High Resolution Ecosystem Modeling as Part of a Robust Carbon Monitoring System

A.H. Armstrong[1], G. C. Hurtt[1], R. Dubayah[1], J. Fisk[1], N. Pinto[1], J. Suarez[1], S. Franks[2], O. Rourke[1], S. Flanagan[1]

[1]Dept of Geography, University of Maryland, College Park

[2]NASA Goddard SFC, Greenbelt, MD

Introduction

The development of high-resolution ecosystem models is of key importance in the advancement of carbon assessment and monitoring systems. Ecosystem models that have the ability to incorporate fine-scale *in situ* vegetation measurements as well as high-resolution satellite imagery, such as LiDAR, will improve larger-scale estimates of carbon and reduce uncertainties in our overall understanding of global carbon cycle dynamics. The aim of our study was to develop and test a high-resolution version of the Ecosystem Demography (ED) Model (Moorcroft et al 2001, Thomas et al 2008), as well as develop a framework with the capability to model vegetation dynamics at 1-hectare resolution over large geographic areas.

Our experimental approach was designed to quantify the individual effect of each input dataset by running multi-scale model tests using combinations of biotic and abiotic input data. Through this methodology we sought to answer the following:

1) What are the high resolution carbon stocks and fluxes (past, present, future) over the domain and
2) How do different input datasets improve and/or constrain model estimates?

From model results, we developed aboveground biomass and flux estimates for Anne Arundel and Howard Counties in Maryland that in conjunction with other comparative metrics highlight the importance of the high spatial resolution climate, soil and structural inputs (LIDAR and forest masking) toward advancing our ability to predict carbon dynamics across heterogeneous landscapes with unprecedented accuracy and precision. The application of this system will monitor changes in carbon stocks over large continental areas through time and will introduce predictive capability for future planning and management purposes at a more human-relevant scale than has been previously achieved.

Materials and methods

The primary focus of this research to date has been the technological advancement of the ED Model in order to develop the capability to run at high resolution over large domains. The study sites used as the selected domain are Anne Arundel and Howard Counties, Maryland. Soil input data included in the model was adapted from ISLSCP (1-degree) and SSURGO (1-hectare) to match model parameters as found in Cosby and others (1984) and the climate dataset used was also from ISLSCP (1-degree) (Turner et al 2006).

Plant physiology over the domain was gathered from U.S. Forest Service Field Inventory and Analysis (FIA) (USDA 2000) plots accomplished from 1990 to present within the study area. FIA plot data was used to calculate Importance Value Indices (IVI) (Curtis and McIntosh 1951; Kent and Coker 1994) to achieve background information on species abundances over the domain. In addition, allometric comparisons were made between equations found in Ter-Mikaelian and Korzhukin (1997) data per specie and ED Model evergreen and deciduous trees to verify that growth rate, height and biomass fell within regional tree ranges and could therefore be considered acceptable to use as potential vegetation functional types during initial model runs.

In order to test how input datasets improve and constrain model estimates while moving from 1-degree to 1-hectare model resolution, we applied an experimental design approach that is summarized below in Table 1. This poster presents the preliminary model results highlighted in yellow in Table 1: ED Model Versions 1.0, 1.1, 1.4 and 1.5 (further versions are pending). In Version 1.4 and 1.5, a forest/non-forest mask was applied from National Land Cover Database (NLCD) 2006 data (Fry et al 2011). The LiDAR initialization applied in Version 1.5 was the mean-max average tree heights (m) constructed from a mean canopy height derived from a small footprint LiDAR canopy height model (CHM).

