IMPLICATIONS OF CLIMATE CHANGE FOR FOREST STRUCTURE AND CARBON STORAGE IN THE TROPICAL ZONES OF LATIN AMERICA AND THE CARIBBEAN
Emil A. Cherrington ¹
Eric R. Anderson²
Africa I. Flores²
Betzy E. Hernandez¹
Antonio H. Clemente¹
Emilio Sempris¹
Freddy Picado¹
Daniel E. Irwin³

¹ Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC), Panama
² Department of Atmospheric Sciences, University of Alabama-Huntsville (UAHuntsville), USA
³ Marshall Space Flight Center, National Aeronautics & Space Administration (NASA MSFC), USA

May 2011
IMPLICATIONS OF CLIMATE CHANGE FOR FOREST STRUCTURE AND CARBON STORAGE IN THE TROPICAL ZONES OF LATIN AMERICA AND THE CARIBBEAN
ABSTRACT

This study examines the potential impacts of climate change on the structure of forests and their storage of carbon in the tropical zones of Latin America and the Caribbean. As climatic regimes exert strong influences on the composition of trees and other species within forests, the Intergovernmental Panel on Climate Change (IPCC) developed its own system for classifying climate zones, and that system is used in the national submissions to the United Nations Framework Convention on Climate Change. Using IPCC guidelines in combination with historical data, downscaled climate change scenario data as projected by a downscaled HadCM3 global climate model, under A2 and B2 scenarios, and other inputs from the Regional Visualization & Monitoring System (SERVIR), modeling was done to examine both how and where climate zones are expected to shift due to climate change. The data indicate that over the rest of this century, roughly half of Latin America’s current ‘rainforests’ will dry to become seasonal moist and dry forests. Consequently, the region’s above- and below-ground forest carbon stocks could decline some between 11.6% and 16.4% by the 2080s, not considering anticipated deforestation which will even further lower the region’s carbon stocks. This study’s conclusions are in line with those of previous studies which suggest that climate change will indeed have an adverse impact on the storage of carbon in the forest ecosystems of Latin America and the Caribbean. With avoided deforestation being touted as a viable option for climate change mitigation via initiatives such as REDD+, this study points out that with climate change, the capacity of tropical forests to continue sequestering large quantities of carbon may be called into question.

Key words: climate change, downscaling, forest, carbon, scenarios, REDD+, SERVIR
INTRODUCTION

While ongoing international climate change negotiations are placing much emphasis on the capacity of tropical forests to sequester carbon (UNFCCC 2009c), a number of questions remain unanswered regarding how such carbon storage will be impacted by the very climate change that such activities are aimed to mitigate. With forests in the tropical zone of Latin America and the Caribbean region storing and sequestering a significant proportion of the world’s carbon (Trumper et al 2009), this study utilizes modeling to assess (i) how the climate regimes governing such forests is expected to change, and (ii) how the storage of carbon in such forests will change, based on climate change scenarios.

BACKGROUND

In the context of global negotiations on climate change, since the 13th Conference of the Parties (COP13) of the United Nations Framework Climate Change Convention (UNFCCC) in 2007 in Bali, Indonesia, the Reducing Emissions from Deforestation and Forest Degradation (REDD) initiative has been proposed as a viable mechanism for climate change mitigation. The idea behind REDD and its successor proposal REDD+ is to store carbon in forest ecosystems which, in absence of such schemes, would otherwise be converted to other uses (deforested) or degraded. Both the Draft Decision on REDD at the 15th Conference of the Parties (COP15) of the UNFCCC and COP15’s Copenhagen Accord urge that tropical forested countries should be compensated for preventing the deforestation and degradation of their forests (UNFCCC 2009c, UNFCCC 2009d). Key to REDD and REDD+ is the ability to know how much carbon is stored in each country’s forest ecosystems, and how that carbon stock changes over time as a result of natural and human-induced processes.

It has likewise been proposed that the implementation of avoided deforestation schemes like REDD and REDD+ be harmonized with the existing greenhouse gas (GHG) inventory mechanism by which signatory countries to the UNFCCC currently report their GHG emissions (UNFCCC 2009a, UNFCCC 2009b). The methodology for that GHG inventory mechanism is laid out in the IPCC’s Guidelines for National Greenhouse Gas Inventories which acknowledges that the carbon stored in different types of forest depends, among other factors, on (i) the types of soils such forests grow on, (ii) the elevations at which such forests grow, and (iii) the climates where they grow.

