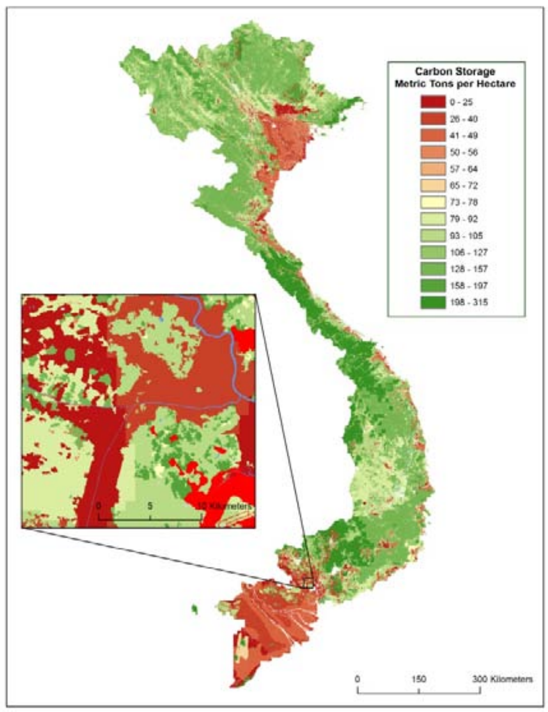
GeoCarbon:

A New Tool for Calculating Terrestrial Carbon



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Executive Summary

The Global Ecosystem Center has developed an innovative tool for estimating stored terrestrial carbon based on IPCC guidelines. When used in conjunction with 30-meter Landsat land cover classifications, the tool is able to produce accurate carbon stock assessments that are ideal for decision making at regional, country, continental and even global scales. As a tool for evaluating development projects, it has several advantages including:

- It provides estimates of sequestered carbon using a standard methodology applicable to any location around the globe;
- It produces accurate terrestrial carbon estimates at a 30-meter resolution; and
- It can be used to track change over time using NASA's Landsat satellite data from 1985 through the present.

This document describes the methodology used to create the GeoCarbon product. It provides comparisons to other carbon storage estimates, demonstrates applications of the model for calculating existing terrestrial carbon, models potential scenarios and addresses the economic implications of scenario modeling.

Introduction

The Earth's climate is regulated through the addition and removal of Green House Gases (GHG) such as carbon dioxide. In recent years, the dramatic increase in atmospheric CO_2 has prompted growing interest in measures to reduce GHG emissions and through terrestrial sequestration and reduced use of fossil fuels.

The methodology developed by the Global Ecosystem Center provides an efficient method for assessing the amount of terrestrial carbon already stored and provides a system for monitoring carbon sequestered by comparing the stored carbon from two separate dates. These comparisons can provide a critical benchmark for measuring the impact of mitigation measures.

Background Science and Future Opportunities

In 1958, Charles Keeling started measuring atmospheric carbon systematically at Mono Loa Observatory in Hawaii. His data illustrated two critical issues about atmospheric CO_2 :

1. CO_2 concentrations have substantially increased every year since 1958, already climbing over the suggested maximum level of 350 ppm. The upward motion of the curve is predominately caused by human activity including combustion of fossil fuels and destruction of carbon sinks such as the earth's forests.

