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Increasing economic opportunity, sustaining natural resources, and protecting the environment.

Progress Report 2 for Year 7

April 2013

WINROCK INTERNATIONAL

Putting Ideas to Work

Increasing economic opportunity, sustaining natural resources, and protecting the environment.

1. Background

This progress report summarizes the activities performed during the second quarter of year 7. Tasks where no progress has been made are not mentioned in this document…..

2. Activities for Year 7

Task 1: Develop a detailed workplan for year 7

Completed

Sub-Task 1a. Data collection for emission factors

Several spatial and literature resources have been identified that are appropriate for improving the ACC (AFOLU C Calculator) and are described in more detail below.

Carbon Stocks

Mangroves

Global mangrove data obtained from USGS's Earth Resource and Observation Science (EROS) center has been fully analyzed and values have been established for 2000 extent (Giri et al, 2011)[1]. Rates of changes have been established based on FAO data (FAO, 2007)[2].

Relevant estimates of mangrove biomass values are derived from remote sensing for most of Africa, and from latitude-based equation for all other regions with mangrove forests. Lola Fatoyinbo from NASA's Goddard Space Flight Center (pers. comm.) provided biomass values for the African countries; the EROS data were then used to develop area weighted averages for sub-administrative units (Fatoyinbo & Simard, 2012)[3]. Biomass estimates for all other mangrove forests were developed using a latitude-based equation from Twilley (1992)[4].

The extent, rate of change, and biomass estimates are currently being entered in the database and these will be incorporated into the functioning calculator, along with growth rates, in the next quarter.

Agroforestry Systems

Significant new data and information have been compiled by two Agroforestry specialists under year 6. The consultants also suggested modifications to the methods for estimating carbon sequestration by Agroforestry Systems (AFS) employed in the Calculator. Currently, Winrock is working on developing methods for grouping the carbon sequestration potential of each of the AFS types into distinct ecological regions dictated mostly by climatic regimes, and geographical regions (per continent). Improved models for carbon sequestration of each AFS are under work, refining the carbon sequestration estimates provided by the ACC.

[1] Giri, C.; Ochieng, E.; Tieszen, L. L.; Zhu, Z.; Singh, A.; Loveland, T. (2011) Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecology and Biogeography. 20:1 154-159

[2] Food and Agriculture Organization of the United Nations [FAO], (2007) The world's mangroves 1980-2005. FAO Forestry paper 153, Rome

[3] Fatoyinbo, T E. & Simard, M. 2012 Height and biomass of mangroves in Africa from ICESat/GLAS and SRTM. International Journal of Remote Sensing. 34:2

[4] Twilley, R.R., R.H. Chen. and T. Hargis. 1992. Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. Water, Air, and Soil Pollution 64:265-288.

In addition to improving the methods in the ACC, Winrock has also initiated and leading the preparation of manuscripts on the work done by the consultants including improved models for C sequestration by AFS in a peer-reviewed scientific journal—the target for submission is June 2013

Selective Logging Timber Extraction Rates

No further progress since Progress Report 1.

Community forest management

Preliminary research was conducted to define community forest management and differences from commercial forest management in terms of practices and emissions. The research consisted of a literature review of existing studies in the area, including with case studies from Africa, Latin America and Asia.[5,6,7,8,9]

The main conclusion from this review is that studies have established a difference worth exploring between community forest management and industrial forest management, which may be related to the policy aspects of the AFOLU Carbon Calculator. The common thread in the research highlights that the more ownership communities have, the bigger their vested interest in sustainably managing their forest resources.

However, no clear difference in GHG accounting from the current methodology employed by the Forest Management Tool was identified. Therefore, community forest management was concluded to be already accounted for in the ACC.

Methodology for even-aged forestry in Temperate Regions

Significant progress was made in this component. More details are available in section 2a below.

Secondary Forests

During this quarter, the report outlining the data and equations used to improve the secondary forest biomass accumulation model in the afforestation/reforestation/forest restoration tools was submitted to two experts to provide a peer reviewer assessment. The report and analysis were revised to address deficiencies identified by peer reviewer comments (Annex 1). Point by point responses to reviewer comments will be submitted to USAID and peer reviewers along with the updated report and analysis.

Additional datasets
No further progress since Year 6.