As climate change is anticipated to alter climate regimes, various questions remain unanswered regarding how and where climate regimes will shift, and how carbon
stores will consequently be affected. With a 2009 UNEP report indicating that the tropical forests of the Latin America and the Caribbean region (LAC region) sequester some 46% of the annual global carbon uptake (Trumper et al 2009), it can and should therefore be expected that the LAC region’s forests will be affected by climate change. Other recent studies also point to potential impacts of climate change on the LAC region’s forests. Various studies have conducted downscaling of global climate models to understand potential climate change impacts in the LAC region and its sub-regions (see Hernandez et al 2006, Taylor et al 2007, Dubrie et al 2008, Perez et al 2009). Not many studies have interpreted climate change scenarios into actual impacts.

Where tropical forests are generally viewed from the REDD perspective as sinks for carbon, Cox et al (2004), concluded that over the rest of the current century, South America’s forests would actually begin to emit the carbon stored in their formations. Phillips et al (2009) show that in 2005, a drought in the Amazon rainforest also caused a significant emission of carbon dioxide to the atmosphere, and Xu et al (2011) find greenness indices pointing to significantly more severe photosynthetic activity decline during the 2010 drought in the Amazon. Anderson et al (2008a, 2008b) explore the general vulnerability of the forests of the Mesoamerican Biological Corridor to climate change, and Malhi et al (2009) likewise explore the possibility of parts of the Amazon rainforest drying and the pathways by which that might occur. That all said, there is a definite need to examine in further detail how climate change might affect the tropical forests of Latin America and the Caribbean.

In 2005, a partnership between the U.S. Agency for International Development (USAID), the U.S. National Aeronautics & Space Administration (NASA), and the intergovernmental Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) established the **Regional Visualization & Monitoring System** (SERVIR) at CATHALAC, in direct response to the expanded CONCAUSA agreement between the Governments of Central America and the USA. SERVIR serves as a regional platform for monitoring and forecasting Mesoamerica’s land surface, oceans, and atmosphere. In 2009, building off of SERVIR’s capacities, CATHALAC developed the **Tropical Carbon Monitoring System** (TROPICARMS) 2.0 specifically for the purpose of supporting national environmental authorities with rapid assessment and long-term national-level monitoring, reporting, and verification of carbon stocks. In that context, the current study was implemented with a view on forest carbon stocks in the LAC region.
OBJECTIVES

This study had two principal objectives. The first main objective was to model how and where, according to climate change scenarios, the climate zones of the tropical areas of Latin America and the Caribbean will change. The study’s second main objective was to evaluate how, according to the modeled climate shifts, the carbon stocks in the region’s forests can be expected to change. The assessment of the forest carbon stock changes included evaluation of both above-ground and below-ground stores of carbon.
METHODOLOGY

Applying the TROPICARMS 2.0 framework developed by CATHALAC, geospatial modeling was used to assess the climate zone shifts, as well as the changes in forest carbon stocks.

Source Data

In terms of climate data inputs, the baseline data used was 1km-horizontal resolution data of both mean annual temperature and total annual precipitation, averaged for the period 1950-2000 from the third release of the WorldClim 1.4 database from the WorldClim consortium (Hijmans et al 2005). Downscaled 1km resolution data on the same variables was also acquired for the B2A and A2A future scenario outputs from the U.K. Hadley Centre’s HadCM3 model. These were also acquired from the WorldClim consortium and used for comparison to the baseline climate data. For the process of assessing climate zones, in addition to the climate data, elevation data which was also needed was sourced from the GTOPO30 database from the U.S. Geological Survey, while soil data was acquired from the SOTERLAC 2.0 database of the United Nations Food & Agriculture Organization (FAO) and the International Soil Reference and Information Centre (ISRIC) of Wageningen University.

In lieu of evaluating climate zone shifts across all of Latin America and the Caribbean, the region’s tropical zones were selected as a focus. While, according to the IPCC’s classification scheme, the LAC region also contains temperate warm and temperate cold areas, at 68.1% of the region’s total area, the tropical areas – with mean annual temperatures exceeding 20° C – predominate (Figure 1). Additionally, as forest carbon was also a focus of this study, emphasis was placed on tropical areas as, according to the IPCC’s Emission Factor Database (EFDB), tropical forests contain higher overall stocks of carbon (both above-ground and below-ground) than temperate forests (IPCC 2010). Data on forests was acquired from the European Space Agency’s validated GlobCover 2.2 land cover database. GlobCover’s coverage was based on satellite imagery captured between December 2005 and June 2006.