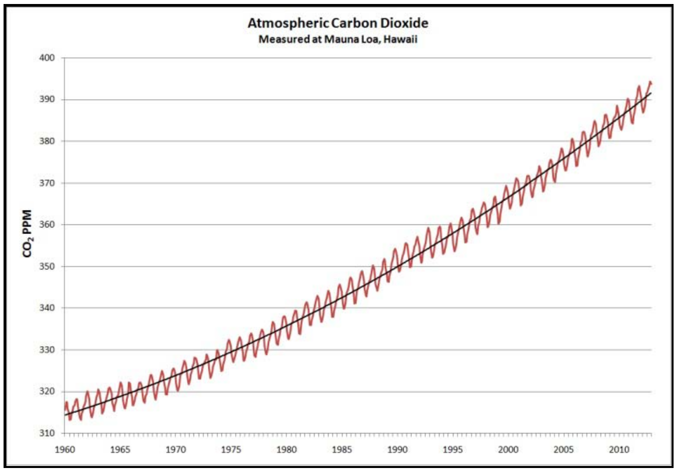

Figure 1 – Atmospheric Carbon Dioxide from 1960 to 2011

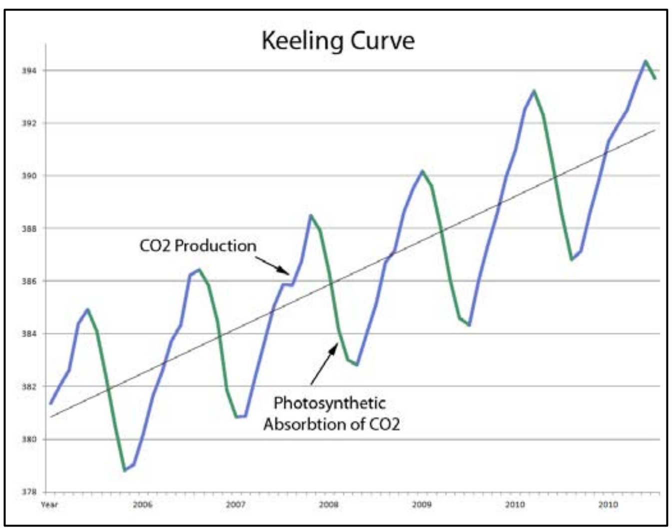

Figure 2 – Annual atmospheric carbon fluctuations

2. The production of CO_2 due to human activity outstrips the capacity of nature to sequester carbon. The result is a continuous increase in the concentration of CO2 in the atmosphere, accelerating the rate of global climate change due to human activity. There is an annual temporary decline in atmospheric CO_2 concentrations due to the positive impact of vegetation.[1]

The zigzag climb of the curve reveals the pulse of the earth's competing systems, the Human Network which produces CO_2 and the Natural System which removes it from the air.

Effective decisions regarding carbon sequestration targets require accurate and consistent baseline data. The GeoCarbon product was designed to meet that need.

The GeoCarbon methodology provides a tool for rapid and cost-effective assessment of baseline carbon storage, consistent with existing carbon storage protocols and accuracy standards.

[1] http://earthguide.ucsd.edu/globalchange/keeling_curve/01.html Keeling Curve, 2002, University of California, San Diego

Terrestrial Carbon Storage and Sequestration

Terrestrial carbon sequestration and storage is perhaps the most widely recognized of all ecosystem services.[2] Managing landscapes for carbon storage and sequestration requires information about how much and where carbon is currently stored and how much carbon will be sequestered or lost over time as land use change and other impacts on the natural system unfold over time. Since decision makers must choose among sites for protection, harvest, or development, large area maps showing terrestrial carbon storage and sequestration opportunities are an important tool in formulating strategy.

Methodology

The methodology for creating the GeoCarbon product has two parts:

1. **Terrestrial Carbon Model** – Developed by the Global Ecosystem Center, using the Intergovernmental Panel on Climate Change (IPCC) guidelines and the best available spatial global data sets which document land cover, soil type, and climate region.

2. **Land Cover Classification** – An 8-class, 30-meter global land cover classification derived from MDA Information System's 13-class GeoCover LC land cover product.

Terrestrial Carbon Model

The process for conducting Terrestrial Carbon Model is divided into 4 sections:

Carbon variables – Terrestrial carbon storage depends on the sizes of four carbon "pools"

- ***Aboveground biomass*** - comprises all living plant material above the soil (e.g., trunks, branches, leaves, etc).
- ***Belowground biomass*** - encompasses the living root systems of aboveground biomass.
- ***Dead organic matter*** - includes litter, lying and standing dead wood.
- ***Soil organic matter*** - is the organic component of soil, and represents the largest terrestrial carbon pool.

[2] The Intergovernmental Panel on Climate Change (IPCC). 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston, HS, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds). Institute for Global Environmental Strategies (IGES), Hayama, Japan. <http://www.ipcc-nggip.iges.or.jp/public/2006gl/ vol4.html>.

The GeoCarbon model aggregates the amount of carbon stored in these pools, providing an estimate of total carbon storage in each 30-meter cell and across the entire landscape.

