NACP Regional Interim Synthesis Project

Standardized Inventory Zones Data Set

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2. Introduction

This data set contains data products that were compiled and used in the model-inventory comparison activities of the North American Carbon Program (NACP) Regional Interim Synthesis. Two categories of data products are included in this data set. The first category is the standardized gridded biospheric model and inverse model output data aggregated onto the inventory zones defined for North America (United States, Canada, and Mexico). Depending on the data availability, the monthly/yearly Net Ecosystem Exchange (NEE), Net Primary

Production (NPP), Total Vegetation Carbon (Veg), Heterotrophic Respiration (Rh), and Fire Emissions (FE) variables from 24 models were aggregated from 1-degree resolution gridded format to inventory zones and further divided into Forest Lands, Crop Lands, and Other Lands sectors for each inventory zone based on the 1-km resolution GLC2000 land cover map. The second category is the North American national Greenhouse Gas (GHG) inventories, which contain estimated land-atmosphere exchange of CO2 (NEE) in Forest Lands, Crop Lands, and Other Lands sectors synthesized from inventory-based data on productivity, ecosystem carbon stock change and harvested product stock change, and additional information from national-level GHG inventories of the United States, Canada, and Mexico.

All the aggregated monthly/yearly model output data are stored in the Microsoft Access MDB format and all the national GHG inventories data are stored in Comma Separated Value (CSV) format. This document provides detailed information about the content, format, and processing procedures of these two categories of data. Detailed description of the terrestrial biospheric and inverse models can be found in a separate document: *Regional - Description of Observations and Models*.

3. Inventory Zones

The NACP standardized-gridded model output data were aggregated onto inventory zones in order to be compared with inventory-based national GHG data. The inventory zones for North America are defined as states for the United States and Mexico and ecoregion-based managed forest reporting zones for Canada. Figure 1 shows the map for all 97 inventory zones in North America and Table 3 lists the zone IDs and names. The definition of inventory zones for North America is consistent between the aggregated standardized-gridded model output data and the national GHG data.

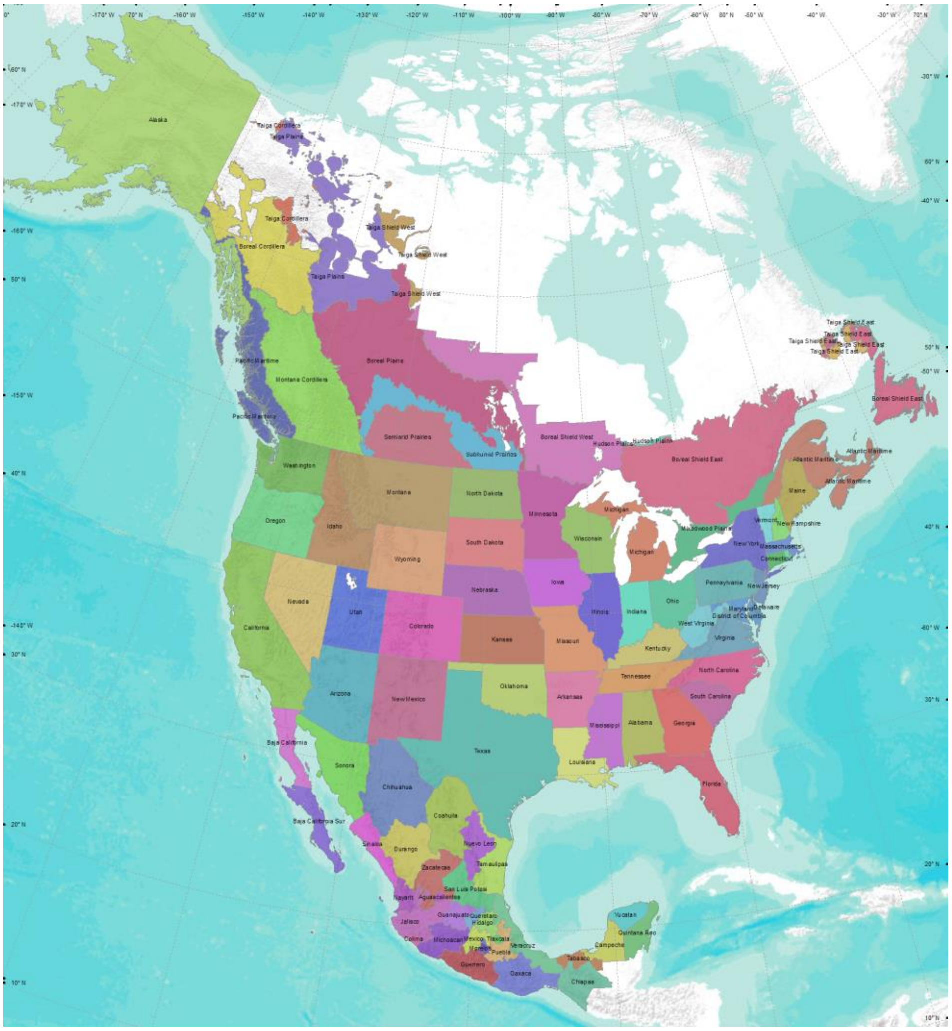

Figure 1. North American Inventory Zones Map

Table 1. North American Inventory Zones

No	Zone ID	Zone Name	Country
1	1	Aguascalientes	Mexico
2	2	Alabama	United States
3	3	Alaska	United States
4	4	Arizona	United States
5	5	Arkansas	United States
6	6	Atlantic Maritime	Canada
7	7	Baja California	Mexico
8	8	Baja California Sur	Mexico
9	9	Boreal Cordillera	Canada
10	10	Boreal Plains	Canada
11	11	Boreal Shield East	Canada
12	12	Boreal Shield West	Canada
13	13	California	United States

14	14	Campeche	Mexico
15	15	Chiapas	Mexico
16	16	Chihuahua	Mexico
17	17	Coahuila	Mexico
18	18	Colima	Mexico
19	19	Colorado	United States
20	20	Connecticut	United States
21	21	Delaware	United States
22	22	District of Columbia	United States
23	23	Distrito Federal	Mexico
24	24	Durango	Mexico
25	25	Florida	United States
26	26	Georgia	United States
27	27	Guanajuato	Mexico
28	29	Guerrero	Mexico
29	30	Hidalgo	Mexico
30	31	Hudson Plains	Canada
31	32	Idaho	United States
32	33	Illinois	United States
33	34	Indiana	United States
34	35	Iowa	United States
35	36	Jalisco	Mexico
36	37	Kansas	United States
37	38	Kentucky	United States
38	39	Louisiana	United States
39	40	Maine	United States
40	41	Maryland	United States
41	42	Massachusetts	United States
42	43	Mexico	Mexico
43	44	Michigan	United States
44	45	Michoacan	Mexico
45	46	Minnesota	United States
46	47	Mississippi	United States
47	48	Missouri	United States
48	49	Mixedwood Plains	Canada
49	50	Montana	United States
50	51	Montane Cordillera	Canada
51	52	Morelos	Mexico
52	53	Nayarit	Mexico
53	54	Nebraska	United States
54	55	Nevada	United States
55	56	New Hampshire	United States
56	57	New Jersey	United States
57	58	New Mexico	United States
58	59	New York	United States

