ANL/ESD/12-5

Carbon **C**alculator for **L**and **U**se Change from **B**iofuels Production (CCLUB)

Users' Manual and Technical Documentation

Energy Systems Division

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Carbon **C**alculator for **L**and **U**se Change from **B**iofuels Production (CCLUB)

Users' Manual and Technical Documentation

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1. Introduction

The Carbon Calculator for Land Use Change from Biofuels Production (CCLUB) calculates carbon emissions from land use change (LUC) for four different ethanol production pathways including corn grain ethanol and cellulosic ethanol from corn stover, miscanthus, and switchgrass. This document discusses the version of CCLUB released May 31, 2012 which includes corn, as did the previous CCLUB version, and three cellulosic feedstocks: corn stover, miscanthus, and switchgrass.

CCLUB calculations are based upon two data sets: land change areas and above- and below-ground carbon content. Table 1 identifies where these data are stored and used within the CCLUB model, which is built in MS Excel. Land change area data is from Purdue University's Global Trade Analysis Project (GTAP) model, a computable general equilibrium (CGE) economic model. Section 2 describes the GTAP data CCLUB uses and how these data were modified to reflect shrubland transitions. Feedstock- and spatially-explicit below-ground carbon content data for the United States were generated with a surrogate model for CENTURY's soil organic carbon sub-model (Kwon and Hudson 2010) as described in Section 3. CENTURY is a soil organic matter model developed by Parton et al. (1987). The previous CCLUB version used more coarse domestic carbon emission factors. Above-ground non-soil carbon content data for forest ecosystems was sourced from the USDA/NCIAS Carbon Online Estimator (COLE) as explained in Section 4. We discuss emission factors used for calculation of international greenhouse gas (GHG) emissions in Section 5. Temporal issues associated with modeling LUC emissions are the topic of Section 6. Finally, in Section 7 we provide a step-by-step guide to using CCLUB and obtaining results.

Table 1. Overview of CCLUB Worksheets

Worksheet	Description
Scenario&Results	Enables selection of biofuels scenario and displays results
GTAP Data	Lists and summarizes GTAP source data
Modeling	Computes carbon emissions from land use change
Direct C-Factors	Derives carbon intensity factors for direct (domestic) land use
Indirect C-Factors	Derives carbon intensity factors for indirect (international) land use
Forest Factor	Computes forest correction factor for shrubland transitions
Saved Data	Shows comparative results from selected CCLUB runs

2. GTAP Data

With the GTAP model, Purdue University modeled land use changes associated with the four biofuel production scenarios CCLUB considers (Taheripour et al. 2011).

Table 2 lists the four production scenarios and associated biofuels volumes. The cellulosic ethanol scenarios (stover, switchgrass, miscanthus) are modeled in GTAP as incremental production volumes on top of corn ethanol production.

Table 2. Biofuels Scenarios

Case	Case Description	Gallons
A	An increase in corn ethanol production from its 2004 level (3.41 billion gallons [BG]) to 15 BG	11.59
E	An increase of ethanol from corn stover (i.e. AdvfE-Stover) by 9 BG, on top of 15 BG corn ethanol	9
F	An increase of ethanol from miscanthus (i.e. AdvfE-Misc) by 7 BG, on top of 15 BG corn ethanol	7
G	An increase of ethanol from switchgrass (i.e. AdvfE-Swit) by 7 BG, on top of 15 BG corn ethanol	7

Note: Case classifications refer to Taheripour et al. (2011)

GTAP permits three land types to be tapped for biofuel production: forest, grassland, and feedstock lands. In a differently nested category the model also accesses a fourth land type: cropland-pasture. Figure 1 illustrates the land transitions considered in CCLUB.