Modeling

The TROPICARMS 2.0 modeling framework is harmonious with the IPCC’s 2003 and 2006 Good Practice Guidance for estimating GHG emissions (IPCC 2003, IPCC 2006). For the first component of the modeling involving the climate zone shifts, using the TROPICARMS 2.0 modeling framework, the baseline climate and future climate change scenario data were combined with the elevation data and reclassified into the climate zones shown in Table 1.

Changes between the baseline climate zones and the climate zones based on the scenarios (A2A and B2A for the 2020s, 2050s, and 2080s) were assessed. Forest carbon stocks for the climate baseline and the climate change scenarios were also estimated based on a stratification of the forest by both climate and soil types. Changes in the forest carbon stocks between the baseline and the climate change scenarios were also evaluated.
Figure 1. Macro-climatic zones of Latin America and the Caribbean
RESULTS

The climate change scenario data indicate that while temperatures across Latin America and the Caribbean could increase on average, there will be a net decline in annual rainfall. These will translate into significant and noteworthy shifts in the region’s current climate regime.

Climate Zone Shifts

In terms of the shifts in the climate zones of tropical Latin America and the Caribbean, Figure 2 illustrates that by the 2080s, under either the pessimistic but not quite ‘worst case’ A2A scenario or the optimistic but not quite ‘best case’ B2A scenario, the extent of the tropical wet zone will be greatly diminished. Under scenario B2A, by the 2080s the tropical wet zone will be reduced 57.3% to 15.9% cover, while the extent of tropical moist seasonal zone will increase 25.8% to 55.7% cover, and the extent of the tropical dry zone will increase 58.2% to 10% cover. The tropical montane moist zones will likewise decrease by 12.7% to 1.1% cover by the 2080s, while the tropical montane dry zones will increase by 166.2% to 0.3% cover.

Under scenario A2A, by the 2080s, the tropical wet zone will be reduced 61.5% to 14.4% cover, while the extent of tropical moist seasonal zone will increase 19.9% to 53.1% cover, and the extent of the tropical dry zone will increase 82.6% to 14.1% cover. The tropical montane moist zones will likewise decrease by 17.6% to 1% cover, while the tropical montane dry zones will increase by 230.4% to 0.3% cover.

In terms of where such changes will occur (based on the climate change scenario data), as illustrated in Figure 3, under both the B2A and the A2A scenarios, much of the eastern Amazon basin becomes drier, as does the majority of Mesoamerica and the Caribbean. The magnitude of those figures become more apparent when one examines the forests within these climate zones, and...
the carbon stored within such forests. In fact, the patterns of drying and decreasing precipitation are similar under both scenarios for the 2080s, although under the B2A scenario, climate zone shifts affect 31.2% of the region’s total area, as compared to scenario A2A in which 35.4% of the region’s total area will be affected.

**Forest Dynamics**

As of ~2005, tropical forest covered some 7.9 million km² of the surface of Latin America and the Caribbean, making up for approximately 88.2% of the region’s forest, and covering almost two-fifths of the region’s entire surface. Applying the TROPICARMS 2.0 modeling framework, it was hence estimated based on that forest area that the region’s tropical forest stored roughly 162.4 billion tonnes¹ (162.4 petagrams) of carbon in 2005. Roughly 92.7% of that forest carbon was stored in South America’s biomes, while Mesoamerica accounted for 6.6%, and the insular Caribbean accounted for the remaining 0.7%. Table 2 elaborates the distribution of tropical forest in the different climate zones recognized under the IPCC’s classification system, with almost 60%² of tropical forest being classified as tropical wet or ‘rainforest.’ Another third of tropical forest are considered seasonal, while dry forest accounts for some 7% of the region’s tropical forest cover. Tropical montane moist and tropical montane dry forests together comprise less than 2% of tropical forest cover.