Sub-Task 1b. Finalizing updating and validation of global forest carbon stock map.

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[5] Barry, D.et al. 2010. Sustainable forest management as a strategy to combat climate change - lessons from Mexican Communities. CCMSS, Rights and Resources Initiative.
[6] Chhatre A. and A. Agrawal, 2009 Trades-offs and synergies between carbon storage and livelihood benefits from forest commons. Availabe at: www.pnas.org/cgi/doi/10.1073/pnas.0905308106
[7] Murdiyarso, D. and M. Skutsch (ed.), 2006. Community forest management as carbon mitigation option: Case Studies. Bogor, Indonesia: Center for International Forestry Research (CIFOR).
[8] Porter-Bolland, L., et al. Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. Forest Ecol. Manage. (2011), doi:10.1016/j.foreco.2011.05.034
[9] Viana, V.M, et al. REDD+ and Community Forestry: Lessons learned from an exchange of Brazilian experiences with Africa. 2012. Manaus, Brazil. 72 PG. The World Bank/Amazonas Sustainable Foundation

No further progress since Progress Report 1. The release of this product has been delayed by the author (Dr. Sassan Saatchi) because some problems were encountered in some of the remote sensing data during validation of the map. Once Winrock acquires the product, we will need to process it to obtain carbon stocks by our administration units and upload the information to the database.

Sub-Task 1c. Refining estimates of deforestation rates.

No progress since Progress Report 1. Once Winrock acquires the product with the author (Dr. Matt Hansen), we will need to process it to obtain deforestation rates by our administration units.

Task 2: Build and test tools

Subtask 2a. Modification of the forest management tool

We proposed to revise this tool to include not just selective harvesting as is typical of tropical countries, but to also include non-selective (typically clear-cut management) timber harvesting as is typical in more temperate countries of USAID's portfolio. We now refer to this tool as including both selective harvesting (uneven-age management) and even-aged management –both of these exist worldwide and the approach is valid worldwide. We already have a tool for selective harvesting (uneven-aged management) and we have worked to develop an accounting approach for eve-aged forest management. Two specific activities are considered that will result in reduction in carbon emisisons:

i. extending timber rotations, and
ii. stopping timber harvest.

The calculation approach looks at the long term carbon stock both under business as usual and in the case of project implementation. The carbon stock is projected forward in both live biomass and in harvested wood products to the point where either the actual stock or the average stock is constant. The difference between long term stocks is the benefit from project implementation. Under Level A (simplest requirements) only the area and implemented activity are required. Under Level B users will have the option of inputing carbon stocks, rotation lengths, mill efficiencies and wood product classes.
Further refinements to the methods are on the works and the Tool shall be implemented online by September 2013.

Subtask 2b. Adding capability to add geographic specific details

We are now working with AGS on updating the calculator to handle the following two cases. However, users will continue to be able to use the ACC the way they do now if desired, thus creating three different ways for depicting spatial extent of projects.

Case 1. The user does not know, or does not want to specify the exact boundary of the activity, but will indicate which admin unit(s) contains the activity.

This is a modification of the current approach. The user will select one or more admin units to be associated with the activity, and then must provide the area of the activity in each of the admin units. For example if the user selects two admin units then they have to provide two area values. Alternatively, we could have a situation where the user enters a single area, but then has to enter a proportion for each admin unit. In the example above, the user would enter three values: total activity area, percent of activity in admin unit "X", and percent of activity in admin unit "Y".

For each admin unit, there is a set of fixed/default parameters, so for each admin unit selected, the calculator will be evaluated for each area and the results summed to produce a single GHG benefit estimate—this will be presented to the user as it is done currently.

A side benefit of this development is that there will be a mechanism for looping over multiple activities to evaluate the calculator. This mechanism could be used to help build a "batch run" functionality, which allows entering of multiple activities at various admin units at the same time. Such feature is expected to reduce the time spent by users who report various activities in an array of admin units (e.g. CARPE, LEAF, ICAA, etc).

Case 2. The user will specify the exact boundaries of the activity by drawing a polygon on a map. Subsequent improvements could allow the boundaries to be provided by uploading shapefiles, and/or selecting from a pre-loaded list of polygons.