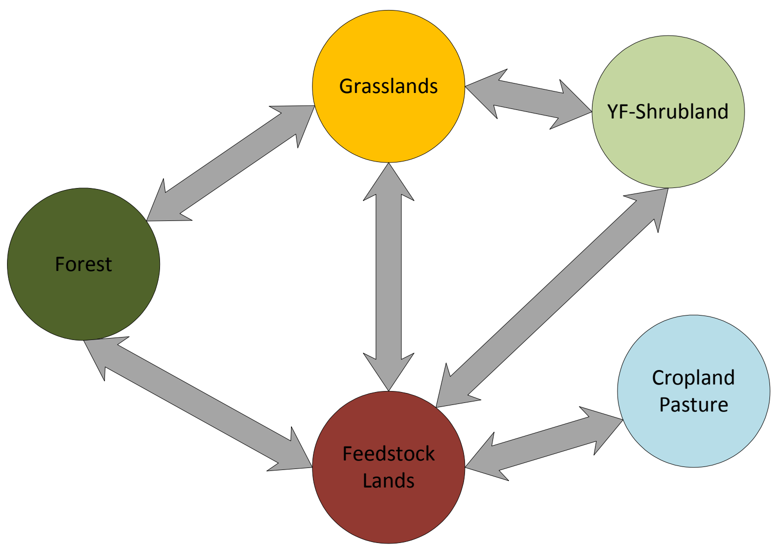

Figure 1. Land Transitions Modeled in CCLUB

Upon receiving the GTAP data from Purdue we, along with collaborators at the University of Chicago, compared the GTAP land database with both the National Land Cover Datasets (NLCD), which are part of the USDA Cropland Data Layers (CDL), and the US Forest Service's Forest Inventory data. The NLCD for 2006 put forest area at 207 million hectares (ha) for the lower 48 states. Including woody wetlands would bring this number up to 240 million ha. This figure is similar to the forest area from the USDA Forest Service's Forest Inventory Data Online (FIDO) database of 254 million ha. If we add forested area in Alaska, the total forest area rises to 285 million ha. However, the GTAP database includes a significantly higher value (370 million ha) for total forested land than these other data sources (see Table 3).

Of the total forest area in both the CDL and GTAP data, some is inaccessible for biofuel production (national and state forest) and the remainder is accessible. Purdue provided the total split between accessible and inaccessible forest land in GTAP with accessible forest land accounting for 225 million ha out of the 370 million total forest ha. Our analysis indicated that the GTAP database uses the methodology by Sohngen (2004) to derive accessible vs. inaccessible land ratios by agro-ecological zone (AEZ) and then applies these ratios to the GTAP forest areas by AEZ. The reproduced GTAP accessible forest land by AEZ is shown in Table 3. A map showing the distribution of AEZs in the United States is in Figure 2. In our CDL analysis, subtracting state and national forest areas from the CDL total forest area data yielded 157 million ha of accessible forest. Across most AEZs (but not all) this is substantially less accessible forest land than GTAP predicts.

Based on the significant differences of accessible forest lands between GTAP and the CDL analysis we hypothesize that some of the GTAP accessible forest land is shrubland rather than mature forest land. To address these issues, we added young forest-shrubland (YF-Shrub) as a fifth land type. Shrubland is defined in the NLCD Classification as "areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall." To determine the amount of land classified as YF-Shrub, we applied a proration factor to the accessible forest land GTAP predicted to be converted. The proration factor is calculated at the AEZ level as the ratio of accessible forest land in the CDL database to accessible forest land in the GTAP database (see Table 3). For example, if in a certain scenario GTAP predicted the conversion of 10,000 ha of forest to feedstock lands in AEZ 14, applying the proration factor results in CCLUB modeling 3,800 ha and 6,200 ha of forest and YF-Shrub lands being converted, respectively. In two AEZs, the proration factor exceeds one. In that case, our approach increases the amount of mature forest that is converted and effectively decreases the amount of YF-Shrub that converts to feedstock production land.

Table 3. GTAP vs. CDL Forest Area Comparison

AEZ	CDL Forest Area (ha)	GTAP Forest Area (ha)	CDL Accessible Forest Area (ha) (CLD_a)	GTAP Accessible Forest Area (ha) ($GTAP_a$)	Proration Factor ($CDL_a/GTAP_a$)
7	47,405,654	8,565,128	4,916,174	3,855,223	1.28
8	17,272,038	16,811,112	3,249,339	7,568,672	0.43
9	10,321,261	10,603,159	4,877,404	4,774,257	1.02
10	57,660,896	68,714,584	38,053,673	51,625,425	0.74
11	49,317,712	56,696,608	41,537,500	41,732,227	1.00
12	48,740,427	69,617,736	41,543,291	53,074,258	0.78
13	10,325,263	17,098,376	2,860,066	7,697,724	0.37
14	24,624,059	61,735,484	10,557,947	27,793,441	0.38
15	18,497,217	55,407,136	9,066,574	24,948,026	0.36
16	780,733	5,180,770	361,713	2,332,297	0.16
Total	284,945,260	370,430,093	157,023,681	225,401,549	0.70