59	60	North Carolina	United States
60	61	North Dakota	United States
61	62	Nuevo Leon	Mexico
62	63	Oaxaca	Mexico
63	64	Ohio	United States
64	65	Oklahoma	United States
65	66	Oregon	United States
66	67	Pacific Maritime	Canada
67	68	Pennsylvania	United States
68	69	Puebla	Mexico
69	70	Queretaro	Mexico
70	71	Quintana Roo	Mexico
71	72	Rhode Island	United States
72	73	San Luis Potosi	Mexico
73	74	Semiarid Prairies	Canada
74	75	Sinaloa	Mexico
75	76	Sonora	Mexico
76	77	South Carolina	United States
77	78	South Dakota	United States
78	79	Subhumid Prairies	Canada
79	80	Tabasco	Mexico
80	81	Taiga Cordillera	Canada
81	82	Taiga Plains	Canada
82	83	Taiga Shield East	Canada
83	84	Taiga Shield West	Canada
84	85	Tamaulipas	Mexico
85	86	Tennessee	United States
86	87	Texas	United States
87	88	Tlaxcala	Mexico
88	89	Utah	United States
89	90	Veracruz	Mexico
90	91	Vermont	United States
91	92	Virginia	United States
92	93	Washington	United States
93	94	West Virginia	United States
94	95	Wisconsin	United States
95	96	Wyoming	United States
96	97	Yucatan	Mexico
97	98	Zacatecas	Mexico

Detailed inventory zones information, including zone names, boundaries, and associated zone attributes are defined in ESRI Shapefile NAZonesFine.shp. The following inventory zones attributes are included in the shapefile.

- Zone (string): Name of the state or reporting zone
- Country (string): The country to which the zone belongs

- SUM_Area (double): Area of the state or reporting zone (in square meters)
- SUM_AreaF (double): Area of forest land cover type within each Zone (in square meters)
- SUM_AreaC (double): Area of crop land cover type within each Zone (in square meters)
- SUM_AreaO (double): Area of "other" land cover type within each Zone (in square meters)

4. Forest/Crop/Other Land Sectors

The aggregation of gridded model output into different land sectors for each reporting zone requires a mechanism to calculate the fraction of forest, crop, and other land sectors for. In this NACP regional interim synthesis activity, it's achieved by analyzing the Global Land Cover 2000 (GLC2000)[1] (Bartholome and Belward, 2005) data at 1km spatial resolution.

GLC2000 data uses a land cover classification scheme containing 22 different types (Table 2). These types were first mapped to 3 sectors: forest, crop, and other, as described in Table 2.

Table 2. Mapping between GLC2000 Land Cover Types and Land Sectors (Forest, Crop, and Other)

Value	GLC2000 Type Description	Land Sectors
1	Tree Cover, broadleaved, evergreen	Forest
2	Tree Cover, broadleaved, deciduous, clsd	
3	Tree Cover, broadleaved, deciduous, open	
4	Tree Cover, needle-leaved, evergreen	
5	Tree Cover, needle-leaved, deciduous	
6	Tree Cover, mixed leaf type	
7	Tree Cover, flooded, fresh water	
8	Tree Cover, flooded, saline	
9	Mosaic: Tree Cover/Other Veg	
10	Tree Cover, burnt	
11	Shrub Cover, closed-open, evergreen	Other
12	Shrub Cover, closed-open, deciduous	
13	Herbaceous Cover, closed-open	
14	Sparse herbaceous or shrub	
15	Regular flooded shrub or herbaceous	
16	Cultivated and managed areas	Crop
17	Mosaic: Cropland/Tree Cover/Other Veg	
18	Mosaic: Cropland/Shrub and/or grass	
19	Bare Areas	Other
20	Water Bodies	
21	Snow and Ice	
22	Artificial surfaces	
23	No data	

[1] Global Land Cover 2000 database. European Commission, Joint Research Centre, 2003. http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php

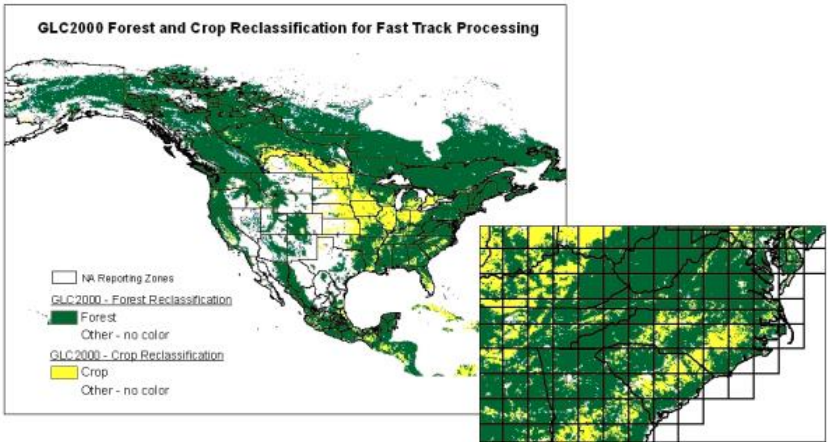

Figure 2. This image shows two separate files; the GLC2000 forest reclassification with all other pixels set to zero and the GLC2000 crop reclassification with all other pixels set to zero. The insert shows details over the eastern United States with the details of the NA Zone Pieces polygon file by which the land cover data are summarized.

The GLC2000 types 1 – 10 were mapped to the forest sector, types 16 – 18 were mapped to the crop sector, and all other types were mapped to the "other" sector. Based on this mapping, a reclassification process was performed to convert the original GLC2000 data into three masks at 1km resolution: 1) forest mask (value 1 represents cells in forest sector with all other cell values set to 0), 2) crop mask (value 1 represents cells in crop sector with all other cell values set to 0), and 3) other mask (value 1 represents cells in other sector with all other cell values set to 0). We then used the 1km resolution U.S. forest biomass data (Blackard, et al., 2008) as a reference forest distribution data to further refine the distribution of forest area in the forest mask. The crop mask and "other" mask maps were then updated accordingly. Figure 2 shows the above three masks overlapped together. With these masks at fine (1km) spatial resolution, we calculated the fraction of each land sector in each 1-degree grid cell and then distributed model output flux into overlapped reporting zones and appropriate land sectors.