This case will work as much like the previous case as possible. However, with the user-provided information about the extent of the activity, the individual area values will not need to be provided. Our plan is that the user will draw instead of click, signifying that they want to associate the activity location with a geographic explicit feature (polygon). The individual areas can be calculated behind the scenes, based on the intersection of the drawn polygon and the admin units, using the units of scale from the map. This mode will be compatible with future updates to the calculator in which some or all activity parameters could be derived using the activity polygon overlaid on a geospatial database.

Subtask 2c. Add an effectiveness rating calculation component

Project effectiveness flowchart (based on questions/ flowchart) has been implemented through the use of a pop-up to guide users through a sequence of questions, the result of which sets the effectiveness percentage rating.

Users' feedback indicate willingness to override the values estimated in the effectiveness rating tool, and therefore we are currently developing a set of criteria stipulating when users should be able to change the effectiveness estimated by the built-in tool.

Subtask 2d. Policy and capacity building impacts

In the past quarter we have investigated approaches for determining greenhouse gas benefit for policy and capacity building focused activities. In discussions with USAID we jointly determined that a full calculating tool based on level of investment will be face so much variability as to be impossible. Thus the focus is on providing guidance to users on the data to bring together to enter into the existing tools to calculate emissions. For example a policy reducing deforestation could look at historic and current deforestation to calculate the emission reduction.

This approach, though, has a great deal of complications associated with it. It is first of all important that double counting be avoided. For example, many instances of capacity building may be to actors in future pilot activities where the emission reduction will be directly captured when a particular area of land is subject to a reportable activity. Moreover, poorly designed capacity building will have little to no benefit if the trained individuals are not given the opportunity to use their new knowledge and they will rapidly lose what was learned. Equally, policy input may improve the quality and efficiency of the implementation of practices that would regardless have occurred. For example MRV systems under REDD+ or capacity for nesting under REDD+ may be improved but likely might just result in lower uncertainty in accounting rather than additional emission reductions.

Our next steps are to produce reports detailing the complexities for accounting benefits from policy and capacity building investments. We will highlight potential circumstances where emission reductions are likely and circumstances where benefit is likely to be zero. For each of the existing tools (forest protection, forest management, afforestation, agroforestry, agriculture and grassland management) we will detail guidance text for users to determine relevant data and where and how to enter these data in the tools.

Subtask 2e. Develop a new bioenergy and land use tool.

We have conducted initial scoping research on basic understanding, overall practices, data availability for improved cookstoves projects and their potential reduction on fuelwood removal from surrounding forest. At this stage, very little quantitative information linking forest degradation from fuelwood removal to cookstoves seems to be available, let alone the reduction in fuelwood consumption as a result of improved cookstoves implementation (most information pertains number of cookstoves, and in some cases, extent of their use, but nothing linking to fuelwood removal reduction). More research on this topic is currently underway, and methods that allow robust estimation of carbon benefits bypassing the existing data gaps are being devised.

<u>Additional subtask 2f. Develop uncertainty estimation for calculated carbon benefits</u>

Uncertainty calculations provide an estimate of the confidence in the carbon benefit numbers calculated using the ACC. Uncertainty estimation also has been a frequent request from most peers who used the ACC. As such, we have decided to include uncertainty estimation as a feature of the Calculator back in the list of tasks.

Uncertainty values are unknown or quite high for a number of default values used in the calculator. This makes it difficult to conduct a reliable propagation of uncertainties for biomass estimates as a whole. However, it is useful to have a general sense of the reliability of data used and biomass estimates produced. We are currently exploring the use of Monte Carlo analysis to propagate an estimate of uncertainty. Due to the lack of complete information regarding uncertainty of default values, propagated uncertainty will likely be expressed qualitatively as “high, medium, and low uncertainty”.

A Monte Carlo type of analysis will be used to define the ranges of each qualitative uncertainty class. At this stage we are devising the methodological approach for running the Monte Carlo analysis, by mapping the various parameters used in each Tool and compiling the exiting uncertainty estimates associated with each parameter.

Task 3. Train USAID GCC Team and mission staff (extension of Task 9 of Year 5)

Presentations have been prepared for two training sessions held in first Quarter of FY 2013 and shared with Evan Notman and Andre Mershon from USAID’s GCC team.