ED Version	1° Climate	0.25° Climate	1° Soil	1ha Soil	LiDAR	NLCD Forest/Non Forest Mask	LandSat Landuse Classification	Landsat Disturbance Product
Version 1.x, Abiotic/Technologial Focus: Designing repeatable, robust process for running ED at high resolution								
1.0	x		x					
1.1	x			x				
1.2		x	x					
1.3		x		x				
1.4	x			x		x		
1.5	x			x	x	x		
1.6		x		x	x	x		
...								
Version 2.X, Biological Focus: Delineating new site/region specific PFTs for ED								
...								
2.X		x		x	x		x	
Version 3.X, Integrated Focus: Initializing/Validating improved ED with Disturbance Product, LandSat, Lidar								
...								
3.X		x		x	x		x	x

Table 1: Experimental design showing the high resolution ED Model experimental approach. Version 1 runs tested and developed high resolution modeling capability. Yellow highlights indicate model versions presented in the results section. Versions 2 and 3 show future directions of this research.

Results

The results of a rapid preliminary assessment comparing allometric equations for evergreen and deciduous trees in the state of Maryland to that of the ED Model can be seen in Figure 1A and 1B below. In both cases, ED Model trees are found to have comparable allometry to those reported for the region by Ter-Mikaelian and Korzhukin (1997). The NLCD mask in Versions 1.4 and 1.5 (Figure 2) was applied by using the 30m 2006 NLCD data where needleleaf, mixed-leaf, broadleaf, and wetland forests were selected and small forest patches located in urban areas were excluded.

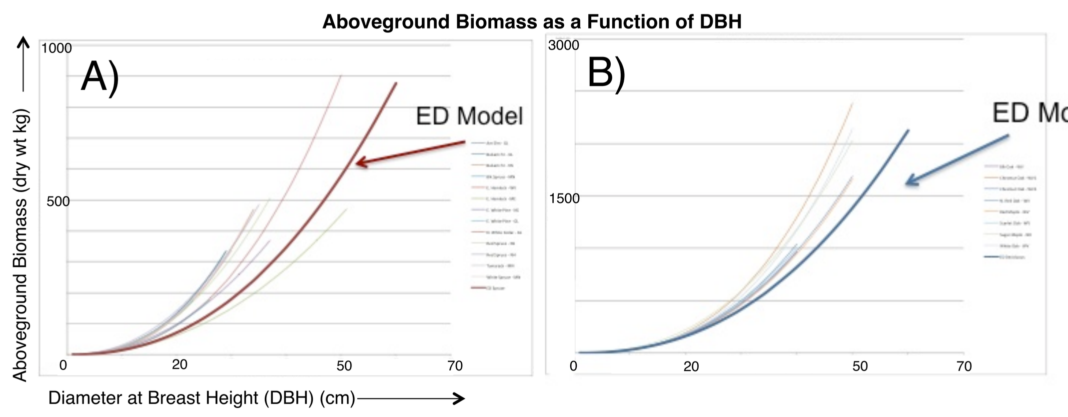


Figure 1. A) Aboveground biomass in dry weight (kg) as a function of DBH (cm) for evergreen trees in Maryland as compared to ED Model evergreen plant functional type, graphed in bold red. Species investigated were taken from Ter-Mikaelian and Korzhukin (1997) for the region and included: American Elm, Balsam Fir, Black Spruce, Eastern Hemlock, Eastern White Pine, Northern White Cedar, Red Spruce, Tamarack and White Spruce. **B)** Aboveground biomass in dry weight (kg) as a function of DBH (cm) for deciduous trees in Maryland as compared to ED Model deciduous plant functional type, graphed in bold blue. Deciduous tree species in comparison were taken from Ter-Mikaelian and Korzhukin (1997) and included the following species: Black Oak, Chestnut Oak, Northern Red Oak, Red Maple, Scarlet Oak, Sugar Maple and White Oak.