For the purpose of creating spatial maps as shown in Fig. 5 of Hayes et al., 2012, we merged the North American reporting zones shapefile with the masks to create a 1km resolution reference raster data (NA_Reporting_Zones_Sectors.tif) to describe which reporting zone and sector each 1km grid cell belongs to. The values in the reference raster data are 3-digit numbers following the pattern of "NXY". If "N" is 1, it means the grid cell belongs to the forest land sector. Value "2" and "3" indicate the crop and "other" land sectors representatively. "XY" is a 2-digit number representing the ID of reporting zones, as listed in Table 1. For example, a grid cell with value 141 means that 1km grid cell belongs to the forest sector and Maryland, US.

5. Aggregated Model Output

Selected variables, including Net Ecosystem Exchange (NEE), Net Primary Production (NPP), Total Vegetation Carbon (Veg), Heterotrophic Respiration (Rh), and Fire Emissions (FE), depending on availability, of the NACP standardized-gridded model output data were aggregated from 1-degree spatial resolution to the North American inventory zones.

5.1. Models and Variables

Table 3 lists all the models and their corresponding output variables that were aggregated to inventory zones, along with their temporal coverage and resolution. For selected models and output variables, other variables were used to derive the data. For example, the aggregated Vegetation Carbon (Veg) variable of model CLM-CASA (Dickinson et al., 2006) was derived from LEAFC+WOODC+FROOTC, which was comparable to variable TOTVEGC of model CLM-CN (Thornton and Rosenbloom, 2005) or variable TotLivBiom of model MC1 (Bachelet et al., 2001). A cell marked with "n/a" means a variable is neither directly available nor derivable from other variables for a model.

Table 3. Models and Variables Aggregated to Inventory Zones

<table>
<tr><th colspan="3" rowspan="2">Model</th><th rowspan="2">Temporal Coverage *</th><th rowspan="2">Temporal Resolution</th><th colspan="5">Variables</th></tr>
<tr><th>NEE</th><th>NPP</th><th>Veg</th><th>Rh</th><th>FE</th></tr>
<tr><td rowspan="17">Terrestrial Biosphere Models</td><td rowspan="4">CLM-CASA</td><td>i01.54</td><td rowspan="4">2000-2004</td><td rowspan="4">monthly</td><td rowspan="4">NEE</td><td rowspan="4">NPP</td><td rowspan="4">(LEAFC + WOODC + FROOTC)</td><td rowspan="4">HR</td><td rowspan="4">n/a</td></tr>
<tr><td>i01.54_q15</td></tr>
<tr><td>i01.55</td></tr>
<tr><td>i01.55_q15</td></tr>
<tr><td rowspan="2">CLM-CN</td><td>i01.56</td><td rowspan="2">2000-2004</td><td rowspan="2">monthly</td><td rowspan="2">NEE</td><td rowspan="2">NPP</td><td rowspan="2">TOTVEGC</td><td rowspan="2">HR</td><td rowspan="2">n/a</td></tr>
<tr><td>i01.57_q15</td></tr>
<tr><td colspan="2">ORCHIDEE</td><td>2001-2007</td><td>monthly</td><td>CO2FLUX</td><td>NPP</td><td>n/a</td><td>HET_RESP</td><td>n/a</td></tr>
<tr><td colspan="2">SiB3</td><td>2000-2005</td><td>monthly</td><td>NEE</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td colspan="2">CASA-Transcom</td><td>2002-2003</td><td>monthly</td><td>NEE</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td colspan="2">CASA GFed2</td><td>2000-2005</td><td>monthly</td><td>NEEF</td><td>n/a</td><td>n/a</td><td>n/a</td><td>CFire (derived from NEEF-NEE)</td></tr>
<tr><td colspan="2">NASA-CASA</td><td>2001-2004</td><td>monthly</td><td>(-1 * NEP)</td><td>NPP</td><td>n/a</td><td>(NPP – NEP)</td><td>n/a</td></tr>
<tr><td colspan="2">MC1</td><td>2000-2007</td><td>monthly</td><td>NEE + BioCons</td><td>NPP</td><td>TotLivBiom</td><td>RespH</td><td>BioCons</td></tr>
<tr><td colspan="2">TEM6</td><td>2000-2006</td><td>monthly</td><td>NCE</td><td>NPP</td><td>VEGC</td><td>RH</td><td>(NCE - NEE)</td></tr>
<tr><td colspan="2">DLEM</td><td>2000-2005</td><td>monthly</td><td>NEE</td><td>NPP</td><td>TotLivBiom</td><td>Rh</td><td>n/a</td></tr>
<tr><td colspan="2">VEGAS</td><td>2000-2007</td><td>monthly</td><td>NEE</td><td>NPP</td><td>cvege</td><td>Rh</td><td>cfire</td></tr>
<tr><td colspan="2">EC-MOD</td><td>2001-2006</td><td>monthly</td><td>NEE</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td colspan="2">MOD17-plus</td><td>2000-2004</td><td>monthly</td><td>(GPP –</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
</table>

				Reco)				
	ISAM	2000-2007	monthly	NEE	NPP	n/a	resp	n/a
	BEPS	2000-2004	monthly	(-1 * NEP)	NPP	n/a	(NPP - NEP)	n/a
	LPJmL	2000-2006	monthly, yearly	NEE (monthly), ANEEF (annually, derived from ANEE+FIRE)	NPP	VEGC (annually)	RH	FIRE (annually)
	Can-IBIS	2000-2005	monthly,yearly	NEE (derived from -1*NEP)	NPP	CBiomass (annually)	Rh	n/a
Inverse Models	UToronto	2001-2003	monthly	NEE	n/a	n/a	n/a	n/a
	CarbonTracker	2000-2007	monthly	NEE	n/a	n/a	n/a	n/a
	LCSE-no1 (Peylin)	2002-2004	monthly	NEE	n/a	n/a	n/a	n/a
	JENA (Rodenbeck)	2000-2007	monthly	NEE	n/a	n/a	n/a	n/a
	Michigan-Geostatistical	2000-2001	monthly	NEE	n/a	n/a	n/a	n/a
	CSU-no1 (MLEF-PCTM)	2003-2004	monthly	NE	n/a	n/a	n/a	n/a
	LSCE-no2 (Chevalier)	2000-2006	monthly	NEE	n/a	n/a	n/a	n/a

Note: * Only data in and after year 2000 were included in aggregation.