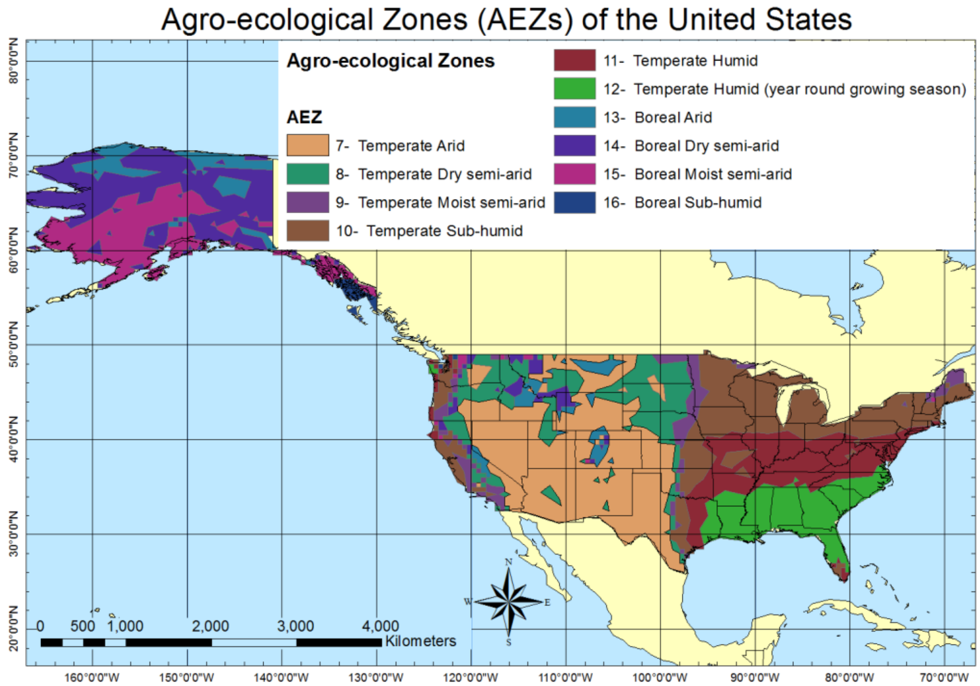

Figure 2. Distribution of AEZs in the United States

Converting YF-Shrub lands will have a lower carbon penalty than converting mature, carbon-rich forests. We therefore modified mature forest carbon emission factors to reflect this difference. The modified forest emissions factor for YF-Shrub is based on the relative height of forest stands in each state compared to shrubland. The relative tree heights for each state were derived from Pflugmacher (2008) and Buis (2012) (see Appendix A).

3. Below-Ground Carbon Data for the United States

This work took advantage of a surrogate model for CENTURY's soil organic carbon sub-model (SCSOC) developed by Kwon and Hudson (2010). Use of CENTURY to estimate soil C stock change was logical as it is well-developed for croplands, grasslands, forests (Parton et al. 1987, Paustian et al. 1992, Kirschbaum and Paul 2002) and can simulate land transitions incorporated in the GTAP modeling framework.

The SCSOC includes mass balance and decomposition kinetics equations for the three primary soil organic matter (SOM) pools (i.e., active, slow and passive SOM) described by CENTURY. Important differences between CENTURY and SCSOC are that SCSOC is coded and solved within the PROC MODEL of SAS (SAS Institute 2004) and decoupled from models of plant growth, nutrient cycling, and hydrologic processes described within CENTURY and associated variants. Use of the SCSOC provides the advantages of transparency and relative simplicity while allowing users to easily modify time-dependent CENTURY inputs. Important inputs to

SCSOC include aboveground and belowground crop/plant C input rates to soil, and the site-specific decay rate coefficient of the SOM pools.

The SCSOC model was used to derive emissions factors based on the scenarios that land presently in croplands, grasslands or pasture/hay (from this point on called grasslands), and forests could be converted to at least one of four likely biofuel (ethanol) feedstock production systems: corn-corn rotations, or corn-corn rotations with stover harvest, switchgrass, and miscanthus. To anticipate soil carbon emissions from agricultural lands set aside for conservation, croplands/conservation reserve modeling scenarios considered lands that had never been cropped (grasslands) and that had reverted to grasslands after a period of cropping.