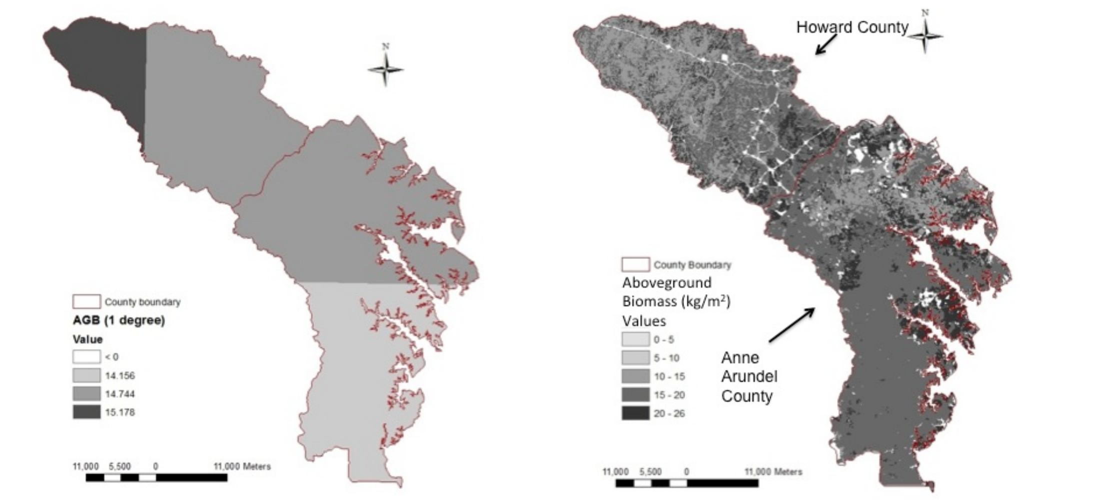
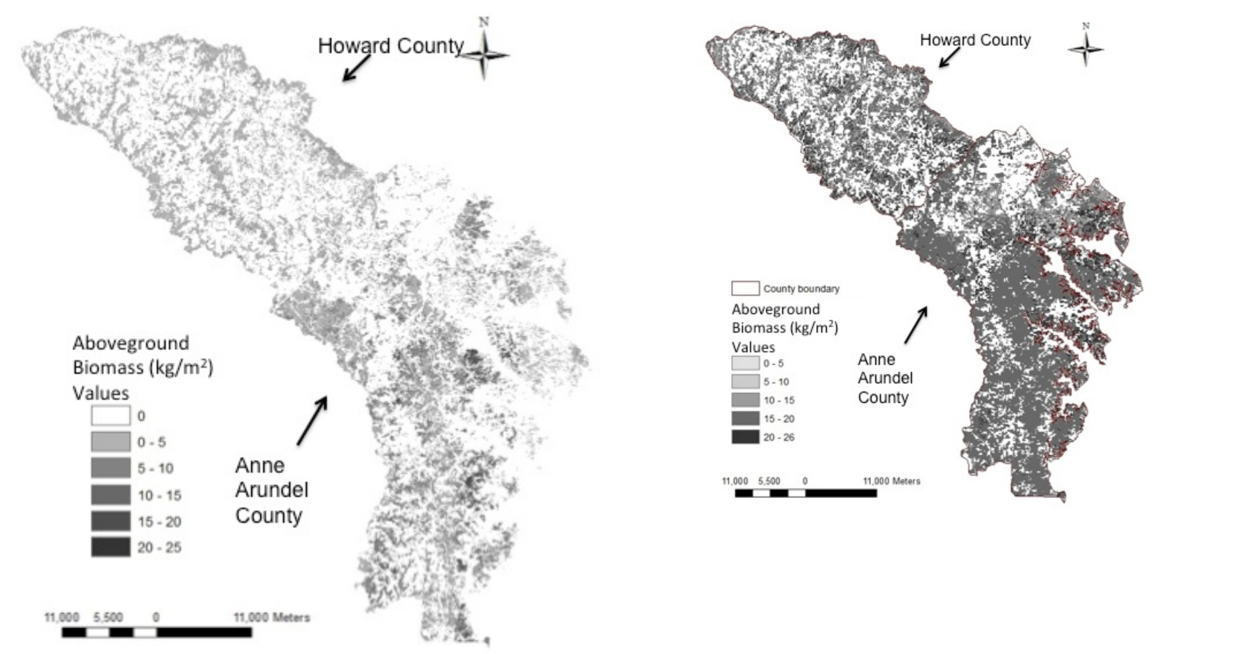