5.2. Aggregation Procedure

The aggregation process started with the standardized gridded model output data that have been standardized to a common geographic projection and a 1-degree resolution gridded format. The aggregation processing was performed using the commercial GIS software, ESRI ArcGIS[2]. Key input layers were derived separately, as described below, and used within a processing model built with the ArcGIS Model Builder. The overall processing model is shown in Figure 2.

The initial challenge in this process was to aggregate the raster-based model output variables onto polygon-based inventory zones: states and reporting units. 1-degree grid cells are fairly big compared with some of the inventory zones. Many 1-degree grid cells overlap with multiple inventory zones. In order to accurately capture

[2] ESRI ArcGIS: http://www.esri.com/software/arcgis

the contributions from grid cells partially overlapped with inventory zones, each raster-based model output data was first converted to polygon-based vector data, which allowed precise polygon shape intersection and area calculation within ArcGIS Model Builder.

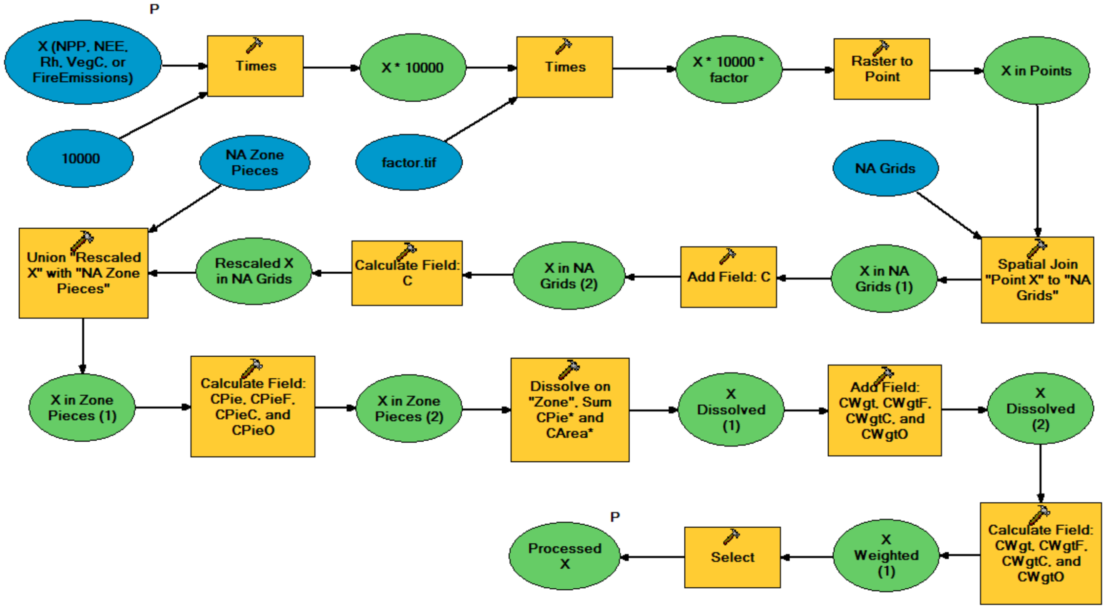

Figure 3. The aggregation model diagram within ArcGIS Model Builder

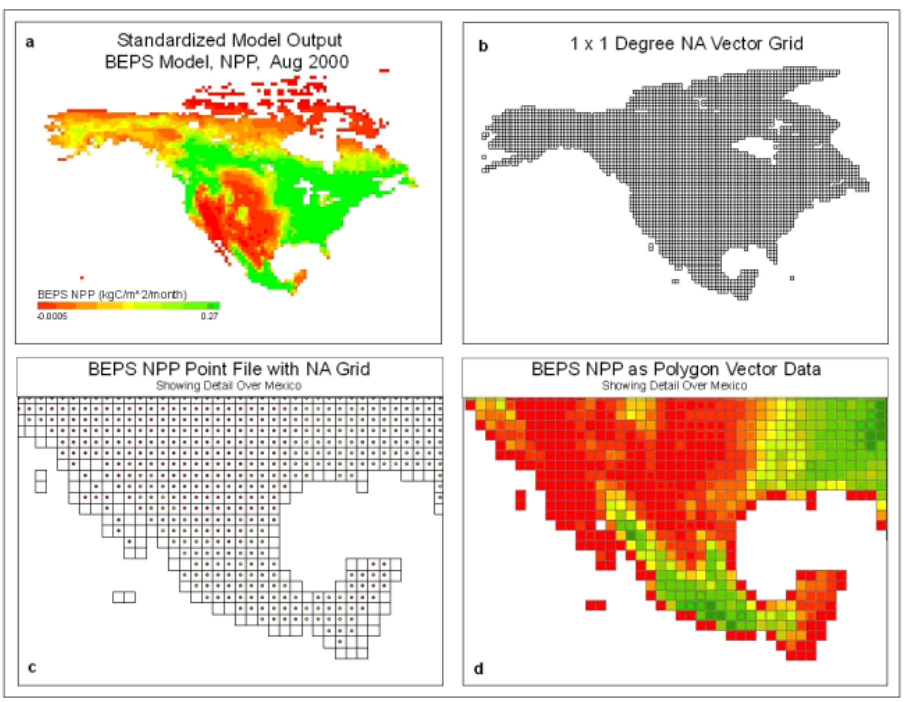

Figure 4. a) Standardized gridded output from the model BEPS showing NPP for August 2000
b) The 1 x 1 degree NA polygon grid used in the spatial join to convert the raster data to polygon-based vector data
c) The BEPS model NPP for Aug 2000 converted to a point vector data shown with the NA polygon grid
d) The NPP variable of model BEPS for August 2000, as a polygon vector data

A few important steps were necessary to perform on each input layer prior to converting each raster variable to a vector file. First, the internal processing within ArcGIS did not maintain the precision of the input model values. In order to maintain the precision, model output variable grid cell values were multiplied by 10000 on a cell-by-cell basis. After raster-to-polygon processing, cell values were divided by 10000 returning each variable to its original value. Also, since the area of a 1 degree raster could be part of more than one reporting zone or a non-land area, an input layer was derived which contained the fraction of area of each 1-degree grid cell that belonged to the overlapped reporting zone. In the aggregation model diagram, this data layer is called "factor.tif".

