# Forest Carbon Edge Effect

## Summary

The InVEST carbon edge effect model extends the approach of the InVEST carbon model to account for forest carbon stock degradation due to the creation of forest edges. It applies known relationships between carbon storage and distance from forest edge to calculate edge effects in carbon storage, and combines these estimates with carbon inventory data to construct the overall carbon map. The model for edge effects pertains to above-ground carbon only, because edge effects have not been documented for the other carbon pools. For all other carbon pools, and for non-tropical forest classes, or if the model is run without edge effects, it follows the IPCC (2006) inventory approach to assigning carbon storage values by land cover class.

## Introduction

The effects of future land-use change on carbon storage or sequestration can be modeled by applying carbon storage estimates found in the literature for different habitat types to each habitat found in a landscape (e.g., Nelson et al. 2010). However, this approach assumes that all habitat is equivalent in its quality of carbon storage, regardless of where it occurs, despite the fact that there is substantial evidence that fragmentation can play a dramatic role in altering carbon storage and sequestration rates in tropical forests (Broadbent et al. 2008, Dantas et al 2011, Laurance et al. 1997, 2000, 2001, 2002). For example, core forest has been shown to store more than three times the carbon of edge forest in Brazilian Atlantic forests (Dantas et al. 2011). Chaplin-Kramer et al. (2015) investigated this pattern for the entire pantropics using remotely sensed data on biomass (Baccini et al 2012) and associated land cover (Friedl et al. 2011) and found a continuous relationship of carbon storage degrading gradually toward a forest edge, which varies substantially from region to region. This model accounts for these documented edge effects in tropical forests, assigning carbon storage based on the distance of a pixel to the nearest forest edge. This can improve the overall accuracy of carbon storage estimates by 20% relative to forest inventory approaches, and better captures the impacts of forest degradation from fragmentation, beyond merely the area of habitat lost.

## The model

The InVEST carbon edge effect model is an update to the InVEST carbon model, which incorporates the degradation of carbon storage that occurs due to edge effects in tropical forests. The user designates which land cover classes are forest, and then the model uses pregenerated regression results to predict the carbon throughout a forest parcel based on its distance to the nearest forest edge. These results are combined with the carbon assigned to non-forest classes through traditional inventory methods (IPCC 2006) used in the InVEST carbon model, to generate a map of above-ground carbon storage for all land cover classes. The InVEST carbon edge effect model can be run to calculate only above ground carbon or all carbon pools, and it can be run with or without edge effects. It is important to note that the edge effects regression only pertains to above-ground carbon stocks because edge effects have only been detected for above-ground biomass. To include the other three carbon pools (below-ground, soil, and standing dead matter), carbon density (Mg/ha) should be included for each land cover class in the biophysical table.

### How it works

This model follows the methodology described in Chaplin-Kramer et al. (2015), which constructs a series of regression models between forest biomass density (Mg/ha) and distance from forest edge (km) for 100 km x 100 km grid cells throughout the pantropics. In grid cells where the majority of pixels were from forest biomes, three candidate regression models are considered to represent the relationship between biomass density and distance to forest edge:

1. Asymptotic:
2. Logarithmic:
3. Linear:

Then, for each grid cell, the candidate with the highest r2 value is used to best represent the relationship between density and distance to forest edge.  Models (2) and (3) were deemed as suitable (and more simplistic) alternatives in cells where higher distances were generally not observed and as a result the forest core was not firmly established. In the vast majority of grid cells, model (1) was optimal.

The results of these regressions can be found in the carbon edge regression parameter shapefile (*core\_data/forest\_carbon\_edge\_regression\_model\_parameters.shp*) in the sample dataset that is provided for the InVEST carbon edge effect model. For any forest pixel within the study region, the model calculates the distance of that pixel from forest edge then calculates biomass to a predefined number of nearest regression models which is then aggregated to a single result using a distance linear interpolation scheme. The model then converts biomass to carbon with a user provided conversion factor, defaulted to 0.47 (IPCC 2006). The user can designate the number of local models used in the interpolation scheme which is defaulted to 10 but can range anywhere from 1 (only closest point) to 2635 (every regression model on the planet). Note that a selection of 1 may result in artificially large differences in carbon when moving from one pixel to the next where they fall in different regression grid cells. The higher the number of regression grid cells selected, the smoother the transition from one pixel to the next. The user may wish to select the number of grid cells overlapping the entire study region in order to eliminate any artifacts of model selection. This can be determined by examining the *intermediate\_outputs\local\_carbon\_shape.shp* geometry overlaid on the area of interest. The linear interpolation scheme for biomass b on pixel p is given below

Where,

* is the interpolated biomass on pixel p
* n is the number of nearest models to interpolate from, a value provided by the user
* i is the ith nearest biomass model from pixel p
* di is the distance from pixel p to the centroid of the ith biomass model.