Data Sources – There are 3 types of geographic datasets that are used for carbon stock calculations (Figure 3)

- **Soil Types** – Based on Harmonized World Soil Data.
- **Climate Zones** – Produced by the IPCC, based on Holdridge Life Zones.
- **Land Cover** -MDA's GeoCover LC 30-meter classification product.

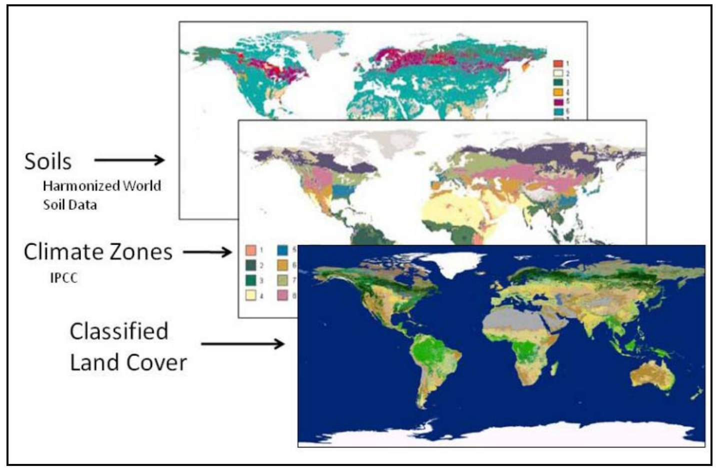

Figure 3 - Geographic datasets used in the IPCC Carbon model

Land Cover Class Interpretation – In order to create a global data set for carbon stock, a high quality Landsat-derived product called GeoCover LC is used. This product is produced by MDA Information Systems and covers most of the global landscape and offers multiple analysis dates for some areas. Since this land cover includes 13 classes it must be translated into the 8 class IPCC guidelines so the calculation can be made.

Carbon Stock Application – In this process, each land cover class is intersected with climate and soil data sets in a matrix table. An intersected land cover class is run through the GeoCarbon model ($CS_i = (SOC + C_{VEG}) \times A$) to calculate the total carbon values for each land cover classes. Carbon value produced from the following algorithm accounts for all four pools of carbon variables.

$$CS_i = (SOC + C_{VEG}) \times A$$

CS_I = the carbon stock per unit area associated with the land use i (measured as mass of carbon per unit area, including both soil and vegetation)
SOC = soil organic carbon (mass of carbon per hectare)
C_{VEG} = above and below ground vegetation carbon stock (mass of carbon per hectare)
A = factor scaling to the area concerned (measured as hectares per unit area)

Land Cover Classification

Remote sensing data from satellites and image analysis technology provides leaders with comprehensive information for decision making.

Landsat imagery - The Landsat program is the United States' oldest and most successful land-surface observation satellite system. Landsat sensors have a moderate 30-meter spatial-resolution. Landsat imagery is coarse enough for global coverage, yet detailed enough to characterize human-scale processes such as highways and buildings. Landsat TM sensors collect data using several wavelengths not visible to the human eye, and these bands were selected to make maximum use of the dominant factors controlling land cover, especially vegetation.

GeoCover LC - GeoCover land cover products are produced by MDA Information Systems and are derived from the classification of Landsat scenes. This 13-class land cover classification is the only commercially available land cover product with 30-meter resolution at a global coverage. The Landsat imagery used to create the GeoCover LC products were hand selected to provide the lowest cloud cover and highest quality data possible.