Modeling of the climate change-induced changes in forest (e.g. illustrated in Figures 2-3) indicate drastic shifts in the climate regimes affecting the region’s forests. As indicated in Tables 3-4, much of the areas

---

¹ A gigagram of carbon – the unit of reference for national greenhouse gas inventories under the UNFCCC – is equal to 1000 metric tonnes of carbon. A petagram of carbon is hence equal to a trillion (10¹²) tonnes of carbon

² This is even though the total area classified as tropical wet represents only 37.3% of the region’s extent (Table 1).
previously classified as tropical wet ‘rainforest’ become tropical moist seasonal forests by the 2080s under either of the HadCM3 model’s B2A or A2A scenarios. Under the B2A scenario that translates to a relative decline of 53.5% of the extent of tropical wet forest while under scenario A2A, the decline is by 54.8%. Under the B2A scenario, the extent of tropical moist seasonal forests expands by 97.5%, while under the A2A scenario the extent of those forests expands by 66.8%. Under the B2A scenario, tropical dry forests actually decline some 3.1%, as compared to the A2A scenario, which sees tropical dry forests expand 149%.

Where the forests of the region’s mountainous areas are also known to be home to high percentages of endemic species (Anderson et al. 2008a), the climate change scenario data likewise indicate that tropical montane moist forests are also likely to be adversely impacted by changes in precipitation regimes. For instance, the analysis for the 2080s based on the B2A scenario indicates that the extent of tropical montane moist forest will decline by 10.6%, while under the A2A scenario, the extent will decline by 14.7%. As such, under the B2A scenario, the extent of the less-biodiverse tropical dry forests will expand by over seven hundred percent, while under the A2A scenario, the extent of such forests expands almost one thousand percent.

In terms of an overall picture, where tropical wet ‘rainforest’ is the ecosystem most affected under the climate change scenarios, it is worth pointing out that the greatest changes are projected to occur in the eastern Amazon, and much of the Mesoamerican Biological Corridor, which both dry to

### Table 2. Current climate regime for LAC tropical forests

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>Area (km²)</th>
<th>Percent cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical montane dry</td>
<td>1,936</td>
<td>0.0%</td>
</tr>
<tr>
<td>Tropical montane moist</td>
<td>128,199</td>
<td>1.6%</td>
</tr>
<tr>
<td>Tropical dry</td>
<td>558,086</td>
<td>7.0%</td>
</tr>
<tr>
<td>Tropical moist seasonal</td>
<td>2,577,927</td>
<td>32.5%</td>
</tr>
<tr>
<td>Tropical wet</td>
<td>4,663,846</td>
<td>58.8%</td>
</tr>
<tr>
<td>All tropical forest</td>
<td>7,929,995</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

### Table 3. 2080s climate regime for LAC tropical forests (B2A scenario)

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>Area (km²)</th>
<th>Percent cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical montane dry</td>
<td>15,601</td>
<td>0.2%</td>
</tr>
<tr>
<td>Tropical montane moist</td>
<td>114,549</td>
<td>1.4%</td>
</tr>
<tr>
<td>Tropical dry</td>
<td>540,848</td>
<td>6.8%</td>
</tr>
<tr>
<td>Tropical moist seasonal</td>
<td>5,091,071</td>
<td>64.2%</td>
</tr>
<tr>
<td>Tropical wet</td>
<td>2,167,927</td>
<td>27.3%</td>
</tr>
<tr>
<td>All tropical forest</td>
<td>7,929,995</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

### Table 4. 2080s climate regime for LAC tropical forests (A2A scenario)

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>Area (km²)</th>
<th>Percent cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical montane dry</td>
<td>20,751</td>
<td>0.3%</td>
</tr>
<tr>
<td>Tropical montane moist</td>
<td>109,384</td>
<td>1.4%</td>
</tr>
<tr>
<td>Tropical dry</td>
<td>1,389,635</td>
<td>17.5%</td>
</tr>
<tr>
<td>Tropical moist seasonal</td>
<td>4,300,141</td>
<td>54.2%</td>
</tr>
<tr>
<td>Tropical wet</td>
<td>2,110,083</td>
<td>26.6%</td>
</tr>
<tr>
<td>All tropical forest</td>
<td>7,929,995</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
become merely “moist” forests. In addition to such dynamics, the projected changes in carbon stocks are just as illustrative.