The carbon calculated for non-forest classes follows the methodology from the InVEST carbon model, assigning values based on forest carbon inventory data designated in the biophysical table. The carbon maps following this inventory approach and the edge effects approach are merged into the final carbon map, such that the forest land covers exhibit edge effects and all other land covers will not.

## Data needs

This section outlines the specific data used by the model. See the Appendix for the Carbon Storage model for additional information on data sources and pre-processing of non-forest or non-tropical LULC classes. Please consult the InVEST sample data (located in the folder where InVEST is installed, if you also chose to install sample data) for examples of all of these data inputs. This will help with file type, folder structure and table formatting. Note that all GIS inputs must be in the same projected coordinate system and in linear meter units.

* **Workspace** (required). Folder where model outputs will be written. Make sure that there is ample disk space, and write permissions are correct.
* **Suffix** (optional). Text string that will be appended to the end of output file names, as "\_Suffix". Use a Suffix to differentiate model runs, for example by providing a short name for each scenario. If a Suffix is not provided, or changed between model runs, the tool will overwrite previous results.
* **Land use/land cover** (required). A GIS raster dataset, with an integer LULC code for each cell. These LULC codes must match \*lucode\* values in the \*\*Biophysical table\*\*.
* **Biophysical table** (required). A CSV (Comma-Separated Value) table providing information about which classes in the land-use/land-cover map are considered forest and should have the edge effect regression applied, and carbon density (Mg per hectare) for the land cover classes that are not forest. If “all carbon pools” is selected for “carbon pools to calculate” in the user interface for the model, columns 3-6 must be included (although 0’s can be placed for any pools that you do not wish to calculate); if “above ground only” is selected, columns 4-6 can be excluded.

The biophysical table columns must be named as follows:

* + - 1. **lucode** (required). Unique integer for each LULC class. *Every value in the LULC raster MUST have a corresponding lucode value in the Biophysical table.*
      2. **is\_tropical\_forest** (required). Integer value of 1 if the LULC class is tropical forest, 0 if it is not tropical forest.
      3. **c\_above** (required for non-tropical forest).Carbon density value for the aboveground carbon pool. Units: megagrams per hectare (Mg/ha). See the Carbon Storage model chapter for more information.
      4. **c\_below** (optional). Carbon density value for the belowground carbon pool. Units: megagrams per hectare (Mg/ha). See the Carbon Storage model chapter for more information.
      5. **c\_soil** (optional). Carbon density value for the soil carbon pool. Units: megagrams per hectare (Mg/ha). See the Carbon Storage model chapter for more information.
      6. **c\_dead** (optional). Carbon density value for the dead matter carbon pool. Units: megagrams per hectare (Mg/ha). See the Carbon Storage model chapter for more information.
      7. **Description** (optional). Text description of each LULC class.

*Example biophysical table (data for Brazil)*:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| lucode | Is\_tropical\_forest | c\_above | c\_below | c\_soil | c\_dead | Description |
| 0 | 0 | 0 | 0 | 0 | 0 | Water |
| 1 | 1 | n/a | 16.8 | 60 | 14.4 | Evergreen Needleleaf Forest |
| 2 | 1 | n/a | 22.4 | 60 | 10.2 | Evergreen Broadleaf Forest |
| 3 | 1 | n/a | 12.8 | 60 | 11 | Deciduous Needleleaf Forest |
| 4 | 1 | n/a | 15.6 | 60 | 13.4 | Deciduous Broadleaf Forest |
| 5 | 1 | n/a | 14.1 | 60 | 12.1 | Mixed Forest |
| 6 | 0 | 10.51 | 6.7 | 60.1 | 1.3 | Closed Shrublands |
| 7 | 0 | 4.51 | 7.3 | 65.5 | 1.1 | Open Shrublands |
| 8 | 0 | 20.12 | 23.6 | 151.4 | 2.6 | Woody Savannas |
| 9 | 0 | 4.42 | 7.1 | 211 | 1.5 | Savanna |
| 10 | 0 | 31 | 7.9 | 71 | 0.9 | Grasslands |
| 12 | 0 | 0.253 | 0.5 | 50.8 | 2.4 | Croplands |
| 13 | 0 | 0 | 0 | 0 | 0 | Urban/Built-up |
| 16 | 0 | 0 | 0 | 0 | 0 | Barren or sparsely vegetated |

Source: (1) Miranda, Sabrina do Couto, et al. Regional variations in biomass distribution in Brazilian savanna woodland. Biotropica 46.2 (2014): 125-138. (2) Saatchi, Susan S., et al. Distribution of aboveground live biomass in the Amazon basin. Global Change Biology 13.4 (2007): 816-837. (3) Fearnside, Philip M. Greenhouse gases from deforestation in Brazilian Amazonia: net committed emissions. Climatic Change 35.3 (1997): 321-360.