A draft version of a document highlighting the difference between the carbon benefits estimated using the AFOLU-CC and marketable offsets estimated for REDD+ project has been written and is currently under internal review. Descriptive text explaining the parameters to be entered has also been added to online to most parameters. Most of the key metrics already have a brief explanation about what such term actually means.

Lastly, a draft scientific article is currently being written for submission to an open source scientific Journal describing the underlying data and methods used in the Agroforestry Tool.

Task 4. Complete Decision Making Tool.

We have developed a beta version of the AFOLU Decision Support Tool (DST). This is a Microsoft Excel based product that is intended to facilitate decisions about USAID’s forestry activities (only forestry tools available at this time) by providing preliminary estimates of what the expected carbon impacts would be of various activities in various locations. The underlying databases and calculations are identical to those found in the AFOLU Carbon Calculator; this tool merely provides a way to create side-by-side comparisons of different scenarios and a way to easily evaluate how changing assumptions associated with each scenario will impact results.

In the beta version of the tool, each scenario is able to accommodate one project activity per administrative unit. Future drafts may allow more than one project activity and/or administrative unit per scenario. The draft DST currently includes activities of Forest Protection, Forest Management, Afforestation/Reforestation, and Agroforestry. Future versions will include Agricultural Land Management and Grazing Land Management. Depending on time and resources, this tool may be transferred from an Excel-based interface to a web-based interface.

Task 5: Management and implementation

Subtask 5b. Host website.

The current version of the ACC will be hosted by Applied Geosolutions during Years 7 and 8.

Subtask 5c. Production of progress reports.

This document represents the second progress report to be delivered to USAID during Year 7.

For more information or comments:

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Annex 1: USAID AFOLU Carbon Calculator: Data and Equations for the Afforestation/Reforestation/Forest Restoration Tool

February 2013

By Erin Swails and Timothy Pearson

Introduction

In cooperation with the USAID Climate Change team, Winrock International has developed a set of simple, user-friendly, web-based calculation tools titled the 'AFOLU Carbon Tool'. The various calculators are meant to give USAID Missions and their partners an easy way to comply with USAID's policy of mainstreaming CO_2 as an Agency-wide results indicator. The tool is not meant to provide the level of accuracy needed for carbon financing, but may provide early indication of areas which have potential for such financing. The calculators produce estimates of sequestration or avoided emissions of carbon dioxide and carbon dioxide equivalents using sound and transparent science.

There are currently six calculators:

- *Forest protection:* activities including reducing deforestation, stopping illegal logging, stopping forest fires;
- *Forest management:* activities including reduced impact logging or stop logging;
- *Afforestation/reforestation/forest restoration:* activities including planting of native or exotic trees as well as natural regeneration;
- *Agroforestry:* activities including aggregated planting of multiple species with agricultural yield;
- *Cropland management:* activities including management of fertilization input and reducing tillage;
- *Grazing management:* activities including improved management of grazing lands.

To our knowledge, this is the first and only web-based tool that contains default values with global coverage, but also allows overriding those values with user data.

All calculators function on two levels. Under Level A, the only data required to generate a CO_2 impact result associated with an afforestation/reforestation/forest restoration activity is the location of the project, a management effectiveness rating, and the project size, or area.

Under Level B, the user is given an option to change default growth parameters by entering project-specific data. Tree species planted is an optional input under Level B for afforestation/reforestation/forest restoration activities using non-native species. If no information on species is entered under Level B, the estimation generated by the calculator assumes that native species are planted and applies Level A calculator defaults. The addition of notes explaining inputs and assumptions is an option for all afforestation/reforestation/forest restoration activities.

This report outlines the data and equations used to improve the secondary forest biomass accumulation model in the **afforestation/reforestation/forest restoration** calculator (**Forest Restoration/ Plantations**). The work undertaken and described in this report represents an improvement to Level A calculator methods. Previously, Level A estimations of CO_2 sequestration in native secondary forests were based on growth parameters developed from Tier I data in IPCC's 2006 Guidelines for AFOLU. However, the uncertainty associated with estimations derived from these growth parameters was quite large. Superior estimations could be derived using growth parameters developed from site-specific data.

To improve Level A calculator generated estimations of sequestration resulting from forest restoration, we developed new growth parameters for native tropical species based on a literature review of biomass accumulation in secondary tropical forests.

