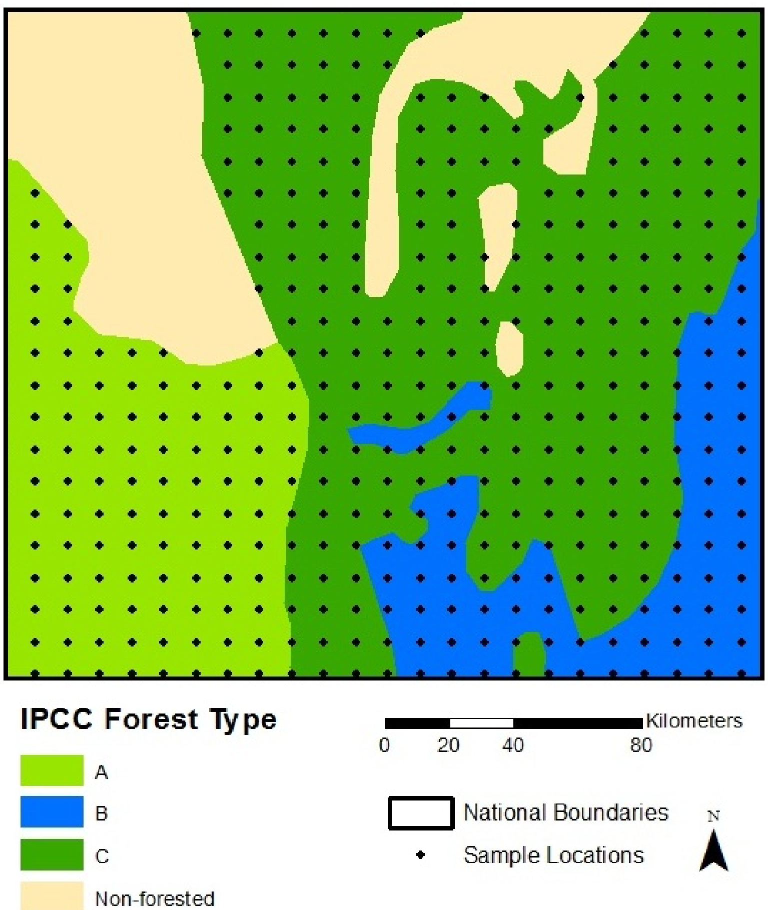

Figure 1: Forest cover map of country "X" according to IPCC forest classes.

By using the National Forest Inventory data, collected systematically at every intersection of a 10km x 10km grid, carbon stocks for each forest type along with the uncertainty were estimated (Table 1).

Table 1: Carbon stocks (t C/ha) of different forest types in country "X" based on IPCC classes.

	A	B	C
Mean (t C ha^{-1})	264.8	95.4	165.1
90%CI	30.4	15.8	48.3
CI as % of mean	11%	17%	29%
N	78	85	96

Based on the data analysis, the carbon stocks of forest types A and B are sufficiently homogeneous; however, forest type C is not. Thus C needs to be further stratified.

By overlaying country “X”’s National forest map, it is identified that forest type C is composed of three defined forest types: Ca, Cb, and Cc (Figure 2).

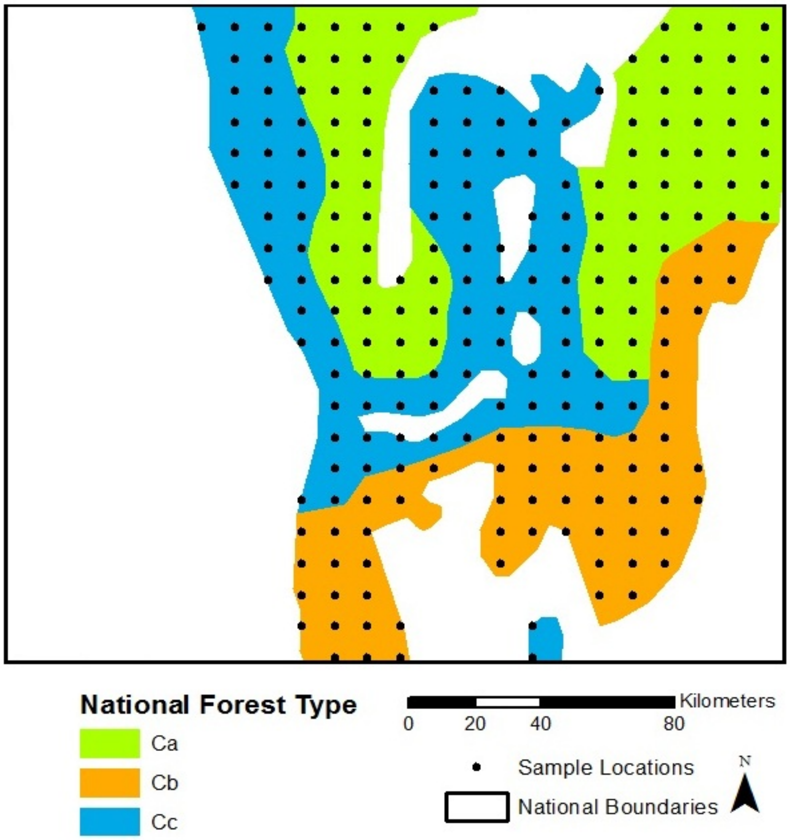

Figure 2: Division of forest type C based on country "X"'s National forest map.