* **Carbon Pools to Calculate** (required, select from menu). Select either “all carbon pools” or “above ground only”.
* **Compute forest edge effects** (optional). Check this box if edge effects on above-ground biomass should be included. If this box is checked inputs 5-7 are required.
* **Global forest carbon edge regression models** (optional, included in sample data). This shapefile was derived from a pantropical analysis of the relationship between forest biomass and distance from forest edge (Chaplin-Kramer et al. 2015). The rows contain the coefficients of the unique parameters for each 100 x 100 km subregion across the tropics. This information need not be altered unless you have run a separate regression for your region and have better or updated information.
* **Number of nearest model point to average** (optional). Integer number used when calculating the biomass in a pixel. This value determines the number of closest regression models that are used when calculating the total biomass. Each local model is linearly weighted by distance such that the biomass in the pixel is a function of each of these points with the closest point having the highest effect. Default value is 10. Higher values smooth the variation in the edge effect detected in the different grid cells (seen in the carbon edge regression parameter shapefile, input 3) to a greater degree.
* **Forest Edge Biomass to Carbon Conversion Factor** (optional). The floating point number by which to multiply forest above-ground biomass to convert to carbon. Default value is 0.47 (according to IPCC 2006). This pertains to the edge-effects regression parameters only; all values in the Biophysical Table should already be in terms of carbon, not biomass.
* **Service areas of interest** (optional). If a summary of the carbon value is desired, a shapefile containing the area(s) of interest, either as a region area or partitioned into subregions (e.g., ecoregions, districts, etc.) can be included. Carbon values will be aggregated within these region/subregion polygons and a single value will be output for each.

## Running the model

To launch the Forest carbon edge effect model navigate to the Windows Start Menu -> All Programs -> InVEST [\*version\*] ->Forest Carbon Edge Effect. The interface does not require a GIS desktop, although the results will need to be explored with any GIS tool such as ArcGIS or QGIS.

## Interpreting Results

The following is a short description of each of the outputs from the Forest carbon edge effects model. Final results are found within the user defined Workspace specified for this model run. "Suffix" in the following file names refers to the optional user-defined Suffix input to the model.

* **Parameter log**. Each time the model is run, a text (.txt) file will appear in the *Workspace*. The file will list the parameter values for that run and will be named according to the service, the date and time. When contacting NatCap about errors in a model run, please include the parameter log.
* **carbon\_map\_<Suffix>.tif**. A map of carbon stock per pixel, with the amount in forest derived from the regression based on distance to forest edge, and the amount in non-forest classes according to the biophysical table. Note that because the map displays carbon (Mg) per pixel, coarser resolution maps should have higher values for carbon, because the pixel areas are larger.
* **aggregated\_carbon\_stocks\_<Suffix>.shp**: If service areas of interest are provided by the user, this output shapefile summarizes the total carbon (column *c\_sum*) and mean carbon per ha (column *c\_ha\_mean*) in the area polygons defined. Values are in Mg.

### Intermediate Results

You may also want to examine the intermediate results. These files can help determine the reasons for the patterns in the final results. They are found in the intermediate\_outputs folder within the *Workspace* specified for this module.

* intermediate\_outputs\**c\_above\_carbon\_stocks\_<Suffix>.tif**. Carbon stored in the aboveground biomass carbon pool.
* intermediate\_outputs\**c\_below\_carbon\_stocks\_<Suffix>.tif**. Carbon stored in the belowground biomass carbon pool.
* intermediate\_outputs\**c\_dead\_carbon\_stocks\_<Suffix>.tif**. Carbon stored in the dead matter biomass carbon pool.
* intermediate\_outputs\**c\_soil\_carbon\_stocks\_<Suffix>.tif**. Carbon stored in the soil biomass carbon pool.
* intermediate\_outputs\**local\_carbon\_shape.shp**. The regression parameters reprojected to match your study area
* intermediate\_outputs\**edge\_distance\_<Suffix>.tif**. The distance of each forest pixel to the nearest forest edge
* intermediate\_outputs\**tropical\_forest\_edge\_carbon\_stocks\_<Suffix>.tif**. A map of carbon in the forest only, according to the regression method

## References

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