Corn-based systems were simulated with three different tillage options [i.e., conventional tillage (CT), reduced tillage (RT), and no tillage (NT)] while the two perennial grass systems were simulated with NT. Under regular tillage 95% surface residue is assumed to be mixed to soils, under reduced tillage 30% is mixed to soils, and under no-tillage 5% is mixed to soils. Stover harvest rates were set at 30% to avoid increasing soil erosion or diminishing soil fertility (Nelson 2002; Wilhelm et al. 2004; Johnson et al. 2006; Tyner et al. 2010a). To leave similar amounts of aboveground residues in place and thus avoid soil depletion, an 80% biomass harvest rate was used for switchgrass and a 90% rate for miscanthus.

Combining original land use, feedstock type, and land management practice resulted in 24 general LUC scenarios to consider for soil carbon emissions. The transitions are diagrammed in Figure 3 and presented in tabular format in Appendix B.

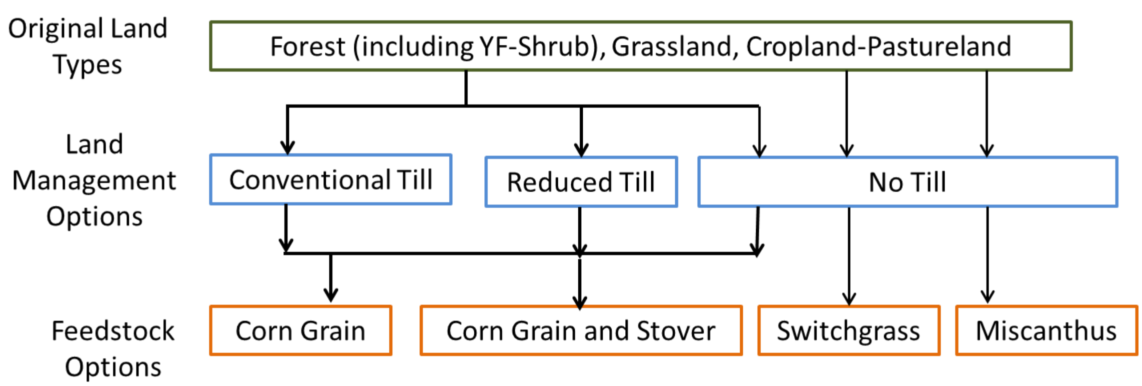

Figure 3. Soil Carbon LUC Scenarios in CCLUB

Within CCLUB, the user can select from five sets of soil organic carbon (SOC) modeling results that are listed in Table 4. To generate these five sets of results, three variables were altered in CENTURY modeling.

First, the soil carbon decay coefficient in CENTURY was adjusted from default values because several studies have shown that CENTURY soil decay coefficients needs to be adjusted upward to properly estimate soil organic carbon (SOC) levels under row-cropped systems (Leite et al. 2004; Matthews and Pilbeam 2005). CCLUB users can select modeling results with either default or adjusted soil decay coefficients.

Second, the effect of different erosion assumptions in CENTURY modeling is a variable. When erosion was included in CENTURY modeling, the average soil loss or erosion rates (Mg soil ha^{-1} yr^{-1}) for croplands and pasture/hay/grasslands were obtained from the National Resources Inventory (NRI) erosion estimates (USDA-NRCS), which are based upon the Universal Soil Loss Equation and Wind Erosion Equation (for wind erosion), by averaging periodic erosion estimates from 1982, 1987, 1992, 1997, 2002, and 2007. For forests and land used for either switchgrass or miscanthus, we assumed zero soil erosion rates. Under a no-erosion scenario we assumed zero soil erosion rates for the croplands and pasture/hay/grasslands as well.

Finally, we included two basic yield scenarios: a constant yield and a yield increase scenario. Under the constant yield scenario crop/plant biomasses of corn-based systems during the LUC period were estimated using the average yield achieved over the last ten years. For switchgrass, we used state-specific yields developed by Graham et al. (1997). For miscanthus, there is no database of yields available for the various states and thus, we used an average estimate of aboveground biomass that was derived from Heaton et al.'s (2004) review of 21 peer-reviewed articles of miscanthus yields. Note that GTAP simulations did not incorporate crop yield increase for any of the feedstocks.