The 96 sample points within forest type “C” are now split into 3 different forest types: Ca, Cb, Cc. By analyzing the data and estimating the carbon stocks of each of the forest types depicted in the National forest type map, it was identified that within forest types Ca and Cc were homogeneous carbon stocks. However, the forest type Cb still showed highly variable carbon stocks (i.e. half width of the 90% confidence interval is greater than 20% of the mean – see STEP 2 in section 3.2.2 above), and therefore requiring further stratification.

Table 2: Carbon stocks (t C/ha) of different forest types in country "X" based on National forest map.

	Ca	Cb	Cc
Mean (t C ha^{-1})	195.2	129.7	170.3
90%CI	17.4	33.4	5.1
% uncertainty	9%	26%	3%
N	31	33	32

Consulting local experts, officials learned that communities located in the area encompassed by forest type Cb gathered fuelwood for cooking and heating. Therefore a decision to further divide Cb based on the human accessibility to the forest was made. Participatory Rural Appraisals (PRAs) were conducted and indicated that a person would travel 5 km into the forest for collecting fuelwood. Thus, a buffer of 5km was created along either side of all roads in forest type Cb (Figure 3).

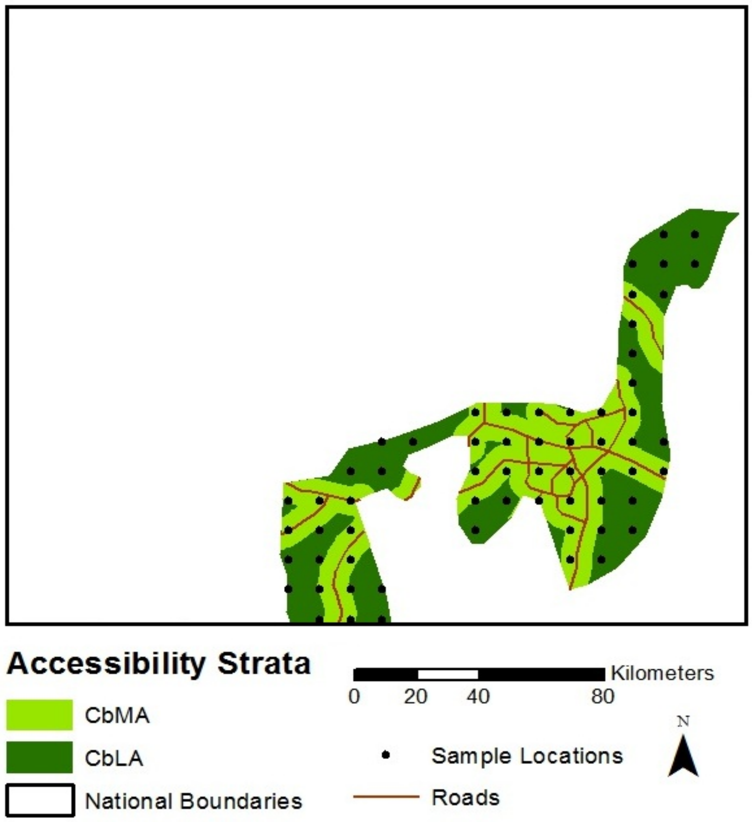

Figure 3: 5km buffers along either side of all roads in Cb: (i) CbMA corresponds to more accessible areas, and (ii) CbLA corresponds to less accessible areas outside of the buffers.

After subdividing forest type Cb, data analysis showed homogeneous distribution of forest carbon stocks in either the More and the Less Accessible areas (MA and LA respectively) (Table 3).

Table 3: Carbon stocks (t C/ha) of More and Less accessible areas (MA and LA respectively) of forest type Cb in country "X"

	CbMA	CbLA
Mean (t C ha^{-1})	115.9	152.7
90%CI	16.7	24.3
% uncertainty	14%	16%
N	19	14

After assessing the data for CbMA and CbLA, it was noted that CbLA has forest carbon stocks ranging from 128.4 to 177 t C ha^{-1} (152.7± 24.3 t C ha^{-1}), and thus similar to carbon stocks of previously identified stratum Cc. Therefore, merging of these two classes is now possible, and CbLA can be grouped with Cc.

Concluding the stratification process, country “X” REDD+ sampling design would encompass a total of 5 strata: 2 strata based on IPCC forest types (A and B), 2 strata based on the National forest map (Ca and Cc), and one strata based on accessibility to the forest (CbMA).

By stratifying country “X” using IPCC forest type classes, and further stratifying it based on the National forest map and on local expert knowledge, country “X” was able to estimate very robust (precise) forest carbon stocks for its REDD+ implementation activities.