After these initial modifications, each gridded model output variable was converted from a raster data format to a vector point data by a Raster-to-Point conversion. At this step in the processing another input layer was introduced; a 1-degree vector polygon "grid" which had been derived over the extent of the North American study area. In the aggregation model diagram, this input layer is called "NA Grids". This polygon-based grid has the same individual cell boundaries as the 1-degree raster-based data from the standardized gridded model output. Each variable point file has its value at the center of the 1-degree polygon grid. From here, a GIS procedure is performed that spatially joins the value of the point-based model output variable data to the polygon-based 1-degree vector grid data, as illustrated in Figure 3 with NPP variable of model BEPS (Chen et al., 1999) as an example. With each gridded model output data converted to a polygon vector data, it is possible to derive area-weighted values of each variable by the inventory zone organization of the inventory-based information.

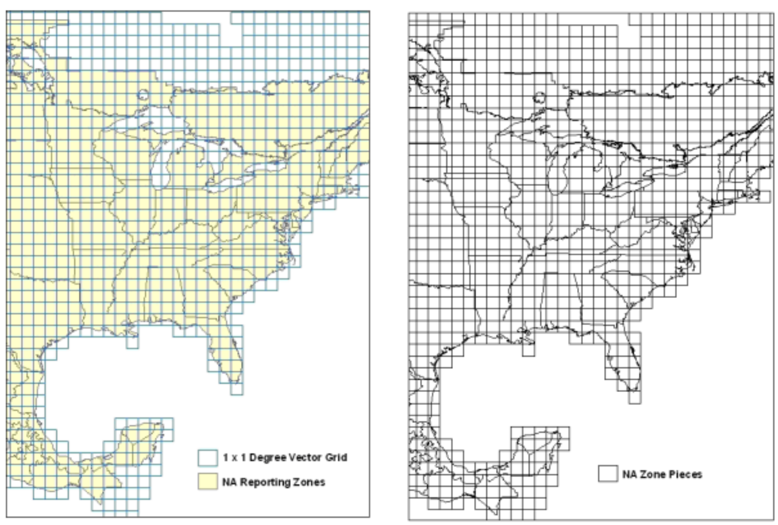

Figure 5. The image on the left shows 2 separate GIS data, the 1-degree polygon grid and the inventory zones polygon data. It shows the eastern portion of the North American study area. The image on the right shows that result of union the 1-degree polygon grid with the NA inventory zones. This data is called the "NA Zones Pieces" in the Model Builder application diagram

Another aggregation processing input file, called "NA Zone Pieces" in the model diagram above, is a polygon-based vector data. This input layer has attribute information necessary for summarizing the gridded model output data by 3 land types (forest, crop, and other) and also contains the area (in km^2) of each polygon that we used in the weighted average calculations for each model output variable. The polygon structure of "NA Zone Pieces" is a combination of the 1-degree polygon grid cells and the inventory zones. The "Union" module in ArcGIS was used to combine these data layers. Figure 4 shows this combining process. The combining of these two data layers into one layer allows for the input of the 1-degree gridded model output data and its eventual summation by the large reporting units of the aggregation process. This is possible because, among other information, the inventory zone to which each polygon belongs is maintained within the attribute table of the layer. Further, many of the input 1-degree grid cells straddle more than one inventory zone. This process allows the appropriate portion of each 1-degree grid cell to be applied to the corresponding inventory zone.

Information about land cover type was also included in “NA Zone Pieces” data by incorporating data from the Global Land Cover 2000 (GLC2000) data. The GLC2000 data has a pixel resolution of 1 km x 1 km. Land cover type classes within the GLC2000 file (Table 2) were reclassified to 3 group classes: forest, crop, and other, as described in Section 4.

The GLC2000 classes 1 – 10 were grouped to forest, classes 16 – 18 were grouped to crop class, and all other classes were grouped to “other” class. From this, 2 separate raster data files were made: one identifying forest pixels with all other values set to zero, the other identifying all crop pixels with all other values set to zero (Figure 5). This allowed for a GIS process that statistically summarized the values of each forest or crop raster file within the zones of the “NA Zone Pieces” and reports the results in a summary table.

The summary table for forest and crop included values of count and sum. Count was the total number of 1-km pixels within each zone piece and sum is the total number of forest or crop pixels for each file, within each zone polygon piece. Using count and sum, the fraction of forest or fraction of crop within each zone piece was determined. The fraction of all other land types, simply called “other”, was calculated as the difference of forest and crop from the whole. Using the total area of each zone piece and the fraction of forest, crop and other, the Area of Forest, Area of Crop, and Area of Other could be determined. These values were joined with the attribute table for the “NA Zone Pieces” file.

The next step in the aggregation process was to “Union” the NA Zone Pieces with the polygon “grid” file of the model output data. The output file, called Y_Zones_Union in the Fast Track model diagram above, now has all the necessary information for calculating the ecosystem variable by area for each polygon within each of the NA Zone Pieces polygons. This includes values for the total area and for the fraction of forest, crop, and other land types. Throughout these steps, the inventory zone to which each polygon piece belongs is maintained. Once the ecosystem variable for each polygon is calculated, a GIS process called “Dissolve” is performed which aggregates features based on a specific attribute, in this case the inventory zone. During the dissolve process, a number of statistics fields are derived which sum the model output variable values for each polygon within the corresponding inventory zone. This results in values for each inventory zone of Total Area, Total Area of Forest, Total Area of Crop, Total Area of Other, Total Ecosystem Variable, Total Ecosystem Variable for Forest, Total Ecosystem Variable for Crop, and Total Ecosystem Variable for Other. From these values, the final average weighted ecosystem variable for the inventory zone and for the area of forest, crop, and other areas within each inventory zone are calculated. The final Select in the Aggregation Model Diagram simply removes empty zone fields for the final ecosystem variable file. Figure 6 illustrates a map of a standardized gridded model output NEE data and the output maps of the aggregation process: NEE in forest, crop, and other sectors for all inventory zones in North America.