Under the yield increase scenario we developed emissions factors for increases in corn productivity based on historical trends. This method is consistent with the approach used by Miranowski et al. (2011) who used linear regression to predict yield trends. We projected corn yields using a simple regression equation derived from yield records from each state (1951-2010). The yield increases for miscanthus and switchgrass were projected to total 1% annually, which is consistent with the recent update of the Billion-Ton Study (U.S. Department of Energy 2012).

In summary, CCLUB can be parameterized with five soil carbon scenarios reflecting different biomass yield assumptions, as well as different erosion and decay coefficients. The five different scenarios are summarized in Table 4.

Table 4. CENTURY Cases in CCLUB

Case	Case Code	Soil Decay Factor		Crop Yield		Erosion	
		CENTURY Default	Adjusted	Increase	No Increase	Erosion	No Erosion
sa	avg noY noErosion	X			X		X
sb	avg Y	X		X		X	
sc	avg noY	X			X	X	
sd	avg new param		X	X		X	
se	avg noY new param		X		X	X	

Alternatively, CCLUB can be parameterized with a direct emissions factor set from the Woods Hole Research Center, which was originally authored by R. Houghton and provided to the California Air Resources Board and GTAP in support of land use modeling efforts. The Woods Hole emissions factor dataset is reproduced in Tyner (2010b). Woods Hole factors are not available by AEZ but are at the biome level.

4. Non-soil Carbon Data for the United States

Non-soil carbon from forest ecosystem conversions are based on data from the USDA Forest Service/NCIAS Carbon Online Estimator "COLE" (Van Deusen and Heath 2010). In order to determine soil carbon impacts of forest-to-cropland conversion scenarios we accessed the state-by-state data for the five different non-soil components: aboveground live tree carbon density, aboveground dead tree carbon density, understory carbon density, forest floor carbon density, and coarse woody debris carbon density.

In time, some feedstock production land may revert back to forest land. Reversion soil carbon factors are based on COLE's net annual growth by tree age database. Foregone sequestration from annual biomass growth is also based on the COLE value for net annual growth. CCLUB calculates soil carbon stock changes from reversion and carbon emissions from foregone sequestration from annual growth based on 30-year-old tree stands. CCLUB, however, is populated with data for other tree stand ages allowing the user to select alternative aged tree stands. The emissions/sequestration effects from root biomass are included in the boundary of the CENTURY modeling runs.

The carbon in some harvested wood will not be emitted, but contained within harvested wood products (HWP) in productive uses such as buildings. Based on Heath et al. (1996) and a follow-up conversion with Heath we determined that 60% of the combined aboveground live and dead tree carbon density can be removed from the forest. 35% of this carbon is stored in products and an additional 35% is converted into useful energy (both considered harvested wood product offsets). The remaining aboveground categories are assumed to be released to the atmosphere. 4 depicts the fates of aboveground live and dead tree carbon based upon Heath et al. (1996). Alternatively, the CCLUB user has the option to exclude any HWP offsets (HWP set to "0").

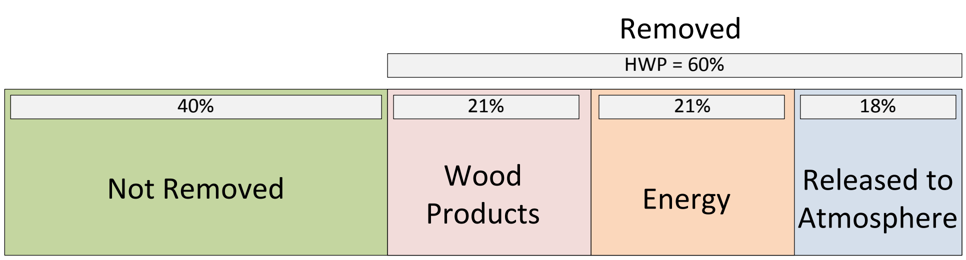

Figure 4. Fate of Aboveground Live and Dead Tree Carbon

For the emissions assessments based on the Woods Hole dataset (direct and indirect), the amount of aboveground carbon emitted to the atmosphere is 75%. CCLUB users can adjust this factor in the respective sections of the Direct C-Factors and Indirect C-Factors worksheet (in the column titled "C Released During Conversion") .

Since all GTAP results are based on AEZ regions we aggregated the higher resolution state-level factors to match the AEZ regions. AEZ-level factors were derived as the weighted average of state-level factors weighted by the fraction of each state's land fraction within each AEZ. The aggregation procedure is presented in CCLUB.