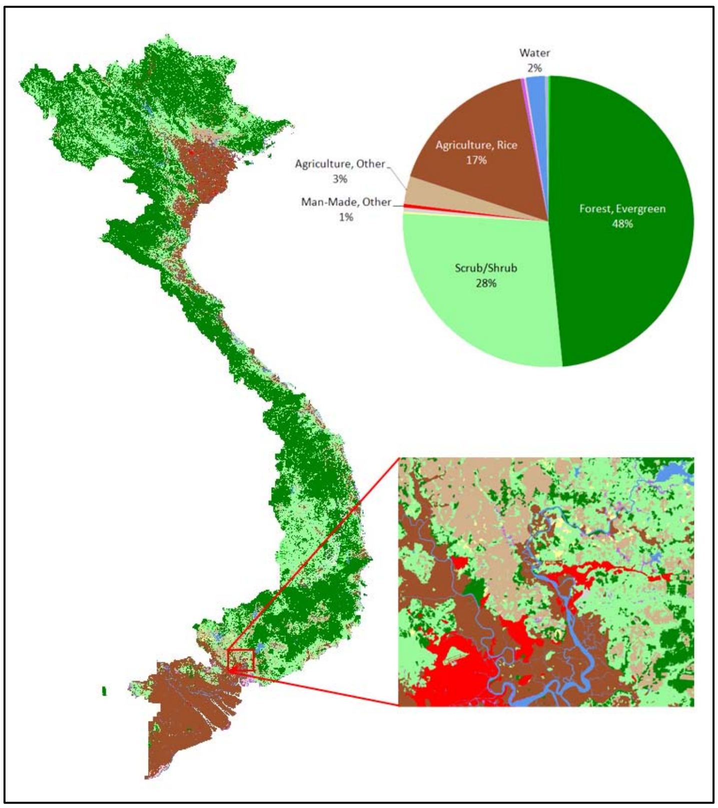

Figure 4 - GeoCover LC Land Cover for Vietnam

Case Study using the GEC GeoCarbon Product

Although terrestrial carbon has been calculated using various methods and resolutions, there is no global standard. The GeoCarbon product calculates terrestrial carbon at a 30-meter resolution producing the most spatially detailed and globally consistent global terrestrial carbon stock inventory available.

There are two global applications for the GeoCarbon product –

1. **Terrestrial Carbon Stock Calculations**
2. **Scenario Modeling**

Terrestrial Carbon Stock Calculations

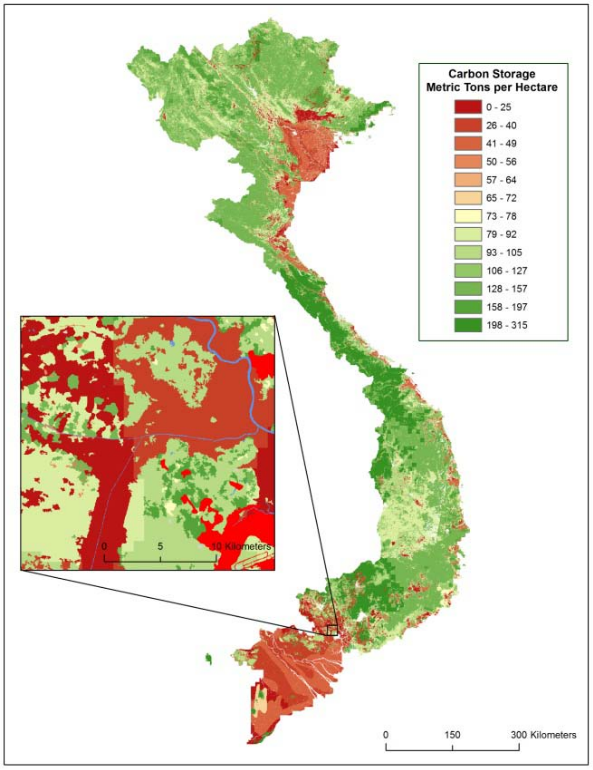

Figure 5 – Carbon calculation based on MDA Information System's GeoCover LC 30-meter land cover product.

The terrestrial carbon stock calculation consists of a digital carbon model developed by the Global Ecosystem Center based on IPCC guidelines and a 30-meter global land cover classification produced by MDA Information Systems. Once the model is run, the appropriate carbon stock values are calculated and embedded in the land cover data itself.

Sample calculation for Vietnam-

Figure 5 illustrates carbon values for each 30m pixel in metric tons. The carbon stock calculations are based on both the above and belowground biomass.

Scenario Modeling

Scenario modeling is a powerful tool to ascertain the effects of proposed changes in land cover resulting from activities like development. The GeoCarbon model is able to model the effects of land use changes on terrestrial carbon stocks. For example, in the Vietnam scenario below, the "Forest Evergreen" category was reduced by 2% and converted to agriculture. The result reveals 104 million metric tons of total carbon loss due to this shift in land use and deforestation (Table 1).