A/R Equation Improvement For Native Tropical Species

The greenhouse gas benefit of afforestation/reforestation/forest restoration activities is calculated as the sum of carbon accumulated in trees over time, estimated using a Chapman-Richards logistic growth equation (Richards 1959; Pienaar and Turnbull 1973), a widely accepted sigmoid-shaped biological growth model. Currently only aboveground biomass is included in the calculations. In equation terms, this becomes:

Benefit (t CO2) = Area * (MAX * (1 – EXP(-k*AGE))^m) * 0.5 * 3.6667 * Effectiveness

Where:

Area	= area of project (user-defined, in hectares, ha)
MAX	= Maximum peak biomass yield; tons dry mass per hectore, or t d.m. ha^{-1}
k	= parameter used in modelling tree growth, dimensionless
m	= parameter used in modelling tree growth, dimensionless
Effectiveness	= management effectiveness rating (%)
0.5	= conversion from biomass to carbon
3.6667	= conversion factor from carbon to carbon dioxide

The variables highlighted in **red** (area of project and % effectiveness) represent data that a user **must enter** under Level A. Variables highlighted in **blue** represent parameters developed for native tropical species using data from the literature.

We searched existing literature on biomass accumulation in secondary forests. Of the studies identified, some were discarded from the analysis due to problems in methodological approach. Information on average biomass stock of secondary forests was compiled from 32 selected studies of aboveground biomass in tropical forest stands of various ages following abandonment of the previous land use. Averaged plot values reported in the studies provided data points for our analysis. These data were used to derive values for the variables MAX, k and m, used to estimate aboveground biomass as a function of age in tropical dry, moist, and wet secondary forests. Key information on the 32 studies included in our analysis is detailed in Table 1.

Table 1 Key information on studies of aboveground biomass included in analysis

No.	Country	Average Annual Precipitation (mm/yr)	Forest Type	Soil	Disturbance History	Reference
1	Malaysia	4200	Wet	Deeply weathered and recent alluvium	Shifting cultivation	Ewel et al. 1983
2	Indonesia	4000	Wet		Shifting cultivation	Lawrence 2005
3	Mexico	4000	Wet		Cropland and pasture	Hughes et al. 1999
4	Costa Rica	5130	Wet	Ultisols and inceptisols	Agriculture	Fonseca et al. 2011
5	Brazil	2200	Wet	Ultisols and spodosols		Feldpausch et al. 2004
6	Belgian Congo	2000	Moist		Shifting cultivation	Bartholomew et al. 1953
7	Ghana	1650	Moist		Cultivated 30 - 50 yrs	Greenland and Kowal 1960
8	French Guiana	2588	Moist		Clear cut for logging	Maury-Lechon 1982
9	Thailand	1150	Moist		Shifting cultivation	Drew et al. 1978
10	Thailand	1400	Moist		Shifting cultivation	Sabhasri 1978
11	Malaysia	2800	Moist		Shifting cultivation	Kenzo et al. 2010
12	Malaysia	3577	Moist		Shifting cultivation	Jepsen 2006
13	Vietnam	1277	Moist		Shifting cultivation	Tran et al. 2010
14	India	2200	Moist	Oxisol	Shifting cultivation	Toky and Ramakrishnan 1983
15	Panama	2000	Moist	Poorly drained alluvium and upland terrace	Shifting cultivation	Ewel 1971, 1975
16	Colombia	3000	Moist		Cleared and burned not cultivated	Folster and de las Salas 1976, Folster et al. 1976
17	Colombia and Venezuela	3500	Moist		Slash-and-burn agriculture	Saldarriaga et al. 1988
18	Venezuela	3520	Moist		Shifting cultivation	Saldarriaga et al. 1986
19	Venezuela	3520	Moist		Shifting cultivation	Uhl 1987
20	Guatemala	2000	Moist		Shifting cultivation	Snedaker 1970
21	Mexico	3640	Moist	Oxisol and alfisol	Cut and cleared, cultivated 1 year	Williams-Linera 1983
22	Brazil	1750	Moist	Oxisols and ultisoles	Pasture	Uhl et al. 1988
23	Brazil	2290	Moist		Cropland	Alves et al. 1997
24	Brazil	2500	Moist		Slash-and-burn agriculture	Johnson et al. 2001
25	Brazil	1825	Moist	Ultisols and oxisols	Shifting cultivation	Salimon and Brown 2000