5. Indirect (International) Emission Factors

The indirect emissions assessment in CCLUB is based on data from the Woods Hole Research Center, which was originally authored by R. Houghton and provided to the California Air Resources Board and GTAP in support of the land use modeling efforts. The Woods Hole emissions factor dataset is reproduced in Tyner (2010b). Woods Hole factors are not available by AEZ but are at the biome level.

6. Temporal Issues in Modeling LUC Emissions

CCLUB's assessment of carbon emissions from LUC depends on two critical time horizons: the duration of biofuels production and the emissions amortization period. Assumptions regarding the duration of biofuels production impact foregone sequestration from annual biomass growth and the associated soil carbon adjustments. Since the data set on soil carbon adjustments from the CENTURY model are based on 30-year equilibrium values, the production duration should not be varied significantly from that value. We assume that a relatively small variation of +/-5 years will not introduce significant errors. The emissions amortization period refers to the duration over which a biofuels policy is analyzed.

7. Using CCLUB

In this section, we explain the contents of the eight sheets that make up CCLUB. We describe them in order of calculation flow rather than the left-to-right progression of sheets.

7.1. Overview Worksheet

This sheet contains author information and a list of worksheets and their descriptions.

7.2. Scenario and Results Worksheet

This sheet contains seven user inputs and a results section. Users select input values in the rose-colored cells. All options are visible in the yellow cells in each section. The first user input is the feedstock-to-fuel pathway. The user can choose from among the biofuel scenarios in Table 2, which include corn and cellulosic ethanol options (corn stover, miscanthus, or switchgrass feedstocks).

The second user input is the scenario selection for domestic (direct) emissions scenarios. The data underpinning these scenarios is described in Sections 3 and 4.

The user selects an HWP scenario for Input 3, either using the assumptions of Heath et al. (1996) or assuming all above-ground carbon is emitted when forests are converted to biofeedstock production.

The land management practice options that constitute Input 4 allow the user to assess the influence of tillage practice on the results for corn and corn stover pathways.

In developing CCLUB, we modified GTAP data for area of converted forest as described in Section 2. Input 5 allows CCLUB users to adopt adjustments to converted forest lands by selecting “Yes” or to use raw GTAP data by selecting “No.”

Users can alter the foregone carbon sequestration period by adjusting Input 6. Users are cautioned, however, that the modeling runs that produced domestic soil carbon values were based on 25-35 year time horizons. Choosing values outside that time window may produce inaccurate results.

Finally, users can alter the amortization period in input 7. See Section 6 for a discussion of how amortization influences results.

Once all inputs are selected, the user can click on the “Run Simulation” button and view results within CCLUB as described in the following paragraph. If the user also clicks on “Copy to GREET”, inputs and results will be transferred to GREET and incorporated into overall biofuel life cycle analysis. The user will have an active GREET spreadsheet after clicking this button.

No input or adjustments are required on other sheets to see the results, which are presented in two side-by-side sections. The first section contains results from the primary model, which combines the newly-developed approach to domestic carbon emission factors (See Sections 3 and 4) and Woods Hole emission factors for international (indirect) emissions. In this section, the emissions are divided into direct and indirect emissions, each of which are broken out as follows by land type.

- Direct or Indirect Emissions (Mg C): Total carbon emissions for the selected scenario by land type
- Direct or Indirect Emissions (Mg CO_2e): The total carbon emissions are converted to carbon dioxide equivalent emissions (3.67 g CO_2/g C)
- Direct or Indirect Annualized Emissions (Mg CO_2e/yr): The total carbon dioxide emissions are divided by the amortization period specified in Input 7
- Direct or Indirect Annualized Emissions (g CO_2e/gal): The annualized emissions are divided by the annual fuel production volume
- Direct or Indirect Annualized Emissions (g CO_2e/MJ): The volume-based emissions are converted to a unit energy basis with the lower heating value of ethanol.

The red highlighted box in the Results section contains the total LUC GHG emissions associated with the selected scenario in units of g CO_2e/MJ.

In the results section, we also provide results obtained when using Woods Hole emission factors for direct emissions. This number can be compared to the direct emissions calculated with the primary model.

7.3. GTAP Data Worksheet

This worksheet contains three sections. The bottom section with a heading of "GTAP Source Data Tables" contains the raw GTAP data generated as described in Taheripour et al. (2011). The data are grouped by scenario. The section above the raw data, entitled "Land Use Summary by Region and AEZ" selects the LUC data from the appropriate scenario. The top section, "Land Use Summary by Region," contains the total of LUC by land type and country/region. These values are multiplied by the appropriate emission factors to generate LUC emissions results.