Class #	Class Name	Carbon Stock (Tons)	New Carbon Stock (Tons)	Carbon Gain/Loss (Tons)
2	Forest, Evergreen	2,812,925,429	2,692,582,159	-120,343,270
7	Agriculture, Other	30,616,451	46,937,431	16,320,980
			Total Carbon Loss =	**-104,022,290**

Table 1 - Loss of 104 million ton of carbon due to 2% decrease in evergreen forest

In terms of economic value, carbon stock value can be translated to carbon dioxide. Using economic data from the Intercontinental Exchange (ICE) the largest carbon market place in the world, carbon is worth €13 per metric tons (July, 2011). According to this carbon exchange rate, a 2% change in forest cover accounts $7.2 billion in economic value.

The 104 million ton carbon loss due to the 2% decrease in forest can be interpreted to 381 million tons of carbon dioxide with a potential market trading value of around €5 billion ($7.2 billion) at today's trading values.

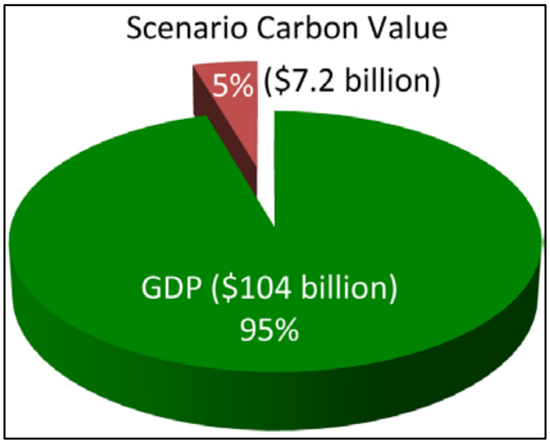

Figure 6 – A decrease of 2% in evergreen forest cover translates to $7.2 billion dollars, which is approximately 5% of Vietnam's economy.

For the emerging economy of 90 million people and gross domestic product of $103.6 billion (official exchange rate 2010 est.)[3], the forests of Vietnam can be considered it's most valuable natural asset. A decrease of a mere 2% in forest cover accounts for billions of dollars in the carbon market. Forests provide substantial additional services including air quality, water runoff, ground water discharge, and other environmental benefits provided by the forests.

Comparisons to Other Estimates of Terrestrial Carbon

In May 2011, NASA published findings from a regional global carbon stock study based on 2000 data to establish a benchmark map to be used as a basis for future comparisons.[4] The research was conducted using data from a combination of satellites including MODIS, QuikScat, and the Shuttle Radar Topography Mission (SRTM) digital elevation models. While results were only obtained in the tropics, GeoCarbon is evaluated with NASA's data below to illustrate its capability and accuracy. In addition, GeoCarbon is also compared with a 1,000-meter resolution global land cover produced by the European Commission Joint Research Center Global Environment Monitoring Unit.[5] This comparison demonstrates the flexibility of GeoCarbon model and its adaptability with different land cover types.

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[3] https://www.cia.gov/library/publications/the-world-factbook/geos/vm.html

[4] Saatchi, S., Harris N., Brown S., Lefsky M., Mitchard E., Salas W., Zutta B., Buermann W., Lewis S., Hagen S., Petrova S., White L., Silman M., Morel A. Benchmark map of forest carbon stocks in tropical regions across three continents. Proceedings of the National Academy of Sciences. 31.may.11, doi: 10.1073/pnas.1019576108