26	Peru	2200	Moist		Cropland	Szott et al. 1994
27	Guatemala	1972	Moist		Shifting cultivation	Tergas and Popenoe 1971
28	Uganda	1707	Dry		Shifting cultivation	Omeja et al. 2012
29	India	964	Dry	Deep alluvial loam	Cleared	Singh 1975
30	Nigeria	1830	Dry		Shifting cultivation	Nye and Greenland 1960
31	Mexico	900, 1150	Dry		Shifting cultivation	Read and Lawrence 2003
32	Mexico	900,1150	Dry	Lithosol-redzina	Shifting cultivation	Eaton and Lawrence 2009

The study areas were categorized as dry, moist, or wet forest according to the following assumptions:

- The absence of precipitation during a prolonged period of the year is the most significant limiting factor on total forest biomass. Therefore the "dry" forest category includes areas with average annual precipitation less than 1500 mm/yr and/or prolonged periods (approximately 6 months) of dry conditions.

- The "moist" forest category includes areas with average annual precipitation between 1500 - 4000 mm/yr without a prolonged dry period.

- The "wet" forest category includes areas with average annual precipitation greater than 4000 mm/yr.

These categories are based on precipitation thresholds for dry, moist, and wet forests in the Holdridge life zones system, with some adjustment to allow for the best model fit.

Data on total aboveground biomass were extracted from the studies and plotted against forest age. Three growth curves were fitted to data on total aboveground live biomass for dry, moist, and wet forests. Growth parameters were developed for the three forest types so that the resulting curve fit the data points (Figure 1, 2, 3).

According to the model used, highest maximum biomass was achieved in wet tropical forests, followed by moist tropical forest and dry tropical forest. The biomass accumulation curve for natural tropical wet forest (Figure 1) approaches a maximum of 300 t/ha, with rate of forest stand aboveground biomass accumulation peaking at around age 30 years, and an R^2 value of 0.59.

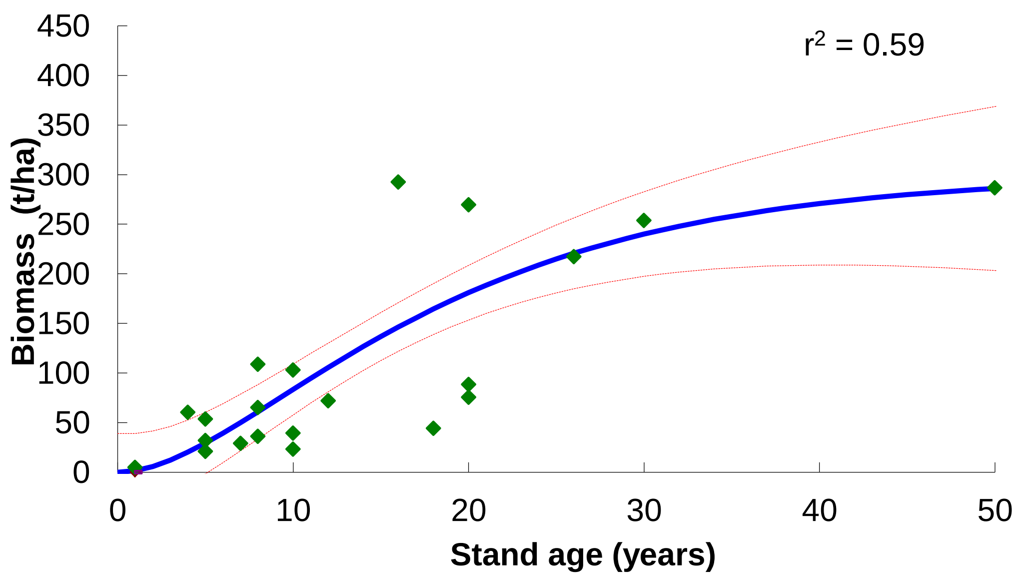

Figure 1 Biomass accumulation curve for natural tropical wet forest, fitted using 21 data points taken from five studies of secondary tropical wet forest and a maximum rate of biomass accumulation assumed to occur at Year 30. Upper and lower curves represent upper and lower bounds of 95% CI.