7.4. Direct C-Factors Worksheet

This worksheet displays the direct emissions factors based on CENTURY/COLE and the direct factors based on Woods Hole. This sheet uses color coding to guide the user's eye. Soil and non-soil carbon stock changes are red- and blue-highlighted, respectively. Annual growth values are green-highlighted.

The first table in the sheet, Table A, contains non-soil carbon by state, developed as explained in Section 4. Note that only above-ground carbon emission impacts of forest conversion are considered because below-ground carbon stock changes (from soil and tree roots) are considered in CENTURY. In this table, the YF-Shrub correction factor described in Section 2 is also calculated.

Next, Table 2 contains soil carbon stock changes by state as modeled in CENTURY and described in Section 3. Separate tables are provided for each scenario option in Input 2.

Table 3 contains data from Van Deusen and Heath (2010) for total net tree growth and calculates from it the carbon contained in that new tree growth using a forest carbon factor of 50%, which is consistent with the IPCC Good Practice Guidance For Land Use, Land Use Change and Forestry (2003).

Table 4 contains calculations to map states into AEZs. The results are used to roll the CENTURY (Table 5), COLE (Table 6), and foregone sequestration from annual growth (Table 7) data up to the AEZ level to match the resolution of the GTAP data.

Section B of this sheet contains the Woods Hole direct emission factor data and calculates emission factors.

7.5. Indirect C-Factors Worksheet

This sheet has the same color scheme as the Direct C-Factors sheet. It calculates indirect emissions factors from Woods Hole data, which is described in Section 5.

7.6. Forest Land Area Worksheet

Section A of this sheet contains state-level land use data from CDL analysis that is mapped to the AEZ level using the matrix displayed in Section B. Forest proration factor calculations are in Section C of the sheet. Section 2 of this document discusses these calculations.

7.7. Modeling Worksheet

At the top of this sheet, conventions used in calculations are defined. Carbon emission and sequestration factors are defined as positive and negative, respectively. Converted land areas are treated as negative whereas reverted lands are defined as positive. The color coding of the spreadsheet is also defined. Soil and non-soil emissions factors are highlighted in red and blue, respectively. The annual growth of forests is highlighted in green. Land areas imported from other tabs are colored gray.

The first data section in the sheet is direct emissions based on data from the CENTURY modeling effort described in Section 3.

Modeling is grouped as follows. First emissions factors for conversion and reversions of forests, grasslands, YF-shrublands, and cropland-pasture lands (as Figure 3 depicts) are calculated as the sum of above-ground carbon, soil carbon, and foregone sequestration from annual growth. Note that the soil carbon emissions factors for the corn ethanol and stover ethanol scenarios are dependent on the selected tillage scenario (CT, RT, NT). In a second step those emissions factors are matched to the selected biofuels scenario and multiplied by the corresponding GTAP land area changes for each transition. It is in this sheet that the forest proration factor is applied.

Direct emissions calculated with Woods Hole emission factors are also displayed in this sheet in Section A.2. They are calculated as the sum of the Woods Hole emissions factors for aboveground and belowground carbon and annual growth multiplied by the GTAP land area changes.

The international components of the Woods Hole emissions factor data dataset described above are used to assess indirect emissions for the selected biofuels scenarios.

7.8. Selected Results

The results for one likely parameterization scenario of CCLUB are shown in Table 5. In this scenario we have selected CENTURY-based soil carbon factors reflective of projected yield increases and an adjusted biomass decay parameter (the "sd" selection in CCLUB) combined with above-ground carbon factors based on USDA Forest Service COLE data. Furthermore, for domestic emissions we have adjusted the GTAP results with YF-Shrub transitions. We have included HWP factors based on Heath et al (1996) for direct emissions and the original Woods Hole HWP assumption of 25% sequestration for indirect emissions (the default for indirect emissions). The chosen scenario would indicate that biofuels production from corn stover and switchgrass would not result in any significant LUC GHG emissions. Miscanthus ethanol would sequester carbon and corn ethanol production would result in net emissions (with less emissions produced under no-till management).