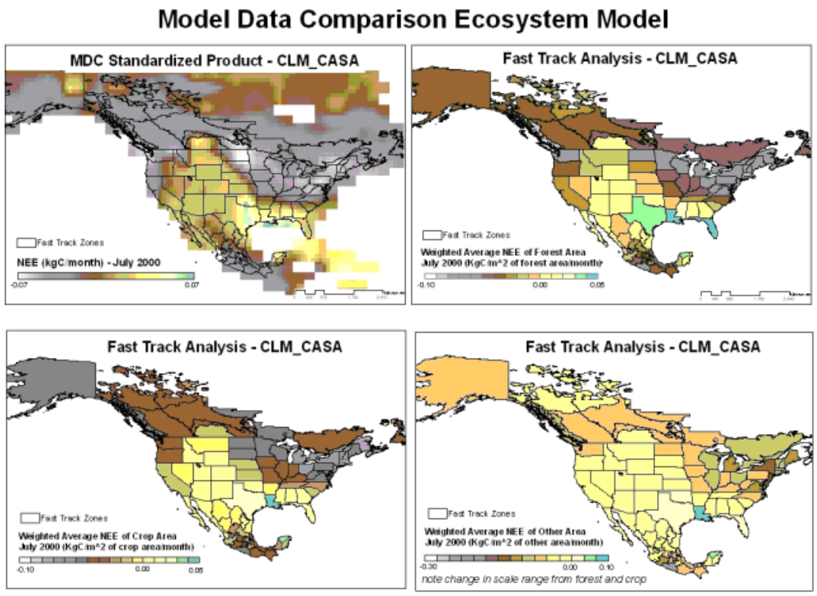

Figure 6. Aggregation output maps showing forest, crop and other NEE from the CLM-CASA model for July 2000

5.3. Data Format and Organization

For each variable available, the following information is provided: a sum and weighted average for each zone, the sum of each variable by land cover type (forest, crop, other), and the weighted average of each variable by land cover type (forest, crop, other). The columns for each table are described below.

> An example database from the aggregation process is described here for model CLM-CASA. The model, CLM-CASA, has 4 variables available for the years 2001 – 2004. Monthly variable tables contained inside the database are named by: MODEL_VARIABLE_YYYYMM (VARIABLE: NEE, NPP, Rh, Veg, FE; YYYY: year; MM: month). Yearly variable tables are named by MODEL_VARIABLE_YYYY (VARIABLE: NEE, NPP, Rh, Veg, FE; YYYY: year).

For example:

Monthly Tables:

- CLMCASA_NEE_200001, ..., CLMCASA_NEE_200412
- CLMCASA_NPP_200001, ..., CLMCASA_NPP_200412
- CLMCASA_Rh_200001, ..., CLMCASA_Rh_200412
- CLMCASA_Veg_200001, ..., CLMCASA_Veg_200412

Annual Tables:

- CLMCASA_NEE_2000, ..., CLMCASA_NEE_2004
- CLMCASA_NPP_2000, ..., CLMCASA_NPP_2004
- CLMCASA_Rh_2000, ..., CLMCASA_Rh_2004
- CLMCASA_Veg_2000, ..., CLMCASA_Veg_2004

6. National GHG Inventories

The national Greenhouse Gas (GHG) inventories compiled for the NACP interim synthesis activities contains inventory-based data on productivity, ecosystem carbon stock change and harvested product stock change to produce estimates of land-atmosphere exchange of CO2 (net ecosystem exchange; NEE) for the 2000 to 2006 time period for the Forest Lands and Crop Lands sectors in Canada and the United States. Additional information from national-level greenhouse gas (GHG) inventories was used to fill in data on carbon balance in the Other Lands sector, including data on human and livestock consumption of harvested products. For Mexico, the national GHG inventories database accounts primarily for carbon flux due to land use change according to the study by deJong et al. (2010), which covers the period of 1993 to 2002. Data on carbon exchange for each sector are summarized according to GHG inventory "reporting zones", as defined in section 2: Inventory Zones.

The methodology for producing estimates of NEE for each country / sector during the study period can be found from S4. Supporting Information Tables and Figures in Hayes et al. (2012). It illustrates details for the quantitative estimates of the indicator variables representing the main components of the carbon budget for each reporting zone. The indicator variables are represented with the sign convention referenced to the atmosphere in which a negative value signifies a carbon gain in the ecosystem. By this definition, productivity and harvest removals have negative values, product and fire emissions have positive values, and negative values of stock change (ΔLive, ΔDOM, and various product pools) represent carbon gains in these pools and vice-versa. The definition, description, data source(s), and equations / calculation(s) used for each indicator variable in each country / sector are provided in Hayes et al. (2012).

6.1. Forest Lands GHG Inventories and NEE_F

6.1.1. Canada Forest Lands

Table 4 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO2 (NEE_F) by Canada reporting zone in forest lands sector.

Table 4. Attributes of Canada Forest Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description
Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
Forest Area	Forest_Area	km^2	Area of forest in each reporting zone.
ΔLiveC	dLiveC	TgC yr-1	Carbon stock change in live biomass pools
ΔDOM	dDOM	TgC yr-1	Carbon stock changes in soil organic matter and in non-live, non-soil pools (standing dead, litter, coarse woody debris)

Fire (C)	FireC	TgC yr-1	Fire emissions (carbon in all forms)
H_R	HCRemoved	TgC yr-1	Total C removed from the stand as harvests in the Managed Forest sector of each reporting zone
NPP	NPP	TgC yr-1	Net Primary Productivity
Rh	Rh	TgC yr-1	Heterotrophic Respiration
Fire (CO_2)	FireCO2	TgC yr-1	Fire emissions (carbon in CO2 only)
H_E	HCEmitted	TgC yr-1	The amount of C emitted from the processing of harvested products within the forest sector = -0.3*H_R
NEE_F	NEE	TgC yr-1	ΔLiveC + ΔDOM - (Fire (C) - Fire (CO_2)) + H_R + H_E = NPP + Rh + Fire (CO_2) + H_E

6.1.2 U.S. Forest Lands:

Table 5 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO_2 (NEE_f) by US States in forest lands sector.

Table 5. Attributes of US Forest Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description
Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
Forest Area	Forest_Area	km^2	Area of forest in each reporting zone.
ΔLiveC	dLiveC	TgC yr-1	Carbon stock change in live biomass pools
ΔDOM	dDOM	TgC yr-1	Carbon stock changes in soil organic matter and in non-live, non-soil pools (standing dead, litter, coarse woody debris)
H_R	HCRemoved	TgC yr-1	Total C removed from the stand as harvested products in each reporting zone
H_E	HCEmitted	TgC yr-1	The amount of C emitted from the processing of harvested products within the forest sector = -0.3*H_R
NEE_F	NEE	TgC yr-1	NEE_F = ΔLive + ΔDOM + H_R + H_E

6.1.3 Mexico Forest Lands:

Table 6 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO_2 (NEE_f) by Mexico States in forest lands sector.