**Forest Carbon Dynamics**

Figure 4 illustrates that the overall forest carbon stocks of tropical Latin America and the Caribbean are expected to decline under either the B2A or A2A scenarios. Where the total stock of forest carbon is estimated at 162.4 billion tonnes in 2005, under the B2A scenario that stock is estimated to decline 11.6% to 143.5 billion tonnes. Under the A2A scenario that stock is estimated to decline 16.4% to 135.7 billion tonnes. Of note is that the forests of the eastern Amazon and the Mesoamerican Biological Corridor see their carbon stocks decline substantially.

Summarizing this study’s results, one sees that based on the WorldClim consortium-downscaled climate change scenario from the Hadley Centre’s global climate model (GCM), HadCM3, the conclusion is that climate change will radically change the climate regimes of tropical Latin America and the Caribbean by the 2080s, with the extent of the tropical wet zone diminishing by roughly 60% under either the pessimistic A2A scenario or the more optimistic B2A scenario. The analysis also concludes that more than half of the region’s rainforest – under either scenario – will become either seasonal or dry forest, although conversion to seasonal forest will be more significant. Based on those assessments, it is expected that even if no net deforestation were to occur across the entire LAC region over the rest of the century, by the 2080s, under the B2A scenario, the forest carbon stock would decline some 11.6%, while under the A2A scenario, that forest carbon stock would decline by 16.4%.

![Figure 4. Scenarios for changes in forest carbon stocks](image-url)
DISCUSSION

It is acknowledged that one limitation of the current study is having examined climate change through the prism of solely the HadCM3 global climate model. Regarding the model’s veracity, it should be noted that the HadCM3 outputs have been utilized and assessed in a variety of peer-reviewed studies (e.g. Anderson 2008b, Cox et al 2004, Malhi et al 2009), as well as being utilized in the IPCC’s 2001 Third Assessment Report. Future research might target comparing the results of the HadCM3 scenarios with scenarios from other GCMs, as it is noted that the outputs of HadCM3 show drier future scenarios than say those of the CCCMA or CSIRO climate models. Future research might also target the combined effects of climate change and land cover change scenarios on future carbon stocks as it is anticipated that the 11.6-16.4% carbon stock declines estimated will be exacerbated by future land cover change.

It is, nonetheless, worth examining this study’s results both in terms how the region’s carbon stocks might be degraded, and the implications of such degradation.

Degradation of Carbon Stocks

Where the IPCC’s climate zone classification scheme – or, for instance, Holdridge’s life zones –merely classifies climate based on patterns of rainfall, temperature, elevation and other factors, it is not difficult to imagine that, with climate change, the overall climatic regimes of tropical Latin America and the Caribbean could indeed change. The conclusion that such climate change should cause a decline in the storage of carbon in the region’s forest ecosystems may be more difficult to conceptualize. This study’s premises are based on the guidelines established by the IPCC (e.g. IPCC 2003, IPCC 2006), which would indicate for instance that a forest in an area classified as tropical wet and sitting on volcanic soil, should have its above-ground and below-ground stores of carbon lowered by significant adverse changes in the precipitation regime. Going on those assumptions, where a hectare of such forest contains 303.5 tonnes of carbon under a tropical wet regime, under a climate change scenario pushing it to a tropical moist seasonal regime, that forest’s carbon content should decline by almost a fifth to 243.5 tonnes of carbon. The question is whether that is a realistic expectation.

Sources in the literature (e.g. Cox et al 2004) point to theories of CO$_2$ fertilization of forests which would lead some to anticipate that increased atmospheric carbon dioxide from increased CO$_2$ emissions should lead forests to become even more carbon-rich. However, in challenging the CO$_2$ fertilization idea, Cox et al (2004: 138) show how based on modeling, planetary warming will actually induce the release of global concentrations of soil carbon rather than sequestration, and this supports the conclusion of this study related to changes in carbon stocks. Likewise, other studies by Malhi et al (2009), Phillips et al (2009), and Phillips et al (2010) indicate that introducing seasonality to forests used to constant rainfall might lead to drought-induced fires which would consequently alter the structure of such forests. Another possibility of how the carbon stores of the region’s forests might
be degraded over time is that the overall regional drying and warming might cause liberation of carbon from tropical soils in a similar fashion to which the warming of permafrost near the planet’s poles is expected to liberate greenhouse gases (Trumper et al 2009).