The biomass accumulation curve for natural tropical moist forest (Figure 2) approaches a maximum of 152 t/ha, with rate of forest stand aboveground biomass accumulation peaking at around age 25 years, and an R^2 value of 0.73.

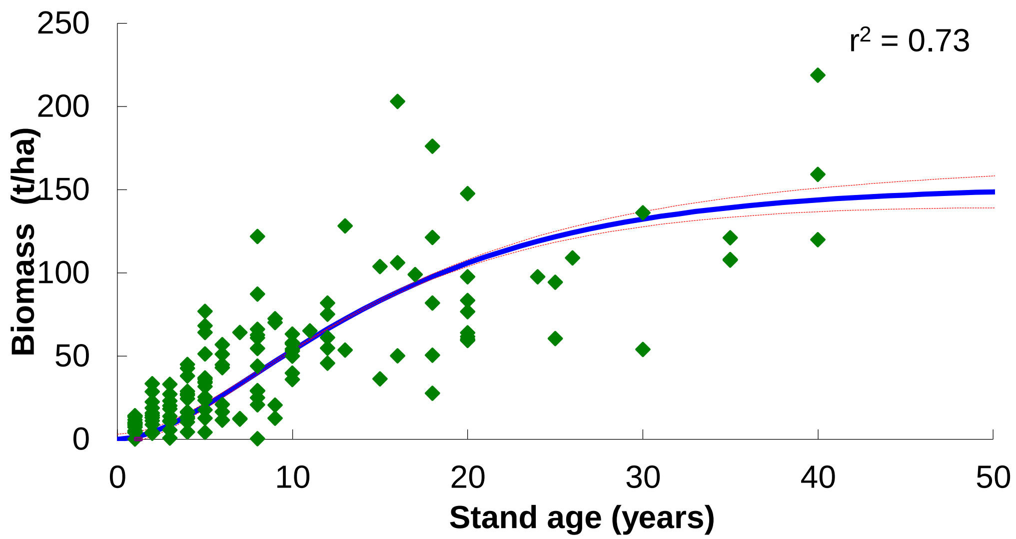

Figure 2 Biomass accumulation curve for natural tropical moist forest, fitted using 145 data points taken from 22 studies of secondary tropical moist forest and a maximum rate of biomass accumulation assumed to occur at Year 25. Upper and lower curves represent upper and lower bounds of 95% CI.

The biomass accumulation curve for natural tropical dry forest (Figure 3) approaches a maximum of 50 t/ha, with rate of forest stand aboveground biomass accumulation peaking at around age 45 years and an R^2 value of 0.35.

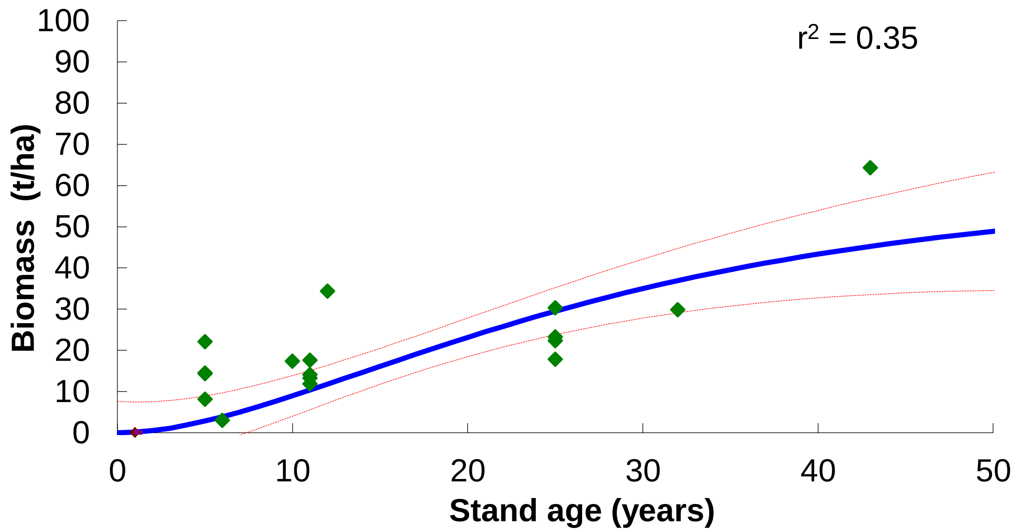

Figure 3 Biomass accumulation curve for natural tropical dry forest, fitted using data 16 points taken from five studies of secondary tropical dry forest and a maximum rate of biomass accumulation assumed to occur at Year 45. Upper and lower curves represent upper and lower bounds of 95% CI.