Table 6. Attributes of Mexico Forest Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description
Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
Forest Area	Forest_Area	km^2	Area of forest in each reporting zone.
$\Delta Live_{LUC}$	Biomass_Conversion	TgC yr-1	Carbon stock change in live biomass pools due to forest land use conversion
$\Delta Soil_{LUC}$	dSoilC	TgC yr-1	Carbon stock change in soil organic matter pools due to forest land use conversion
$\Delta Live_{ABND}$	Abandonment	TgC yr-1	Carbon stock change in live biomass pools due to biomass increment on forest land regenerating after agricultural abandonment
$\Delta Live_{MNGD}$	Fuelwood+Uptake	TgC yr-1	Carbon stock change in live biomass pools due to biomass increment and fuelwood harvest in managed forest land
Total NEE	Total_NEE	TgC yr-1	Total Net Ecosystem Exchange from forest land

6.2. Attributes of Crop Lands GHG Inventories and NEE_c

6.2.1 Canada Crop Lands:

Table 7 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO_2 (NEE_c) by Canada reporting zone in crop lands sector.

Table 7. Attributes of Canada Crop Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description

Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
Crop Area	Crop_Area	km^2	Area of crop in each reporting zone.
NPP	NPP	TgC yr-1	Crop Net Primary Productivity
H_R	Harvest	TgC yr-1	Total C removed as harvested crop products in each reporting zone
ΔSOILC	dSoilC	TgC yr-1	Carbon stock change in soil organic matter pools in agricultural land
NEE_C	NEE	TgC yr-1	NEE = H_R + ΔSOILC

6.2.2 US Crop Lands:

Table 8 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO_2 (NEE_c) by US States in crop lands sector.

Table 8. Attributes of US Crop Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description
Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
Crop Area	Crop_Area	km^2	Area of crop in each reporting zone.
NPP	NPP	TgC yr-1	Crop Net Primary Productivity
H_R	Harvest	TgC yr-1	Total C removed as harvested crop products in each reporting zone
ΔSOILC	dSoilC	TgC yr-1	Carbon stock change in soil organic matter pools in agricultural land
NEE_C	NEE	TgC yr-1	NEE = H_R + ΔSOILC

6.3. Other Lands GHG Inventories and NEE_o

Canada Other Lands:

Table 9 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO_2 (NEE_o) by Canada reporting zone in other lands sector.

Table 9. Attributes of Canada Other Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description
Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
A_O	Other_Area	km^2	Area represented in the Other Lands sector: the Total Reporting Zone Area minus Inventory Forest Area minus Inventory Crop Area
Pop_H	Population	10^3	Human population (thousand persons) in each reporting zone estimated by overlaying reporting zone boundaries on census units containing year 2006 population estimates from Statistics Canada (www.statcan.gc.ca)
C_H	Human_Crop_Consumption	TgC yr-1	Human crop consumption and CO_2 emissions from human respiration estimated using per capita consumption (61.6 kg C yr-1) and respiration (54.0) rates from the U.S. data ([West et al., 2009])
E_H	Human_CO2_Respiration	TgC yr-1	
E_L-CH_4	Livestock_CH4_Emissions	TgC yr-1	Livestock (cattle and swine) methane emissions from Statistics Canada 2006 Census of Agriculture
E_L	Livestock_CO2_Emissions	TgC yr-1	Estimated livestock CO_2 emissions; the column total is equal to the national total HR adjusted for the net crop harvest export out of the country (27%*), minus national total human crop consumption and total C emitted as CH_4 from livestock; the column total is distributed proportional to C emitted as CH_4 from livestock in each reporting zone; *national-level crop harvest imports vs. exports is based on cash value, from

			the Canadian Socio-Economic Information Management System (Statistics Canada)
E_F	Forest_Product_CO2_Emissions	TgC yr-1	Estimated CO_2 emissions from decay of forest products; the column total is equal to the national total emissions from HWPE which is distributed proportional to human population in each reporting zone
NEE_G	NEE_Grasslands	TgC yr-1	NEE for grasslands estimated by multiplying the average grassland sink per area from the U.S. data (2.1 g C m-2 yr-1) by the "other" land area in each reporting zone
NEE_S	NEE_Settlements	TgC yr-1	NEE for settled areas estimated by multiplying the average settlements sink per capita from the U.S. data (95.6 kg C per capita yr-1) by the human population in each reporting zone
NEE_O	Total_NEE_Other_Lands	TgC yr-1	$NEE_O = E_H + E_L + E_F + NEE_G + NEE_S$

6.3.2 U.S. Other Lands:

Table 10 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO_2 (NEE_o) by US States in other lands sector.

Table 10. Attributes of US Other Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description
Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
A_O	Other_Area	km^2	Area represented in the Other Lands sector: the Total Reporting Zone Area minus Inventory Forest Area minus Inventory Crop Area (average area years 2000 - 2006)
Pop_H	Population	10^3	Human population (thousand persons) is the average state population between 2000 and 2006, estimates from U.S. Census Bureau [2009]

C_H	Human_Crop_Consumption	TgC yr-1	For human consumption of crop products , there is a consistent respiration-to-consumption multiplier (1.14) across all age/gender classes in Table 1 of West et al., [2009], which was applied to the data on human respiration.
E_H	Human_CO2_Respiration	TgC yr-1	
E_L-CH_4	Livestock_CH4_Emissions	TgC yr-1	Livestock methane emissions from enteric fermentation from the USDA Greenhouse Gas Inventory [2008]
E_L	Livestock_CO2_Emissions	TgC yr-1	Estimated livestock CO_2 emissions; the column total is equal to the national total crop harvest (HR from Table A5), adjusted for the net crop harvest export out of the country (HCPIMP – HCPEXP = -46.7 TgC yr-1between 2000 and 2006*), minus national total human crop consumption and total C emitted as CH_4 from livestock; the column total is distributed proportional to C emitted as CH_4 from livestock in each reporting zone; *national-level crop harvest imports vs. exports is based on volume converted to dry-weight biomass carbon using data in USDA Economic Research Service (2010)."Foreign Agricultural Trade of the United States (FATUS)" [2010] http://www.ers.usda.gov/data/fatus/
E_F	Forest_Product_CO2_Emissions	TgC yr-1	Estimated CO2 emissions from decay of forest products; the column total is equal to the national total emissions from HWP; the column total is distributed proportional to human population in each reporting zone
NEE_G	NEE_Grasslands	TgC yr-1	NEE for grasslands estimated by distributing the annual, national-level grassland sink estimates from the U.S. Environmental Protection Agency Greenhouse Gas Inventory [2010] proportional to the area of the Other Land sector in each reporting zone
NEE_S	NEE_Settlements	TgC yr-1	NEE for settled areas estimated by distributing the annual, national-level settlements / other sink estimates from the U.S. Environmental Protection Agency Greenhouse Gas Inventory [2010] proportional to the human population in each reporting zone
NEE_O	Total_NEE_Other_Lands	TgC yr-1	$NEE_O = E_H + E_L + E_F + NEE_G + NEE_S$

6.3.3 Mexico Other Lands:

Table 11 lists the major components of GHG inventories and the estimation of land-atmosphere exchange of CO_2 (NEE_o) by Mexico States in other lands sector.