A related issue that should likewise be addressed is how drastically projected precipitation regime changes should influence forest vegetation structure. For instance, Malhi et al (2009) discuss the possibility of parts of the Amazon rainforest potentially becoming savanna because of projected (scenario) declines in rainfall and consequent increased water deficit. They simplify the predominant vegetation types of the Amazon to “rainforest,” “seasonal forest” and “savanna.” In terms of imagining future structure of the region’s forests, it must be noted however that the absence of rainfall does not necessarily drive the creation of savannas. As pointed out earlier, the low annual precipitation in parts of tropical Latin America and the Caribbean has led to the development of dry forests. Furthermore, regarding what causes savannas to form, the Central America Ecosystems Mapping Project likewise pointed out that in areas such as Belize, savannas grow in tropical moist and tropical wet climate zones but are caused largely by poor soils and not a lack of rainfall (Meerman & Sabido 2001, Vreugdenhil et al 2002). The current study supports the idea that drying forests of the Amazon and the Mesoamerican Biological Corridor should indeed remain forests, although it cannot be ruled out that anthropogenic forces could indeed further alter vegetation composition.

Policy Implications

Further regarding the point on changes in carbon stocks, it is worth pointing out that this study has not factored in future land cover change into the estimations of carbon stock change. Without even considering future land cover change – which could further degrade forest carbon stocks – this study can conclude that just with climate change, the region’s tropical forest carbon stocks could decline by between 11.6% and 16.4% by the 2080s. With REDD and REDD+ focusing on the sequestering capabilities of tropical forests, this study therefore points out that avoided deforestation schemes must consider how, over time, climate change too may adversely impact national carbon accounts.

Following the conclusions of Phillips et al (2009) which showed how the Amazon rainforest could go from being a net carbon sink to being a net carbon source, schemes such as REDD / REDD+ must carefully consider how countries which now sequester large, significant quantities of carbon may inadvertently end up re-emitting such carbon simply due to climate change. In addition to needing to re-examine carbon stocks in areas such as the Amazon, this likewise implies that the estimates of rates of carbon sequestration will also need to be re-examined. In other words, a country or a region’s carbon bank account in the future may not be worth as much as it is worth today simply because of a sort of climate change-induced ‘devaluation.’
CONCLUSIONS

This study indicates that over the rest of this century, over a third Latin America’s tropical wet ‘rainforests’ will dry to become ‘moist’ seasonal and ‘dry’ forests. Based on the scenarios of those climate zone shifts, changes in above ground and below ground carbon stocks were likewise assessed. Under the pessimistic but not quite ‘worst case’ A2A scenario, the region’s forest carbon stocks could decline some 16.4% by the 2080s. This decline is solely due to climate change, and does not take into consideration anticipated deforestation which will even further lower the region’s carbon stocks. Under the more optimistic B2A scenario, forest carbon stocks are expected to decline 11.6%.

This study’s conclusions are in line with previous studies which suggest that climate change will indeed have an adverse impact on the storage of carbon in the forest ecosystems of Latin America and the Caribbean (e.g. Cox et al 2004, Malhi et al 2009, Phillips at al 2009, Phillips et al 2010). With avoided deforestation being touted as a viable option for climate change mitigation via initiatives such as REDD+, this study points out that the capacity of tropical forests to continue sequestering large quantities of carbon under climate change scenarios is called into question.
ACKNOWLEDGEMENTS

This work was partially supported under NASA Contract # NNM07AB02C with CATHALAC, through the generous support of the USAID. In particular, Carrie Stokes, William Breed, John Furlow, Anne Dix, Ruben Aleman, Michelle Jennings, and Orlando Altamirano of USAID must all be acknowledged for their support. NASA Earth Science Division Director Michael Freilich, NASA Ecological Forecasting Program Manager Woody Turner, and NASA SERVIR International Programs Director Gwendolyn Artis must also be acknowledged for their support. Alejandro del Castillo, Juan Benavides, and John Flores of CATHALAC also provided support for this project.
REFERENCES


________________. 2009b. “Cost of implementing methodologies and monitoring systems relating to estimates of emissions from deforestation and forest degradation, the assessment of carbon stocks and greenhouse gas emissions from changes in forest cover, and the enhancement of forest carbon stocks.” Technical paper. Bonn, Germany. FCCC/TP/2009/1. 44pp.