[5] http://bioval.jrc.ec.europa.eu/products/glc2000/products.php

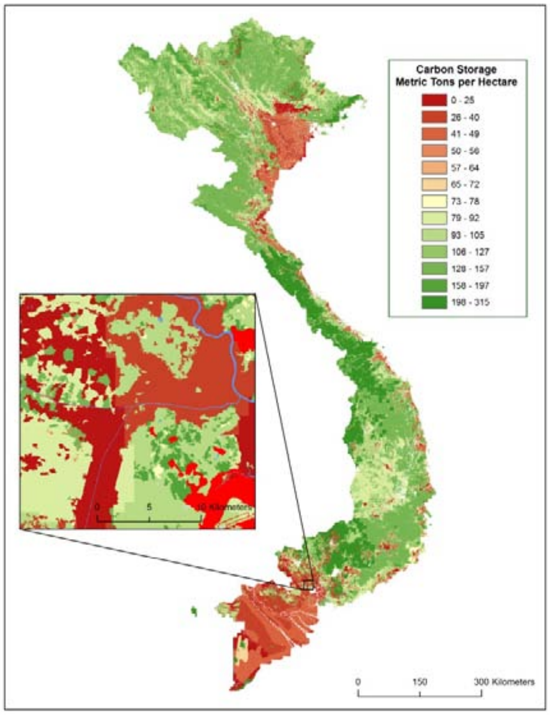

Figure 7 - Carbon storage using MDA's GeoCover Land Cover

MDA's GeoCover Land Cover (Figure 7)

- Spatial Resolution: 30 meter
- Coverage: Global (multi-date available for the most parts of the world)
- Categories: 13 land cover categories
  11 carbon stock categories
- Average Forest Carbon: 189 tons/hectare
- Ground Truth: Remote sensing using high -resolution imagery

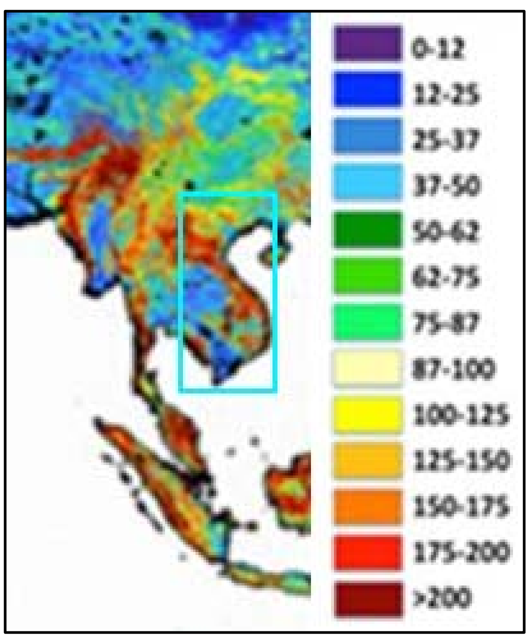

Figure 8 - NASA's Benchmark Map of Forest Carbon Stocks

NASA's Benchmark Map of Forest Carbon Stocks in Tropical Regions across Three Continents (Figure 8).

- Spatial Resolution: 250 – 1,000 meters
- Categories: 3 Forest categories (% coverage)
- Comparison Area: Vietnam Forest Carbon: 175 - 200 tons per hectare
- Ground Truth: In-situ

In these two datasets, most of the carbon is concentrated in the central part of Vietnam with very close forest carbon values per hectare. However, the GeoCarbon analysis reveals carbon values at a higher resolution, creating more accurate carbon stock calculations. Additionally, GeoCarbon also reveals greater amounts of carbon storage near the eastern edge of the country compared other datasets.

NASA's Benchmark Carbon Map primarily focuses on forest carbon storage in forests, while GeoCarbon also calculates carbon storage in other vegetation types such as scrub/shrub, grassland, and various different types of crops, which store significant amounts of carbon.

Conclusion

Over the coming decades, concern for climate change and its impacts is likely to continue to increase and, along with that concern, policies to reduce the buildup of greenhouse gasses in the atmosphere will strengthen. Simultaneously, the pace of land use change through conversion to agricultural, plantations, human settlements and infrastructure will accelerate. If unchecked, land use change will diminish the capacity of the natural system to sequester greenhouse gas at the same time as concern for slowing the pace of climate change will grow.

The model developed by the Global Ecosystem Center offers a cost-effective means of making better decisions concerning growth and development. It provides the data needed to quantify existing stores of carbon sequestered, and a means of making informed decisions about growth and development scenarios. The GeoCarbon tool allows policymakers to quickly identify scenarios that can minimize or eliminate reductions in carbon storage capacity.