Table 11. Attributes of Mexico Other Lands GHG Inventories

Attribute	Attribute Column Name	Units	Description
Zone ID	Zone_ID		Unique ID of each reporting zone. It can be used to link back to the reporting zone polygons for mapping and spatial analysis.
SectorZone ID	SectorZone_ID		Unique ID of each reporting zone and land sector combination. It can be used to link back to reference land sector mask data for mapping and spatial analysis.
Zone Name	Zone_Name		Name of reporting zone.
A_O	Forest_Area	km^2	Area of forest in each reporting zone.
$\Delta Live_{LUC}$	Biomass_Conversion	TgC yr-1	Carbon stock change in live biomass pools due to non-forest land use conversion
$\Delta Soil_{LUC}$	dSoilC	TgC yr-1	Carbon stock change in soil organic matter pools due to non-forest land use conversion
$\Delta Live_{ABND}$	Abandonment	TgC yr-1	Carbon stock change in live biomass pools due to biomass increment on non-forest land regenerating after agricultural abandonment
$\Delta Live_{MNGD}$	Fuelwood+Uptake	TgC yr-1	Carbon stock change in live biomass pools due to biomass increment and fuelwood emissions in managed non-forest land
Total NEE	Total_NEE	TgC yr-1	Total Net Ecosystem Exchange from forest land

7. Annual Mean NEE (2000-2006) by Sectors and Zones in North America

Combining the aggregated model output and the national GHG database, as described in sections 5 and 6 above, we created the annual mean NEE (2000-2006) summary data by both land sectors and reporting zones in North America (NEE_Zones_Sectors_Mean_2000-2006.csv). This NEE summary data can be used for model-inventory comparison purpose directly or be linked with the reference raster data (NA_Reporting_Zones_Sectors.tif) for mapping purpose.

Table 12 describes the fields included in the NEE summary data.

Table 12. Attributes of NEE summary data

Attribute	Attribute Column Name	Units	Description

Sector Zone ID	Zone_ID		Unique ID for each sector-zone combination in the pattern of "NXY", see section 4 for details
Sector	Sector		Sector type: forest, crop, or other
Zone Name	Zone_Name		Name of reporting zone
Country	Country		Country
NEE from Forward Model	NEE_Forward	g C m-2 yr-1	Annual mean NEE (2000-2006) from mean of multiple forward models
NEE from Inverse Model	NEE_Inverse	g C m-2 yr-1	Annual mean NEE (2000-2006) from mean of multiple inverse models
NEE from GHG Inventory	NEE_Inventory	g C m-2 yr-1	Annual mean NEE (2000-2006) from national GHG database

Figure 7 (Hayes, et al., 2012) maps the NEE summary data by linking it to the reference raster data (NA_Reporting_Zones_Sectors.tif).

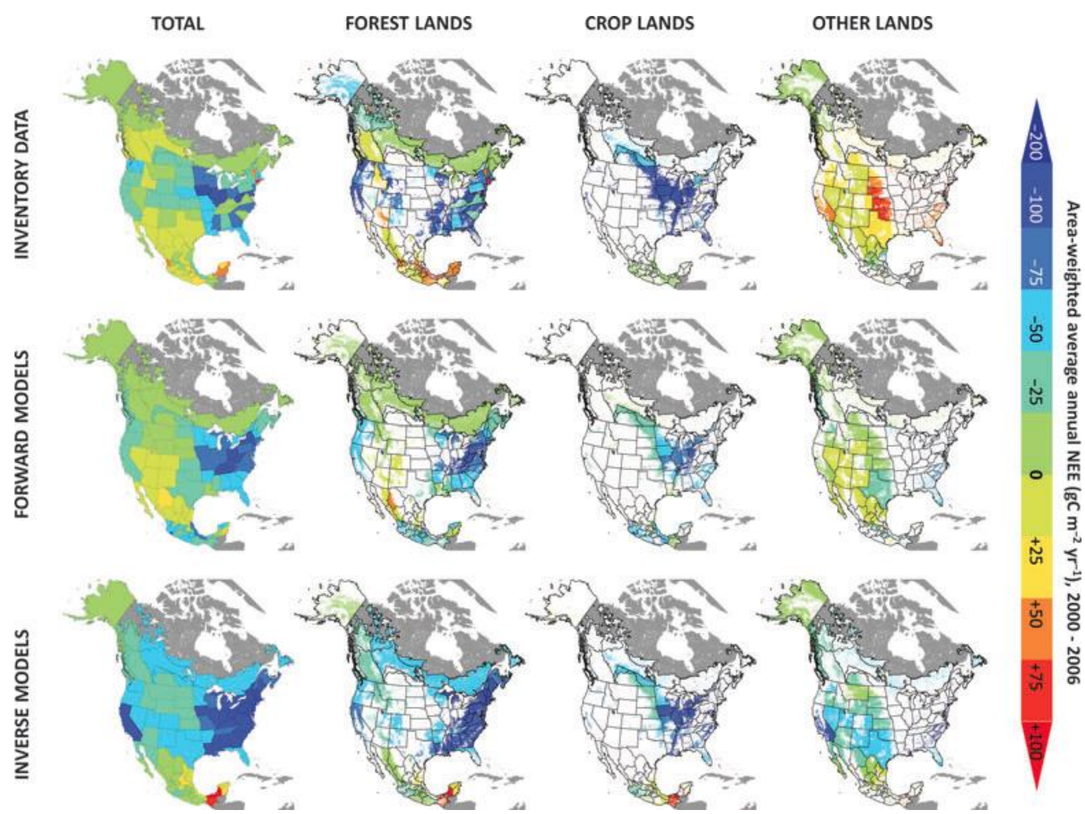

Figure 7. Mean area-weighted average annual NEE (g C m-2 yr-1), 2000–2006 for the Forest Lands, Crop Lands and Other Lands sectors, along with all land (total), in each reporting zone, from inventory-based estimates against mean results from the sets of terrestrial biosphere (forward) models and inverse models. (*source: Hayes, et al., 2012*)

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