Growth parameters developed for the three forest types are summarized in Table 2.

Table 2 Literature based growth parameters for estimating biomass accumulation in tropical forests using a Chapman-Richards logistic growth equation

Forest type	MAX	k	m
Tropical dry forest	58	0.050	0.05
Tropical moist forest	152	0.090	0.5
Tropical wet forest	300	0.075	0.5

Growth parameters for dry, moist, and wet forests are assigned to each administrative unit based on the dominant ecological zone in which non-forest area is located within the administrative unit (according to a MODIS forest/non-forest land cover map).

Discussion

Compared to the curves for tropical moist forest and tropical wet forest, the tropical dry forest curve shows lower maximum biomass accumulation, and this maximum is reached later than in tropical moist and tropical wet forests. This is reasonable assuming that absence of precipitation during a prolonged period of the year is the most significant limiting factor on total forest biomass.

However, other factors also impact biomass accumulation. In addition to climate, studies of biomass accumulation in secondary tropical forests have investigated the impact of prior land use and soils. Although at a global scale, differences in climate and soil type have been found to be principal factors influencing aboveground biomass accumulation (Johnson et al. 2000), prior land use (both land use type and intensity) may also impact forest recovery (Silver et al. 2000, Chazdon 2003, Kauffman et al. 2009). Some examples of different factors that tend to increase or decrease biomass accumulation within the expected range for a given ecological zone are listed in Table 3. These factors may lead to increased or decreased biomass accumulation by forests within the expected range for the ecological zone.

Table 3 Examples of different factors that may increase or decrease biomass accumulation in secondary forests

Factors that increase forest biomass accumulation	Factors that decrease forest biomass accumulation
• Available moisture • Available soil nutrients • Adequate drainage	• Insect attack • Frequent drought • Poor drainage • Previous grazing activities • Intense and/or prolonged previous cultivation of soil

In addition to the small number of data points identified for development of growth parameters for tropical dry forest, the impact of soil and prior land use on biomass accumulation could explain the relatively poor fit of the tropical dry forest curve to the data, since data was not stratified by soil type or prior land use.

The global values developed for the parameter *MAX* and presented in the report would appear to be less location specific than 2003 IPCC GPG for LULUCF figures which are differentiated by continent. However, due to the overall paucity of data on biomass accumulation in secondary forests and uncertainty associated with more granular continent specific values, global values are in fact preferable for application within the AFOLU Carbon Tool, which is ultimately used to estimate emission reductions by USAID projects on a global scale. In addition, our analysis includes a greater number of site specific studies than the 2003 IPCC GPG data as well as new site specific data that was not available for the development of the 2003 IPCC values.

Averaged plot values from the studies provided data points for our analysis, resulting in some studies being underrepresented in the analysis. As well, some identified studies focused on biomass increment, and did not report average biomass stocks in forest stands measured, and therefore could not be used in our analysis. Although the model could be improved with additional data points, it is considered adequate for its intended application, which is to provide estimates of the emission reduction impact of USAID project activities, and not to provide creditable estimates of emission reductions for offsetting purposes. As stated in the introduction to the report, the tool is not meant to provide the level of accuracy needed for carbon financing, but may provide early indication of areas which have potential for such financing. As well, curves for all three forest types could potentially be improved further by stratification of data by soil type and prior land use. Though information on soils should generally be available, the current version of the tool is not designed to consider soil type in its spatially explicit approach to estimations of emission reductions based on location. Information on prior land use may be available to Tool users, but more data on the impact of prior land use on biomass accumulation is needed to further parameterize the model. In the future, Level B user input options for afforestation/reforestation/forest restoration activities may include previous land use and soil type. For now, the dominant ecological zone in which non-forest area is located is considered a reasonable predictor of biomass accumulation rate considering that the tool is not meant to provide the level of accuracy needed for carbon financing.

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