Table 5. Selected CCLUB Summary Results for Feedstock-to-Ethanol Pathways (gCO_2e/MJ)

	Emission Factor Source	HWP Factor	Corn CT	Corn NT	Corn Stover	Miscanthus	Switchgrass
Direct (domestic) emissions	CENTURY/ COLE modeling with case sd	60%[a]	5.6	4.5	-0.2	-14	-5.4
Indirect (international emissions)	Woods Hole	25%[b]	3.5	3.5	-1.0	1.7	6.7
Total			9.1	8.0	-1.2	-12	1.3

a. Per Heath et al. as explained in Section 4
b. Per Woods Hole data set as explained in Section 4

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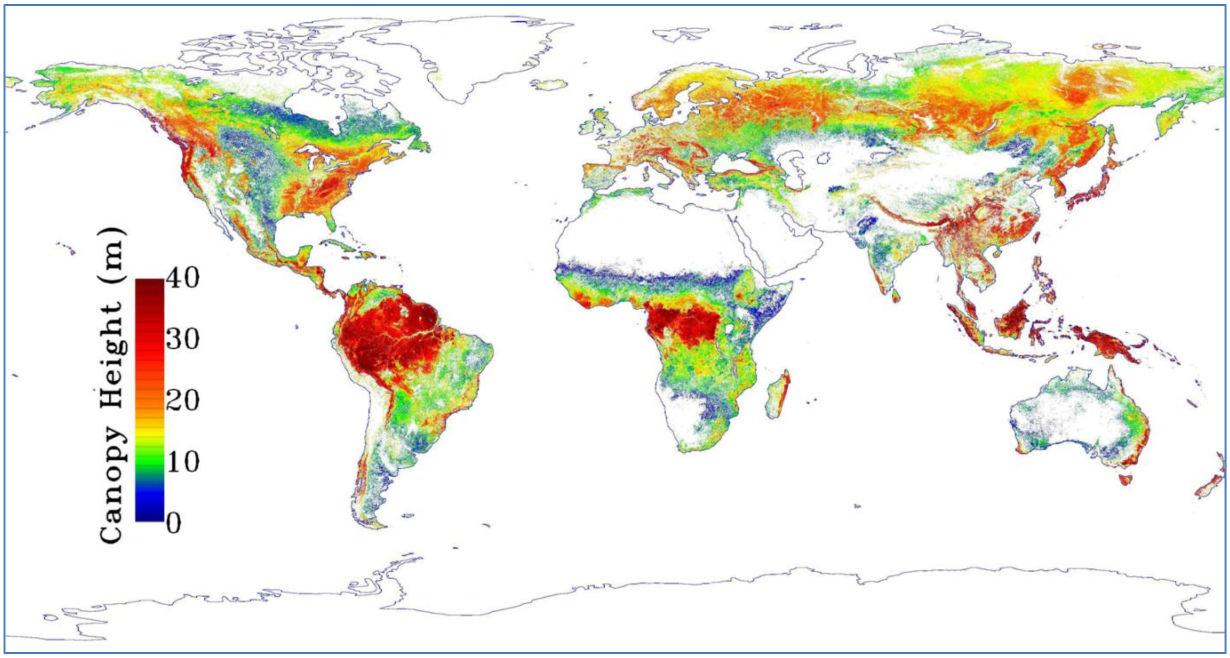
Appendix A: Global Map of Forest Height

Source: Alan Buis, Jet Propulsion Laboratory, Pasadena, Calif. Global map of forest height produced from NASA's ICESAT/GLAS, MODIS and TRMM sensors.

http://www.nasa.gov/topics/earth/features/forest20120217.html



Appendix B: Tabular Summary of Land Conversions

This table contains 24 land conversions modeled in CENTURY. The results are contained in CCLUB.

Original Land Type	Land Management Practice	Feedstock
Forest	Conventional Tillage	Corn Corn and Corn Stover
	Reduced Tillage	Corn Corn and Corn Stover
	No Tillage	Corn Corn and Corn Stover
	No Tillage	Switchgrass Miscanthus
Grassland	Conventional Tillage	Corn Corn and Corn Stover
	Reduced Tillage	Corn Corn and Corn Stover
	No Tillage	Corn Corn and Corn Stover
	No Tillage	Switchgrass Miscanthus
Cropland-Grassland	Conventional Tillage	Corn Corn and Corn Stover
	Reduced Tillage	Corn Corn and Corn Stover
	No Tillage	Corn Corn and Corn Stover
	No Tillage	Switchgrass Miscanthus

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