Figure 2. Clockwise from top left: ED Version 1.1: potential Aboveground Biomass (AGB) for Maryland counties with 1-degree soil initialization; ED Version 1.2: ED potential AGB for Maryland Counties with 1-hectare soil initialization; ED Version 1.4: ED Potential AGB for MD Counties with 1ha soil, NLCD 2006 Forest/Non-Forest mask applied; ED Version 1.5: LiDAR initialized ED AGB for MD Counties with 1ha soil, with Forest/Non-Forest Mask.



Results at year 500 of model runs compared between versions 1.0 and 1.1 (Figure 2) show an increase of total AGB over the domain with the higher resolution model. Application of the forest/non-forest mask in version 1.4 reduces overall biomass by excluding non-forested areas within the domain. When the LiDAR initialization is applied (version 1.5), overall AGB for the area decreases substantially as the model output reflects the state of current forests for these two Maryland counties. A preliminary estimate of total C flux is 0.1Tg C.

ED Version	Total AGB (dry wt kg)	Total C (Tg C)	Avg AGB (kg C/m²)	Avg AGB (Mg/ha)
1.0	4.90E+10	24.51	14.67	293.48 *
1.1	5.53E+10	27.66	16.56	331.31 *
1.4	3.87E+10	19.36	16.61	332.20 *
1.5	5.60E+9	2.80	4.50	90.00 *

Table 2. Aboveground biomass results from ED Model runs, versions 1.0, 1.1, 1.4 and 1.5. Results are shown in multiple units to match formats of preliminary comparisons to results derived from numerous studies in conjunction with the carbon monitoring project. *Note: These numbers are preliminary and were included as illustrative only as the model is undergoing on-going refinement.

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Conclusions

The results of this research to date are on-going and clearly highlight importance of high resolution modeling for the establishment of long-term carbon monitoring systems in the US. Given the heterogeneity of the two Maryland counties that were the selected domain, the the ability to accurately assess aboveground biomass is diminished in the low resolution product as compared to what is captured at 1-hectare resolution. With the advent and increased accessibility of high resolution datasets for both initial input and land–use change and disturbance applications, the need for high resolution products has never been more attainable or essential toward creation of robust, long-term monitoring systems.

This research accomplished the following goals during year one of this on-going project:

1) Developed the technological capacity to run high resolution ED Model over the selected domains
2) Through model experiments we have developed a framework designed to isolate the effect of each input dataset
3) The results of these initial model experiments have highlighted the importance of the high resolution product as well as the interactive effects of soils, LiDAR and forest masking.

Our focus thus far has been on the technological challenge of creating a high resolution ED Model version. The computing power required to run such a highly complex model over large domains is tremendous and unprecedented.

The next critical step in this process is toward ecological refinement of the high resolution ED Model. Through analysis of field data collected May through August 2011 and FIA data, our future work will characterize actual vegetation structure over each domain in order to develop and test model experiments for ED Model Versions 2.x and 3.x (see Table 1). In addition, future high resolution ED Model versions will link to LiDAR/RADAR data, Landsat land-use data and a disturbance product created by Chengquan and others (2010). The resultant high resolution multi-faceted ED Model product of this research will produce results at the resolution where most local and federal management decisions take place (1ha). The validated results will establish a framework to allow decision makers to predict climatic impacts under future scenarios of forest disturbance and management. In this sense, the Ecosystem Demography model will represent a critical link between top-down (flux) and bottom-up (biomass) components of NASA's Carbon Monitoring System (CMS) project.

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For further information

Please contact aha@umd.edu or ghurtt@umd.edu or see the following: http://carbon.nasa.gov/index.html